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A Combined ex-post/ex-ante impact analysis for improved sorghum varieties in Tanzania

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International Crops Research Institute for the Semi-Arid Tropics

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Our special thanks go to all scientists from the Department of Research and Development, Ministry of Agriculture, Tanzania DRD who participated in the two days impact assessment workshop in Arusha (Tanzania) and/or contributed to this report. Without their enthusiasm, profound knowledge of all aspects of the sorghum sector in Tanzania and their commitment in elaborating the underlying economics and adoption information from all sorghum regions this study could not have been undertaken.

Executive Summary

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

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

A three days impact assessment workshop was conducted in August 2013 in Arusha, Tanzania, organised by ICRISAT and the Department of Research and Development DRD. Sorghum breeders, agronomists and socio-economists were invited to elaborate on the necessary information for an impact assessment, guided by an ICRISAT facilitator and an eight-stage data elicitation process.

General findings: The Sorghum breeding program in Tanzania suffered from initial difficulties due to substandard breeding technologies, quality of breeding material and a small number of released varieties with attractive features and competitiveness. As a result early generation varieties performed somewhat poorer than later generation varieties which are reflected in the varieties internal rate of returns IRR as well as modest research benefits generated in the past. On aggregate, the economic gains from research are lower than for comparable crops (maize) with higher production values and market sales but all show high internal rate of return due to moderate research costs. Markets scenarios with low/high price elasticity coefficients and increasing cross-border trade do not affect the overall research benefits but show pronounced distributional effects between consumers and producers. Sorghum with a low price elasticity reacts vividly to different market set-ups causing prices and consumer and producer surplus to vary within a large bandwidth. The spatial pattern of research gains towards the major sorghum regions is fairly in line with the general size of production indicating that the set of varieties are suitable for most of the sorghum regions and show similar performance and adoption rates.

Detailed results: The research gains (in terms of economic surplus) from improved varieties accounts for USD 1.2 bln over the entire period from the first release in 1986 until 2030. On an annual base this translates into USD 23 Mio. Due to the particular price inelasticity in the sorghum markets, most of the gains are captured by consumers: USD 800 Mio in total and USD 15.7 Mio. per year. Results reveal a strong performance from all improved varieties with a rate of returns (IRR) above 30%. In general, newer varieties seem to be superior to the 1st generation varieties Pato and Tegemeo which stems from the fact that the sorghum experts put high expectations in the varieties under development regarding future performance even under low input management. Other reasons for the high IRR are the

relatively low research costs. On an inflation adjustment base, annual average research costs only accounts for USD 40,000. High inflation rates above 20% between 1980 and 1995 were inflicting a strong discounting factor on the nominal research costs.

Examination of regional pattern of the research gains shows a clear trend towards the major sorghum regions, namely Dodoma, Singida and Shinyanga. They make up around USD 900 Mio. which constitute over 80 % of the overall research gains. The reasons are that those regions are large producers by definition and much of the producer surplus are directed to them, but they are large consumer regions as well with a high population (esp. Dodoma and Shinyanga) and elevated sorghum consumption between 30-60 kg/per capita annually. Non-adopting sorghum regions such as Lindi, Mwara and all other miscellaneous regions with some minor production are losing around USD 170 Mio. as a result of low prices that are transmitted from the major adoption regions. Net losses to producers (USD 473 Mio) outweigh the gains to consumers (USD 304 Mio) from lower prices.

A break up of the research gains by ex-post and ex-ante shows that only 10 % of the gains (around USD 110 Mio.) have materialized since the start of sorghum breeding in 1980 until now in 2013 while 90% of the gains are expected to occur in the future. The low share of past versus future gains is certainly a result of the dominance of the varieties under development that have contributed nothing to the past performance but take a large share in future research gains. Changes in the market framework via price responsiveness and cross- border trade have little bearing on the overall size of the research gains. A similar finding applies to the regional distribution of the research gains that seem largely unaffected across all market scenarios.

In sharp contrast are the effects markets have on the allocation of research gains between consumers and producers. Cut across all market scenarios, volatility on the producer side (87%) is very high and somewhat lower on the consumer side (61%). Model results provide ample evidence to the importance of markets and trade for sorghum producers. Bigger and better markets can shift large parts of the research gains from the consumers back to the producers in terms of limiting the price pressure and proving additional market opportunities.

Poverty targeting: How much of the research gains go to the poor? In terms of total research gains around USD Mio. 500 (41%) out of USD 1,200 Mio. are directed towards the ‘poor’. Similar to the baseline results, most of the gains occur on the consumption side (USD 334 Mio) and much less on the production side. A decisive factor in the allocation of the research gains is how well the sorghum varieties perform and generate gains in the three major sorghum districts. Any research gains in the Dodoma region which has a relatively low poverty rate of 24.6 tend to dilute the poverty focus. The contrary holds true for the Singida and Shinyanga regions that exhibit much higher poverty rates (49 and 42%). If the research gains are compared with the poverty share in sorghum production, one can conclude that the sorghum research program in Tanzania is fairly ‘poverty neural’. If compared with the national poverty rate, it can be labelled as ‘poverty friendly’.

Keywords: Sorghum, research impact, economic surplus, dream model, Tanzania

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Acronyms

CFSVA	Comprehensive Food Security & Vulnerability Analysis
CGIAR	Consultative Group for International Agricultural Research
CPI	Consumer Price Index
CS	Consumer Surplus
DIVA	Free computer program for mapping and geographic data analysis
DRC	Democratic Republic of Congo
DRD	Department of Research and Development, Ministry of Agriculture, Tanzania
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
HOPE	Harnessing Opportunities for Productivity Enhancement
ICRISAT	International Crops Research Institute for the Semi-arid Tropics
IFRPRI	International Food Policy Research Institute Wash. DC
IMOD	Inclusive Market Oriented Development
IRR	Internal Rate of Return
NARO	National Agricultural Research Organisation
NARS	National Agricultural Research Station
NGO	Non-Government Organisation
NSMIP	National Sorghum and Millet Improvement Program
OECD	Organisation for Economic Co-operation and Development
PS	Producer Surplus
SMIP	Sorghum and Millet Improvement Program
TS	Total Surplus
TSh	Tanzanian Shilling
USD	United States of America Dollar
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 breeding program in Tanzania, 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 Tanzania. Study results are useful for donors and research institutions during periods of reviews and planning by examining the economic returns to breeding programs and the performance of each 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), regions, producers and consumers, 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 systems, higher yields and 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 small pace, but often remain stagnant since the last 10 years for example in Uganda, Kenya and Tanzania. The only country in which dryland crops kept pace with other cereals is Ethiopia. There seems to be a structural supply side problem in the ESA region where ICRISAT's research instruments such as germplasm improvement in combination with agronomic advice and expertise can help overcome the existing supply side bottlenecks and contribute to sustained and dynamic sector growth. On the other hand, demand for dryland cereals is forecast to grow strongly in our target regions. Growth in demand will be driven primarily not only by population growth but also by new market opportunities such as demand for clear sorghum beer and from the feed industry

This study contributes to the CGIAR Research Program on Dryland Cereals, CRP 3.6 where ICRISAT is the lead and the HOPE project (Harnessing Opportunities for Productivity Enhancement for Sorghum and Millets), the main implementer. 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 Tanzania

2.1. Climate, Land Use and Crop Production

Tanzania is located in East Africa, with Mozambique and Malawi to the south and Uganda and Kenya to the north. Tanzania's western border is primarily marked by Lake Tanganyika, with Zambia, DRC, Burundi and Rwanda all bordering the country and to the east Tanzania borders the Indian Ocean (Map 1). Near the border with Kenya, Africa's tallest mountain Mt Kilimanjaro towers over the plains and in the west the world's second largest lake, Lake Victoria is shared by Tanzania, Uganda and Kenya. Together with Tanzania's two other major lakes, Tangenyika and Nyasa, the country has significant freshwater resources. Tanzania's land elevation is mainly 1,000～1,400m above sea level, with the elevation rising as one moves west. Plains cover the areas from the coastal areas moving to inland areas while the inland has hilly savannah and dry highlands.

Tanzania's area is 947,300 ha. Within this, land area is 880,000 ha and water area is 60,000 ha. Of the land area, 440,000 ha is arable（about half of the country's land）but only 95,000 ha is currently under cultivation – about 10% of Tanzania's land. Because of the lack of irrigation it is not likely that the amount of cultivated land will increase significantly in the coming years. In addition 500,000 ha of pasture land is suitable for livestock; but half of this area is infected with tsetse fly and cannot be used, resulting in only 260,000 ha in use for grazing land (Agriculture, Forestry and Fisheries of Tanzania, 2011).

Food Crop Production

Tanzania's main food crops include maize, cassava, bananas, potatoes, rice and beans. Generally cereals are the main crops grown across the country occupying 5, 830,972 ha (71%) of the land under annual crops followed by pulses (chick peas, beans, cowpeas and green grams) planted on 1,002,819 ha (12%), oil seeds and oil nuts are planted on 966,583 ha and a very small proportion (1%) equivalent to 78,711 ha is planted with fruits and vegetables. A large proportion of all the crops are planted during the long rainy season with the exception of cereals for which the planted area for the short rainy season is about 20 percent of the planted area during the long rain season (National Sample Census of Agriculture Small Holder Agriculture, 2012). The most critical crop in Tanzania's food security strategy is maize. However due to increasing demand, production of potatoes, beans, bananas, rice, and cassava are also increasing. The use of modern inputs such as pesticides, fertilizer, and improved seeds is limited and food crop productivity is generally very low compared to international standards and to the neighbouring countries in the region. In 2010, both maize and rice productivity was only 1.5 mt/ha.

Tanzanian agriculture is dominated by small-scale crop and livestock production, conducted by small scale farmers and traditional pastoralists. Over 80% of cultivated land is held by small scale farmers, and on average, each farmer has 0.2-2 ha of land. Medium and large scale farming utilizes about 1,500,000 ha of land, or less than 16% of cultivated land. However a large amount of the main cash crops including tea, sugar, coffee, and tobacco are cultivated by the medium and large scale farmers.

Map 1: Map of Tanzania

Tanzania's cereal sector has undergone significant expansion (Table 1). Between 2000 and 2012 area under cereals more than doubled from 2.5 Mio. ha to over 6 Mio ha. Maize and rice are the two major cereals driving this development. The area under maize increased fourfold from just over 1 Mio ha to over 4 Mio ha, and rice from 0.4 Mio ha to over 1 Mio ha (20010/11) The expansion of both crops happened at the expense of the dryland cereals sorghum and millets which remained basically constant in terms of area. Consequently, sorghum and millets fell short in terms of value of production and dropped in rank to only the 3rd and 4th most important cereal crops in Tanzania (Table 2).

Table 1: Area of cereal crops (2000 – 2012) in ha

	Maize	Sorghum	Millet	Rice paddy	Wheat	Barley	Buck wheat	Cereals
2012	4,118,117	839,423	260,417	799,361	109,816	8,000	10,000	6,145,134
2011	3,287,850	811,164	328,112	1,119,324	108,287	7,508	9,000	5,671,245
2010	3,050,710	618,370	345,855	1,136,290	54,570	7,568	9,500	5,222,863
2009	2,961,334	874,219	398,506	805,630	149,200	9,065	8,500	5,206,454
2008	3,982,284	597,296	213,972	896,023	43,160	8,000	7,000	5,747,735
2007	2,600,341	817,946	400,000	557,981	75,369	8,500	6,000	4,466,137
2006	2,570,147	715,884	325,000	633,770	53,224	9,000	5,000	4,312,025
2005	3,109,590	737,080	283,180	701,990	35,370	8,000	4,000	4,879,210
2004	3,173,070	697,220	347,910	613,130	34,380	7,500	2,500	4,875,710
2003	3,462,540	449,590	201,850	620,800	26,890	7,000	2,000	4,770,670
2002	1,718,200	655,380	358,830	565,600	30,670	5,500	1,500	3,335,680
2001	845,950	691,690	201,100	405,860	52,120	4,500	1,000	2,202,220
2000	1,017,600	736,200	251,900	415,600	71,700	3,500	500	2,497,000

Source: FAOSTAT

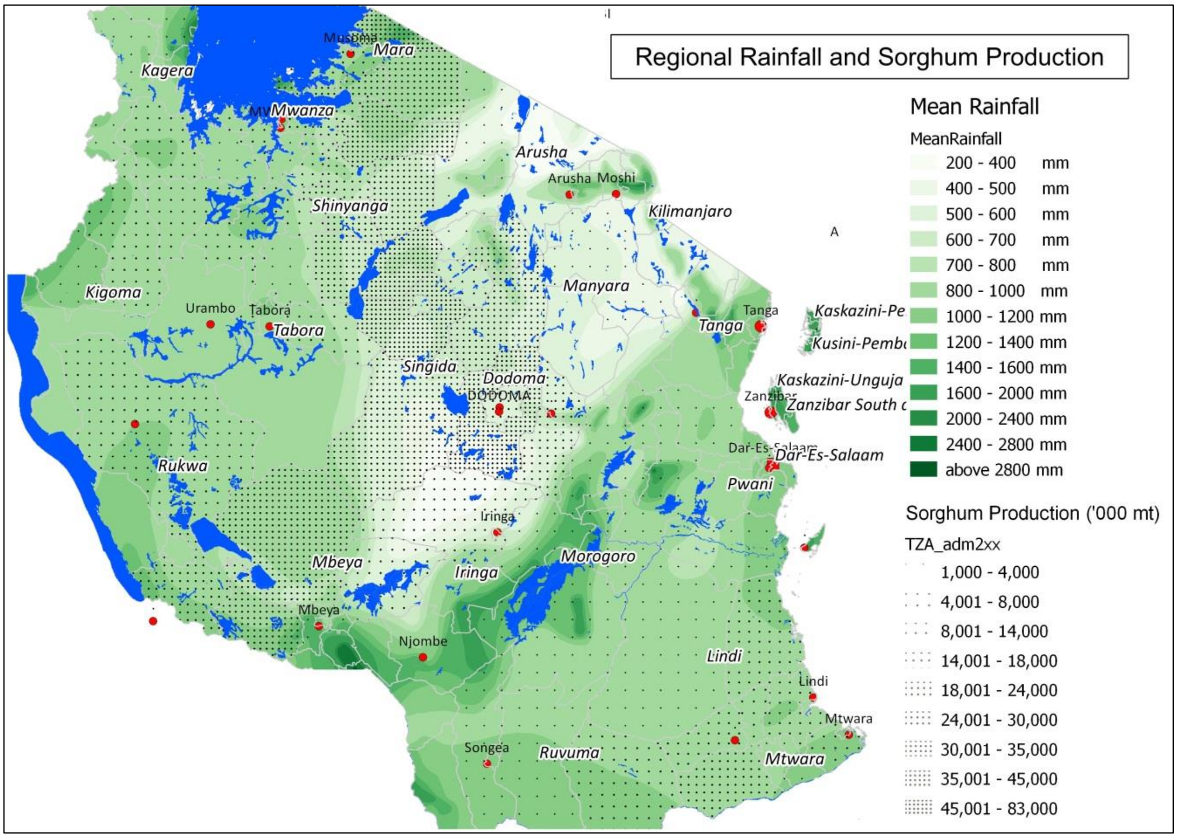
Table 2: Gross production value of cereal crops (constant 2004-2006) in '000 USD

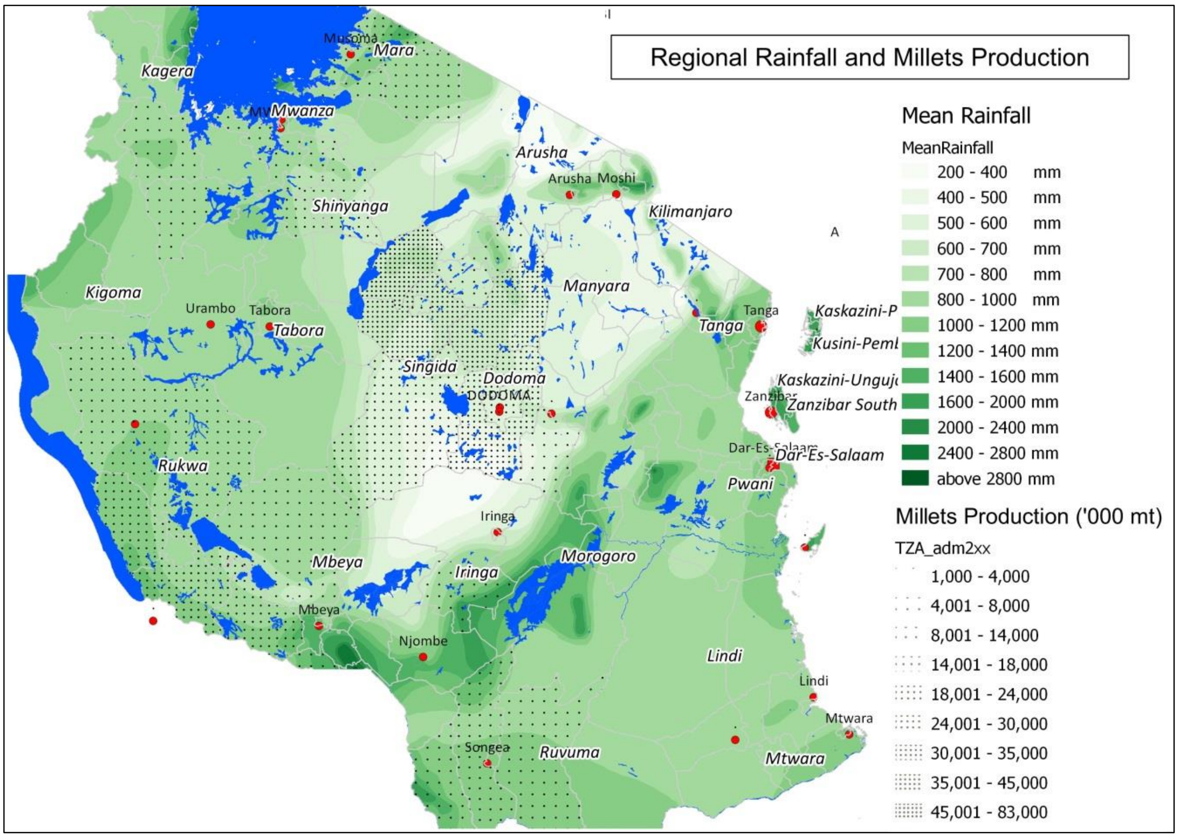
	Maize	Sorghum	Millet	Rice paddy	Wheat	Barley	Buck wheat	Cereals
2012	723,093	128,998	38,784	501,742	17,180	1,071	2,171	1,413,039
2011	614,943	124,054	56,618	626,517	17,775	821	1,910	1,442,639
2010	670,510	122,819	63,665	738,482	9,841	1,812	1,737	1,608,865
2009	471,206	109,095	56,688	371,955	12,997	1,750	1,628	1,025,318
2008	770,758	84,788	27,130	395,856	6,841	1,904	1,302	1,288,579
2007	518,352	149,374	55,869	373,919	13,064	2,121	1,085	1,113,785
2006	484,922	109,452	44,757	336,107	17,356	2,450	868	995,912
2005	443,640	112,237	39,694	325,389	16,094	2,142	760	939,954
2004	658,936	99,748	44,682	294,951	10,571	1,904	434	1,111,226
2003	370,308	30,587	16,563	305,669	11,676	1,725	326	736,853
2002	624,519	97,779	42,352	274,373	12,149	1,547	217	1,052,936
2001	375,810	106,385	37,469	241,791	14,043	1,368	163	777,029
2000	278,428	92,006	39,737	217,783	5,159	1,071	87	634,272

Source: FAOSTAT

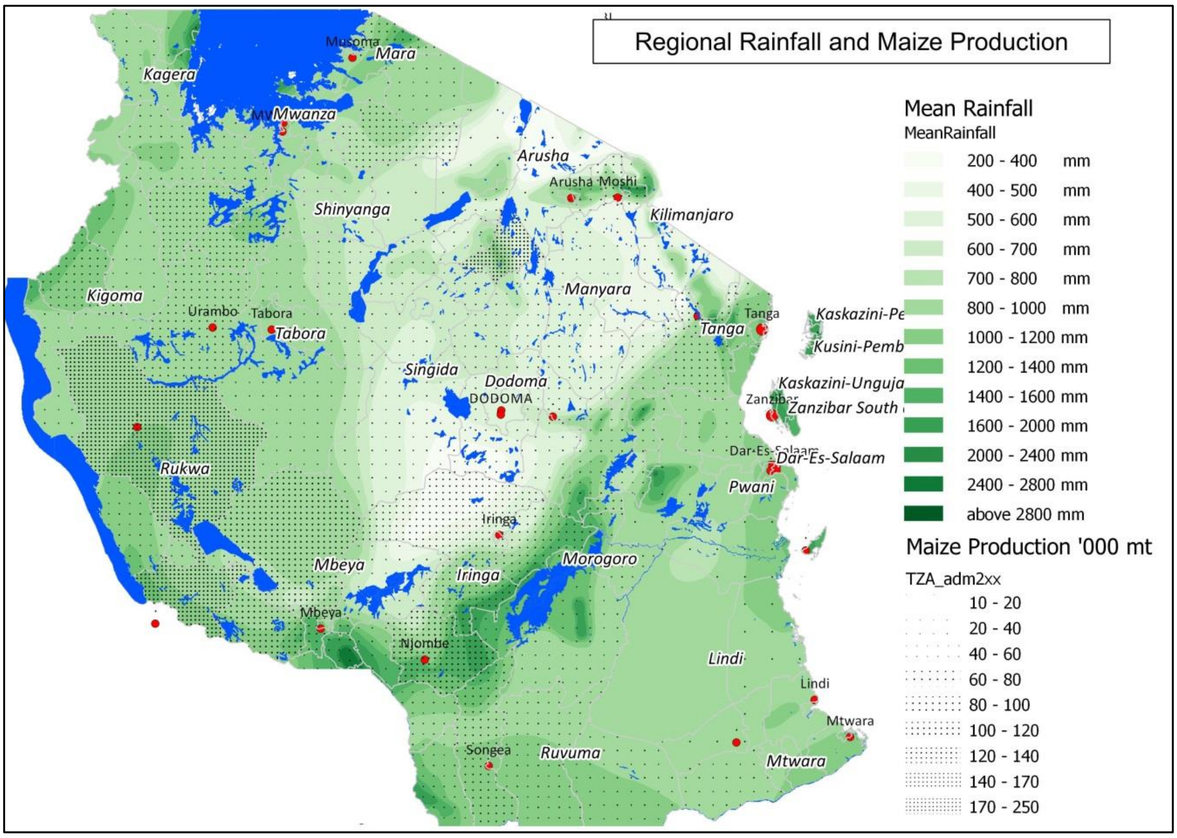
The maps 2 and 3 exhibit the spatial pattern of cereal production in Tanzania based on 5 year average production between 2005 and 2009. Sorghum and millets are mostly grown in the drylands of Tanzania with a few exceptions for finger millet where significant production is based in the more humid Rukwa region bordering the D.R. of Congo and Zambia. Maize is grown across the country but with concentration in the western parts around Rukwa, the Southern Highlands with plenty of rainfall and the coastal regions. Rice is grown based on the availability of water (rainfed or irrigation schemes) and topography. Much of the rice is therefore grown in the lowlands of the lake region and around the Rukwa region.

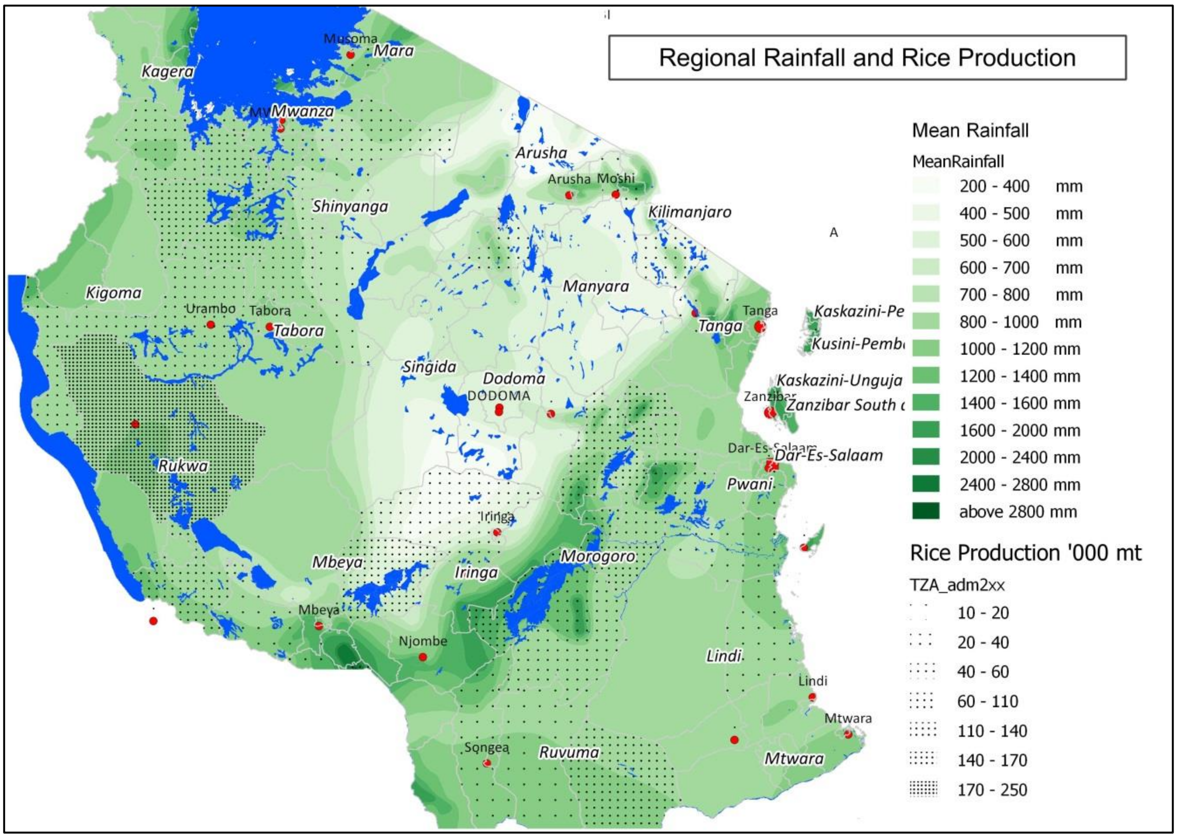
Map 2: Regional rainfall pattern and production of dryland cereals in Tanzania





Map 3: Regional rainfall and production of maize and rice in Tanzania





2.2. Tanzania Sorghum Sector: Selected Overview:

Sorghum and millets are important food crop in Tanzania. They are widely grown in three of the country's six zones, i.e. the Central, Western, and Lake Zones. In other zones cultivation is more localized but is nevertheless important in some districts, particularly in the Southern Zone. Sorghum and to a lesser extend millets are the main food security cereals in the central high plateau (Singida and Dodoma), and second in importance only to maize in the Western, Lake, and Southern Zones (Monyo et al. 2004). Sorghum is grown in low-potential areas unsuitable for maize and other cereals. However, drought tolerant maize varieties DTMA together with other advantages maize has over sorghum (e.g. tradability at markets, lower labour intensity and drudgery) contribute to the expansion and encroachment of Maize into the drier core sorghum and millet areas.

Long term trends in sorghum between 1980 and 2011 as outlined in Table 3 and Figure 1 show the absence of dynamics of sorghum on all fronts, at least compared to maize and rice. The long term trend in area and production trend is slightly positive (this trend is incorporated into the impact 'DREAM' model) but with considerable variation from year to year. The high volatility in sorghum area and production steams from the direct competition with maize as the dominant crop and farmers' decision behaviour in choosing between sorghum or maize in accordance to the rainfall and soil moisture at the beginning of the planting season. This competition is present even in the traditional sorghum regions.

As Monyo (2004) points out, Maize can replace sorghum in seasons of good rainfall. Farmers in these areas normally sow maize; if they suspect the season will be poor, they quickly sow sorghum as well. Maize is sown with the first rains in November. If January rainfall is good, farmers concentrate their efforts on maize, rather than sorghum. But if January rainfall is poor, they quickly expand the area sown to sorghum or millet.

It seems area and production became more stable in recent years compared to the 1980s and 1990s. Progress in yields was modest as the use of modern production inputs such as fertilizer and pesticides remains very low. The predominant mode of production in sorghum is low/zero input except for family and hired labour. Yields remain at low levels around 1 mt/ha at national level. Year-to- year yield fluctuations are significant. National yields in bad years are around 800 kg/ ha and in a good year around 1.2 mt/ha. It is reported that every five years farmers suffer from extreme losses due to insufficient rainfalls and pests/ diseases.

Sorghum area, production and yields by regions

The major production areas (Table 4) are Dodoma and Singida in the Central Zone; Tabora in the Western Zone; Shinyanga, Mwanza and Mara in the Lake Zone; and Lindi and Mtwara regions in the Southern Zone. Dodoma, Singida, Shinyanga, Mwanza and Mara account for most of the national sorghum area. Although sorghum is grown in over 20 regions in Tanzania, area and production under sorghum is concentrated in 4 regions (Dodoma, Singida, Shinyanga and Mara) that make more than 60% of national area and production. Interesting to note that the highest yields are not found in the 'big 4' but except for the Mara in the less important sorghum regions Tanga, Rukwa, Mwanza with yield levels around 1.5 – 2 mt /ha. Yields in Dodoma, Singida and Shinyanga are much lower between 0.8 and 1.2 mt/ha.

Table 3: Long term trends in sorghum (1980 – 2011)

Year	Area Harvested	Production	Seed	Yield
	ha	metric tons (mt)	metric tons (mt)	kg/ha
2011	811,164	806,575	12,168	994
2010	618,370	798,540	12,168	1,291
2009	874,219	709,310	9,276	811
2008	597,296	551,270	13,113	923
2007	817,946	971,198	8,959	1,187
2006	715,884	711,631	12,269	994
2005	737,080	729,740	13,350	990
2004	697,220	648,540	11,056	930
2003	449,590	198,870	10,458	442
2002	655,380	635,740	6,744	970
2001	691,690	691,690	9,831	1,000
2000	736,200	598,200	9,060	813
1999	659,868	561,031	8,686	850
1998	596,200	563,380	8,328	945
1997	622,400	538,200	7,985	865
1996	665,500	872,000	7,655	1,310
1995	689,500	839,000	7,840	1,217
1994	663,700	478,300	7,034	721
1993	641,610	719,140	6,750	1,121
1992	683,071	587,128	9,624	860
1991	600,000	612,000	10,246	1,020
1990	380,000	464,000	9,000	1,221
1989	486,960	537,150	5,700	1,103
1988	476,700	409,660	7,304	859
1987	758,000	663,000	7,151	875
1986	800,000	650,000	11,370	813
1985	445,880	615,000	12,000	1,379
1984	459,800	455,000	6,688	990
1983	476,220	475,000	6,897	997
1982	322,890	580,000	7,143	1,796
1981	700,000	425,000	4,843	607
1980	740,000	510,000	10,500	689

Source: FAOSTAT

Figure 1: Long term trends in sorghum (1980 – 2011)

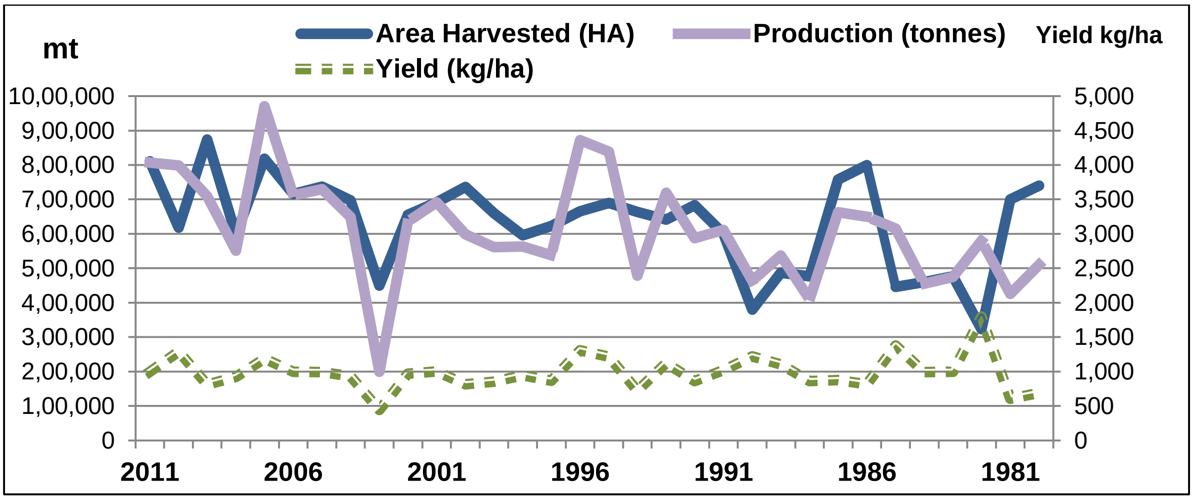


Table 4: Sorghum area by region

Regions	Sorghum Area ('000' ha)					5 Year average. (2005/06 - 2009/10)	Area in percent
	2005/ 2006	2006/ 2007	2007/ 2008*	2008/ 2009	2009 /2010	('000' ha)	%
National	715.87	817.95	566.76	874.22	618.37	718.63	100.0
Dodoma	176.19	138.76	96.15	184.99	215.70	162.36	22.6
Shinyanga	129.44	205.31	98.15	169.24	85.35	137.50	19.1
Singida	82.41	104.30	97.51	139.67	74.74	99.73	13.9
Mara	33.62	60.70	73.62	127.52	56.54	70.40	9.8
Lindi	50.45	64.50	37.97	45.52	39.23	47.53	6.6
Mbeya	35.65	42.49	19.65	49.21	28.86	35.17	4.9
Tabora	21.10	30.37	45.84	41.02	27.81	33.23	4.6
Mwanza	42.03	37.83	14.63	38.06	15.44	29.60	4.1
Mtwara	36.34	36.64	19.62	5.73	22.70	24.20	3.4
Manyara	24.25	25.56	8.36	13.28	5.55	15.40	2.1
Kagera	12.48	19.91	13.29	11.80	5.60	12.62	1.8
Morogoro	12.38	10.82	11.53	9.87	10.42	11.00	1.5
Rukwa	15.51	7.27	8.78	10.84	8.10	10.10	1.4
Iringa	16.89	13.62	4.37	0.90	6.68	8.49	1.2
Kigoma	6.90	7.41	8.38	10.60	5.59	7.78	1.1
Pwani	6.72	5.19	4.45	10.73	4.55	6.33	0.9
Kilimanjaro	5.08	3.82	0.13	0.57	2.34	2.39	0.3
Arusha	3.02	2.81	1.66	2.57	1.81	2.37	0.3
Ruvuma	5.29	0.30	2.09	1.87	1.08	2.13	0.3
Tanga	0.13	0.34	0.59	0.24	0.25	0.31	0.0

Source: own table. Data based on the National Sample Census of Agriculture: Small Holder Agriculture Volume II Crop Sector – National Report 2012

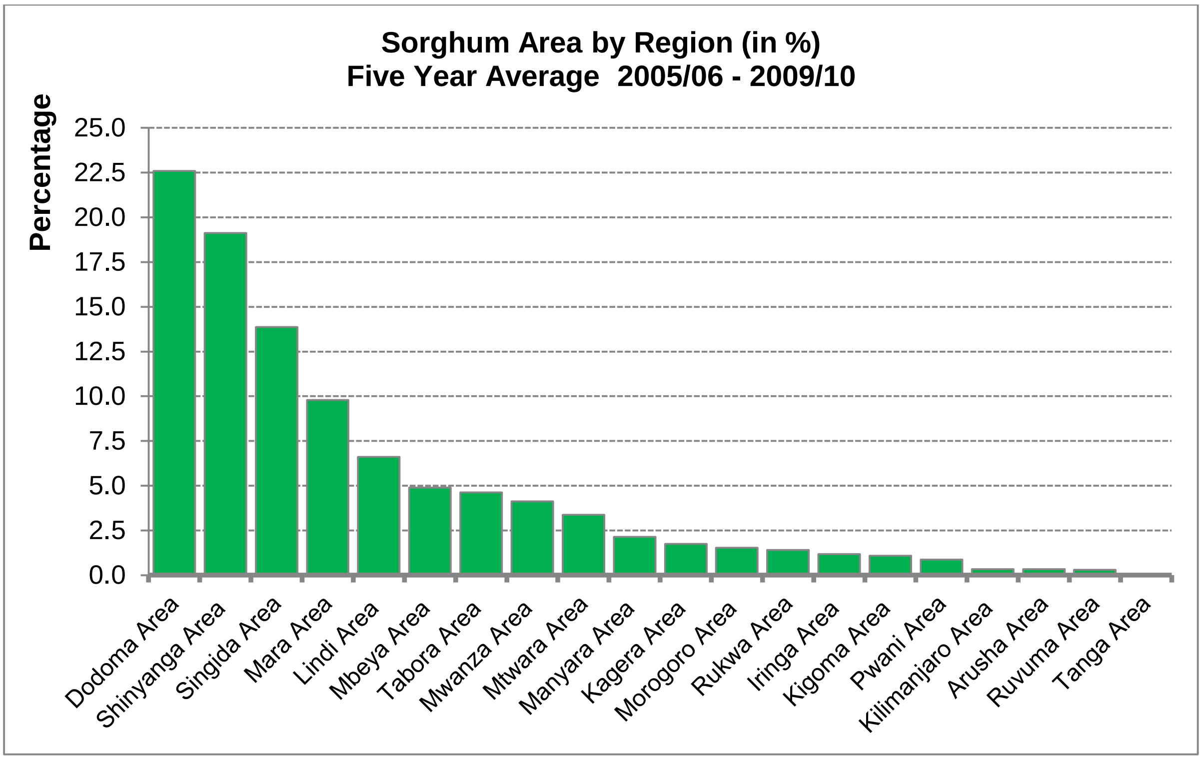


Table 5: Sorghum production by region

Regions	Sorghum Production ('000'tons)					5 year average (2005/06-2009/10)	
	2005/ 2006	2006/ 2007	2007/ 2008*	2008/ 2009	2009/ 2010	('000'tons)	%
National	**711.64**	**971.20**	**550.65**	**709.31**	**798.54**	**748.27**	**100.0**
Singida	124.73	157.03	111.96	137.47	97.04	125.65	16.8
Mara	57.92	109.86	92.69	61.86	256.16	115.70	15.5
Shinyanga	141.05	89.05	99.77	152.99	82.93	113.16	15.1
Dodoma	53.89	224.65	68.74	64.69	96.00	101.60	13.6
Mwanza	89.60	83.12	11.51	56.06	30.93	54.24	7.2
Mbeya	19.05	71.45	21.48	61.30	54.98	45.65	6.1
Lindi	38.03	58.23	26.71	50.52	37.51	42.20	5.6
Tabora	16.85	29.24	47.99	24.55	35.15	30.76	4.1
Mtwara	31.55	29.11	9.03	22.13	26.97	23.76	3.2
Manyara	41.59	38.43	7.78	10.17	6.41	20.88	2.8
Rukwa	17.15	11.15	8.08	25.57	25.98	17.58	2.3
Morogoro	14.41	17.67	9.18	13.07	10.69	13.00	1.7
Iringa	17.34	21.56	4.17	1.13	18.35	12.51	1.7
Kagera	0.00	14.70	17.00	8.86	4.80	9.07	1.2
Kigoma	6.23	7.00	7.93	9.72	4.56	7.09	0.9
Ruvuma	29.48	0.12	1.20	1.01	0.62	6.49	0.9
Pwani	5.50	4.15	2.67	4.46	4.07	4.17	0.6
Arusha	3.31	2.27	1.82	2.48	1.76	2.33	0.3
Kilimanjaro	3.52	2.28	0.05	0.63	2.95	1.88	0.3
Tanga	0.43	0.13	0.88	0.66	0.67	0.55	0.1

Source: own table. Data based on the National Sample Census of Agriculture: Small Holder Agriculture Volume II Crop Sector – National Report 2012

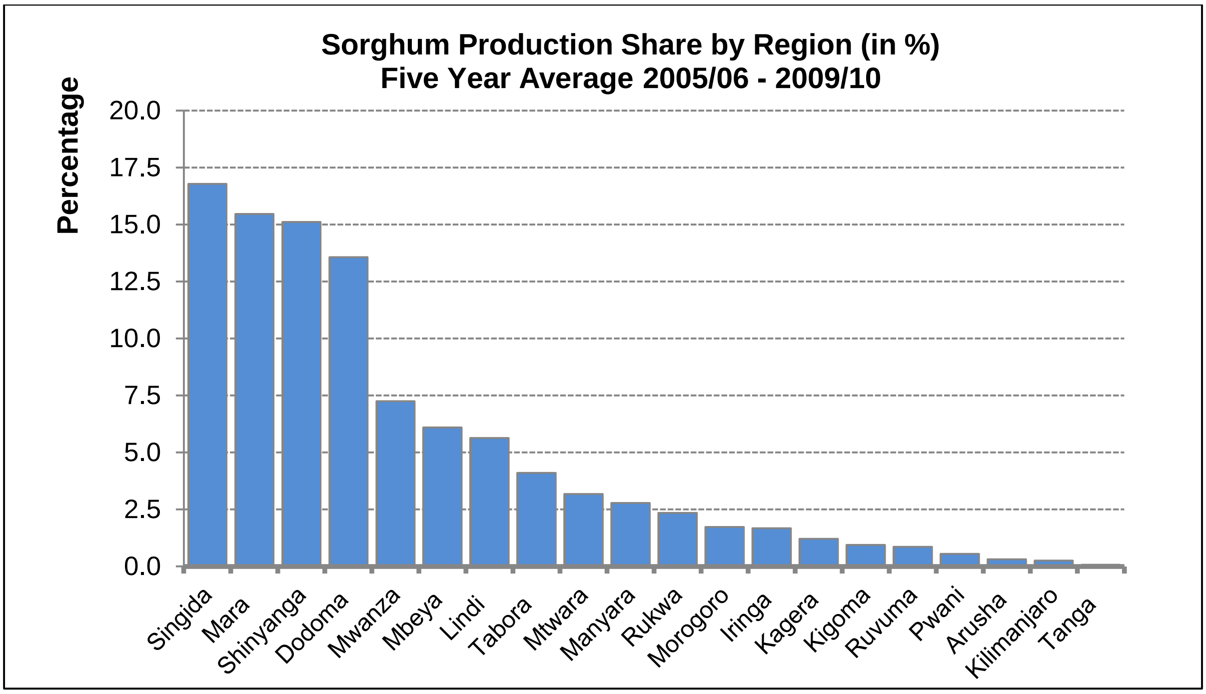
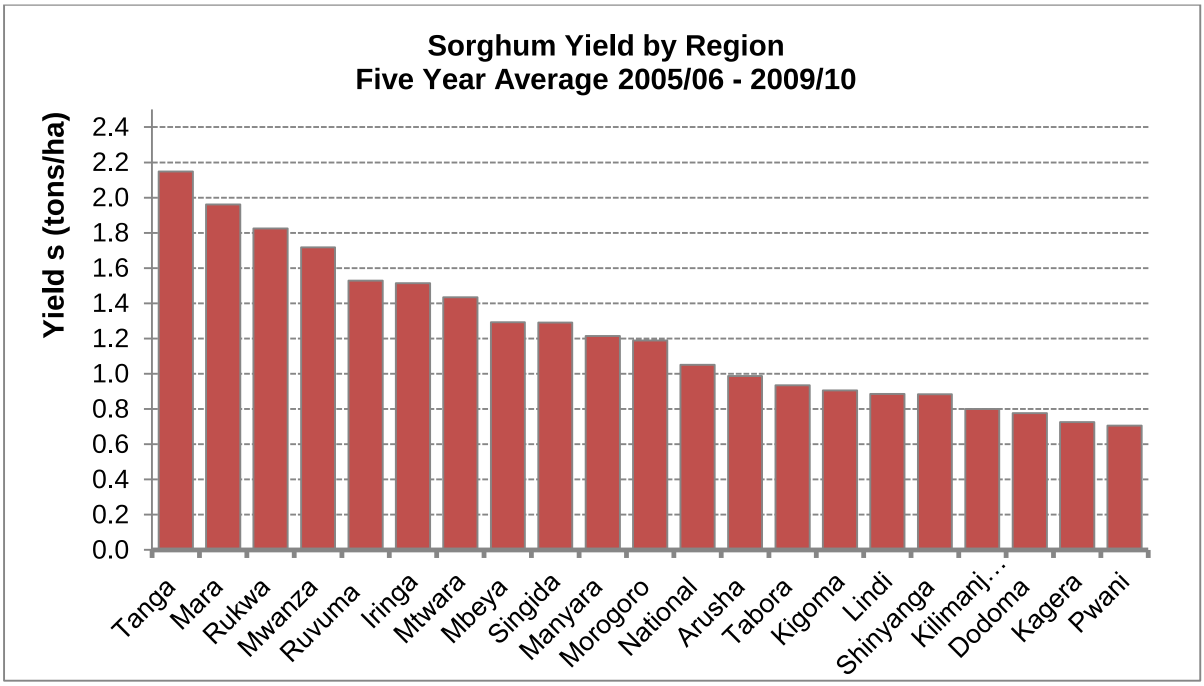


Table 6: Sorghum yields by region

Regions	Sorghum Yields (tons/ha)						
	2005/ 2006	2006/ 2007	2007/ 2008	2008/ 2009	2009/ 2010	5 year average 2005 - 2010	Variation (std. dev. in mt/ha)
Tanga	3.41	0.38	1.49	2.74	2.73	2.15	1.2
Mara	1.72	1.81	1.26	0.49	4.53	1.96	1.5
Rukwa	1.11	1.53	0.92	2.36	3.21	1.82	1.0
Mwanza	2.13	2.20	0.79	1.47	2.00	1.72	0.6
Ruvuma	5.57	0.39	0.57	0.54	0.57	1.53	2.3
Iringa	1.03	1.58	0.96	1.26	2.75	1.51	0.7
Mtwara	0.87	0.79	0.46	3.86	1.19	1.44	1.4
Mbeya	0.53	1.68	1.09	1.25	1.90	1.29	0.5
Singida	1.51	1.51	1.15	0.98	1.30	1.29	0.2
Manyara	1.72	1.50	0.93	0.77	1.16	1.21	0.4
Morogoro	1.16	1.63	0.80	1.32	1.03	1.19	0.3
National	0.99	1.19	0.97	0.81	1.29	1.05	0.2
Arusha	1.09	0.81	1.10	0.97	0.97	0.99	0.1
Tabora	0.80	0.96	1.05	0.60	1.26	0.93	0.3
Kigoma	0.90	0.94	0.95	0.92	0.82	0.91	0.1
Lindi	0.75	0.90	0.70	1.11	0.96	0.89	0.2
Shinyanga	1.09	0.43	1.02	0.90	0.97	0.88	0.3
Kilimanjaro	0.69	0.60	0.35	1.10	1.26	0.80	0.4
Dodoma	0.31	1.62	0.71	0.35	0.89	0.78	0.5
Kagera	0.00	0.74	1.28	0.75	0.86	0.73	0.5
Pwani	0.82	0.80	0.60	0.42	0.89	0.71	0.2

Source: own table. Data based on the National Sample Census of Agriculture: Small Holder Agriculture Volume II Crop Sector – National Report 2012



Sorghum utilization and consumption

Utilization balance of sorghum between 2000 and 2009 is outlined in Table 7. Production and domestic supply in most years are very similar as Tanzania imports and exports sorghum only on a small and erratic scale. If differences exit (year 2002, 2003) they come from Tanzania's food security and buffer stock policies in the past, adding part of the sorghum harvest to the strategic food reserve. Non-food utilization is made up of feed, seed and waste at the range of 20% of sorghum supply. This proportion remained fairly stable between 2000 and 2009. Food utilization distinguishes between food grain and food processing. The 'Food grain' category subsumes farmers' food storage for later consumption, while 'food processed' subsumes selling sorghum to local and central flour mills for further procession. The share of food grain and flour changed frequently from year to year.

Table 7: Sorghum utilization in Tanzania (2000 – 2009)

	Dom. Prod	Domestic Supply				Domestic Utilization						Ratio
						Non-Food Utilization			Food Supply	Food Utilization		Food Supply / Prod.
	Prod	Import	Export	Stock Var.	Supply	Feed	Seed	Waste		Food Grain	Food (Proc)	
	1	2	3	4	5 = 1-(2+3+4)	6	7	8	9 = 5-(6+7+8)			9/1
Unit	mt	mt	mt	mt	mt	mt	mt	mt	mt	mt	mt	
10 Y av.	*675,600*	*958*	*885*	*0*	*673,756*	*31,753*	*11,246*	*69,856*	*560,901*	*281,409*	*279,492*	*83.02*
2009	709,000	4,643	420	30,000	673,937	14,873	13,113	74,364	571,587	320,436	251,151	80.62
2008	861,386	2,100	4,089	40,000	815,197	18,070	13,113	90,349	693,665	388,933	304,732	80.53
2007	971,198	390	427	-70,000	1,040,381	19,432	13,469	97,159	910,321	385,551	524,770	93.73
2006	711,631	1,226	273	0	710,132	71,286	12,269	71,286	555,291	278,872	276,419	78.03
2005	729,740	20	1,814	0	727,906	72,976	13,350	72,976	568,604	284,322	284,282	77.92
2004	648,540	619	272	0	647,649	64,916	11,056	64,916	506,761	254,000	252,761	78.14
2003	198,870	296	299	150,000	48,275	17,458	10,458	34,917	-14,558	143,017	157,575	-7.32
2002	635,740	94	181	-150,000	785,465	12,717	6,744	63,583	702,421	201,305	501,116	110.49
2001	691,690	20	301	0	691,369	13,834	9,831	69,171	598,533	299,287	299,246	86.53
2000	598,200	173	776	0	597,251	11,967	9,060	59,837	516,387	258,366	258,021	86.32

Source: FAOSTAT

There are few sources that report in regard to cereal consumption and particularly of dryland cereals in Tanzania. ICRISAT conducted several studies which contain consumption information at a detailed level. Schipmann et al. (2012) in a baseline survey studied utilization and consumption of sorghum among sorghum growers. In another ICRISAT survey, Schipmann and Orr (2012) studied cereal consumption of non-producers in rural and urban areas and by different income strata. Selected results are outlined in Table 8. The most recent ICRISAT study on food consumption pattern in Tanzania was undertaken by Macharia et al. (2014). The data utilized in the latter study come from the 2007 Tanzania Household Budget Survey (HBS) with additional information extracted from the production statistics of the Agriculture Sample Census, 2007/08 and the National Bureau of Statistics (NBS) – Tanzania. Macharia et al. (2014) distinguish per capita cereal consumption by sorghum and non-sorghum regions, urban and rural and by different income strata.

Table 8: ICRISAT study on sorghum consumption

monthly consumption of selected cereals on a household level, N=439)							
Cereal	Total	Rural non-producer	Urban non-producer	Urban producer	Low income	Middle income	High income
Mean amount consumed (in kg)							
Maize	21.4	18.5	21.0	23.6	26.0	20.7	27.1
Wheat	6.5	5.6	7.5	4.7	8.6	7.0	8.6
Sorghum	6.9	6.5	5.8	15.8	5.5	5.8	7.6
Finger millet	7.8	11.0	8.2	3.0	5.1	5.2	5.5

Source: Schipmann and Orr 2012

IFPRI did a similar study in 2007 (Lisa and Subandoro 2007) within the framework of its research in food security using data from National Household Budget Surveys (HBS) to assess the level of food security and poverty rate (Table 9). The IFPRI study has the particular advantage over the sorghum impact study in that it indicates per capita consumption by region but does not differentiate further into income and rural/urban at the regional level. Per capita sorghum consumption at national level is 14.5 kg a year. With the most recent regional population census data from 2012, total consumption comes close to annual production, net of trade, waste and seed.

Table 9: IFPRI study on food consumption incl. sorghum by region (kg/capita/year)

	Maize	Wheat	Rice	Sorghum	Millet	Cassava	Sweet potatoes	Plantain/ Bananas	English potatoes
National	137.4	5.8	24.7	14.5	1.4	77.2	12.1	19.0	4.7
Rural areas	145.8	4.0	20.7	18.1	1.5	92.0	13.1	21.6	4.1
Urban areas	106.9	12.4	39.6	1.5	1.1	23.4	8.7	9.7	6.7
Dodoma	161.2	3.0	10.3	71.4	1.4	4.0	6.5	0.8	3.0
Arusha	143.0	8.9	15.8	1.0	1.8	3.6	5.5	16.3	8.4
Kilimanjaro	76.8	4.4	26.7	0.1	1.9	34.2	1.9	75.5	6.0
Tanga	136.3	8.7	16.5	0.4	0.2	90.8	7.7	20.1	8.2
Morogoro	130.1	5.3	51.3	1.7	0.4	23.2	6.8	20.7	2.4
Pwani	140.6	9.0	43.8	0.6	0.4	73.1	5.2	7.3	1.5
Dar es Salaam	65.9	15.5	45.4	0.1	0.5	7.5	3.5	5.1	5.4
Lindi	106.5	5.4	40.9	21.2	0.5	177.6	4.8	10.9	0.7
Mtwara	121.3	5.5	30.7	9.2	1.5	193.1	3.8	6.5	1.1
Ruvuma	151.9	3.3	28.4	3.9	2.8	206.8	18.1	5.6	1.5
Iringa	197.8	9.1	19.0	1.6	3.1	10.6	10.1	3.0	20.6
Mbeya	155.6	6.7	28.8	0.7	2.0	18.4	15.9	27.6	9.5
Singida	94.1	8.8	13.3	78.8	2.8	2.6	5.7	1.0	2.1
Tabora	233.0	4.4	29.3	5.1	1.1	37.0	14.9	2.1	0.6
Rukwa	210.5	1.9	8.2	3.2	2.3	110.7	7.1	1.9	3.2
Kigoma	122.9	2.5	14.7	2.9	2.1	145.5	23.3	15.8	2.4
Shinyanga	202.1	3.3	26.6	49.6	0.5	18.6	26.9	0.7	0.5
Kagera	64.4	1.6	9.4	4.5	1.6	109.5	20.9	115.9	5.8
Mwanza	144.0	3.6	24.0	6.8	0.9	195.6	20.9	1.4	0.7
Mara	71.1	3.5	12.2	28.0	2.1	284.8	20.4	5.1	1.0

Source: Smith and Subandoro 2007

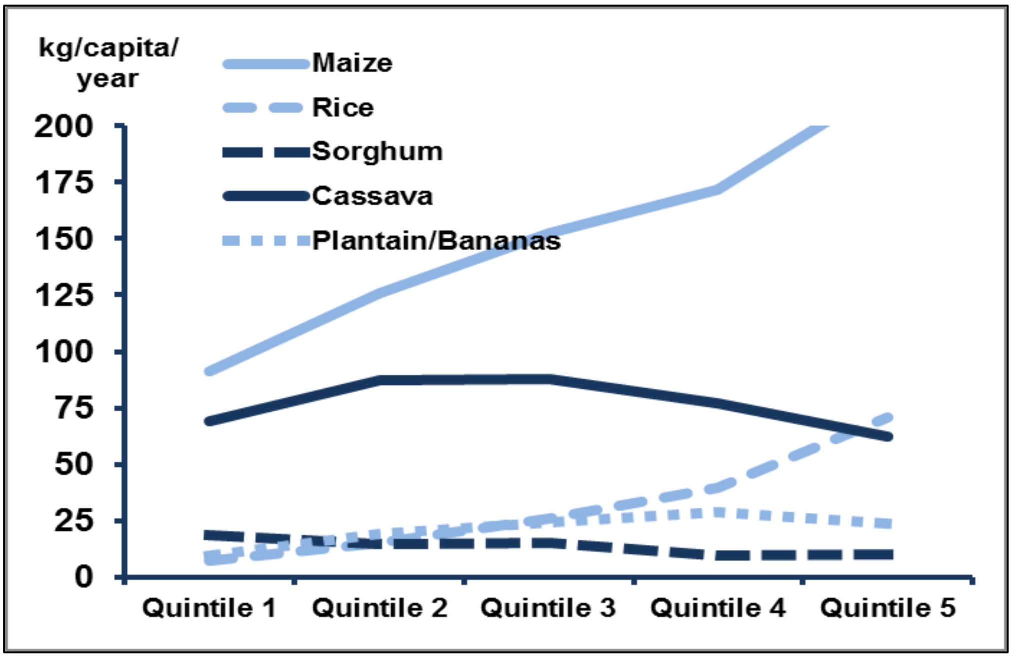
Sorghum consumption is highest in rural regions with 18 kg/capita/year and over ten times higher than consumption in urban areas which underlines the perception of sorghum as inferior and as the poor man’s crop and staple diet. Even in rural areas sorghum consumption is fairly uneven and highest in the three biggest producing areas Dodoma, Singida and Shinyanga. Consumption levels there are as high as 50 – 70 kg/capita/year. In less important sorghum regions the per capita consumption ranges between 10 – 30 kg/year. In all other rural regions and urban areas, sorghum is almost excluded from the dietary mix of food staples. A look at the other food staples such as Maize, rice, cassava and plantains underlines the fact that the local food basket in rural Tanzania is very much influenced by the predominant staple crops grown in that area and also gives proof to the high level of subsistence agriculture and limited trade of staple food across regions.

Sorghum consumption is unique compared to all other food staples in its sensitivity to household income and it is the only crop that has a negative income elasticity. Consumption in the lowest 20% income group (Quintile 1 in Table 10) amounts to 18 kg/capita/year and drops to only 10 kg in the highest 20% income group. Even plantain and maize that are in many countries considered inferior show increasing consumption within the higher income groups.

Table 10: Consumption of food staples by income group (kg per capita/year)

Increasing income level	Maize	Wheat	Rice	Sorghum	Millet	Cassava	Sweet potatoes	Plantain/ Bananas	English potatoes
Quintile 1	91.116	0.864	7.2	18.432	0.72	68.94	10.692	9.288	1.872
Quintile 2	125.82	2.232	15.084	14.508	1.152	86.976	11.808	19.332	3.528
Quintile 3	152.35	5.184	25.776	15.156	1.296	87.588	14.328	24.228	4.86
Quintile 4	171.72	9.288	39.78	9.36	2.304	77.076	14.364	28.98	6.732
Quintile 5	218.88	23.22	70.992	10.116	3.24	62.46	10.692	23.688	11.664

Source: Smith and Subandoro 2007



Production and consumption balance

With production and consumption know in each region it is possible to calculate the regions' status as surplus or deficit area and to assess the magnitude or interregional trade between surplus and deficit regions (Table 11). Surprisingly, the group of the seven largest sorghum producers end up as being sorghum deficient at a magnitude of around 50,000 mt. The reason is the high per capita consumption and consequently high deficits in Dodoma, Singida and Shinyanga that outweigh the surplus in the other regions of the same group. On contrary, all other minor sorghum regions have a small surplus of 37,000 mt. The capital Dar es Salaam and Zanzibar are insignificant in terms of production and consumption.

Table 11: Sorghum production and consumption balance by region

		Population/ Region	Production	Supply	Cons.	*Prod./ Capita*	*Supply/ Capita*	*Cons./ Capita*	Surplus/ Deficit
		2012	5y av. 2005-09	83.% of Prod					
	Unit	No.	000"mt	000"mt	000"mt	*kg*	*kg*	*kg*	000"mt
Major Sorghum Regions	Dodoma	2,083,588	102	85	149	48.8	40.6	71.4	-64.2
	Singida	1,370,637	126	105	108	91.7	76.4	78.8	-3.3
	Shinyanga	4,161,091	113	94	206	27.2	22.7	49.6	-112.2
	Mara	1,743,830	116	96	49	66.3	55.3	28.0	47.6
	Lindi	864,652	42	35	18	48.8	40.7	21.2	16.8
	Mbeya	2,707,410	46	38	2	16.9	14.0	0.7	36.1
	Tabora	2,291,623	31	26	12	13.4	11.2	5.1	14.0
	Mwanza	3,771,067	54	45	26	14.4	12.0	6.8	19.5
	Sub-Total	18,993,898	629	524	570	33.1	27.6	30.0	-45.7
Minor Sorghum Regions	Mtwara	1,270,854	24	20	12	18.7	15.6	9.2	8.1
	Manyara	1,425,131	21	17	13	14.6	12.2	9.0	4.6
	Kagera	2,458,023	9	8	11	3.7	3.1	4.5	-3.6
	Morogoro	2,218,492	13	11	4	5.9	4.9	1.7	7.0
	Iringa**	1,789,779	13	10	3	7.0	5.8	1.6	7.6
	Rukwa ***	1,615,098	18	15	5	10.9	9.1	3.2	9.5
	Kigoma	2,127,930	7	6	6	3.3	2.8	2.9	-0.3
	Pwani	1,098,668	4	3	1	3.8	3.2	0.6	2.8
	Kilimanjaro	1,640,087	2	2	0	1.1	1.0	0.1	1.5
	Arusha	1,694,310	2	2	2	1.4	1.1	1.0	0.3
	Ruvuma	1,376,891	6	5	5	4.7	3.9	3.9	0.0
	Tanga	2,045,205	1	0	1	0.3	0.2	0.4	-0.4
	Sub-total	20,760,468	119	99	62	5.7	4.8	3.0	37.0
Dar es Salaam/Zanzibar	Dar es Salaam	4,364,541			0			0.1	-0.1
	Pemba North	211,732			0			0.1	0.0
	Pemba South	195,116			0			0.1	0.0
	Zanzibar	1,303,569			0			0.1	-0.1
	Sub-total	6,074,958	0	0	0	0.0	0.0	0.1	-0.4
	National	45,829,324	748	623	632	16.3	13.6	13.8	-9.1

Source: own Table

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 market values. However, based on the production and consumption balance as reported in Table 11 it is possible to estimate the share of sorghum that is traded across regions.

The trade matrix in Table 12 captures the extent of sorghum trade between regions from the producer and consumer side. In the surplus regions around 47 % of production is consumed in the region of origin and 52 % of sorghum is sold to markets in other regions. In the sorghum deficit regions, around 38 % of the consumption is sourced from other regions while the majority of 62 % comes from local supply. Assuming that all production in the deficit regions stays in the region, the share of national production that is traded across regional borders is around 28 %. On the other hand, the share of national consumption that is sourced from other regions is close to 29 %.

Table 12: Sub-regional trade matrix for sorghum in Tanzania (based on food use)

All numbers 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	**47.03**	**52.97**		
Major sorghum regions			%	
Mara	50.61	49.39		
Lindi	52.07	47.93		
Mbeya	5.13	94.87		
Tabora	45.40	54.60		
Mwanza	56.79	43.21		
Minor sorghum regions				
Mtwara	58.95	41.05		
Manyara	73.76	26.24		
Morogoro	35.39	64.61		
Iringa**	27.20	72.80		
Rukwa ***	34.93	65.07		
Pwani	20.50	79.50		
Kilimanjaro	7.53	92.47		
Arusha	84.92	15.08		
Ruvuma	99.09	0.91		
Deficit regions			**61.73**	**38.27**
Dodoma	%		56.87	43.13
Singida			96.90	3.10
Shinyanga			45.66	54.34
Kagera			67.78	32.22
Kigoma			95.14	4.86
Tanga			52.31	47.69
Dar es Salaam/Zanzibar			0.00	100.00
Total Tanzania	Production share	**27.91**	Consumption share	**28.92**

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

Sorghum prices

Food price indices based on the National Panel Survey (NPS) are shown in Table 13. Rural areas are less expensive than the national average, while urban areas are more expensive. Across strata, Dar es Salaam is the most expensive stratum. Other urban areas in Mainland and Zanzibar are fairly similar in terms of the cost of living, while rural areas in Mainland constitute the least expensive stratum. Overall, spatial price differences have remained approximately constant in each round of the NPS in 2008/09 and 2010/11. However, food prices have increased 22 percent between the NPS 2008/09 and the NPS 2010/11. Rural areas experienced higher inflation than urban areas.

Table 13: Spatial and temporal food prices in Tanzania

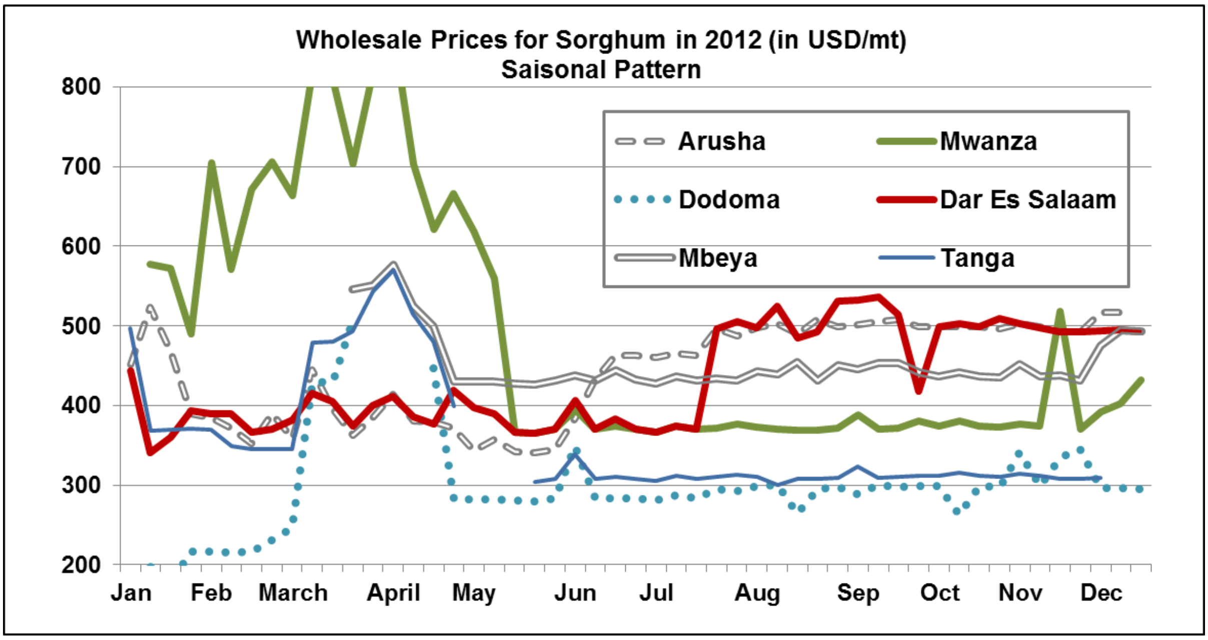
Area	Differences in the cost of living in each round (Spatial price indices)		Increase in the cost of living between rounds
	NPS 2008/09	NPS 2010/11	Inflation between NPS 2008/09 and the NPS 2010/11
Tanzania	100	100	22
Rural	93	93	24
Urban	112	109	17
Mainland	100	100	22
Dar es Salaam	116	114	20
Other urban	102	102	19
Rural	93	93	22
Zanzibar	105	103	23

Source: NPS 2008/09; NPS 2010/11

Regarding the relationship between international and domestic prices Delgado et al. (2005) discovered that price connectivity increases with the tradability of the commodity on the international markets. Rice prices in all local markets are connected to the international rice price with a 20-40% transmission, though local prices are also influenced by the size of the local harvest. In contrast, cassava prices in all local markets are not connected to the international prices of rice, wheat, and maize, but are connected to local cassava production. Maize is in an intermediate position, its prices being influenced by the size of the harvest in all markets and by international prices only in the well-connected markets (Minot 2010). Based on this pattern, price determinants for sorghum seem to be solely the domestic production and to a lesser extend the price of maize via cross-price elasticity.

Figure 2 and Table 14 show weekly wholesale prices for sorghum in different market places gathered from Ratin Net. Compared to Uganda (previous study) average prices are somewhat slightly higher than in Uganda. In Dodoma, Tanga and other producing areas, prices are lower than in the capital Dar es Salaam or other rural market places with minor sorghum production like Arusha or Mbeya (Table xxx). Prices show a seasonal pattern with price spikes in the pre harvest season between January and April (uni-modal regions). After harvest prices drop and stabilise at a much lower level for the second half of the year.

Figure 2: Sorghum prices in local markets



Source: own figure, based on price data from Ratin Net. Weekly wholesale prices for selected regional markets in USD/tons converted from TSh/ 90kg bag at an exchange rate of TSh/USD in Feb 2014 of 1,620 TSh/USD.

Table 14: Sorghum prices in Tanzania, 2012 (USD/mt): selected statistics

	Songea	Iringa	Arusha	Mwanza	Dodoma	Morogoro	Tanga	Dar Es Salaam	Mbeya
No. Of observations	14	14	50	50	47	48	46	51	41
2012 average	271	161	444	487	295	464	355	435	456
Minimum	228	0	341	365	177	335	301	341	426
Maximum	498	485	523	873	506	680	570	536	576
Std. Dev.	70	161	62	157	61	77	75	62	39

Source: own calculation, based on Ratin Net price data

Adoption of modern technologies and profitability

There are a multitude of field studies??? that examine the type of seed sorghum farmers use in the field. Over the years ICRISAT conducted a series of baseline, adoption and impact surveys that looked at the spread of improved technologies such as use of fertilizer, modern seeds and pesticides as major components in famers' crop management choices. Another source is the Tanzanian agricultural census published on an annual base but in different formats and content. In general, the Tanzanian agricultural census together with the crop reports present crop management information at depth, but remain vague on the type of technologies and do not differentiate in the seed section between individual improved varieties.

In its 2012 report, the National Sample Census of Agriculture in Tanzania indicates a low adoption rate of improved sorghum varieties in the short rains season of 3% (of households) 5 % (of area), and 7 % in the long rain season, both in terms of area and percentage of households. ICRISAT's research found much higher adoption rate for improved sorghum varieties. An early study conducted in 2001 by Monyo et al. (2004) counted the sorghum area under improved varieties as 36% of the total area and 48% in terms of farmers (Table 15).

Table 15: Adoption rates from the ICRISAT study (Monyo et al. 2004)

Area ('000') planted to improved sorghum varieties by region, based on 2001 adoption survey

	Dodoma	Singida	Shinyanga	Mwanza	Other major prod. areas	Other minor prod. areas	Total	% area under impr. variety
Planted area	97	60	121	73	158	165	674	
Improved area	46	18	50	37	53	40	244	**36.20**
Local Varieties	51	42	71	36	105	115	420	

Percentage of farmers planting improved sorghum varieties, 2000/01 season

2000/01	Dodoma	Singida	Tabora	Shinyanga	Mwanza	Mara	Lindi	Mtwara	Arusha	Weighted average
Serena	10.0	12.9	37.5	34.4	30.0	11.8	0.0	0.0	0.0	15.7
Lulu	10.0	0.0	0.0	0.0	24.0	0.0	0.0	0.0	0.0	4.6
Pato	70.0	35.5	37.5	53.1	12.0	0.0	3.0	3.1	0.0	27.6
Tegemeo	37.5	12.9	0.0	9.4	14.0	0.0	0.0	0.0	18.0	11.0
Macia	12.5	0.0	6.3	3.1	0.0	0.0	0.0	0.0	0.0	2.8
Total Impr. V.	**52.5**	16.1	18.7	**46.9**	**62.0**	10.0	0.0	6.2	18.7	**48.4**
Local varieties	47.5	83.9	81.3	53.1	38.0	90.0	100	93.8	81.3	51.6

Source: Monyo et al. 2004

Makindara et al. (2012) conducted a value chain study for sorghum beer in Singida region, an important worksite for ICRISAT's sorghum breeding program. He discovered high adoption rates for improved varieties as high as 52%, for mixed varieties (local and improved) at 18% and around 30% of local varieties. Fredy et al. (2006) reported a similarly high rate of adoption from a study conducted in 2006, indicating adoption for sorghum (59%), even higher than for improved maize varieties (37%).

A quite different finding is reported from the ICRISAT baseline survey conducted in the 'Singida rural' and 'Kondoa' districts of the Singida region (Schipmann et al. 2012). Adoption rates were found much lower: on average only 27 % and 11% in Singida rural and 42 % in Kondoa districts which show that the spread of improved varieties can vary considerably within a single region. In light of the scattered picture in adoption rates, Mausch et al. (2012) analysed the reliability and consistency of adoption information dependent on the type of investigation (ICRISAT DIVA report), namely expert panel discussions, community focus groups and household surveys from Tanzania.

Table 16: Comparing adoption rates by type of survey/investigation (DIVA report)

	By Region			By Variety		
Region	Community Group Discussion	Expert Panel	Household Survey (n=1622)	**Variety**	Expert Panel	Household Survey (n=1622)
Arusha	2.5%	1-5%	0.0%	Macia	20.8%	15.9%
Dodoma	23.0%	50-70%	60.2%	Tegemeo	8.1%	5.1%
Manyara	7.5%	20-50%	45.2%	Wahi	7.1%	1.8%
Shinyanga	55.0%	50-70%	70.2%	Hakika	6.2%	0.3%
Singida	12.8%	50-70%	8.5%	Sila	0.0%	0.1%
Tabora	26.8%	10-20%	28.3%	Others		15.5%
Total	32.4%	42.3%	43.6%	All MVs	42.3%	38.7%
				Local	57.7%	61.3%

Source: Mausch et al. (2012)

Results show a tolerable range of adoption estimations across all types of data inquiry.at aggregate level. Adoption levels by variety match well between expert panels and household surveys. However, location specific adoption seems to be cumbersome and exhibits large variability depending on the source.

Another interesting observation is the adoption process which does not work out as a linear and consistent process but is rather fuzzy in nature as farmers are innovative and flexible in their choice of the type of sorghum seed from year to year. Evidence from the Singida region in Tanzania suggests a high degree of farmers exchanging varieties among each other, testing them in the fields for one season and then deciding whether to continue or skip for other varieties (Table 17). This may inflict high variation in the variety mix of farmers in certain regions and across years, mislabelling of local versus improved varieties and may explain in the end the inconsistency found in the adoption literature Even the well-known improved varieties such as Macia, Pato and Tegemeo are affected by farmers’ choice not to replant them in the season 2010. This happened not as an incidence from few farmers but at large scale between 50 and 100% of all farmers who ever planted those varieties in the past. Another conclusive explanation is simply the non-availability of seed that forces farmers to resort to other varieties from year to year.

Information regarding profitability of improved versus local varieties at farmers’ level is less abundant than adoption rates. Schipmann et al. (2012) examined the profitability of sorghum in ICRISAT and DRD major domain regions. Partial budgets and gross margin of improved varieties (141,371 TSh) indicate a minor advantage over local varieties (111,100 TSh) in Singida and no difference when Singida and Kondoa are combined (Table 18). The reason for the poor performance of improved varieties is the disappointing yields of only 486 kg/ha. It is not known what causes the low yield in the planting season of 2009/10 and in what ways this season deviates from a normal planting season.

Table 17: Farmers seed change from improved to local varieties

	Total (Singida & Kondoa)		Abandoned in %	Singida		
Improved Variety	ever planted	planted in 2009/10	abandoned (not planted in 2009/10 but before) in %	ever planted	planted in 2009/10	abandoned (not planted in 2009/10 but before) in %
Pato	76	20	74	65	4	94
Macia	84	38	55	69	3	96
Tegemeo	67	6	91	56	1	98
Serena	3	6	-100	57	6	89
Sila	100	6	94	-	-	
Lulu	100	0	100	100	-	

Source: Schipmann et al. 2012

Table 18: Partial budget for improved and local sorghum varieties TSh/ha (2009 - 10)

	Total (Singida & Kondoa)				Singida			
Revenues and costs (TSh/ha)	Local	Improved	Net gains	Change (%)	Local	Improved	Net gains	Change (%)
Yield (kg/ha)	451	486	35	7.76	493	682	189	38.34
Price (TSh/kg)	239	211	-28	-11.72	251	211	-40	-15.94
Revenues	107,789	102,546	-5,243	-4.86	123,743	143,902	20,159	16.29
Material costs			0				0	
Seed	3,799	3,645	-154	-4.05	3,993	2,531	-1,462	-36.61
Fertiliser	0	0	0		8,650	0	-8,650	
Manure	4,690	11	-4,679	-99.77	0	0	0	
Pesticides	0	0	0		0	0	0	
Sub-total	8,489	3,655	-4,834	-56.94	12,643	2,531	-10,112	-79.98
Labour			0				0	
Family	207	207	0	0.00	217	217	0	0.00
Hired	26	26	0	0.00	17	17	0	0.00
Total	234	234	0	0.00	234	234	0	0.00
Gross Margin	**99,300**	**98,891**	**-409**	**-0.41**	**111,100**	**141,371**	**30,271**	**27.25**

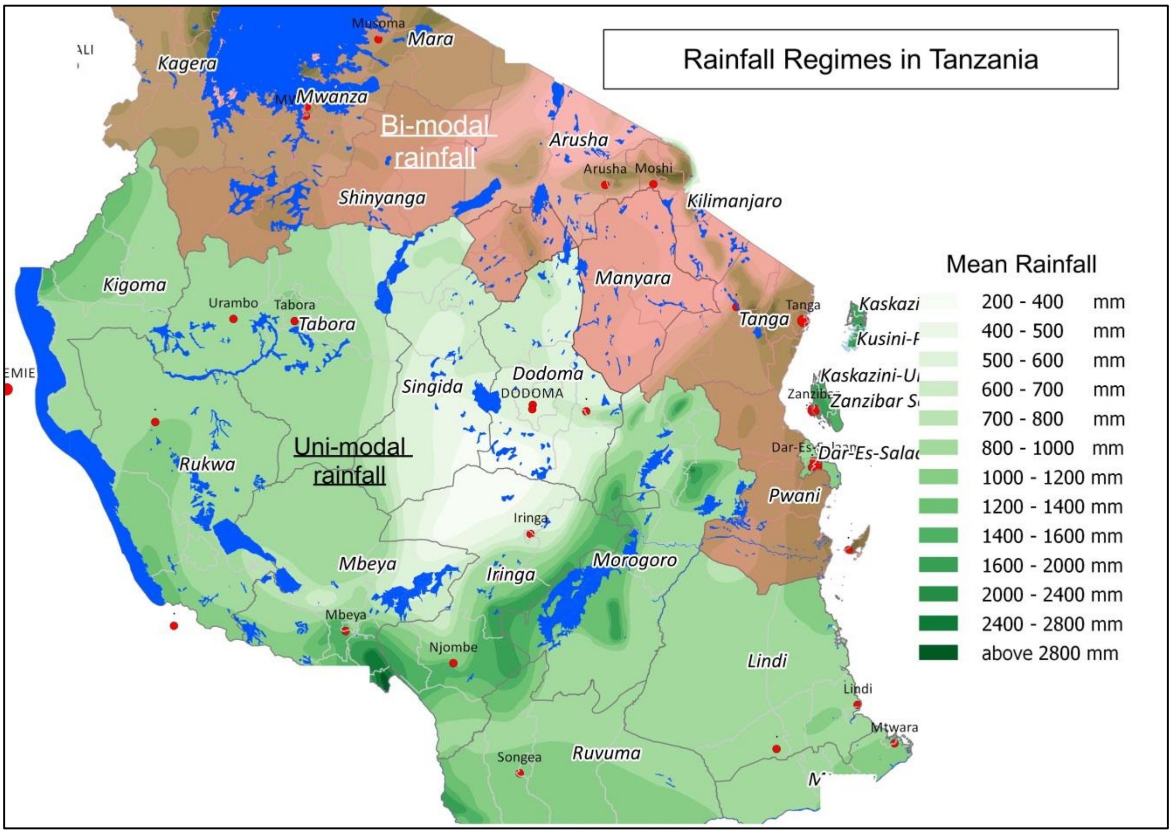
Source: Schipmann et al. 2012

2.3. Seasonal Calendar and Sorghum Management

The climate of Tanzania varies from tropical, high humidity conditions along the coast to lower rainfall (<500mm), semi-arid conditions in the Central region, and high rainfall areas (>2000mms/ year) in the mountains of the northeast and southwest. The mean annual rainfall varies from 320mm to 2400mm, with about half the country receiving less than 750 mms of rain annually. Any spatial impact analysis of Tanzania must consider the country's dual rainfall regimes (CFSVA Tanzania, 2012). These regimes divide the country into two large areas known as the unimodal and bimodal zones (Map 4). Tanzania's unimodal zone, covering the country's south, central and west, experiences one long rainy season from December to April. The bimodal zone – Tanzania's north, east, northern coast and north western - experiences a 'short rains' period from October to December and a 'long rains' period from March to May.

The cropping calendar for sorghum varies depending on whether households experience bimodal or unimodal rainfall regimes (see Figures 3 and 4). Households in unimodal areas experience one cropping season, beginning with pre-planting and land preparation activities in September and October, followed by planting in November and December. Harvesting begins in May and continues until August. Marketing activities largely overlap with harvesting, but extend for two months after the harvest ends.

Map 4: Rainfall regimes in Tanzania: unimodal and bimodal rainfall pattern



Source: own map, based on data from the CFSVA Tanzania, 2012

Households in bimodal areas, on the other hand, experience two cropping seasons. Pre-planting and land preparation for the Masika season begin in mid January and continue until mid March. Planting occurs thereafter (mid March to mid May), with harvesting beginning in July and continuing to September. Marketing of this harvest largely corresponds with the harvesting season itself. Pre-planting and land preparation activities for the Vuli season begin in September, one month before the rains usually begin. Planting then begins in October and continues through November. Harvesting starts in mid January and ends mid march. Marketing of this crop starts in mid February and runs to the end of March. Land preparation activities, harvests from the previous season and marketing of previous season harvest all occur at the same time in the bimodal areas of the country. Therefore, mid January to the end of March and July to the end of September are highly labour-intensive periods for farmers in these areas.

Figure 3: Sorghum management by region

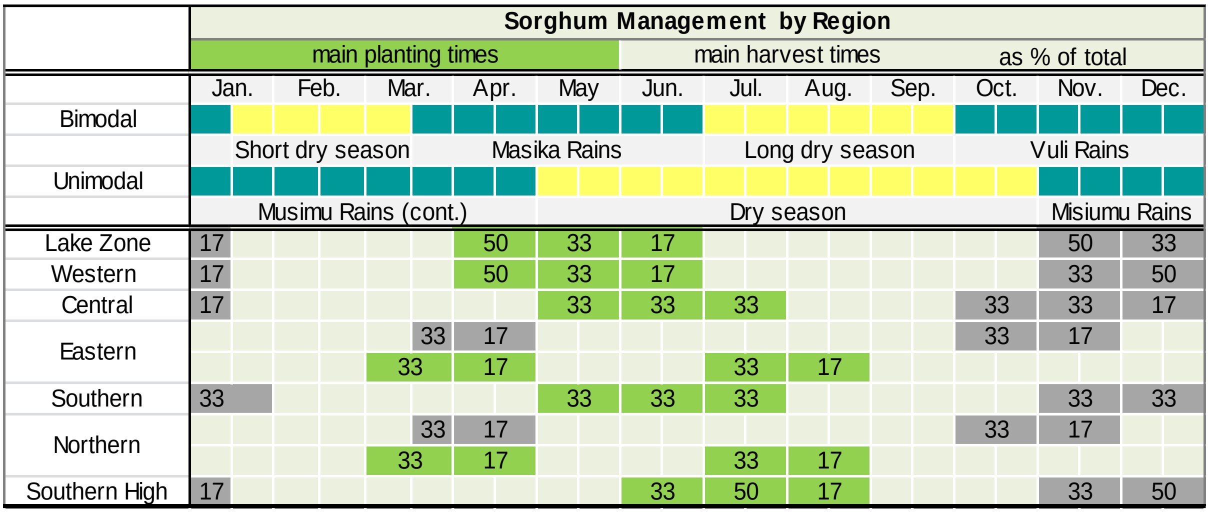
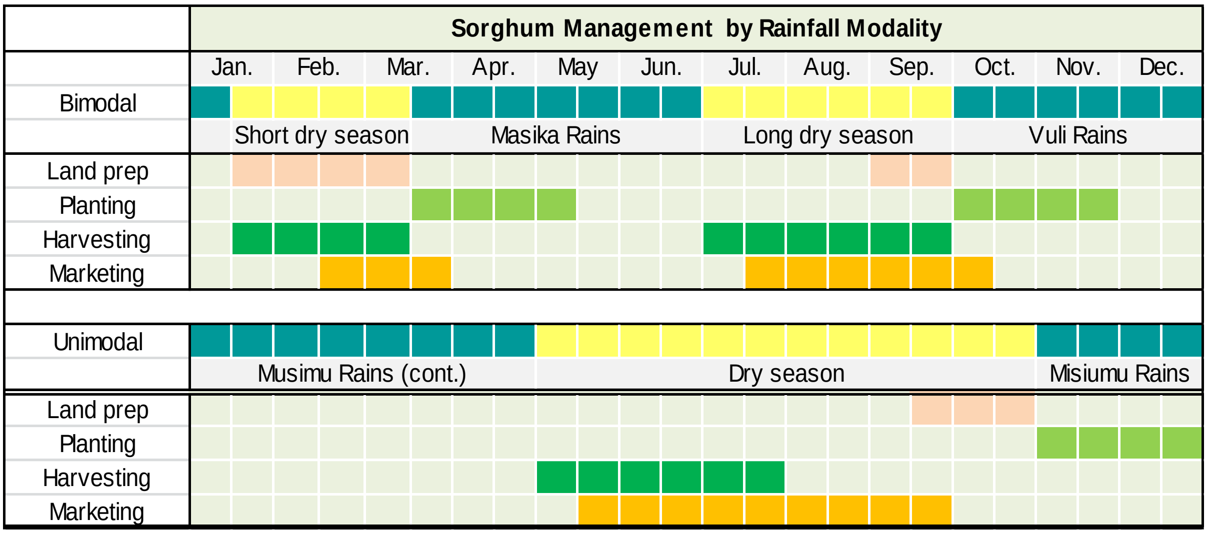


Figure 4: Sorghum management by rainfall modality



Source: Atlas of Sorghum, 2009

Areas with bimodal rainfall regime are largely confined to the northern regions of the country, from coastal regions of Pwani and Dar es Salaam to Kagera on the western shore of Lake Victoria. Overall 60-70 percent of all cereal is believed to be grown in the regions of the country with unimodal rainfall, which makes the food availability situation of the country highly dependent on the timeliness and adequacy of the Musimu rains.

Sorghum grown during the short rainy season in the bimodal regions is only around 12 % compared to the sorghum area in the long rainy season in the uni-modal regions. There are three different cropping pattern from Table 19: regions where sorghum is exclusively grown during the long rain (Iringa, Mbeya, Singida, Tabora and Rukwa), regions with long rain and miscellaneous short rain production (Shinyanga, Manyara, Lindi, Tanga, Dodoma), and regions with considerable short and long rain production shares (Kagera, Mwanza, Mara, Kigoma, Morogoro).

Table 19: Sorghum cultivation in the short and long rainy season

Regions	Short rainy season					Long rainy Season				
	No. of HH	Area	Area in % of S&L	Prod.	Yields	No. of HH	Area	Area in % of S&L	Prod	Yields
Unit	HH	ha	%	mt	mt/ha	No. HH	ha	%	mt	mt/ha
Dodoma	142	115	0.12	58	0.50	115,694	96,032	99.88	68,682	0.72
Arusha						4,157	1,658	100.00	1,825	1.10
Kilimanjaro	140	46	34.85	9	0.20	635	86	65.15	37	0.43
Tanga	232	56	9.46	46	0.82	364	536	90.54	834	1.56
Morogoro	7,869	4,004	34.73	2,668	0.67	15,150	7,526	65.27	6,513	0.87
Pwani	2,388	774	17.39	554	0.72	8,062	3,678	82.61	2,114	0.57
Dar es Salaam						37	3	100.00	4	1.33
Lindi	181	48	0.13	32	0.67	71,946	37,975	99.87	26,675	0.70
Mtwara						60,428	19,610	100.00	9,035	0.46
Ruvuma	132	21	1.00	9	0.43	7,988	2,069	99.00	1,191	0.58
Iringa						6,733	4,365	100.00	4,169	0.96
Mbeya						24,308	19,646	100.00	21,480	1.09
Singida						108,206	97,513	100.00	111,959	1.15
Tabora						34,390	45,837	100.00	47,994	1.05
Rukwa						9,031	8,784	100.00	8,079	0.92
Kigoma	19,514	6,704	80.04	6,320	0.94	4,093	1,672	19.96	1,615	0.97
Shinyanga	685	403	0.41	211	0.52	82,569	97,742	99.59	99,558	1.02
Kagera	14,608	4,051	30.64	4,927	1.22	24,263	9,171	69.36	12,074	1.32
Mwanza	21,760	12,142	82.99	9,820	0.81	5,404	2,488	17.01	1,690	0.68
Mara	76,770	40,647	55.22	51,642	1.27	63,242	32,968	44.78	41,052	1.25
Manyara	57	46	0.55	160	3.48	15,627	8,313	99.45	7,619	0.92
Mainland	**144,478**	**69,057**	**12.19**	**76,456**	**1.22**	**662,327**	**497,672**	**87.81**	**474,199**	**0.95**
Zanzibar	1,951	414	21.54	270	0.65	6,775	1,508	78.46	1,429	0.95
National	146,429	69,471	12.22	76,726	1.10	669,102	499,180	87.78	475,628	0.95

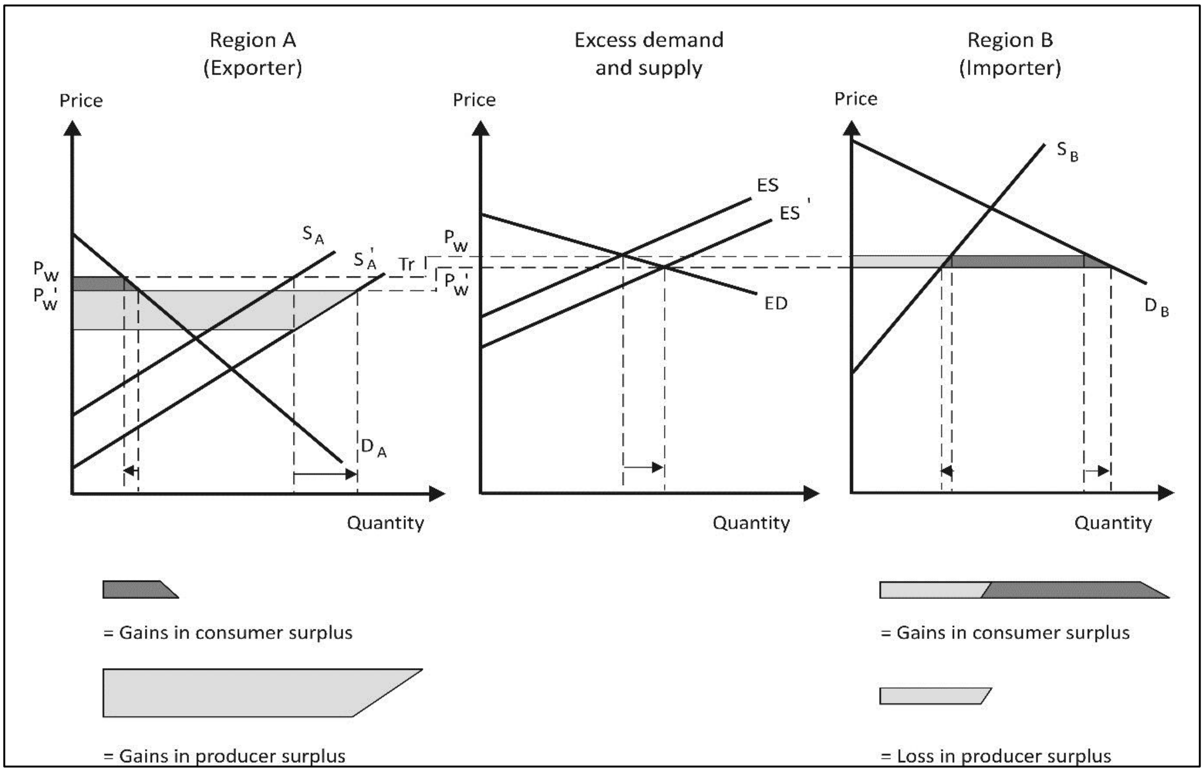
Source: National Sample Census of Agriculture, Small holder agriculture. Vol II, Crop Sector-National Report MoA April 2012

3. Research Impact Assessment: Analytical Framework and Data Elicitation

3.1. 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 Tanzanian 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-region market 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 5. 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 5: 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 Tanzanian sorghum markets 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 from a closed economy to an open market economy.
- Regional markets are fully interlinked via price spill-over effects. Sorghum is 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 assessment), 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.

3.2. 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 rates and profitability. The experts at the workshop in Tanzania choose regions as the appropriate level but made some simplifications by grouping regions with similar impact conditions. 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 households using an improved variety, or share in areas cultivated. In an impact study 'adoption rate' should always refer to the share of production as modelling based impact assessment relies on a market framework with prices and quantities as market 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 as 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 20.

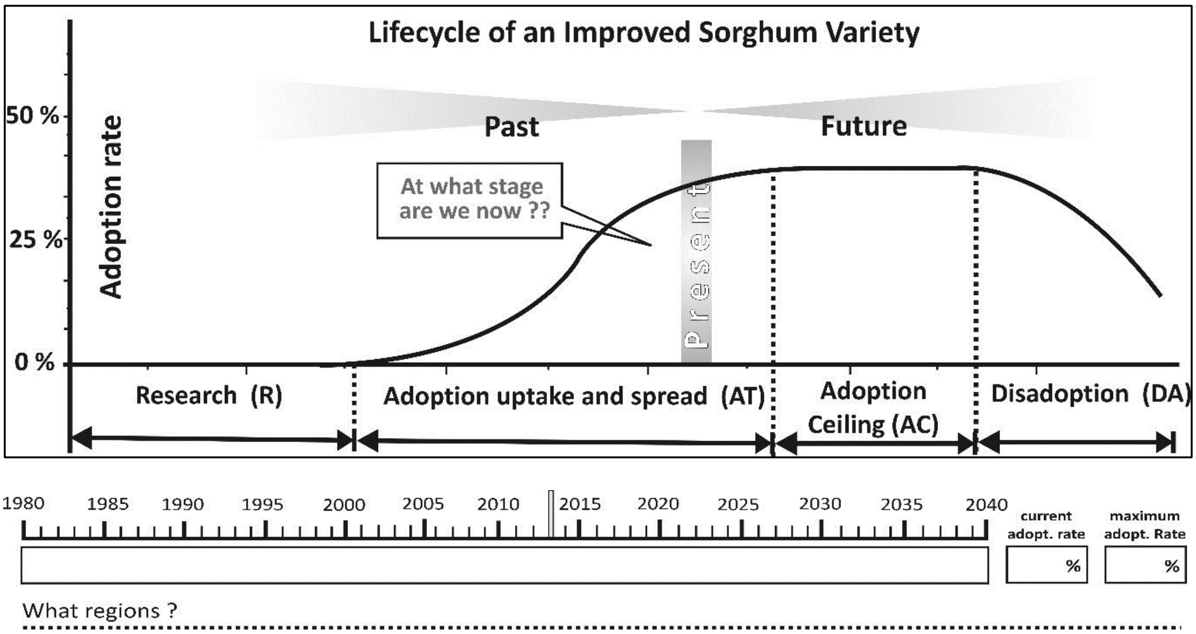
Table 20: Data sheet for current and future adoption rates

current adoption rates						
			Variety			
Zone (sub-region)	Cumulative rate (target)	Sum of Individual rates	Macia	Wahi	Hakika	Pato
Dodoma	18	18	5	6	3	4
Singida	14	14	3	3	2	6
future adoption rates (10 years ahead)						
Dodoma	25	25	7	7	5	6
Singida	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 6. 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 6: Adoption information by variety



Source: own diagram.

7. Incremental profitability of improved over local varieties

Profitability is the second shift parameter that' 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 21 showcases a fictive example from Tanzania with a representative local variety that serves as benchmark to measure and compare the profitability of all improved varieties in that region (Dodoma). 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 is a labour intensive crop enough attention should be given to the proper assessment and costing of family and hired labour. 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 21: Partial budget template for profitability comparison of improved varieties

Dodoma		Local variety	Improved variety		Percentage increase over local variety	
	Unit		Macia	Wahi	Macia	Wahi
Yield	kg/ha	600	1,200	1,100	DREAM model '% revenue shifts'	
Price	USD/mt	250	260	260		
Revenues	USD/ha	150	312	286	**108.00**	**90.67**
Labour costs	USD/ha	60	70	70	DREAM model % 'cost shifts'	
Other costs	USD/ha	40	60	55		
Total costs	USD/ha	100	130	125	**20.00**	**16.67**
Gross margin	USD/ha	50	182	161		

*fictive numbers Source: own table

Assessment of adoption rates and profitability can run in parallel whenever 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 the percentage revenue changes in the ‘DREAM’ model. Calculating the percentage cost increase (decrease) must be done by discounting the differences the value differences between revenues and costs.

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 from the records.

The approach used in this study is a simple sheet that accounts for the costs of the breeding program at an annual base, see Table 22. 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 22: Research budget template for sorghum

Cost item	USD/year
1. Casual Labour	22,600
2.Salaries-Scientist	42,900
(I breeder. 0.1 Socio Economist, 0.4 agronomist, 0.5 entomology, 0.4 pathology, 0.1)	
3. Technicians	18,800
Human resource costs	84,300
4. Field and laboratory supplies	25,000
5. Office supplies	5,000
6. Vehicle	8,700
7. Vehicle maintenance/operation	3,000
Sub-total	41,700
8. Domestic Travel	17,000
9. International Travel	11,250
9. Meeting and training costs	16,000
Sub-total travel/training	44,250
10. Communications	3,000
11. Equipment	2,600
12. Statutory Variety Release	1000
13. Overheads	17,685
Total	**194,535**
Source: data from the workshop in Arusha	

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 23: 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	16.0	12.7	6.2	12.1	10.3	7.0	7.3	5.0	4.7	5.3	5.3
Deflated research costs	194,535	167,703	148,819	140,122	124,950	113,312	105,869	98,712	93,984	89,730	85,209
Year	**2001**	**2000**	**1999**	**1998**	**1997**	**1996**	**1995**	**1994**	**1993**	**1992**	**1991**
Inflation rate	5.1	5.9	7.9	12.8	16.1	21.0	27.4	34.1	25.2	21.9	28.7
Deflated research costs	80,905	76,946	72,642	67,332	59,691	51,419	42,506	33,355	24,876	19,861	16,297
Year	**1990**	**1989**	**1988**	**1987**	**1986**	**1985**	**1984**	**1983**	**1982**	**1981**	**1980**
Inflation rate	35.9	25.9	31.1	30.0	32.5	33.3	36.1	27.1	28.6	25.8	30.9
Deflated research costs	12,665	12,665	12,665	12,665	12,665	12,665	12,665	12,665	12,665	12,665	12,665

Source: http://www.indexmundi.com/facts/tanzania/consumer-price-index, based on data from the International Monetary Fund, International Financial Statistics 2013 World Economic Outlook

Table 23 shows inflation rates and the annual deflated research budget for Tanzania between 1980 and 2012. Between 1980 and 1990 the country experienced a period of elevated inflation with rates above 30% annually which would have eroded the budget and brought down close to zero. Therefore, the budget during that period was kept flat at around 12,665 USD/year.

Each variety in the list is then allocated an equal share from the annual budget. Costs that were 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.

4. Impact Analysis for Sorghum

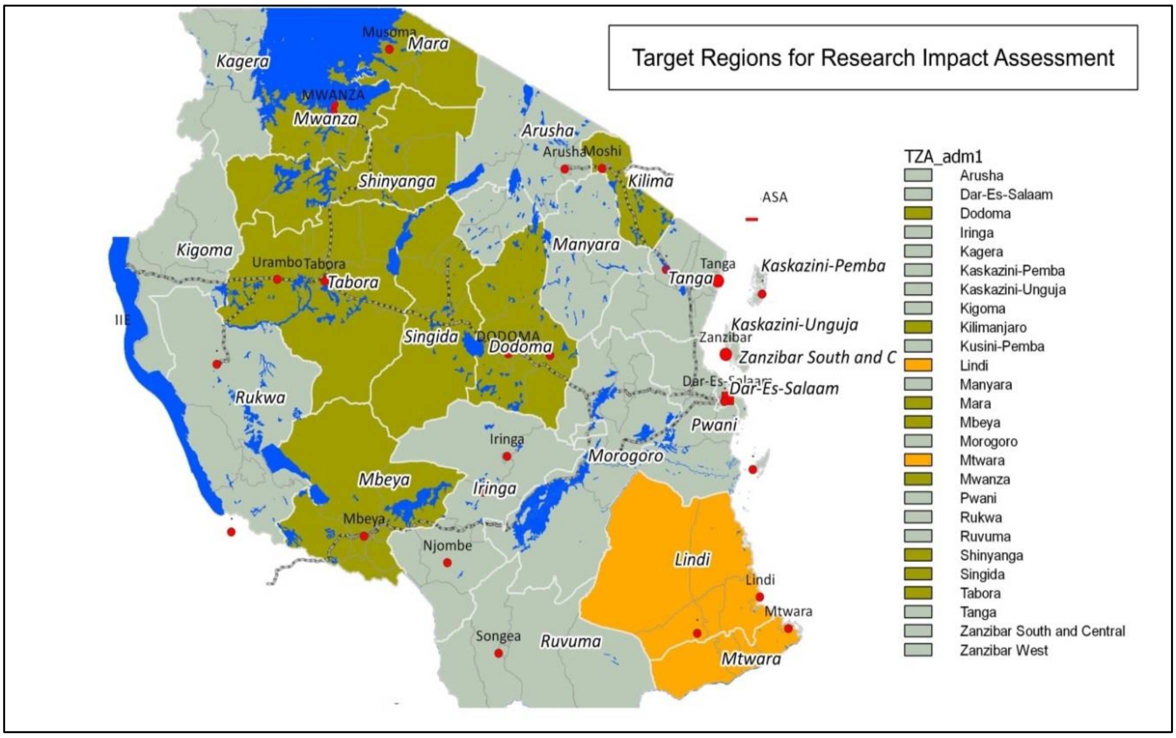
4.1. Defining the Varieties, Impact Zones and Performance Parameters

The Sorghum experts at the workshop in Arusha, Tanzania decided to cut short the number of regions for the impact assessment study in order to save time in the elicitation of adoption rates and yield differentials (Table 24 and Map 5). Lindi and Mtwara were initially included but later dropped after discussion in the group and recognizing that the regions are predominantly grown with local varieties and are not particularly suited for the new and forthcoming improved varieties. The remaining eight regions make up around 85% of national production and over 90 % of consumption.

Table 24: Target regions for sorghum impact assessment

Sorghum target regions			
Dodoma	Shinyanga	Singida	Mara
Mbeya	Tabora	Mwanza	Kilimanjaro
Lindi	*Mtwara*		

Map 5: Target sorghum regions for impact assessment



List of varieties

Sorghum experts at the workshop developed a list of sorghum varieties that includes all relevant varieties from the start of the Tanzanian breeding program until now (Table 25). Relevant varieties are those that have been adopted at a commercially relevant level and with proper seed multiplication and maintenance in place. The National Sorghum and Millet Improvement Program (NSMIP), in collaboration with the SADC/ICRISAT Sorghum and Millet Improvement Program (SMIP), have developed several new varieties that mature earlier and give higher yields than landraces – the yield advantage is more pronounced in seasons of poor rainfall. SMIP has taken the responsibility for providing improved germplasm, while NSMIP has led country-wide efforts for multi-locational evaluation of this germplasm, compiling and presenting the data to the national variety release committee. This has led to the release of three sorghum varieties – Tegemeo (1986), Pato (1995), and Macia (1999) – and two pearl millet varieties. Only three improved varieties had been released earlier: sorghums Lulu and Serena in the 1970s.

A few varieties (e.g. Serena and Lulu were dropped because of their age, low spread since release and their current disappearance from the market. In total 14 varieties were chosen. Pato and Tegemeo are the oldest varieties in the list, Macia, Wahi, Hakika, Naco (Mtama1) as the most recent varieties and 6 varieties under development, three open pollinating varieties and three hybrid varieties.

Short description of the improved varieties

Pato: Pato was fully released in 1995 as a medium stalk height variety with white bold grains and black glum. The variety is an open pollinated (pure line) of purple plant with a semi loose head. It matures early and has 65-70 days to 50% flowering, 116 days to 75% maturity. It is adapted to medium season and has a yield potential of 2.5-4t/ha (ICRISAT, 2009). According to Kaliba (2014), Pato is adapted to loamy and sandy-loam soils of dry central and eastern Tanzania. These areas have an intermediate rainy season (120 – 150 days) with rainfall average of 450 – 600 mm. The plant is resistant to lodging and to most common leaf and head diseases but susceptible to leaf blight and stem borers. Utilization of Pato flour includes food, baking, animal feed, malting and brewing of opaque beer.

Tegemeo: Kaliba (2014) describes Tegemeo as an open-pollinated (pure line) sorghum variety; selected at Ilonga Agricultural Research Institute located in the Morogoro Region, Tanzania. The plant is adapted to loam and sandy-loam soils. The production altitude range is between 600 and 1500 meter above sea level (masl). The variety is for intermediate to long rain-season areas (120-150 days) with average rainfall of 450-600 mm. Plant characteristics include medium to late duration, 70-80 days to 50% flowering, and 135-140 days to maturity. The grains are creamy white with medium size. The grain has no tannin but has poor malting quality due to low sorghum diastatic power (SDU). The yield potential is 2.5-3.0 metric tonnes/ha. Grain are utilization for food and livestock and poultry feed. The grains are susceptible to bird damage and the plant is susceptible to Striga *hemonthica*, Striga *asiatica*, and Striga *forbesiss*.

Table 25: List of improved sorghum varieties

	Year of release	Traits	Use	Positive characteristics	Negative characteristics	Regional coverage	Remarks
1st generation varieties							
Pato	1995			Early maturing, draught resistant, good taste	birds, field insects (stem borer, storage pests	commonly planted	
Tegemeo	1986	64-68 days for half bloom, 85 days for landraces		Early mature\drought resistant, high yields	Birds, field insects, storage pests		
2nd generation varieties							
Macia	1999	Medium maturity Seed Co. Ltd		Good taste, high yield, draught resistant	Field insects, storage pests, birds	2 regions only	Little seed distributed
Wahi	2002	Striga Tolerant				2003 limited number 1000+	
Hakika	2002	Striga tolerant		Striga, early maturing, draught resistant		2003 limited number 1000+	
Naco (Kari Mtama1)	2013	Namburi Co	Food, feed brewing	Early maturing, large grain size, high yields	Birds, field pests, shattering	Central, Northern, Southern, Lake	Just released seeds production underway
Varieties under development: open pollinating varieties OPV							
Wagita		Midge resistance	Uji and Ugali, brewing	Resistant to midge	Susceptible to striga		
Gadam		Short semi-dwaft, large grey grain	Uji and Ugali, breweries	Very early maturing (90-105 days)		Dry areas	Most preferred by farmers in dry areas
IESV9110 4DL			Food	Resistant to Buseola fusca	Susceptible to Chillo partellus		
ICSV111 IN		108 days to maturity White seed	Food	Stem borer resistant, Early maturing		Lowland areas, 600-900 mm rainfall	
IESV9204 1SH							
Varieties under development: hybrids							
ATX623 xMACIA	2014		High yielding, high grand extract and nitrogen percentage	Food, brewing	Good for brewing	Dry lowland agro ecology	Release Jan 2014
IESH2200 2							
IESH2201 2	2014		High yielding, high grand extract and nitrogen percentage	Food, brewing	Good for brewing	Dry lowland agro ecology	Released Jan 2014

Source: elaborated at the workshop in Arusha

Macia: According to ICRISAT (2000), the improved sorghum variety Macia (SDS 3220) was released on 14 Dec 1999 by the Tanzania National Variety Release Committee. Macia is a high-yielding, early maturing, white-grained variety developed jointly by ICRISAT and national scientists in southern Africa. It has so far been released in five SADC countries—

Mozambique, Botswana (under the name Phofu), Zimbabwe, Namibia, and now Tanzania. It is suitable for areas with a growing season of 3-4 months. Grain yields of Macia in these trials were 15% higher than those of two released, improved varieties, Pato and Tegemeo. Macia has several other advantages. It has large heads and a high degree of uniformity. It matures earlier than other improved varieties, and is thus less susceptible to terminal drought. Plants are short, making bird scaring easier. It is also a multipurpose variety, suitable for food, fodder, and other uses.

Hakika is a striga resistant variety originating from Purdue. It is an early maturing variety (110 days) and has white bold grains. The variety is targeted to Dodoma, Singida and Lake zone of Tanzania. The variety can mature within 110 days and like Wahi, it is resistance to Striga. The grains are bold white, therefore suitable for food and brewing. Its yield potential is 2.5 to 3.5 metric tonnes per hectare.

Similarly, **Wahi** is a striga resistant variety originating from Purdue. It is an early maturing variety (100 days) and has white bold grains. Released in 2004, the variety is suitable for semi-arid areas especially in those areas where Striga is a major biotic stress. Production altitude ranges from 600 to 1500 masl. This is an early maturing variety. It matures in 100 days. The grains are bold white with no tannins; therefore, suitable for human food and livestock feed. With SDU value of over 36, the variety is suitable for brewing. The variety is gaining popularity in the central zone of Tanzania (Singida and Dodoma regions) as well as in the Lake Zone (Mwanza, Geita, Musoma, and Shinyanga Regions). Its yield potentials range between 3.0 and 3.5 metric tonnes/ha.

Naco (Mtama1): NARCO Mtama 1 has been introduced in Tanzania by ICRISAT-Nairobi in 2008. The materials were tested as KARI Mtama 1. The Dry Lowland (DL) agro ecology in Tanzania is proposed area for adoption. The agro-ecology includes Dodoma, Singida, Shinyanga, Kilimanjaro and Tanga regions with elevation of up 1200 masl. The Arusha based, Namburi Agricultural Company/SEEDS is responsible for maintenance and supply of pre-basic and basic seeds. The grains are white with large and bold size. The variety yield potential is about 2-2.5 metric tonnes/ha. The grains are suited for food and brewing due to high percent extract (above 82%) and low nitrogen contents (less than 2.0%). The grain has no tannin, therefore can be used in poultry feed production. Because it is a tan plan, the plant residues are suitable as animal fodder (Kaliba 2014).

Gadam Hamman This is a short semi-dwarf, very early maturing (90-105 days) variety with large grey grains and is very good for Ugali and Uji; and is suitable for semi arid zones. The breeder seed is being undertaken by icrisat and nars while the foundation and certified seed production is by nars, ngos and private companies. The yields range between 2-4 tons per hectares on-station and 1-2 tons per hectare on farmers' fields. It is mainly grown for the breweries.

Adoption and profitability estimates

Table 26 summarizes the experts' assessment of the current and future adoption levels on aggregate and by individual variety. Part of the assessment was based on prior study of adoption reports and baseline studies conducted by ICRISAT and DRC its major intervention regions such as Dodoma, Singida and Shinyanga. Adoption rates for other regions are less abundant and reliable. The highest adoption levels are found in the major sorghum areas in Dodoma, Singida, Shinyanga and Mwanza due to widespread cultivation of Macia and Wahi. Tegemeo is less prominent in those regions but enjoys a good coverage in the lake region (Mwanza). Hakika shows a similar adoption level as Tegemeo except for the Mwanza region. Since release in 1995 Pato has not been taken up well by farmers. Current adoption levels are low across all major sorghum regions and are forecast to decline further until Pato will face out in a couple of years.

Table 26: Current and future adoption rates by variety and region

		Macia	Tege-meo	Wahi	Hakika	Wagita	Pato	Naco Mtama1	Gadam	IESV9 1104DL	ICSV1 11 IN	IESV9 2041SH	IESH2 2012	ATX623 x MACIA	IESH 22002
	Cum. adoption rate	Current adoption rate in % of production (year 2013)													
Dodoma	40	15	5	10	5		3	2							
Shinyanga	26	8	2	2	2	8	2	0	2						
Singida	40	10	5	5	5		3	2	10						
Mara	18	10	2	2	2			2							
Tabora	17	15	17	5	2	5	5								
Mwanza	25	25	25	3	1	5	5	10	1						
Mtwara	0	2	0												
Kilimanjaro	11	10	11	6						5					
	Cum. adoption rate	Future adoption rate in % of production (year 2018)													
Dodoma	65	20	6	3	3		0	8		5	5		5	5	5
Shinyanga	55	10	3	2	2	5	0	5	6	5	5	3	3	3	3
Singida	75	10	5	10	10		0	5	10	5	5		5	5	5
Mara	44	5	3	3	3	10		3		3	3	5	2	2	2
Tabora	40	6	5	6	5		0		5	5	2		2	2	2
Mwanza	40	6	5	6	5		0		5	5	2		2	2	2
Mtwara	30	0						5		5	5		5	5	5
Kilimanjaro	54	15						5	5	5	3		7	7	7

Source: own calculations from workshop data in Arusha

Experts forecast a continuation of adoption of improved varieties for the next 15 years reaching a level of 55 to 75 % in the three largest sorghum areas but also considerable increase in all other regions. The Kilimanjaro and Mara regions are examples of an opposite trend away from maize due to the Maize lethal necrotic disease (MLND) that affects several regions, esp. Kilimanjaro, but also Manyara and Mara in the North. Maize farmers are expected by the experts to resort increasingly to Sorghum in order to secure their subsistence level in cereals and minimize the risks of crop failure from MLND. Over the next 15 years, the share of sorghum under improved varieties are predicted to reach over 50 % in the Kilimanjaro region (up from 11 %) and 44 % for the Mara regions region (up from 18 %).

The experts in Arusha developed a table (Table 27) that subsumes the major 'pros'-and 'cons' and underpins the rationale in the future adoption success of improved sorghum varieties differentiated by the major sorghum regions.

Table 27: Factors affecting adoption rates with the next 15 years

Region	Cum. Adoption at Present (%)	Expect. Adoption in 15 yrs. (%)	Driving Factors for Adoption	Constraining Factors
Dodoma	40	60	➢ Climate change and market opportunity ➢ Support given to small seed companies ➢ Seeds subsidy offered now ➢ The emerging maize lethal Necrosis disease (MLND) ➢ Sorghum as a healthy crop	Sustainability of seeds subsidy (policy changes)
Shinyanga	20	50	➢ Climate change and market opportunity ➢ Support given to small seed companies ➢ Seeds subsidy offered now ➢ Ample area for sorghum production ➢ The emerging maize lethal Necrosis disease (MLND) ➢ - Sorghum as a healthy crop	The slow release of improved varieties(red types) Sustainability of seeds subsidy (policy changes)
Singida	40	70	➢ Climate change and market opportunity ➢ Support given to small seed companies ➢ Seeds subsidy offered now ➢ Sorghum as a healthy crop	Sustainability of seeds subsidy (policy changes
Mara	15	40	➢ Climate change and market opportunity ➢ Support given to small seed companies ➢ Seeds subsidy offered now ➢ The emerging maize lethal Necrosis disease (MLND)	The slow release of improved varieties (red types)
Lindi	2	30	➢ Climate change and market opportunity ➢ Support given to small emerging seed companies ➢ Sorghum as a healthy crop	The slow release of improved varieties
Mbeya	10	25	➢ Climate change and market opportunity ➢ Support given to small seed companies ➢ Seeds subsidy offered now ➢ Sorghum as a healthy crop	Sustainability of seeds subsidy (policy changes)
Tabora	15	40	➢ Climate change and market opportunity ➢ Support given to small seed companies ➢ Seeds subsidy offered now	The slow release of improved varieties (red types)
Mwanza	20	40	➢ Climate change and market opportunity ➢ Support given to small emerging seed companies ➢ Seeds subsidy offered now ➢ Sorghum as a healthy crop	The release of improved varieties
Mtwara	2	30	➢ Climate change and market opportunity ➢ Support given to small seed companies	The slow release of improved varieties
Kilimanjaro	5	40	➢ Climate change and market opportunity ➢ Support given to small seed companies ➢ Seeds subsidy offered now ➢ Sorghum as a healthy crop	Land area ownership is diminishing

Source: expert group from the workshop in Arusha

Yields and profitability

Profitability comparisons between local and improved varieties are presented in Table 28 and 29. 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 1.5 – 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 into positive margins between 400 and 800 USD/ha depending on the variety and region. Especially for varieties under development, experts see a very strong yield performance exceeding 3.3 tons/ha which translates into gross margins that are 5 – 10 times higher than for local varieties. Differentiating yield potential by region has been done but margins are small and hardly exceeding 10% variation.

Table 28: Yields and profitability of improved (established) sorghum varieties

	Local Variety		Macia	Tegemeo	Wahi	Hakika	Wagita	Pato	Naco Mtama1
	mt/ha		Yields						
Dodoma	600		2,000	1,800	1,500	1,300	1,500	1,800	1,800
Shinyanga	700		1,800	1,600	1,500	1,200	1,200	1,600	1,600
Singida	600		2,000	1,800	1,500	1,300	1,500	1,800	1,800
Mara	700		1,800	1,600	1,500	1,200	1,200	1,600	1,600
Mbeya	500		1,800	1,600	1,300	1,200	1,200	1,600	1,600
Tabora	500		1,800	1,600	1,300	1,200	1,200	1,600	1,600
Mwanza	700		1,800	1,600	1,500	1,200	1,200	1,600	1,600
Kilimanjaro	600		1,800	1,600	1,300	1,200	1,200	1,600	1,600
	USD/ha		Profitability						
Dodoma	Revenue	225	625	563	469	406	469	563	563
	Costs	59	111	118	111	68	68	74	111
Shinyanga	Revenue	263	563	500	469	375	375	500	500
	Costs	59	111	120	120	68	69	76	120
Singida	Revenue	225	625	563	469	406	469	563	563
	Costs	59	111	118	111	68	68	74	111
Mara	Revenue	263	563	500	469	375	375	500	500
	Costs	59	111	120	120	68	69	76	120
Mbeya	Revenue	188	563	500	406	375	375	500	500
	Costs	59	68	67	111	67	68	67	68
Tabora	Revenue	188	563	500	406	375	375	500	500
	Costs	59	68	67	111	67	68	67	68
Mwanza	Revenue	263	563	500	469	375	375	500	500
	Costs	59	111	120	120	68	69	76	120
Kilimanjaro	Revenue	188	563	500	406	375	375	500	500
	Costs	54	90	90	92	104	104	104	104

Source: own calculation based on workshop data

Table 29: Yields and profitability of improved (under development) sorghum varieties

	Local Variety		Gadam	IESV91104DL	ICSV111IN	IESV92041SH	IESH22012	ATX623xMACIA	IESH22002
	mt/ha								
Dodoma	600		1,300	3,300	3,300	3,300	3,300	3,300	3,300
Shinyanga	700		1,300	3,200	3,200	3,200	3,200	3,200	3,200
Singida	600		1,300	3,300	3,300	3,300	3,300	3,300	3,300
Mara	700		1,300	3,200	3,200	3,200	3,200	3,200	3,200
Mbeya	500		1,250	3,200	3,200	3,200	3,200	3,200	3,200
Tabora	500		1,250	3,200	3,200	3,200	3,200	3,200	3,200
Mwanza	700		1,300	3,200	3,200	3,200	3,200	3,200	3,200
Kilimanjaro	600		1,500	3,500	3,500	3,500	3,500	3,500	3,500
	USD/ha								
Dodoma	Revenue	225	406	1,031	1,031	1,031	1,031	1,031	1,031
	Costs	59	68	116	116	116	116	116	116
Shinyanga	Revenue	263	406	1,000	1,000	1,000	1,000	1,000	1,000
	Costs	59	75	125	125	125	125	125	125
Singida	Revenue	225	406	1,031	1,031	1,031	1,031	1,031	1,031
	Costs	59	68	116	116	116	116	116	116
Mara	Revenue	263	406	1,000	1,000	1,000	1,000	1,000	1,000
	Costs	59	75	125	125	125	125	125	125
Mbeya	Revenue	188	391	1,000	1,000	1,000	1,000	1,000	1,000
	Costs	59	67	116	116	116	116	116	116
Tabora	Revenue	188	391	1,000	1,000	1,000	1,000	1,000	1,000
	Costs	59	67	116	116	116	116	116	116
Mwanza	Revenue	263	406	1,000	1,000	1,000	1,000	1,000	1,000
	Costs	59	75	125	125	125	125	125	125
Kilimanjaro	Revenue	188	469	1,094	1,094	1,094	1,094	1,094	1,094
	Costs	54	92	153	153	153	153	153	153

Source: own calculation based on workshop data

Dream model set-up

The market structure and specifications in the 'Dream' model are outlined in Table 30. Markets are the eight major sorghum regions where improved varieties have been adopted at a larger scale and/or in which future adoption are likely to take place for the varieties under development. In addition the two regions 'Lindi' and 'Mtwara' are defined as stand-alone markets though they have been dropped from the assessment list as the current and future adoption level was deemed insignificant. All unaccounted sorghum production from other regions is subsumed under 'others minor sorghum regions'. The 'residual market' is defined for technical reasons to balance aggregate supply with demand. The last market in the 'Dream' model allows or prohibits cross border trade depending on the set value of the foreign demand price elasticity. Supply and demand figures show that some of the core sorghum markets show a large supply deficit (Dodoma and Shinyanga) while others regions like Mara, Mbeya and Mwanza have excess production. For that reason cross-regional trade mostly takes place between the major sorghum regions and, to a much lesser extent, between and with other minor regions and consumer markets.

Market prices are taken from Ratin Net and calculated as average annual price for 2012. Markets with no available price data from Ratin Net are assigned the prices from neighbouring regions if appropriate. Prices for Singida, Shinyanga and Tabora are set equal to the prices in the Dodoma region. Mara and Kilimanjaro take the prices from the Arusha region, Lindi and Mtwara from the Songea region, and all other minor production regions are set at average price between Dodoma and Arusha.

Supply and demand own price elasticities are set at 0.2 for supply and -0.1 for demand for the base run and later modified during sensitivity analyses. Empirical elasticity values are not available from the literature except indications that demand elasticity is extremely low, below 'one' (ICRISAT 2014). The discount rate is set at 5%.

Table 30: The 'DREAM' model configuration of markets and parameters

Markets in the DREAM model	Supply	Demand	Surplus / Deficit	Price level	Elasticity		Discount rate %	Exogenous growth %	
Regions	mt	mt	mt	USD/mt	Supply	Demand		Supply	Demand
Dodoma	81,772	143,794	-62,022	295	0.2	-0.1		(5.5) (1.5) (1)	(5.5) (1.5) (1)
Shinyanga	91,080	199,455	-108,375	295	0.2	-0.1		(5.5) (1.5) (1)	(5.5) (1.5) (1)
Singida	101,131	104,365	-3,235	295	0.2	-0.1		(5.5) (1.5) (1)	(5.5) (1.5) (1)
Mara	93,124	47,132	45,992	444	0.2	-0.1		(5.5) (1.5) (1)	(5.5) (1.5) (1)
Mbeya	36,744	1,884	34,860	456	0.2	-0.1		(5.5) (1.5) (1)	(5.5) (1.5) (1)
Tabora	24,756	11,240	13,517	295	0.2	-0.1		(5.5) (1.5) (1)	(5.5) (1.5) (1)
Mwanza	43,660	24,792	18,867	487	0.2	-0.1		(5.5) (1.5) (1)	(5.5) (1.5) (1)
Kilimanjaro	1,516	114	1,402	444	0.2	-0.1		(5.5) (1.5) (1)	(5.5) (1.5) (1)
Lindi	*33,966*	*17,685*	*16,281*	*271*	*0.2*	*-0.1*		(5.5) (1.5) (1)	(5.5) (1.5) (1)
Mtwara	*19,123*	*11,273*	*7,850*	*271*	*0.2*	*-0.1*		(5.5) (1.5) (1)	(5.5) (1.5) (1)
Others minor sorghum regions	75,395	48,855	26,540	369	0.2	-0.1		(5.5) (1.5) (1)	(5.5) (1.5) (1)
Residual markets	8,745	423	8,323	435	0.2	-0.1		(5.5) (1.5) (1)	(5.5) (1.5) (1)
Trade market	5	5		400		(0;-2;-10)			
Total (2009)	611,011	611,011	0		0.2	-0.1	5		
Total (1990)	385,120	385,120	0		0.2	-0.1	5		
Total (1970)	142,687	142,687	0		0.2	-0.1	5		

Source. Own calculations

Exogenous growth

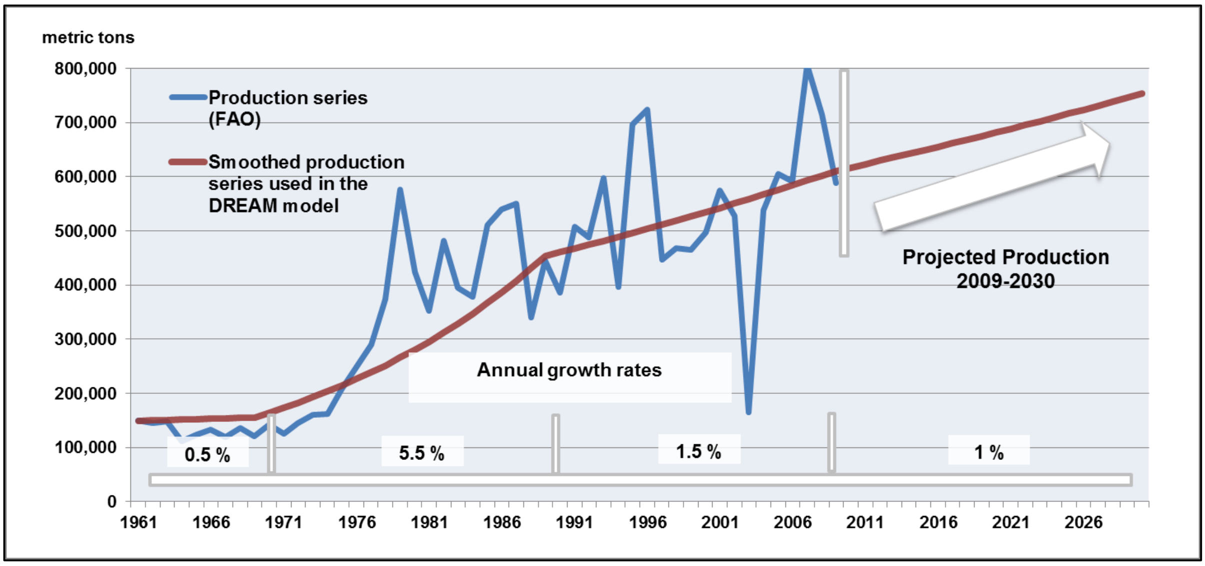
The economic surplus concept requires a proper account of the market size and production and consumption figures at any time of the simulation period. Unlike Uganda, where sorghum and millet did not follow a steady production trend, the situation for Tanzania is different. Figure 7 highlights the FAO production series between 1961 and 2009 which shows a high year- on-year fluctuation but a long-trend in production from just over 100,000 mt to over 600,000 mt in 2009 a five-fold increase in 50 years which needs to be accommodated into the 'Dream model' for the 'ex-post' part. Failure to account for production trends results in wrong and misleading economic surplus estimates as research impact is sensitive to the size of markets in which research-induced supply shifts occur. The contrary holds true for prices: research impact is sensitive to price differentials between 'with' and 'without' research case but invariant to absolute prices. Thus, prices changes over time can be neglected.

A good approximation of the FAO production series is to distinguish four different time intervals with constant annual growth rates and then impute the rates into the 'Dream' model accordingly. Only three intervals are relevant for the study:

- 5.5% annual growth rates between 1972 and 1991
- 1.5% annual growth rates between 1992 and 2009
- and 1 % annual growth rates between 2010 and 2030

The same growth rates apply to domestic supply and demand as Tanzania does not indicate significant foreign trade volumes between 1961 and 2009. The markets are defined in terms of food supply and food demand in contrast to the Uganda impact study which was based on gross production. Alternative sorghum utilization as feed, seed and waste is therefore left out, thus avoiding valuation issues for feed and seed and making assumptions regarding sorghum demand for non-food use. The proportion of food supply to gross production stays rather constant over time at a level of around 83%. In the worst case, model results fall short of maximum 17% of the economic surplus estimates.

Figure 7: Sorghum production between 1961-2009: trends and growth rates



Source: own figure based on FAOSTAT production series and average growth rates calculations

4.2. Baseline Model Results for Sorghum

The research gains (in terms of economic surplus) from improved varieties accounts for USD 1.2 bln. over the entire period from the first release in 1986 until 2030 (Table 31). On an annual base this translates into USD 23 Mio. Due to the particular price inelasticity of sorghum markets, most of the gains are captured by consumers: USD 800 Mio. and USD 15.7 Mio. per year. Results reveal a strong performance from all improved varieties with a rate of returns (IRR) above 30%. In general, newer varieties seem to be superior to the 1st generation varieties Pato and Tegemeo which stems from the fact that the sorghum experts have high expectations in the varieties under development regarding future yield performance even under low input management and reasonable adoption rates.

Others reasons for the high performance are the relatively low research costs. On an inflation adjusted base, annual average research costs only accounts for USD 40,000. High inflation rates above 20% between 1980 and 1995 were inflicting a strong discounting factor on the nominal research costs.

Table 31: Economic surplus and internal rate of returns (IRR) by variety

		Economic Surplus ('000 USD)			('000 USD)		
	Release	PS	CS	TS	Research Costs	TS - Costs	**IRR %**
1st generation varieties							
Pato	1995	2,410	7,669	10,078	107	9,972	**31.6**
Tegemeo	1986	9,094	21,361	30,456	38	30,418	**56.0**
2nd generation varieties							
Macia	1999	30,456	76,395	106,851	195	106,655	**72.5**
Wahi	2002	13,203	31,511	44,713	125	44,589	**97.4**
Hakika	2002	8,576	21,998	30,574	125	30,450	**79.4**
Naco Mtama1	2013	22,728	46,484	69,212	149	69,063	**141.1**
Varieties under development: open pollinating varieties OPV							
Wagita	2013-14	8,516	10,906	19,422	330	19,092	**111.3**
Gadam	2013-14	8,462	23,044	31,506	149	31,357	**104.0**
IESV91104DL	2013-14	54,672	112,392	167,063	149	166,915	**191.2**
ICSV111 IN	2013-14	44,848	100,256	145,104	149	144,956	**184.2**
IESV92041SH	2013-14	41,654	49,153	90,807	149	90,658	**163.5**
Varieties under development: hybrids							
ATX623 x Macia	2013-14	51,711	100,957	152,667	149	152,519	**186.8**
IESH22002	2013-14	51,711	100,957	152,667	149	152,519	**186.8**
IESH22012	2013-14	51,711	100,957	152,667	149	152,519	**186.8**
Total surplus		399,750	804,039	1,203,788	2,107	1,201,681	
Annual surplus		7,838	15,765	23,604	41	23,562	

Source: own calculations

Examination of the flow of benefit by region (Table 32) shows a clear trend towards the major sorghum regions, namely Dodoma, Singida and Shinyanga. They make up around USD 900 Mio. which constitutes over 80 % of the overall research gains. The reasons are that those regions are large producers by definition and much of the producer surplus are directed to them, but they are large consumer regions as well with a high population density (esp. Dodoma and Shinyanga) and high per capita consumption of sorghum. Non-adopting sorghum regions such as Lindi, Mwara and all other miscellaneous regions with some minor production are losing around USD 170 Mio. as a result of low prices that are transmitted from the major regions. Net losses to producers (USD 473 Mio) outweigh the gains to consumers (USD 304 Mio) from lower prices.

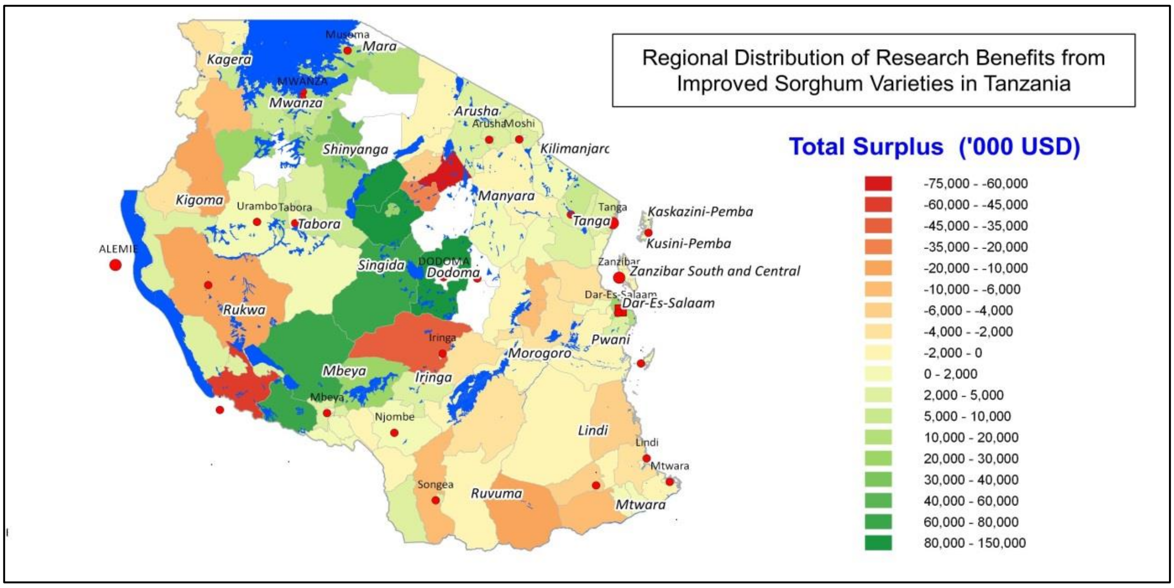
Table 32: Baseline research gains for sorghum by region (all varieties)

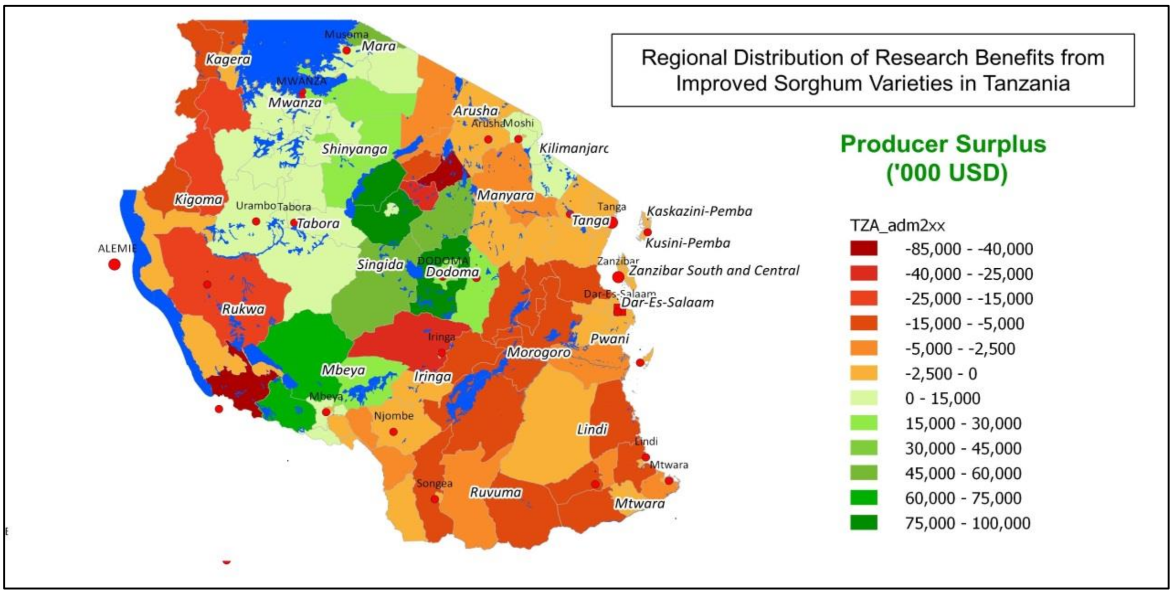
Regions	Economic Surplus ('000 USD)			('000 USD)		% of Total Surplus by Region
	PS	CS	TS	Research Costs	TS - Costs	
Sorghum regions with variety adoption						
Dodoma	206,913	134,873	341,787		339,680	28.4
Shinyanga	97,297	187,080	284,377		284,377	23.6
Singida	246,614	97,891	344,505		344,505	28.6
Mara	63,918	44,177	108,095		108,095	9.0
Mbeya	162,020	1,762	163,782		163,782	13.6
Tabora	27,946	10,540	38,486		38,486	3.2
Mwanza	60,329	23,238	83,566		83,566	6.9
Kilimanjaro	8,560	111	8,670		8,670	0.7
Sub-total	873,596	499,672	1,373,268	2,107	1,371,161	114.1
Sorghum regions with no variety adoption						
Lindi	-31,670	16,588	-15,082		-15,082	-1.3
Mtwara	-17,830	10,570	-7,260		-7,260	-0.6
Misc. sorghum regions with no variety adoption	-416,182	276,810	-139,371		-139,371	-11.6
Residual markets	-8,165	398	-7,767		-7,767	-0.6
Sub-total	-473,847	304,367	-169,480		-169,480	-14.1
Total Tanzania	399,750	804,039	1,203,788	2,107	1,201,681	100
Annual surplus	7,838	15,765	23,604	41	23,562	
Source: own calculations						

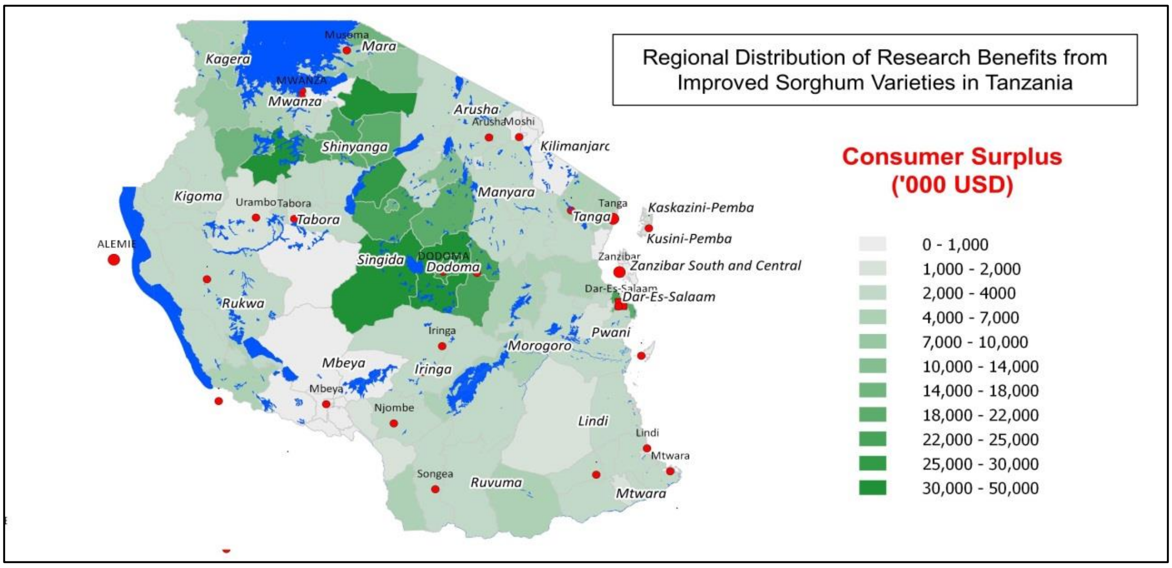
Table 33: Baseline research gains for sorghum by region (only established varieties)

Regions	Economic Surplus ('000 USD)			('000 USD)		% of Total Surplus by Region
	PS	CS	TS	Research Costs	TS - Costs	
Sorghum regions with variety adoption						
Dodoma	83,058	34,483	117,541	738	116,803	40.3
Shinyanga	11,086	47,828	58,913	0	58,913	20.2
Singida	73,796	25,027	98,823	0	98,823	33.9
Mara	11,925	11,296	23,220	0	23,220	8.0
Mbeya	1,958	451	2,408	0	2,408	0.8
Tabora	7,547	2,695	10,242	0	10,242	3.5
Mwanza	17,632	5,943	23,574	0	23,574	8.1
Kilimanjaro	1,252	28	1,280	0	1,280	0.4
Sub-total	208,253	127,749	336,002	738	335,265	115.1
Sorghum regions with no variety adoption						
Lindi	-8,111	4,241	-3,870	0	-3,870	-1.3
Mtwara	-4,567	2,703	-1,864	0	-1,864	-0.6
Misc. sorghum regions with no variety adoption	-107,019	70,624	-36,395	0	-36,395	-12.5
Residual markets	-2,090	101	-1,989	0	-1,989	-0.7
Sub-total	-121,787	77,668	-44,118	0	-44,118	-15.1
Total surplus Tanzania	86,467	205,418	291,884	738	291,146	100
Annual surplus	1,695	4,028	5,723	14	5,709	
Source:						

Map 6: Improved sorghum varieties in Tanzania: research gains by regions







A look at the research gains without the varieties under development shows a more modest picture about the economic implications from sorghum (Table 33). Though the regional patters stays large unaffected, the magnitude of the research gains differs significantly. Past and future gains from the established varieties (Pato, Tegemeo, Macia, Wahi, Hakika and Naco Mtama) amount to USD 290 Mio. and around USD 5.7 Mio. per year. The gains are even more concentrated on the major three sorghum regions Dodoma, Singida and Shinyanga compared to the wider regional focus of the newer varieties. This may add evidence to the early-stage circumstances and objectives in sorghum breeding in targeting all efforts towards the three core regions with regard to variety traits, provision of seed and other marketing activities to promote those varieties.

Map 6 provides a visual insight into the regional allocation of the research gains split up into total, producer and consumer surplus. Regardless of the type of surplus, the majority of the gains are concentrated in the regions of the central plains.

A break up of the research gains by ex-post and ex-ante can be studied from the Table 34, and 35. Less than 10 % of the gains (around USD 110 Mio.) have been materialized since the start of sorghum breeding in 1980 until now in 2013 while 90% of the gains are expected to occur in the future. The low share of past versus future gains is certainly a result of the large share in gains from the varieties under development that have contributed nothing to the past performance. Even an isolated view on the established varieties alone tells that past gains make up only 38% of the total gains.

Table 34: Past and future research gains from improved sorghum varieties by region

by Region	Economic Surplus ('000 USD)				Economic Surplus ('000 USD)			
	Past Surplus	Past Surplus (% of total)	Future Surplus	Total Surplus	Past Surplus	Past Surplus (% of total)	Future Surplus	Total Surplus
	All Varieties				Only Established varieties			
Sorghum regions with variety adoption								
Dodoma	52,807	15.45	288,980	341,787	52,807	44.93	64,735	117,541
Shinyanga	23,890	8.40	260,487	284,377	23,890	40.55	35,023	58,913
Singida	35,605	10.34	308,900	344,505	35,605	36.03	63,218	98,823
Mara	7,471	6.91	100,624	108,095	7,471	32.17	15,749	23,220
Mbeya	-3,279	-2.00	167,061	163,782	-3,279	-136.15	5,687	2,408
Tabora	4,742	12.32	33,744	38,486	4,742	46.30	5,500	10,242
Mwanza	7,731	9.25	75,835	83,566	7,731	32.80	15,843	23,574
Kilimanjaro	465	5.37	8,205	8,670	465	36.34	815	1,280
Sub-total	129,432	9.43	1,243,836	1,373,268	129,432	38.52	206,570	336,002
Sorghum regions with no variety adoption								
Lindi	-1,523	10.10	-13,559	-15,082	-1,523	39.36	-2,347	-3,870
Mtwara	-734	10.11	-6,526	-7,260	-734	39.36	-1,130	-1,864
Misc. sorghum regions	-14,370	10.31	-125,001	-139,371	-14,370	39.48	-22,026	-36,395
Residual markets	-783	10.08	-6,984	-7,767	-783	39.36	-1,206	-1,989
Sub-total	-17,409	10.27	-152,071	-169,480	-17,409	39.46	-26,709	-44,118
Total Tanzania	**112,023**	**9.31**	**1,091,766**	**1,203,788**	**112,023**	**38.38**	**179,862**	**291,884**
Total surplus/year	3,295		64,222	23,604	3,295		10,580	5,723

Table 35: Past and future research gains from improved sorghum varieties by variety

by variety	Economic Surplus ('000 USD)			
	Past Surplus	Past Surplus in % of total	Future Surplus	Total Surplus
Establishe varieties				
Pato	7,937	78.7	2,142	10,078
Tegemeo	20,928	68.7	9,528	30,456
Macia	52,089	48.7	54,761	106,851
Wahi	19,826	44.3	24,887	44,713
Hakika	11,243	36.8	19,332	30,574
Naco Mtama1	0	0.0	69,212	69,212
Sub-total	112,023	38.4	179,862	291,884
Varieties under developmentt				
Wegita			19,422	19,422
Gadam			31,506	31,506
IESV91104DL			167,063	167,063
ICSV111 IN			145,104	145,104
IESV92041SH			90,807	90,807
ATX623 xMACIA			152,667	152,667
IESH22002			152,667	152,667
IESH22012			152,667	152,667
Total	112,023	9.31	1,091,766	1,203,788

These results underpin the long-term nature of the sorghum breeding program in generating the first returns to investments as the varietal development and dynamic in farmers' uptake need time to gain momentum. With over 80% of the gains lie ahead all concerned stakeholders in the sorghum sector should ensure that the varieties can develop their full potential in terms of widespread use, good agronomic practises and superior yields and tackling the existing bottlenecks e.g. in seed availability.

4.3. Modelling Scenarios and Sensitivity Analysis

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 36).

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 36: 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 resistance, early maturing Var.	Agronomic best- practise and modern inputs	e.g. seed multiplication and quality	Linking poor farmers with markets, product innovations.	Specialised var.with high foreign demand (e.g. for brewing)
DREAM model scenarios					
Scenario type	Base Run	Adoption and yields		Markets and trade	
Model parameters		Variation in the yield levels	Variation in the adoption rates	Variation in domestic price elasticity	Variation in price elasticity of foreign demand

Source: own table

Markets and trade scenarios

Three different market scenarios are tested in addition to the baseline (Table 37). Each scenario is defined by a set of price elasticity parameters for the domestic market and cross-border trade (foreign demand).

- Scenario 1 (high market integration) 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. No cross-border trade allowed
- Scenario 2 opens up cross border trade within the baseline modelling framework. Foreign demand for Tanzanian sorghum is assumed to be medium with price elasticity of the foreign demand (η_{ex}) set at -2. Trade is only allowed in one direction as exports. Tanzania as a major sorghum importer is not a realistic assumption.
- Scenario 3 is similar to scenario 2 except foreign demand is set very high (η_e set at -10). Any reduction in the price of sorghum in Tanzania from surplus production from improved varieties triggers a high demand from foreign buyers.

Table 37: Configuration of price elasticity parameters for the trade scenarios

	Trade regime	Baseline (0)	High domestic market integration (1)	Cross-border trade: medium foreign demand elasticity (2)	Cross-border trade: high foreign demand elasticity (3)
Domestic Market	(ε_p)	0.2	1.5	0.2	0.2
	(η_p)	-0.1	1.5	-0.1	-0.1
Foreign Markets	(ε_{im})	0	0	0	0
	(η_{ex})	0	0	-2	-10

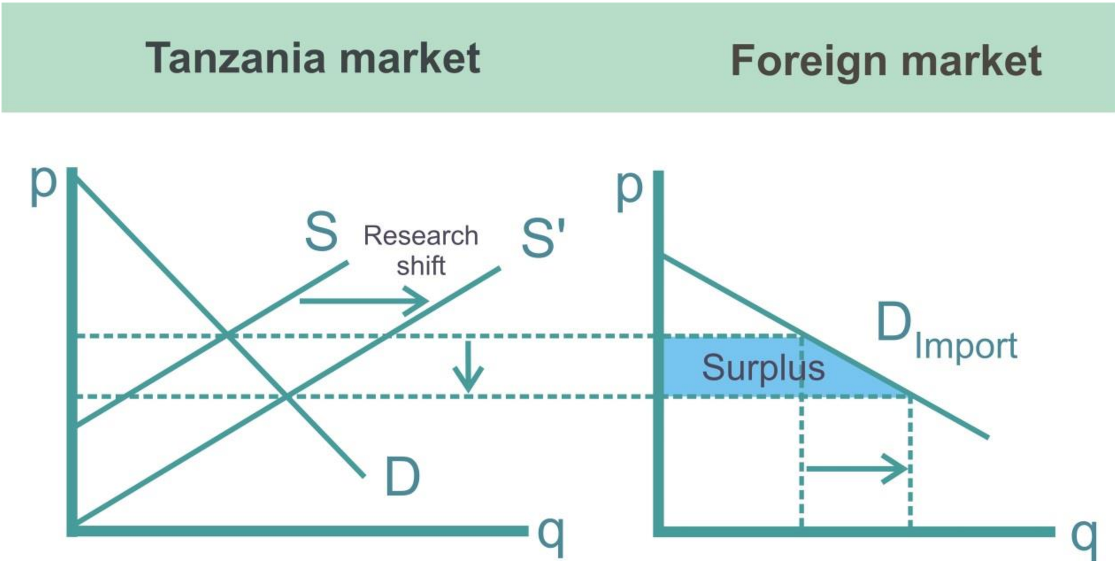
Source: own table:

Why does cross-border trade matters for sorghum breeders?

Introducing foreign trade into the DREAM has several implications for the Tanzanian market, the prices for sorghum and the distribution of the research gains. The foreign market as depicted in the diagram below creates additional demand for Tanzanian sorghum from foreign buyers. Adoption of improved varieties induce the domestic supply to shift outwards (research shift) as a consequence of higher yields and production compared to local varieties. Prices in all parts of Tanzania regardless of adoption or non-adoption regions, consumer or producer markets fall. Lower prices make Tanzania sorghum more attractive and increases demand from foreign buyers.

The effects of cross-border trade for sorghum producers are twofold: a) they gain from additional production and market opportunities provided by foreign buyers and b) from lower price pressure in the local market as some part of production is sold to the foreign market. Both effects combined create significant benefits to farmers. Tanzanian sorghum consumers on the other hand loose from higher market prices and reduced consumption as it would be without cross-border trade. Part of local consumption is replaced by foreign demand in terms of sorghum exports. As a consequence consumers face significant economic losses.

Cross-border trade creates additional gains in the importing country for consumers in terms of lower import prices and higher consumption levels. But these 'spill-over' effects are not accounted for in the analysis as they occur outside the Tanzanian border.



Model results from trade scenarios

Inspection of the results from the market and trade scenarios shows that changes in the market framework have little effects on the overall size of the research gains (see Table 38) The difference in total economic surplus between the least (baseline) and the most favourable scenario (high market integration) is just over 10 %. A similar conclusion can be drawn for the regional distribution of the research gains that seem large unaffected across all market scenarios. However there is more variation in the non-adoption regions Lindi, Mtwara and all other miscellaneous regions. Admittedly, in reality cross-border trade may have a stronger regional connotation as the 'Dream' model results suggest in its simplistic market setup. Real cross border trade is highly centralized and location specific around the border points and with the traded sorghum procured from the sorghum regions in close proximity.

Table 38: Market & trade scenarios: model results

Economic Surplus (in '000 USD)	Baseline (0)	High market integration (1)	Cross-border trade-medium demand (2)	Cross-border trade-high demand (3)	Spread in %
By type of economic surplus					
Producer Surplus	399,750	721,096	499,618	747,754	87.1
Consumer Surplus	804,039	637,173	716,041	498,677	61.2
Total Surplus	**1,203,788**	**1,358,269**	**1,215,659**	**1,246,430**	**12.8**
Regions with adoption					
Dodoma	341,787	350,600	335,583	320,287	9.5
Shinyanga	284,377	267,510	273,330	246,061	15.6
Singida	344,505	364,613	344,339	343,976	6.0
Mara	108,095	123,426	112,799	124,468	15.1
Mbeya	163,782	190,121	167,435	176,473	16.1
Tabora	38,486	43,629	39,886	43,361	13.4
Mwanza	83,566	90,392	85,517	90,355	8.2
Kilimanjaro	8,670	10,319	8,818	9,185	19.0
Sub-total	1,373,268	1,440,610	1,367,707	1,354,165	6.4
Regions with no adoption					
Lindi	-15,082	-10,754	-13,454	-9,408	-37.6
Mtwara	-7,260	-5,100	-6,478	-4,532	-37.6
Misc. sorghum regions	-139,371	-60,662	-125,194	-88,965	-56.5
Residual markets	-7,767	-5,827	-6,922	-4,830	-37.8
Sub-total	-169,480	-82,342	-152,049	-107,735	-51.4
Total Tanzania	**1,203,788**	**1,358,269**	**1,215,659**	**1,246,430**	**12.8**

Source:

In sharp contrast to the finding above stand the strong effects of market behaviour on the distribution of research gains between consumers and producers triggered by different responsiveness of the market framework with regard to prices and quantities. Volatility on the producer side (87%) is very high and somewhat lower on the consumer side (61%). Highly price responsive local markets seem to have a bigger effect that allowing cross-border trade at moderate levels. As this example shows, improvements in local markets towards more efficiency and lifting consumer preferences for sorghum can even reverse the main beneficiaries from consumers back to producers. Cross-border trade with a very high foreign demand for sorghum works in the same direction with at a higher intensity.

Results clearly show how effective and necessary interventions at market levels are in conjunction with improved varieties and all other agronomic research and extension. An efficient market framework with interlinked markets across the regions, with sufficient trade volume and feed-back from market signals can effectively smooth out large fluctuations in production while keeping price fluctuations and price levels at tolerable levels. All of this for the benefits of farmers in providing a stable market with attractive prices.

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 elevated scale in adoption and yields, only the downside of the value range is tested with adoption rates and yield levels reduced to 50% of their original values.

Table 39 summarizes the major results. Higher adoption rates and yields simply reduce the impact dynamic without changing much in the distribution pattern between consumers and producers and between regions. In general a 50% cut in yields reduces the IRR and research gains more than a comparable 50% cut in adoption rates. But this depends on the particular shape of the adoption curve. The internal rates of returns for each variety remain high (above 25%) which indicate a robust performance even though yields in the field and future adoption do not develop as good as expected by the experts.

Table 39: Adoption and yield scenarios: model results

	Baseline (0)	Yield decrease 50%	Adoption rates - 50%
Economic surplus '000 USD			
Producer Surplus	399,750	178,401	212,969
Consumer Surplus	804,039	362,107	417,257
Total Surplus	1,203,788	540,508	630,227
Internal rate of return IRR			
Established varieties			
Pato	31.6	26.7	27
Tegemeo	56	44	46.3
Macia	72.5	58.7	60.5
Wahi	97.4	70.3	77.8
Hakika	79.4	62.1	63.2
Naco Mtama1	141.1	103.8	112.2
Varieties under development			
Wagita	111.3	67.3	83.6
Gadam	104	73.3	82
IESV91104DL	191.2	148.8	161.8
ICSV111 IN	184.2	143.4	152.5
IESV92041SH	163.5	117.6	127.8
ATX623 xMACIA	186.8	145.4	147.4
IESH22002	186.8	145.4	147.4
IESH22012	186.8	145.4	147.4

Source: own calculations

5. Poverty and Improved Sorghum 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 as it is 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 as a 'poor man's crop and to assess how successful and inclusive the sorghum breeding program in Tanzania is 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 the improved varieties, but allows a general assessment whether the sorghum breeding program in Tanzania is neutral or has 'poor' or' non-poor' bias in the allocation of research benefits.

5.1. Prevalence of Poverty in Tanzania

According to the Millennium Development Goal (MDG) poverty target of a 50% reduction in the incidence of poverty between 1990 and 2015, the MDG target is to reduce this proportion of poverty to 19.5% by 2015 (Poverty and Human Development Report, 2009). In 1991/92, 39% of Tanzanian households were living below the basic needs poverty line (Table 40). Data from 2001/01 and 2007 show a rather limited decline in income poverty levels over the period in all areas, urban and rural. More recent data from the income poverty statistics for 2011/12 HBS household budget survey from 2011/12 shows that some progress has been made in reducing poverty over the last 20 years. According to the 2011/12 HBS the basic needs poverty line is 36,482 (USD 23) Tanzanian Shillings per adult equivalent per month and food poverty line is 26,085 Tanzanian Shillings (USD 16) per adult equivalent per month. Using these two poverty lines, more than a quarter (28.2 percent) of the Tanzanian population fall below the basic needs poverty line and 9.7 percent falls below the food poverty line.

Poverty rates for rural households are more than six fold the rates of Dar es Salaam, and since almost three-quarters of the population resides in rural areas, poverty remains a predominantly a rural phenomenon. Most of the progress in poverty eradication has been achieved in Dar es Salaam, a reduction from 28 % in 1991 to 4 % in 2011. Other urban areas in Tanzania have been less successful, basic needs poverty remains high at 24% in 2011. The least progress was made in rural areas, only down to 28% in 2011 from 38% in 1991. Fortunately, more progress was achieved in rural in lowering severe food poverty which dropped from 21% in 1991 to 9.7% in 2011.

As with poverty, a similar urban-rural divide exists with food security. Results from the Comprehensive Food Security & Vulnerability Analysis 2012 are outlined in Table 41. Rural areas fall short on all four selected food security indicators by a large margin. Though the dietary choice became more abundant in rural areas (indicator diet diversity), food energy deficit aggravated between 2008 and 2011 from 25% of the rural population to 33%. Also the food bill (food expenditure indicator) for rural households in terms of household income share remains very high at 63% which may steam from two facts: modest income level and rise in staple food prices.

Table 40: Food and basic needs poverty in Tanzania from 1990 - 2012[1]

Poverty line	Year	Dar es Salaam	Other urban areas	Rural areas	Mainland Tanzania
Food poverty	1991/92	13.6	15.0	23.1	21.6
	2000/01	7.5	13.2	20.4	18.7
	2007	7.4	12.9	18.4	16.6
	20011/12	**1**	**8.7**	**11.3**	**9.7**
Basic needs poverty	1991/92	28.1	28.7	40.8	38.6
	2000/01	17.6	25.8	38.7	35.7
	2007	16.4	24.1	37.6	33.6
	20011/12	**4.2**	**21.7**	**33.3**	**28.2**

Source: Household budget survey Tanzania (HBS) 2011/12
Household budget survey 2009 (NBS 2009)

Table 41: Selected food security indicator by area (2008-09 and 2010-11)

	Poor dietary intake		Low diet diversity		Highly food energy deficient		Very high food expenditures	
Year	2008-09	2010-11	2008-09	2010-11	2008-09	2010-11	2008-09	2010-11
Tanzania	9.8%	8.3%	25.1%	18.0%	23.7%	29.2%	56.9%	51.6%
Dar es Salam	1.0%	1.4%	4.2%	5.0%	13.5%	14.0%	15.0%	12.3%
Rest of urban	6.7%	4.2%	15.3%	9.8%	18.8%	22.2%	31.6%	32.5%
Rural	11.4%	10.5%	29.9%	21.6%	25.2%	33.1%	68.0%	62.6%
Zanzibar	16.8%	10.3%	25.8%	17.1%	45.6%	40.5%	58.0%	58.9%

Source: CFSVA Tanzania 2012

Another finding from the Comprehensive Food Security & Vulnerability Analysis (2012) was that poverty and food insecurity varies widely across regions. In 2010-11, the poorest geographic zones were also the least food secure. By zone, the highest rates of poverty were in the Central (27%), Western (25%) and Southern (23%) zones. Correspondingly, households in these three zones were the least likely to consume diets that were satisfactory in terms of both quality and quantity – Central (47% of households classified as having poor dietary intake), Western (61%), and Southern (52%).

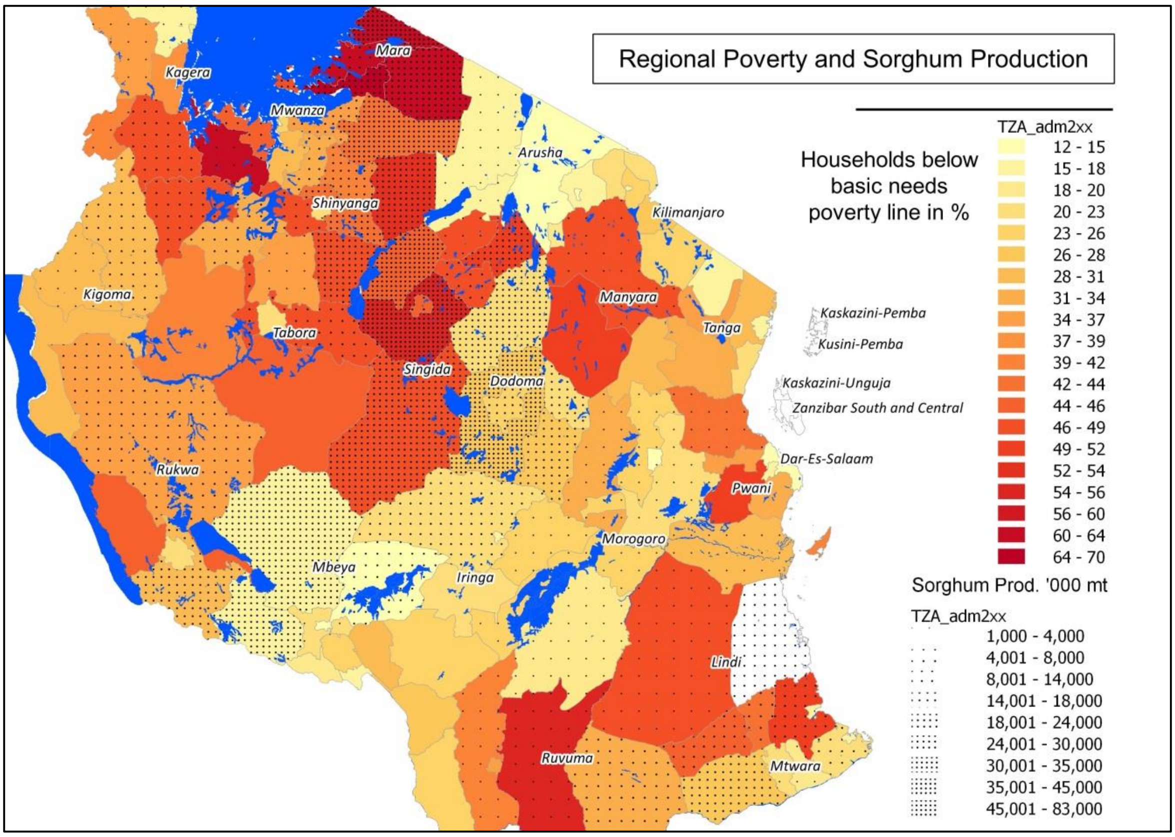
Map 7 shows basic needs poverty rate in Tanzania in more detail together with the major sorghum areas. Poverty rates were gathered at district level from the Poverty and Human Development Report 2005, the most recent poverty data set available at district level. The regions with the highest incidence of poverty are at the same time major sorghum producing

[1] The **basic needs** approach is used to measure absolute poverty in Tanzania Mainland. It attempts to define the absolute minimum resources necessary for long-term physical well-being in terms of consumption of goods. Poverty lines are then defined as the amount of income required to satisfy those needs.

The **food poverty line** is the level at which households total spending on all items is less than they need to spend to meet their needs for food. It is also often referred to as the extreme poverty line. Individuals who fall below this level are classified as extremely poor.

areas, especially the Mara, Shinyanga, and Singida regions that stretch as a band across the central region from North to South. The exception is the Dodoma region that is one of the largest sorghum area but has a relatively and below poverty rate below national average.

Map 7: Regional poverty and sorghum production in Tanzania



Food insecurity has a seasonal pattern. Tanzanian households experience food shortages most commonly between October-February. This period of heightened food shortage is most pronounced in uni-modal households, reaching a shortage peak at the onset of the rainy season and dipping to a very low rate of reported shortages during harvest. In contrast, for the reporting period, Tanzania's bi-modal north experienced a more consistent – though much higher – rate of food shortages throughout the year. These households were most likely to experience food shortages during the short rains (8%, October-December), and their prevalence did not drop below 5% for any month (CFSVA Tanzania 2012).

5.2. Targeting Poverty in the Sorghum Breeding Program

A straight way forward to define the extent to which the research gains from a breeding program is targeting the 'poor' in Tanzania is to compare the general level of poverty of a country or the share of production of a crop coming from 'poor' farmers with the percentage of the research gains that are captured by those farmers below the poverty line.. A breeding program can then be labelled as 'poverty neutral, friendly or adverse' if the share of the research gains are fairly equal, higher or lower than the benchmark poverty rate. A complete analysis requires a broad range of production and consumption data as well as a detailed market system in the impact model. Both conditions are hard to meet for reasons of unavailability of market data at micro-level and time requirement to run the model with a large number of individual markets.

This study simplifies the calculation in several ways. The share of production by 'poor' farmers is assumed equal to the basic needs poverty level in each district from the PHDR 2005 while ignoring crop preferences by rural income strata. On the consumption side, the ICRISAT per capita cereal consumption (ICRISAT 2014) and population data from the 2012 Population and Housing Census are taken to calculate the absolute and relative level in cereal consumption by the 'poor'. Table 42 outlines the results.

Table 42: Poverty levels in cereal production and allocation of research gains

	Population	Cereal production (consumption)						Research gains		
		Sorghum prod.	(Sorghum cons.)	Finger Millet prod.	Pearl Millet prod.	Maize prod.	Paddy prod.	Total surplus	Producer surplus	Consumer surplus
Unit	'000	mt	mt	mt	mt	mt	mt	Mio. USD	Mio. USD	Mio. USD
Poverty share in %	**29.5**	**42.2**	**44.3**	**39.3**	**38.6**	**34.1**	**33.3**	**40.9**	**39.7**	**41.5**
'Poor' in abs, units	11,925	348	366	34	84	1,475	583	495	162	334
Total in abs. units	40,386	826	826	85	217	4,326	1,750	1,212	408	804
Poverty levels in% (basic needs) by selected regions and crops										
Dodoma	24.6	24.8		21.6	23.8	23.6	26.8			
Shinyanga	42.1	44.7		47.6	42.0	42.8	41.7			
Singida	49.2	50.1		54.2	49.3	48.5	49.7			
Mara	63.5	63.7		63.1	63.5	63.1	64.5			
Mbeya	17.6	16.9		18.1	18.0	18.6	15.4			
Tabora	40.9	47.0		42.2	47.6	42.6	40.5			
Mwanza	38.0	41.8		48.0	39.7	46.8	45.1			
Kilimanjaro	23.8	24.7		23.9	no production	24.2	24.8			
Lindi	*34.2*	*44.3*		*46.8*	no production	*44.0*	*45.4*			
Mtwara	*22.9*	*24.8*		*22.3*	*27.0*	*24.9*	*23.1*			

Source: own calculations based on data from:

1) per capita sorghum consumption from: ICRISAT 2012
2) basic needs poverty rate at district level from : PHDR 2012
3) Population data by district from: Tanzania Population and Housing Census 2012
4) District sorghum production data from: National Sample Census Of Agriculture 2007/2008, different regional reports

According to this calculation the share of persons below the needs poverty line at national level is 29.5 %. The sorghum regions in Tanzania show a very diverse poverty incidence varying between 17 and 64%. The lowest poverty share is found in Mbeya and Mtwara, the highest in the Mara and Singida region followed by Dodoma. As expected, sorghum is the cereal crop with the highest share from producers below the poverty line and is followed by finger millet and pearl millet. Maize and rice paddy show the least but still a significant share. Having in mind the particular preference of poor farmers' for dryland cereals it can be assumed that the differences between drylands cereals on the one hand and Maize and Paddy on the other hand are larger in reality.

How much of the research gains go to the poor? In terms of total research gains, around USD Mio. 500 (41%) out of USD 1,200 Mio. are directed towards the 'poor' including all post and future gains. Similar to the baseline results, most of the gains are on the consumption side (USD 334 Mio) and much less on the production side. A decisive factor in the allocation of the research gains is how well the sorghum varieties perform and generate gains in the three major sorghum districts. A high performance in the Dodoma region (24.6 poverty rate) tends to lower the poverty focus, the contrary holds true for the Singida and Shinyanga regions that exhibit much higher poverty rates (49 and 42%). If the research gains are compared with the poverty share in sorghum production, one can conclude that the sorghum research program in Tanzania is fairly 'poverty neural'. If compared with the national poverty rate, it can be labelled as 'poverty friendly'.

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