Working Paper Series No. 5

Harnessing Opportunities for Informed Investments in the Sorghum Commodity Value Chain in Tanzania: A Business Case

Ndossi J, Kalema EP, Kimbi GT, Akpo E, Kongola E, Ringo J, Makoye LY, Gekanana R, Waithira G, Ojiewo CO and Varshney RK

CGIAR
RESEARCH PROGRAM ON
Grain Legumes and Dryland Cereals

Citation: Ndossi J, Kalema EP, Kimbi GT, Akpo E, Kongola E, Ringo J, Makoye LY, Gekanana R, Waithira G, Ojiewo CO and Varshney RK. (2021). Harnessing opportunities for informed investments in the sorghum commodity value chain in Tanzania: A business case. Working Paper Series No. 5. Hyderabad, India: CGIAR Research Program on Grain Legumes and Dryland Cereals, and International Crops Research Institute for the Semi-Arid Tropics (ICRISAT). 69 pp.

ISBN: 978-81-954541-9-8

Front cover image: A sorghum seed production demonstration site in Kongwa district of Dodoma, Tanzania.

Photo credit: Elizabeth Kalema

Title: Harnessing Opportunities for Informed Investments in the Sorghum Commodity Value Chain in Tanzania: A Business Case

Author: Ndossi J, Kalema EP, Kimbi GT, Akpo E, Kongola E, Ringo J, Makoye LY, Gekanana R, Waithira G, Ojiewo CO and Varshney RK

Address: Patancheru-502324, Telangana, India

About the authors

Judith Ndossi: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru 502 324, Telangana, India & Tanzania Agricultural Research Institute (TARI), P O Box 1571, Dodoma, Tanzania

Elizabeth P Kalema: ICRISAT, Patancheru 502 324, Telangana, India & TARI, P O Box 1571, Dodoma, Tanzania

Thedy G Kimbi: ICRISAT, Patancheru 502 324, Telangana, India & TARI, P O Box 1571, Dodoma, Tanzania

Essegbemon Akpo: ICRISAT, Patancheru 502 324, Telangana, India & Ecole de Gestion et de Production Végétale et Semencière, Université Nationale d'Agriculture, Kétou, Bénin

Eliud Kongola: TARI, P O Box 1571, Dodoma, Tanzania

Justin Ringo: TARI, P O Box 1571, Dodoma, Tanzania

Lameck Y Makoye: TARI, P O Box 1571, Dodoma, Tanzania

Risper Gekanana: ICRISAT, Patancheru 502 324, Telangana, India

Grace Waithira: ICRISAT, Patancheru 502 324, Telangana, India

Chris O Ojiewo: Formerly of ICRISAT, Patancheru 502 324, Telangana, India

Rajeev K Varshney: ICRISAT, Patancheru 502 324, Telangana, India

Abstract

This study was conducted among sorghum farmers, focus groups, seed producers and extension officers in 10 districts of Tanzania to map out business opportunities along the sorghum value chain. Results obtained demonstrated that socio-economic factors such as number of years spent in school, group membership, availability of free seeds, market accessibility and seed accessibility influenced the adoption of improved varieties among sorghum farmers. Improved sorghum seeds reflected the profitability from positive gross benefits obtained among sorghum farmers and seed producers. The general adoption rate among sorghum farmers was low (39.0%), with variety NACO Mtama 1 having the highest adoption rate among farmers (17.0%). Among traders, a majority were large off-takers (79.0%). These off-takers experienced issues such as quality (71.4%), quantity (15.9%), lack of market information (7.9%), unreliable markets (36.3%), low grain quality (24.8%) and high tax levies (10.6%). Further, financial constraints and poor linkages among stakeholders were some inefficiencies in the sorghum value chain. The study recommends greater accessibility to improved sorghum seeds as well as reliable policies that enable processes for sorghum stakeholders along the sorghum value chain.

Acknowledgements

The authors wish to thank ICRISAT for facilitating, funding and supporting this research. We also thank the Tanzania Ministry of Agriculture for supporting us with information, the Tanzania Agricultural Research Institute (TARI) Naliendele for administrative facilitation and work implementation during the study period, as well as Hombolo and Ilonga research centers for their logistical and information support. We acknowledge the assistance provided by government officials from various ministries, and the cooperation of officials in all the districts in which data was collected. Finally, we wish to thank the farmers who provided us valuable information to facilitate this study.

Funding

This research was undertaken as part of and funded by the CGIAR Research Program on Grain Legumes and Dryland Cereals (CRP-GLDC) and supported by CGIAR Fund Donors. Funding support was provided by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) through the Harnessing Opportunities for Productivity Enhancement (HOPE) of Sorghum and Millets in sub-Saharan Africa and the Accelerated Varietal Improvement and Seed Delivery of Legumes and Cereals in Africa (AVISA) projects funded by the Bill & Melinda Gates Foundation (BMGF).

Acronyms and abbreviations

asl	above sea level
ASA	Agricultural Seed Agency
AVISA	Accelerated Varietal Improvement and Seed Delivery of Legumes and Cereals in Africa project
BRELA	Business Registration and Licensing Agency
BMGF	Bill & Melinda Gates Foundation
CBO	Community-Based Organization
CRP-GLDC	CGIAR Research Program on Grain Legumes and Dryland Cereals
DAICO	District Agricultural Irrigation and Cooperation Officer
DC	District Council
EABL	East Africa Breweries Limited
EAC	East African Community
HOPE	Harnessing Opportunities for Productivity Enhancement (HOPE) of Sorghum and Millets in sub-Saharan Africa project
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IITA	International Institute of Tropical Agriculture
NBS	National Bureau of Statistics
NGO	Non-Governmental Organization
QDS	Quality Declared Seed
SACCOS	The Savings and Credit Cooperative Societies
SADC	Southern African Development Community
SBL	Serengeti Breweries Limited
SPSS	Statistical Package for Social Science
SUA	Sokoine University of Agriculture
TANTRADE	Tanzania Trade Development Authority
TARI	Tanzania Agricultural Research Institute
TASTA	Tanzania Seed Trade Association
TBL	Tanzania Breweries Limited
TOSCI	Tanzania Official Seed Certification Institute
TRA	Tanzania Revenue Authority
TZS	Tanzanian Shillings
TL	Tropical Legumes
UAE	United Arab Emirates
VIF	Variance Inflation Factor
WFP	World Food Programme

List of tables

List of figures

List of appendices

CONTENTS

EXECUTIVE SUMMARY

Sorghum is a major staple food crop grown in Tanzania. However, farmers face difficulties in growing it despite efforts by the government and research and development organizations. It is therefore imperative to develop a business case for the crop's growers to overcome these challenges and provide opportunities for stakeholders to invest along the value chain. This study aims at determining current sorghum grain production, its main uses; grain market demand and main grain off-takers; ascertaining existing varieties, their current rate of adoption and actual yields; determining seed demand and requirements in response to grain demand and analyzing institutional linkages, policies, roles and the capacity of the private sector to enhance the performance of the commodity value chain.

The study was conducted in 10 districts of Tanzania covering sorghum farmers, grain off-takers, research institutions, seed producers, extension officers and policymakers. Purposive and simple random sampling were used to choose the respondents: 212 individual farmers, 80 from 10 focus groups, 63 grain off-takers, 8 seed producers and 3 extension officers. Data was then analyzed using descriptive statistics, probit regression model and cost benefit analysis.

Among the sampled sorghum farmers, 62.3% were male. About 84.0% of them had spent 1-7 years in school. A total of 50.5% were smallholder farmers with less than 0.5 ha of land, 60.4% did not belong to any farmer group and 60.8% had no access to grain markets. Among grain off-takers, the grain market was dominated by men (84.1%), aged between 41 and 60 years (63.5%). About 39% of the sample farmers used improved varieties, of whom 30.7% were from intervention districts and 8.5% from non-intervention districts. The factors that influenced farmer adoption of improved sorghum seeds were the number of years spent in school, group membership, availability of free seed, market accessibility and seed accessibility.

A total 1,048,781 farming household were engaged in sorghum production. The leading sorghum producing zones were Central zone (199,509 t), Lake zone (130,251 t) and Southern Highlands zone (37,840 t). Improved varieties with high adoption rates were NACO Mtama 1 (17.0%), Macia (9.0%), Tegemeo (6.6%) and Pato (4.2%). NACO Mtama 1 was highly preferred because it is disease resistant, drought tolerant and preferred in the market. The study also showed that sorghum farmers obtained improved seeds from their own stock (48.2%), the government (25.3%), Non-Governmental Organizations (NGOs) (13.3%), neighbours (9.6%), Quality Declared Seed (QDS) producers (2.4%) and agro-dealers (1.2%).

Sorghum seeds in Tanzania are produced and multiplied mainly by Tanzania Agricultural Research Institute (TARI - Ilonga and Hombolo centers), Agricultural Seed Agency (ASA), private seed companies and QDS producers. Other actors in the seed system include Tanzania Seed Trade Association (TASTA), Tanzania Official Seed Certification Institute (TOSCI), NGOs, farmer organizations and farmers.

With financial constraints and the lack of proper linkages between entities in the value chain, inefficiencies have crept into the sorghum value chain. A cost benefit analysis of seed production showed an average positive gross benefit of TZS 5.2 million/ha for seed companies and TZS 3.4 million /ha for QDS producers. A cost benefit analysis of grain production showed that improved varieties Pato (TZS 531,220/ha), Macia (TZS 425,563/ha) and NACO Mtama 1 (TZS 401,097/ha) gave high gross benefits.

The study found that a majority of grain off-takers were large off-takers (79%). In terms of trade, grain was exported to Uganda (53.6%), Rwanda (45.6%), Kenya (0.5%), Burundi (0.2%) and United Arab Emirates (UAE) (0.1%). The main drivers in the grain market were alcohol (43.2%), food (40.4%), price (9.5%) and animal feed (6.9%). Among the policy gaps reported were high tax, weak

market links and inadequate promotion of the crop. Most off-takers experienced gaps in quality (71.4%), quantity (15.9%) and market information (7.9%), market unreliability (36.3%), low grain quality (24.8%) and high tax levies (10.6%).

This study suggests the production of improved seeds by institutions, seed companies and QDS producers for accessibility to farmers. Reliable policies subsidizing farm inputs that lower production costs will encourage their use by farmers. Investing in breeding and post-harvest technologies is also crucial. Also required are improvements in market linkages, market intelligence, quality assurance and reduction in tax levies. Enhancing the awareness of processors, consumers and farmers on multiple uses of sorghum through better promotion will also be highly beneficial.

1. INTRODUCTION

1.1. Background

Sorghum [*Sorghum bicolor* (L.) Moench] is among the major staple food crops around the world, mostly grown in semi-arid and arid regions of Africa and Asia. Apart from its use as food, sorghum is used as animal feed in forage and fodder, alcoholic beverages and as biofuel (Prasad and Staggenborg 2011). Sorghum is a nutrient-rich cereal containing carbohydrates, protein, fat, vitamins and minerals (Rao 2010) and is gluten free. It contains phenolic and antioxidant compounds that have health benefits (Xiong et al. 2019). Its morphological and physiological characteristics contribute to its adaptability to drought conditions, including an extensive root system, waxy brooms on leaves that reduce water loss and the ability to stop growth under drought conditions (Brown 2013).

Sorghum is the world's fifth important cereal crop after wheat, rice, maize and barley (FAOSTAT 2014). In 2013, USA was its largest producer (11.5 million MT annually) followed by India (7.5 million MT), Nigeria (7.4 million MT) and Mexico (6.1 million MT). In 2017, it remained the fifth most important grain produced worldwide (about 57 million MT), with USA leading in production (FAOSTAT 2017). Africa has a mean sorghum yield of 0.8 t/hectare (t/ha) and a production of about 20 million t, making it the second most important cereal grain after maize, and accounting for about 70% of the continent's production (Msongaleli et al. 2017).

In Tanzania, sorghum is the third most grown cereal with a production of approximately 500,000 t/year (FAOSTAT 2018). It is mainly grown in semi-arid regions that include Dodoma, Singida, Mara, Shinyanga, Mwanza and Tabora regions. It is largely used for food, feed and brewing. Sorghum demand has seen a recent surge due to its growing use by brewery companies (FEWSNET 2018). Given the crop's importance, farmers need to use and follow best agronomic practices to improve yields, profitability and livelihoods (Kaliba et al. 2018). Despite efforts to improve productivity and integrate consumer preferences into varietal development, the adoption rate of improved sorghum varieties remains low. Low public and private investments, limited ability to forecast seed demand, farmers' limited purchasing power and unreliable markets have been limiting factors in value chain development (AGRA 2016). This underlines the need for further research to address these problems.

1.2. Challenges

Sorghum production in Tanzania increased from 676,772 t in 2015 to 798,172 t in 2017 (FAOSTAT 2017). Nevertheless, production is low and is primarily for consumption. Sorghum productivity in Tanzania is reported to be 1.0 t/ha compared to 2.8 t/ha in Ethiopia and 1.2 t/ha in Nigeria (FAOSTAT 2017). Production has been carried out mainly at subsistence level, and less than 17% of the harvest enters the formal market; the rest is consumed at the farm level (FEWSNET 2018). Commercialization of sorghum is moving at a slow pace, with business entities attempting to add value through its uses in brewing, baking and animal feed. According to Monyo et al. (2002), linking farmers to these commercial markets could stimulate the production and adoption of new technologies, including seeds of improved varieties. Unfortunately, many farmers still use old varieties and traditional post-harvest methods which lead to poor quality grain and low incomes (Simtowe and Mausch 2019). The low adoption of improved varieties and other allied technologies have been attributed to limited availability, inaccessibility, high prices, market accessibility and low income. As a result of this, both quality and quantity of produce in the market have been compromised (Elsheikh et al. 2018). Moreover, the seed sector is underdeveloped, seriously limiting its performance in sub-Saharan Africa (Djamen 2016). In addition, low performance by stakeholders in the value chain has contributed to failure in delivering the required amount of quality seed to

farmers, unreliable grain markets and the provision of quality grain to off-takers and final consumers.

1.3. Objectives

The objective of the study was to develop a business case for sorghum to overcome challenges facing the sorghum sub-sector and provide opportunities for stakeholders to invest along the value chain.

Specifically, it intends to:

- Determine current grain production and its main uses;
- Determine grain market demand and the main grain off-takers;
- Examine existing varieties, the current rate of adoption of improved varieties and their actual yield;
- Determine seed demand and seed requirements in response to grain demand; and
- Discuss institutional linkages, policies and the role of the private sector.

2. LITERATURE REVIEW

2.1. Understanding the process of technology adoption

According to Hall and Khan (2003), the adoption of a technology is defined as the choice to acquire and use an invention or new innovation. The meaning of adoption differs widely across studies and the type of technology adopted. Adoption can be categorized into full adoption (adoption of technologies during production and marketing) or partial adoption (adoption of one technology during the production or marketing process). According to Ogunyemi and Ojo (2014), when at least one of the advanced technologies is used for at least one production season, it can be defined as adoption. Also, according to Doss (2003), if a farmer is using any advanced technology, for instance improved variety of seed, then that can be regarded as adoption. According to Das (2014), if a farmer uses at least any improved technology for at least two consecutive seasons, then it indicates that the farmer is an adopter. The definition adopted in this study corresponds to the last three definitions.

2.2. Theoretical framework

2.2.1. Theory of the firm

This study is based on the Theory of the firm at a micro level, wherein the behaviour of any business entity is said to be driven by profit maximization, subject to budget constraints. When adopting a new technology, simple and minimal production costs are highly anticipated in order to generate more profit from the technology. According to Nicholson and Snyder (2008), the Theory of the firm involves the market in determining price, demand, resource allocation and decision making. In this case, the adoption by seed producers of a new technology in seed production or by farmers of any improved technology increases the chances of high yields that cover production costs, resulting in high gross benefits compared to non-adopters.

2.2.2. Theory of innovation diffusion

According to Rogers (1995), the decision by farmers to adopt any technology occurs through five stages: knowledge, persuasion, the decision to adopt, implementation and confirmation. The decision is affected by different factors. Yates (2001) points out that the diffusion theory is a meta-theory, i.e., a collection of theoretical perspectives that explain the stages of adoption that are affected by different factors. These factors are the nature of the innovation itself, communication channels and time and characteristics of the social system, as explained in the context of this study:

- The innovation: Improved sorghum varieties;
- Communication channels: Extension agents that act as channels to diffuse the agricultural technology to farmers;
- The time needed for the innovation to be adopted: A gradual process beginning with a low adoption rate that may increase or decrease depending on circumstances; and
- The social system or external and internal characteristics that affect farmers' decisions to adopt: The improved technologies were grouped into socio-economic, institutional and technological.

According to Isham (2002), the diffusion of innovation theory by Rogers (1995) has been tested empirically to ascertain the factors that affect adoption of improved technologies by farmers using data from developing countries. Socio-economic factors (age, gender, experience, income, farm size, access to finance, price of the technology, availability of labour, participation in off-farm activities, land tenure, market availability and extension services) explain the adoption of improved technologies.

2.3. Empirical framework

2.3.1. Rate of adoption

Most scholars use descriptive analysis to summarize data on the rate of adoption. A study by Kaliba et al. (2018) noted higher adoption rates of Macia and Tegemeo varieties in Tanzania that accounted for 22% and 18%, respectively. NACO Mtama 1 was less adopted by farmers (adoption rate of 4%). Kinfe and Tesfaye (2018) attribute the low adoption rate (9.5%) of improved sorghum varieties among farmers in Ethiopia to agro-ecological differences.

2.3.2. Determinants of adoption of improved varieties by farmers

Kaliba et al. (2018) showed that farmers' knowledge, capital, market availability, age, marital status and quality of extension services influenced their decision to adopt new sorghum varieties. A study by Oladeji et al. (2015) on determinants of adoption of improved rice varieties in Nigeria demonstrated that income and credit accessibility had a positive influence on the probability of a farmer adopting improved varieties. Awotide et al. (2014) showed that gender negatively influenced the adoption decision of farmers to use seeds, while education, credit accessibility and farm size positively influenced adoption. Gender, availability of labour, soil characteristics, market forces, environmental concerns and technological changes have been shown to influence adoption decisions of sorghum farmers (Kinfe and Tesfaye 2018).

2.3.3. Sorghum value chain in Tanzania

Value chains in agriculture involve the flow of products, knowledge and information among stakeholders and include added value in each stage of production. Value chains differ across countries and products (Agriculture for Impact 2018). Findings by Kilimo Trust (2017) indicate that the sorghum value chain consists of four nodes: input, production, processing and trading (Table 1). Input supply consists of an informal and formal supply system. Informal seed supply involves farmers

obtaining seeds from own stock, neighbours and local markets, whereas the formal seed system involves supply from the government, NGOs and agro-dealers. Sorghum production is done mostly by smallholder farmers (85%) and farmer groups in contracts (15%); hardly any large farmer is involved in its production. Processing is mainly done by small processors (95%) and large processors (5%) in the brewing and food processing industries (Kilimo Trust 2017). Trade is done in local and national markets by small and large traders who trade in and outside the country. There are also support agents and enablers at every stage of the value chain, such as NGOs, financial institutions, government and farmer cooperatives, to mention a few (Table 1).

Table 1. Actors at different nodes of the sorghum value chain in Tanzania.

	Input	Production	Processing	Trading
Actors	Formal seed system Informal seed system	Individual farmers and farmer groups	Small and large processors	Small and large traders
Support agents	Financial institutions (microfinance, banks, SACCOS) Universities (technical/ vocational colleges) Trade Associations	Local government NGOs/ Community-Based Organizations (CBOs) Private companies Cooperative unions Farmer associations	Financial institutions (banks, SACCOS) Ministry of Finance Ministry of Trade and Industry Processors' associations Research institutes, universities/vocational colleges	Financial institutions Ministry of Finance Ministry of Trade and Industry Trade ssociations National standards bodies
Enablers	Ministry of Agriculture Seed inspection and certification service agencies Ministry of Finance Ministry of Trade and Industry	Ministry of Agriculture Seed inspection and certification services Ministry of Finance Ministry of Trade and Industry Universities/vocational colleges	Ministry of Trade and Industry	Ministry of Trade and Industry Revenue authority agencies (TRA)

Source: Kilimo Trust (2017).

2.3.4. Challenges and opportunities along the sorghum value chain

2.3.4.1. Production

Sorghum farmers in Tanzania are mostly smallholders producing at subsistence level, with low yields and incomes (Kimaro 2016). The area under sorghum has increased over the years, yet production has remained low compared to cereals like maize and rice (Macauley and Ramadjita 2015). The low productivity is mainly due to low farmer incomes, pests, diseases, lack of access to inputs, inadequate literacy among farmers and unreliable markets (Mrema et al. 2017). Anderson et al. (2013) report that farmers also experience pre-harvest losses. Chiona (2012) has demonstrated that variability in production has been due to differences in environment, scale of production and

technologies. Farmers and other stakeholders need to concentrate not only on the adoption of new technologies but also on how farmers use them efficiently.

Recently in Tanzania, Serengeti Breweries Limited (SBL) spotted an opportunity for sorghum farmers due to the increase in demand for sorghum by breweries. The brewing industry has established demonstration farms in Kilosa district in Morogoro to help farmers shift to profitable commercial production (American sorghum 2016). In Kenya, East Africa Breweries Limited (EABL) increased its demand for white sorghum, creating opportunities for sorghum farmers (EABL 2017). Global climatic changes too have created opportunities for this drought-resistant crop.

2.3.4.2. Improved varieties

Sorghum is an important source of food for many households in Tanzania and is also used for brewing purposes. This has led to the improvement and development of improved varieties. Kaliba et al. (2017) report that ICRISAT and TARI as well as other NGOs developed three varieties of sorghum, Tegemeo in 1986, Pato in 1995 and Macia, in 1999. In 2002, a collaborative effort led to the release of Wahi and Hakika varieties. This was followed by the release of NACO Mtama 1 in 2012 by Namburi Seed Company and Sila in 2005 by SeedCo. Improved varieties benefit farmers by reducing the risk of crop failure, providing yield advantage and reducing the threat from climate change (Mpangwa 2011). According to Meinzen-Dick et al. (2004), it is imperative that farmers adopt improved varieties to experience these gains. Mpangwa (2011) reports the low adoption of improved varieties, supported by Anderson et al. (2013) who reveal that few plots planted to sorghum had improved variety of seeds.

2.3.4.3. Marketing

Most of the sorghum produced in the country is consumed by farmers. According to FEWSNET (2018), about 83% is consumed and about 17% is sold either at the farm gate or in the market, both urban and rural. However, Orr et al. (2017) believe that the trade in sorghum cannot be generalized since about 64% of sorghum produced in northern Tanzania is sold, while 30% or less produced in central Tanzania is sold and the rest is consumed. Export challenges faced by farmers include low volume of produce, poor quality, storage, transportation costs and competition from other major world sorghum exporters. Erbaugh et al. (2010) report that if processors can provide an assured market for smallholder grain producers, they can provide a stable market for farmers. Sorghum can also be used to make multiple products ranging from food and refreshments to alcoholic products (Dera 2017).

2.3.4.4. Institutions and policy framework

According to Hamukwala et al. (2010), though the private sector is engaged in the seed system and investing in research, extension and markets, the projected output has not been met by the firms, especially in terms of benefits to poor smallholder farmers in the country. Policies governing the seed sector are still not well implemented despite the public-private partnerships in the country, impacting the sector. ESAFF (2013) notes that policies rarely take into account the informal seed sector, local farmers producing seeds are not acknowledged and farmers' varietal preferences are not fully considered. Balie et al. (2013) believe that for production in cereal crops to increase, a subsidy program should be considered, with emphasis on inputs such as fertilizers and pesticides. The government should also reform subsidy programs for these important cereals.

2.4. Economic analysis

2.4.1. Probit analysis of factors influencing adoption decision of sorghum farmers

Jatoe et al. (2005) used the probit model in analyzing these factors among farmers, and observed that age, family labour, farm size and farmers' perceptions positively influenced adoption decision while the distance to seed markets, extension visits and length of fallow periods negatively influenced adoption. According to Timu et al. (2014), taste, ease of cooking, yield, drought tolerance and the ability of the sorghum varieties to fetch a premium price are drivers of adoption by farmers.

2.4.2. Cost-benefit analysis of sorghum production

According to Kumar et al. (2017), a cost-benefit analysis of sorghum seed production resulted in positive average gross benefit for producers. In a cost-benefit analysis of sorghum grain production, Rao et al. (2017) obtained higher net returns despite the rise in production costs. A study conducted in Mali showed that production of improved sorghum varieties gave an average positive gross return (Miklyaev et al. 2017), implying an opportunity for investment.

3. METHODOLOGY

3.1. Study area

The study was conducted in 10 districts, of which 8 had been part of HOPE and TL III project interventions. These districts are Mkalama, Singida DC, Iramba, Ikungi, Serengeti, Rombo, Momba and Nkasi. The districts with no project interventions were Kongwa and Tarime. Grain off-takers were located in Dodoma, Singida, Dar es Salaam, Arusha, Songwe, Mbeya and Kilimanjaro regions. Off-takers were chosen from marketplaces, companies, industries and warehouses. Figure 1 shows regions that produce and trade in sorghum. Secondary data was obtained from the Ministry of Agriculture, Ministry of Industry and Trade and Government agencies such as Tanzania Trade Development Authority (TANTRADE), Business Registration and Licensing Agency (BRELA) and National Bureau of Statistics (NBS).

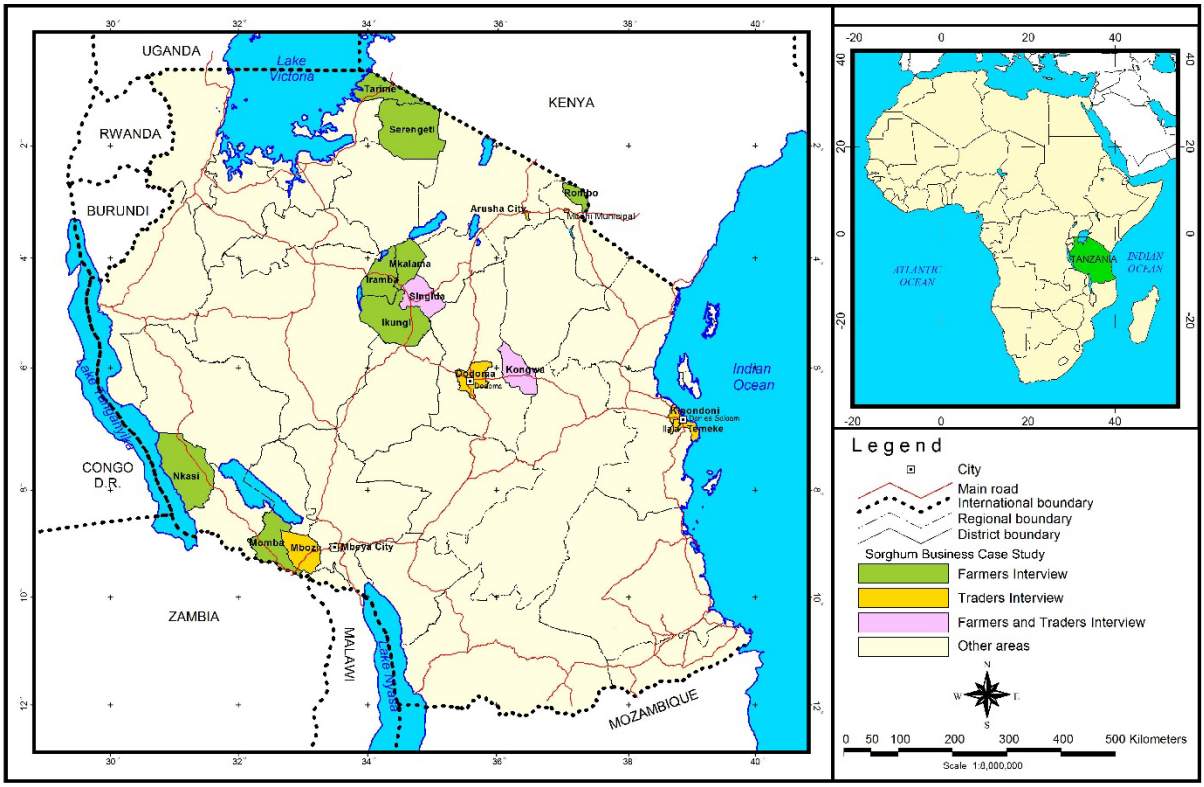

Figure 1. Regions in Tanzania producing and trading in sorghum.

Source: Business case survey (2019).

3.2. Data source and sampling procedures

A cross-sectional research design was employed, and the study used both primary and secondary data. Data from a representative subset in all the districts were collected at a specific point in time. Household surveys, informative interviews and group discussions were the main approaches used to get in-depth information. Secondary data comprised journal articles, government reports and academic dissertations.

The sample included farmers, off-takers, extension officials, researchers, seed producers and government officials. Purposive sampling was employed to select production districts and grain off-takers while simple random sampling was used to select the villages, farmers and seed producers. Kothari (2004) recommends these methods as they focus directly on the intended area of study. The sample size consisted of 212 individual sorghum farmers, 80 farmers from 10 focus groups, 63 grain off-takers, 3 extension officers and 8 seed producers. The list of respondents was obtained from village executives and extension officers who aided the selection of farmers.

3.3. Data processing and analysis

Descriptive statistics were used to analyze seed and grain production, rate of adoption and grain market. Descriptive statistics such as central tendency (percentages and frequencies) was used to summarize the data. The probit model was used to analyze factors affecting the adoption of improved varieties based on gender, age, education, group membership, production purpose, farm size, seed price, availability of free seeds, grain market accessibility and seed accessibility. The dependent variables of the model are 0, 1 (dummy variables); 1 if a farmer adopted improved varieties and 0 if a farmer did not. The model is an appropriate econometric model for the binary dependent variable and the error term is assumed to be normally distributed (Gujarati 2004). The model can be specified as follows:

Probit model: $Y=F(X_i \beta) + \varepsilon_i$..... (1)

$Y_i = \begin{cases} 1= \text{adopter} \\ 0= \text{non-adopter} \end{cases}$

Where, $\varepsilon \sim N(0, 1)$

β = maximum likelihood

i = cumulative distribution functions of standard normal distribution

ε = error term

x = set of independent variables.

The independent variables included gender, age, education, group membership, production purpose, farm size, seed price, free seeds availability, market accessibility and seed accessibility. After analysis, the marginal effect was used to interpret the actual magnitude of change of probability of independent variables.

$$\frac{\delta E(\frac{Yi}{Xi})}{\delta Xi} \quad \text{..... (2)}$$

Where,

Y_i= dependent variable, i.e., the use of seed of improved varieties

X_i= independent variables (gender, age, education, group membership, production purpose, farm size, seed price, free seed availability, market accessibility and seed accessibility)

δ = change in the probability of independent variables with a given change in the dependent variable.

Cost and return analysis

In the cost and return analysis, production costs included those of land, seed, fertilizer, weeding, ridging, herbicides, insecticides, pesticides, labour, transportation, security, threshing, winnowing, shelling, grading and packaging. Total production cost was computed for each farmer to get the average production cost for each variety per hectare. However, total costs varied among farmers depending on the location and range of activities during production. Total revenue was obtained from yield and the average price (in kg) for each individual farmer; hence,

Gross benefits = Total revenue – Total production costs..... (3)

Estimating seed requirement

To estimate the amount of seed of improved varieties required by farmers, the minimum amount of seed that farmers needed in the producing zones to meet the minimum amount of grain demanded was estimated. Estimations were done by considering the grain bought by traders as the minimum amount of grain demanded. The number of hectares needed was estimated using yield per hectare from different varieties depending on the preference in the zones. However, the varieties differed in yield obtained. The computed hectares were then multiplied with seed required to be planted per hectare, wherein 7.5 kg was the sorghum seed required per hectare. This was calculated as follows:

Minimum grain demanded (t) **/** Yield per variety (t/ha) = Area to be planted (ha)…… (4)

Area to be planted (ha) × 7.5 kg of seed/ha = Seed required by farmers…….. (5)

4. RESULTS

4.1. Socio-economic profile of the respondents

4.1.1. Socio-economic profile of farmers

The study districts had a higher proportion of male farmers (62.3%) than female farmers (37.7%) (Table 2). Most of the respondents (51.9%) were between the ages of 45 and 65 while 38.7% were between 25 and 44 years. The time spent in school by most farmers (84.0%) was 1-7 years. Most sorghum farmers (50.5%) owned less than 0.5 ha while 27.4% owned between 0.5 ha and 1 ha. Further, the study shows that 60.4% of the farmers were not organized into farmer groups, 60.8% had no access to markets and about 77% did not have access to seed of improved varieties.

Table 2. Socio-economic and demographic profile of the respondent farmers.

Variable	Category	Farmer (%)
Gender	Male	62.3
	Female	37.7
Age	<25	2.8
	25-44	38.7
	45-65	51.9
	>65	6.6
Number of years in school	0	9.4
	1-7	84.0
	8-13	5.2
	>13	1.4
Farm size (ha)	<0.5	50.5
	0.5-1.0	27.4
	1.2-1.5 1.6-2.0 >2.0	8.8 5.7 7.6
Group membership	Yes	39.6
	No	60.4
Market access	Yes	39.2
	No	60.8
Seed access	Yes	23.1
	No	76.9

4.1.2. Socio-economic profile of grain off-takers

Trade in sorghum was dominated by men (84.1%) compared to women (15.9%) (Table 3). The study also showed that mainly traders aged between 41 and 60 were involved in the sorghum business

(63.5%). Results also indicated that 25.4% of grain off-takers traded between 50 t and 200 t and 38.1% traded more than 500 t. For 55.6% of the grain off-takers, sorghum was not the main crop traded while it was for 31.7% of them. Most off-takers were traders (93.7%) and a few were processors (6.3%).

Table 3. Socio-economic profile of sorghum grain off-takers.

Variable	Category	Off-takers (%)
Gender	Male	84.1
	Female	15.9
Age	<18	-
	18-40	34.9
	41-60	63.5
	>60	1.6
Capacity (t)	<50	20.6
	50-200	25.4
	201-500	15.9
	>500	38.1
Business proportion	<50	55.6
	50	12.7
	>50	31.7
Grain off-takers	Traders	93.7
	Processors	6.3

4.2. Current grain production and its main uses

4.2.1. Current grain production

4.2.1.1. Population, households, farm size and farm households

The population of Tanzania mainland is estimated to be 48,871,466 (2017 projection based on 2012 census data) with 9,109,184 households. While Dar es Salaam had the highest population of 5,781,557 with 1,095,095 households, Katavi had the lowest population of 663,685 with 101,224 households (Table 4). There were also regions with high population and small households and vice versa, such as Mwanza with a population of 3,217,328 and 486,184 households and Kagera with a population of 2,879,231 and 524,793 households.

The average farm size at the national level was 1.35 ha. Dodoma had the largest farm size of 2.6 ha, followed by Manyara with 2.2 ha and Shinyanga and Tabora with 2.0 ha each (Table 4). The regions with the smallest farm sizes were Kagera and Njombe with 0.7 ha each. A total of 4,777,531 households (52.4%) were engaged in crop production activities (Table 4). Appendix 1 shows the area and production of major crops grown in different zones in Tanzania.

Kigoma had the largest number of 617,520 farming households (12.9%), followed by Coast with 435,917 (9.1%) and Tabora with 340,756 (7.4%). Dar es Salaam had the least number of farm households (28,402, 0.6%).

Table 4. Population, number of households, farm size and farming households in the study zones.

Zone	Region	Population	Household	Farm size (ha)	Farm households (no)	Farm households (%)
Southern	Mtwara	1,351,038	344,834	1.6	307,326	6.4
	Lindi	905,947	225,972	1.2	247,079	5.2
Southern Highlands	Mbeya	1,929,359	635,047	1.1	168,643	3.5
	Iringa	996,105	223,028	1.1	77,453	1.6
	Njombe	730,555	170,160	0.7	154,523	3.2
	Rukwa	1,179,149	199,766	1.4	67,941	1.4
	Ruvuma	1,530,955	303,071	0.8	114,850	2.4
	Katavi	663,685	101,224	1.1	61,972	1.3
Central	Dodoma	2,312,141	453,844	2.6	286,123	5.9
	Singida	1,539,286	258,280	1.8	123,141	2.6
Coastal	Dar es Salaam	5,781,557	1,095,095	0.8	28,402	0.6
	Morogoro	2,495,462	506,289	1.6	198,824	4.2
	Coast	1,224,120	257,511	1.2	435,917	9.1
Northern Highlands	Arusha	1,943,196	378,825	1.2	29,478	0.6
	Kilimanjaro	1,790,113	384,867	1.1	49,602	1.0
	Manyara	1,670,191	273,284	2.2	68,110	1.4
	Tanga	2,286,528	438,277	1.5	327,831	6.9
Lake	Mwanza	3,217,328	486,184	0.9	338,109	7.1
	Kagera	2,879,231	524,793	0.7	176,909	3.7
	Geita	1,983,653	286,757	1.5	189,896	3.9
	Shinyanga	1,701,220	261,766	2.0	163,524	3.4
	Simiyu	1,736,839	229,946	1.6	90,151	1.9
	Mara	1,972,173	312,444	1.1	113,451	2.4
Western	Kigoma	2,399,121	374,488	1.0	617,520	12.9
	Tabora	2,652,514	383,432	2.0	340,756	7.4
Total		48,871,466	9,109,184	1.35	4,777,531	100.0

Source: NBS (2013) and NBS (2017).

4.2.1.2. Main crops produced and their land share

Different crops were grown by farmers across the surveyed districts (Table 5). Maize and sorghum had the largest share of land compared to other crops. Maize took the largest share of land in Mkalama (51.0%), Serengeti (47.2%), Iramba (43.0%) and Ikungi (42.0%). Sorghum was mostly grown in Kongwa (43.0%), followed by Momba (43.0%) and Iramba (31.0%). Sunflower was grown in seven districts even though its share of land was less compared to maize. Mkalama had the highest share of land for sunflower (22.0%) after maize, and Singida DC had 22.0% share of the land after maize and sorghum. Pearl millet occupied the largest share of land in Ikungi (22.0%) and finger millet in Singida DC (15.0%). Other crops like cassava, rice, cotton, sesame and sweet potato varied in their availability from one district to another. Sweet potato was grown in Singida DC, rice and sesame were mostly grown in Momba district while cassava and cotton were grown in Serengeti district.

Table 5. Main crops produced and their share of area in the surveyed districts.

District	Crop	Share in area (%)
Ikungi	Maize	42.0
	Pearl millet	22.0
	Finger millet	14.0
	Sorghum	11.0
	Sunflower	11.0
Iramba	Maize	43.0
	Sorghum	31.0
	Sunflower	14.0
	Pearl millet	12.0
Kongwa	Sorghum	43.0
	Pearl millet	18.0
	Maize	17.0
	Sunflower	14.0
	Groundnut	8.0
Mkalama	Maize	51.0
	Sunflower	22.0
	Sorghum	14.0
	Onion	11.0
	Finger millet	2.0
Momba	Sorghum	43.0
	Maize	33.4
	Sesame	8.2
	Sunflower	6.2
	Rice	6.0
	Finger millet	3.2
Singida DC	Maize	33.0
	Sorghum	25.0
	Sunflower	22.0
	Finger millet	15.0
	Sweet potato	2.9
	Pearl millet	2.1
Serengeti	Maize	47.2
	Sorghum	26.5
	Cassava	10.7
	Finger millet	9.3
	Cotton	6.3
Rombo	Maize	38.0
	Sorghum	24.5
	Sunflower	19.8
	Finger millet	10.0
	Groundnut	7.7

4.2.1.3. Average farm size

The total number of sorghum farm households reported in this study was 1,048,781 (Table 6). Dodoma had the highest number of about 237,926, followed by Mwanza with 115,914. Kilimanjaro region had the least number of 966 farm households. Data shows that most of the farmers had small farm sizes. The average farm size of sorghum farmers at the national level was 0.69 ha. Morogoro had the highest farm size of about 1.4 ha, followed by Mbeya with 1.2 ha, while Dodoma and Singida who are the largest producers of sorghum, had small farm sizes of 1.1 ha and 0.9 ha, respectively (Table 6). Regions with the smallest farm sizes were Kigoma with 0.2 ha and Kilimanjaro with 0.1 ha.

Table 6. Sorghum farm households and average farm size by zone.

Zone	Region	Farm households (no)	Average farm size (ha)
Southern	Mtwara	23,228	0.3
	Lindi	43,098	0.5
Southern Highlands	Mbeya	20,924	1.2
	Iringa	3,980	1.1
	Rukwa	5,637	0.9
	Ruvuma	1,544	0.4
	Katavi	3,152	1.1
Central	Dodoma	237,926	1.1
	Singida	103,037	0.9
Costal	Morogoro	7,127	1.4
	Pwani	44,019	0.3
Northern Highland	Arusha	4,719	0.4
	Kilimanjaro	966	0.1
	Manyara	33,863	0.6
Lake	Mwanza	115,914	0.5
	Kagera	13,633	0.5
	Geita	68,052	0.5
	Shinyanga	40,752	1.0
	Simiyu	82,165	0.9
	Mara	96,020	0.6
Western	Kigoma	20,539	0.2
	Tabora	78,486	0.7
Total		1,048,781	0.69

Source: NBS (2017).

4.2.1.4. Total area and production

A total of 812,488 ha was planted with sorghum at the national level and 464,249 t was produced (Table 7). Dodoma was the leading region with a total area of 257,690 ha (31.72%) and production of 133,976 t (28.86%), followed by Singida with 98,263 ha (12.09%) and production of 65,533 t (14.12%) and Simiyu with 76,620 ha (9.43%) and production of 42,168 t (9.08%). Ruvuma cultivated

the least area of 620 ha (0.08%) with a production of 34 t (0.01%) followed by Kilimanjaro with 101 ha (0.01%) and 86 t (0.02%).

Table 7. Area and production of sorghum by region in Tanzania.

Zone	Regions	Area (ha)	Area (%)	Production (t)	Production (%)
Southern	Mtwara	6,766	0.83	3,847	0.83
	Lindi	21,092	2.60	21,497	4.63
Southern Highlands	Mbeya	25,346	3.12	28,931	6.23
	Iringa	4,371	0.54	1,665	0.36
	Rukwa	4,838	0.60	3,177	0.68
	Ruvuma	620	0.08	34	0.01
	Katavi	3,407	0.42	4,033	0.87
Coastal	Morogoro	10,204	1.26	7,508	1.62
	Pwani	11,788	1.45	11,759	2.53
Northern Highlands	Arusha	1,644	0.20	957	0.21
	Kilimanjaro	101	0.01	86	0.02
	Manyara	21,415	2.64	13,412	2.89
Central	Dodoma	257,690	31.72	133,976	28.86
	Singida	98,263	12.09	65,533	14.12
Lake	Mwanza	53,915	6.64	15,464	3.33
	Kagera	6,440	0.79	1,780	0.38
	Geita	34,704	4.27	14,911	3.21
	Shinyanga	42,409	5.22	29,325	6.32
	Simiyu	76,620	9.43	42,168	9.08
	Mara	69,325	8.53	26,603	5.73
Western	Kigoma	4,274	0.53	1,225	0.26
	Tabora	57,256	7.03	36,358	7.83
Total		812,488	100.0	464,249	100.0

Source: NBS (2017).

4.2.1.5. Varieties produced and grain yield

The household survey shows that farmers were using old as well as improved varieties to produce sorghum grain (Table 8). Old varieties originated from farmers, either given by relatives or neighbours. Data shows that old varieties were grown over the largest area (110 ha) with a yield of 122.5 t/ha. Improved varieties -- Pato, Hakika, NACO Mtama 1, Tegemeo and Macia -- were produced by research institutions, seed companies and farmers who produced quality declared seeds (QDS). Improved varieties with the highest area and production were Pato with 27.1 ha and 40.6 t/ha followed by NACO Mtama 1 with 21.3 ha and 26.4 t/ha. Hakika had the lowest area of 1.0 ha and yield of 1.3 t/ha.

Table 8. Varieties produced and grain yield per variety.

Varieties	Area (ha)	Yield (t/ha)
Hakika	1.0	1.3
Tegemeo	17.6	19.3
Macia	12.3	21.1
NACO Mtama 1	21.3	26.4
Pato	27.1	40.6
Local	110	122.5

4.2.1.6. Cost-benefit analysis of grain production by farmers

Results show that farmers were obtaining profits from growing sorghum regardless of the variety they used (Table 9). Of the five improved varieties grown by farmers, four varieties (Pato, Macia, NACO Mtama 1 and Tegemeo) generated higher profits compared to the old varieties. The most profitable improved variety grown by farmers was Pato with an average revenue of 1,415,389 Tanzanian Shillings (TZS)/ha and gross benefit of 531,220 TZS/ha, followed by Macia with an average revenue of 851,228 TZS/ha and gross benefit of 425,563 TZS/ha, NACO Mtama 1 with an average revenue of 795,510 TZS/ha and gross benefit of 401,097 TZS/ha (Table 9). Hakika gave the least average revenue of 866,250 TZS/ha and gross benefit of 351,562 TZS/ha.

Table 9. Costs and returns of grain production by farmers.

Seed variety	Average revenue (TZS/ha)	Average variable cost (TZS/ha)	Gross benefit (TZS/ha)
Pato	1,415,389	881,468	531,220
Macia	851,228	425,664	425,563
NACO Mtama 1	795,510	394,413	401,097
Tegemeo	1,138,750	754,286	384,463
Local	830,218	461,482	368,735
Hakika	866,250	514,687	351,562

4.2.1.7. Main challenges faced by farmers

Farmers faced multiple challenges in production and marketing (Table 10). The most reported production challenges were pest infestation (19.0%), extreme weather (16.6%), lack of inputs (16.0%) and weed infestation (14.2%). Other challenges included insect infestation (14.0%), diseases (9.0%), high input costs (6.1%) and lack of capital (2.8%). The least reported production challenges were the nonavailability of extension services (2.3%) and high transportation costs (4.0%). An unreliable market (44.8%) was the most reported market challenge followed by low prices (32.0%), lack of standardized weights/measures (9.9%) and lack of formal market arrangements (9.3%).

Table 10. Production and marketing challenges faced by farmers.

	Challenge	Farmers (%)
Production		
	Pests infestation	19.0
	Extreme weather	16.6
	Lack of agricultural inputs	16.0
	Weed infestation	14.2
	Insect infestation	14.0
	Diseases	9.0
	High input costs	6.1
	Lack of capital	2.8
	Lack of extension services	2.3
	Total	100.0
Marketing		
	Unreliable grain market	44.8
	Low prices	32.0
	Lack of standard weights/ measures	9.9
	Lack of formal arrangements	9.3
	High transportation costs	4.0
	Total	100.0

4.2.1.8. Interventions suggested by farmers

Farmers proposed interventions for the challenges that they were facing. Under production, the most suggested interventions were providing input subsidies (41.5%), making available inputs (35.8%), providing extension services (8.2%), enabling the availability of threshing machines (6.1%), and providing loans (4.2%) and irrigation technology (4.2%) (Table 11). The farmers also proposed reliable market links (54.7%), fair selling prices (15.4%), contractual farming (11.3%), building rural markets (9.3%) and standard weights/measures (9.3%).

Table 11. Interventions suggested by farmers in the production and market segments.

	Possible interventions	Farmers (%)
Production	Input subsidies	41.5
	Availability of inputs	35.8
	Provision of extension services	8.2
	Threshing machine	6.1
	Loans	4.2
	Irrigation technology	4.2

Market	Reliable markets	54.7
	Fair selling prices	15.4
	Contractual farming	11.3
	Build rural markets	9.3
	Standardized weights/measures	9.3

4.2.2. Main uses of sorghum, production trend and challenges foreseen by farmers

4.2.2.1. Main sorghum uses by region

The main uses of sorghum fall under consumption and commercial categories (Table 12). From the total production of 464,249 t, 419,603 t (90.4%) of grain was used for consumption at the national level. Central zone had the highest consumption, with Dodoma region consuming about 119,199 t (25.68%) and Singida about 61,230 t (13.19%). Simiyu consumed about 41,598 t (8.96%), Tabora 31,052 t (6.69%) and Mbeya 26,601 t (5.73%). Regions with low grain consumption were Kigoma with 689 t (0.15%), Ruvuma with 26 t (0.01%) and Kilimanjaro with 23 t (0.001%) (Table12).

A total of 44,566 t (9.6%) was used for commercial purposes at the national level. Data shows that the Central zone sold more sorghum compared to other zones, with Dodoma region selling about 14,777 t (3.18%) from total production. Tabora region sold about 5,306 t (1.14%), followed by Mara with 4,620 (1.00%) and Singida with 4,303 t (0.93%). Kilimanjaro sold the least amount of 63 t (0.01%) followed by Ruvuma with about 8 t (0.001%) (Table 12).

Table 12. Main uses of sorghum by region in Tanzania.

Zone	Region	Production (t)	Consumption (t)	Percentage (%)	Commercial (t)	Percentage (%)
Southern	Mtwara	3,847	3,847	0.83	-	-
	Lindi	21,497	21,432	4.62	65	0.01
Southern Highlands	Mbeya	28,931	26,601	5.73	2,330	0.50
	Iringa	1,665	1,521	0.33	144	0.03
	Rukwa	3,177	2,817	0.61	360	0.08
	Ruvuma	34	26	0.01	8	0.001
	Katavi	4,033	3,958	0.85	75	0.02
Central	Dodoma	133,976	119,119	25.68	14,777	3.18
	Singida	65,533	61,230	13.19	4303	0.93
Coastal	Morogoro	7,508	7,508	1.62	-	-
	Pwani	11,759	11,759	2.53	-	-
Northern Highlands	Arusha	957	892	0.19	65	0.01
	Kilimanjaro	86	23	0.001	63	0.01
	Manyara	13,412	9,389	2.02	4,023	0.87
Lake	Mwanza	15,464	13,661	2.94	1,803	0.39
	Kagera	1,780	1,308	0.28	472	0.10

	Geita	14,911	12,240	2.64	2,671	0.58
	Shinyanga	29,325	26,950	5.81	2,375	0.51
	Simiyu	42,168	41,598	8.96	570	0.12
	Mara	26,603	21,983	4.74	4,620	1.00
Western	Kigoma	1,225	689	0.15	536	0.12
	Tabora	36,358	31,052	6.69	5,306	1.14
Total		464,249	419,603	90.4	44,566	9.6

Source: NBS **(**2017).

4.2.2.2. Per capita consumption of sorghum

In Tanzania, national per capita sorghum consumption was 9.10 kg/year, while it differed among regions (NBS 2017). In the Central zone, high per capita consumption was observed in Dodoma (51.5 kg/year) and Singida (40.0 kg/year) regions (Table 13). Other regions with high per capita consumption were Simiyu (24.0 kg/year), Shinyanga (15.8 kg/year), Mbeya (13.8 kg/year) and Tabora (11.7 kg/year). Regions with the least per capita consumption were Kigoma (0.3 kg/year), Ruvuma (0.02 kg/year) and Kilimanjaro (0.01 kg/year).

Table 13. Per capita consumption of sorghum by region.

Zone	Region	Consumption (t)	Population	Per capita consumption (kg/year)
Southern	Mtwara	3,847	1,351,038	2.8
	Lindi	21,432	6,905,947	3.1
Southern Highlands	Mbeya	26,601	1,929,359	13.8
	Iringa	1,521	996,105	1.5
	Rukwa	2,817	1,179,149	2.4
	Ruvuma	26	1,530,955	0.02
	Katavi	3,958	663,685	6.0
Central	Dodoma	119,119	2,312,141	51.5
	Singida	61,230	1,539,286	40.0
Coastal	Morogoro	7,508	2,495,462	3.0
	Coast	11,759	1,224,120	9.6
Northern Highlands	Arusha	892	1,943,196	0.5
	Kilimanjaro	23	1,790,113	0.01
	Manyara	9,389	1,670,191	5.6
Lake	Mwanza	13,661	3,217,328	4.2
	Kagera	1,308	2,879,231	0.5
	Geita	12,240	1,983,653	6.2
	Shinyanga	26,950	1,701,220	15.8
	Simiyu	41,598	1,736,839	24.0

	Mara	21,983	1,972,173	11.1
Western	Kigoma	689	2,399,121	0.3
	Tabora	31,052	2,652,514	11.7
Total		419,603	46,072,826	9.10

Source: NBS (2017).

4.2.2.3. Sorghum consumption and commercialization trends, 1995-2018

Data shows that over 23 years (1995-2018), sorghum has been mostly used for consumption rather than commercialization. For instance, the highest amount of sorghum grains ever commercialized was 176,600 t in 2014 (Figure 2). Nevertheless, trends in both consumption and commercialization have been erratic. Between 2009 and 2015, consumption was near consistent, followed by a slight fall from 2016 to 2017, followed by an increase and then a decline in 2018. Commercial use of sorghum has seen an increase since 2009, with a very slight decrease in 2015. Since then, commercialization has been almost constant.

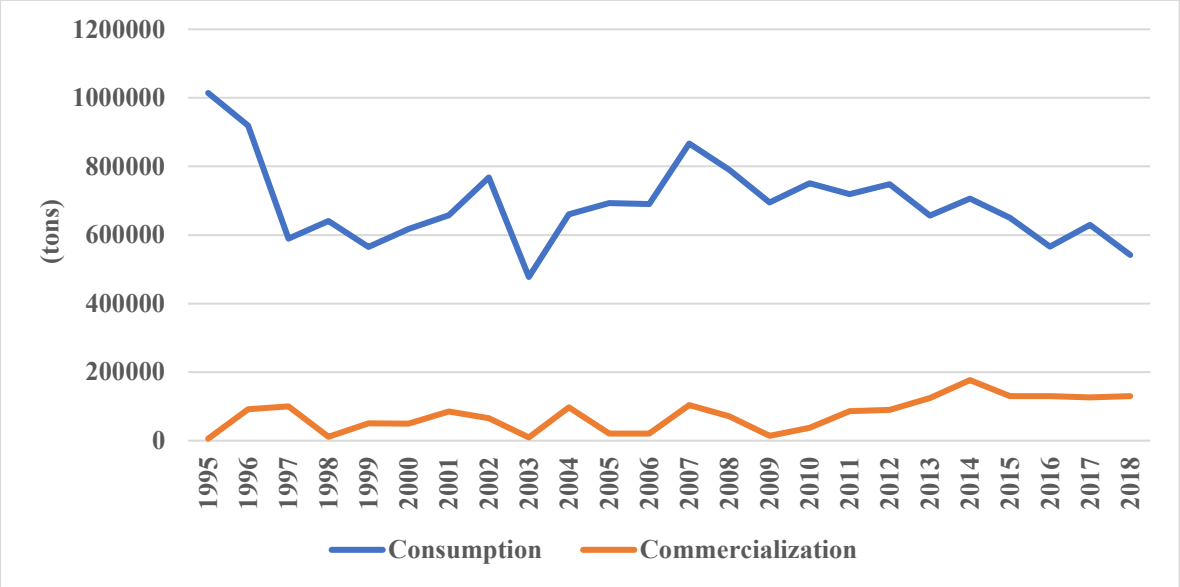

Figure 2. Sorghum consumption and commercialization trends from 1995 to 2018.

Source: NBS (2018).

4.2.2.4. Sorghum production and area, 1980-2018

The study found an inconsistent trend in sorghum area and production over the years. From 1980 to 2009 (Figure 3), there was a dramatic fall in area and increase in production. The highest production was observed in 2007 (971,198 t) and the lowest in 2003 (198,870 t). With regard to area grown to the crop, the largest area planted was in 2009 (874,219 ha) and the smallest area in 1982 (322,890 ha). From 2010 to 2014, there was a gradual increase in production, followed by a decrease in 2015 and a continuous increase from 2016 to 2018.

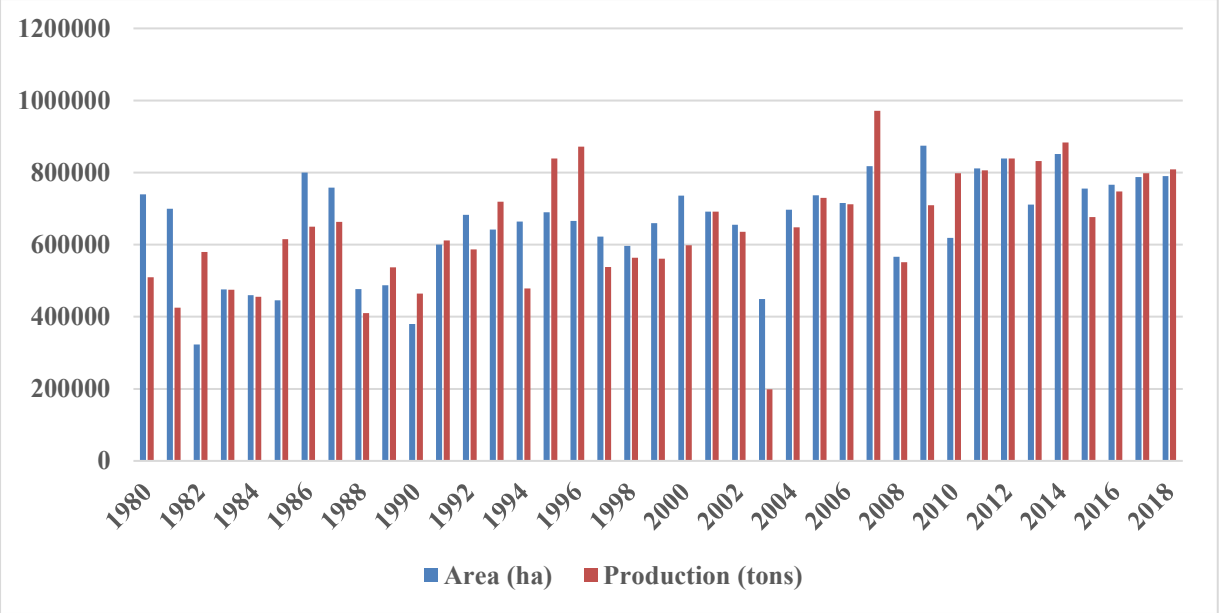

Figure 3. Trends in sorghum production and area from 1980 to 2018.

Source: FAOSTAT (2019).

4.2.2.5. Challenges grain farmers foresee

The main challenges foreseen by farmers (Table 14) were a decrease in grain production (25.4%), a fall in market demand (15.9%), limited alternative grain use (12.7%), unstable market prices (11.1%), nonavailability of desired grain (11.1%), a shift in preference to other foods (11.1%), low quality grain (6.4%) and lack of market incentives (6.3%).

Table 14. Challenges foreseen by farmers.

Challenges	Farmers (%)
Decrease in production	25.4
Decrease in grain market demand	15.9
Limited alternative grain use	12.7
Unstable market prices	11.1
Nonavailability of desired grain	11.1
Shift to other food crops	11.1
Low quality grain	6.4
Lack of incentive to trade sorghum grain	6.3
Total	100.0

4.2.2.6. Interventions suggested by farmers

Farmers suggested interventions to combat these challenges (Table 15). A total of 30.7% of the farmers recommended knowledge dissemination on modern farming practices while 24.6% suggested accessibility to sorghum markets by farmers and off-takers which would push the grain from the farm gate to various users. Providing incentives such as improved varieties, warehouses, loans, fertilizer and pesticide that would help farmers increase production were suggested by 22.4%

of them. Additionally, they sought post-harvest equipment, more alternative uses of sorghum grain (17.5%) to attract more sorghum consumers and the provision of extension services (4.8%) that would allow them to circumvent hindrances to production.

Table 15. Interventions suggested by farmers.

Interventions	Farmers (%)
Knowledge on modern farming	30.7
Market accessibility	24.6
Provision of incentives	22.4
Multiple uses of sorghum	17.5
Provision of extension services	4.8
Total	100.0

4.3. Grain market demand and main grain off-takers

4.3.1. Major grain off-takers

Results show that the major grain off-takers were processors and traders who were either small or large. Off-takers who bought less than 50 t were regarded as small and accounted for about 21.0%, and included only traders. Large off-takers who bought 50 t and more accounted for about 79.0% (Figure 4), with 73.0% being large traders and processors (6.0%).

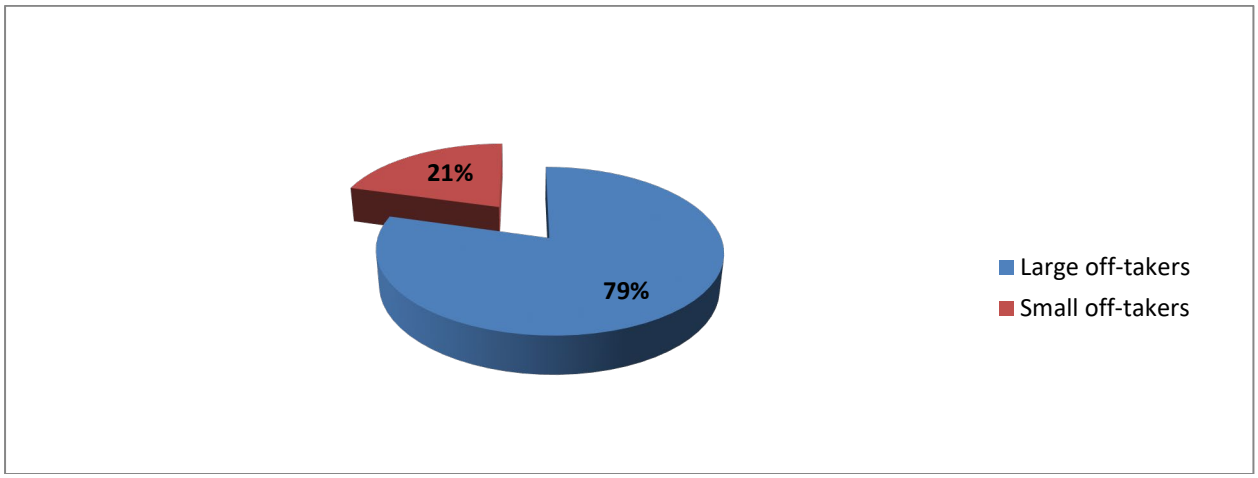

Figure 4. Major sorghum grain off-takers.

Major grain buyers were interviewed from the Central (61.9%), Coastal (20.6%), Northern Highlands (11.1%) and Southern Highlands (6.4%) zones. About 344,312 t of sorghum was bought by different off-takers, with the Central zone having a share of about 70.1% (Table 16). Appendix 2 shows the purchasing capacity of grain off-takers in the surveyed regions.

Table 16. Quantity of sorghum grain bought by off-takers.

Zone	Off-takers (%)	Quantity bought (t)	Quantity bought (%)
Central	61.9	241,233	70.1
Southern Highlands	6.4	71,350	20.7
Northern Highlands	11.1	23,860	6.9
Coastal	20.6	7,869	2.3
Total	100.0	344,312	100.0

Further, sorghum grain was exported to other countries (Table 17): Uganda (53.6%), Rwanda (45.6%), Kenya (0.5%), Burundi (0.2%) and UAE (0.1%). Uganda and Rwanda were the leading importers with 117,100 t and 99,690 t, respectively.

Table 17. Quantity of grain bought by importing countries.

Countries	Quantity bought (t)	Quantity bought (%)
Uganda	117,100	53.6
Rwanda	99,690	45.6
Kenya	1,010	0.5
Burundi	410	0.2
UAE	300	0.1
Total	218,510	100.0

4.3.2. Quality attributes demanded by off-takers inside and outside the country

Three types of sorghum grains were traded inside and outside the country. The most sought was the white variety followed by red and tan varieties. Table 18 shows the types in relation to grain off-takers' preferences. The white variety was in high demand in Southern Highlands zone (100.0%), followed by the Central zone (97.2%), Coastal zone (84.0%) and Northern Highlands zone (66.5%). The red variety was highly preferred in Lake zone (81.7%), Northern Highlands zone (33.5%), Coastal zone (16.0%) and Central zone (2.8%). In Tanzania, the tan variety was demanded only in Lake zone. Outside the country, the white variety was mostly preferred in Kenya (86.0%) and Uganda (80.0%); the red variety in Burundi (100%) and Rwanda (72.7%) and the tan variety in Uganda (20.0%), Kenya (14.0) and Rwanda (9.1%), but in smaller quantities.

Table 18. Preferred sorghum types in and outside Tanzania.

Country	Zone	White (%)	Red (%)	Tan (%)
Tanzania	Central	97.2	2.8	0.0
	Coastal	84.0	16.0	0.0
	Northern Highlands	66.5	33.5	0.0
	Southern Highlands	100.0	0.0	0.0
	Lake	9.0	81.7	9.3
Kenya		86.0	0.0	14.0

Burundi		0.0	100	0.0
Rwanda		18.2	72.7	9.1
Uganda		80.0	0.0	20.0

4.3.3. Market drivers of sorghum grain

Off-takers reported four different drivers that influenced purchase of sorghum grain. Most off-takers bought it for brewing purposes (43.2%), about 40.4% bought it for food purposes and about 6.9% for animal feed. Some off-takers were price driven (9.5%), meaning the decision to buy was mainly influenced by the market price (Table 19).

Table 19. Off-takers' market drivers for sorghum grain.

Market drivers	Off-takers (%)
Alcohol	43.2
Food	40.4
Price	9.5
Animal feed	6.9
Total	100.0

4.3.4. Average grain prices at different market levels and zones

Results show that off-takers bought and sold grain at different market levels and prices in each zone. At the farm gate level, prices were low in each zone compared to other market levels (Table 20). Off-takers from Northern Highlands zone only bought grain at the farm gate and urban markets, and only sold at urban markets. Off-takers from Southern Highlands and Coastal zones bought grain from all three market levels but sold grain only at urban markets. Only off-takers from Central zone traded grain across all market levels.

Table 20. Grain buying and selling prices at different market levels by zone.

Market levels	N/Highlands (TZS/kg)	S/Highlands (TZS/kg)	Central (TZS/kg)	Coastal (TZS/kg)
Farm gate Lowest buying price Average buying price Highest buying price Global average	500 650 925 692	325 365 400 363	223 506 650 460	450 500 550 500
Rural market Lowest buying price Average buying price Highest buying price Global average	- - - -	450 500 600 517	300 566 700 522	600 625 750 658
Urban market Lowest buying price t Average buying price Highest buying price Global average	636 730 960 775	600 800 1,000 800	348 580 880 603	659 771 950 793

Urban market Lowest selling price at urban Average selling price at urban Highest selling price at urban Global average at urban	750 817 1,150 905	638 900 1,100 879	530 725 1,200 752	677 812 1,011 833
Export market Lowest buying price Average buying price Highest buying price Global average	- - - -	- - - -	763 882 1,136 927	- - - -

The study shows that most of the off-takers from Northern Highlands (71.4%), Central (64.0%) and Coastal (58.3%) zones bought grain from urban markets while about 50.0% from Southern Highlands zone bought grain from the farm gate. All the interviewed off-takers in the Central zone sold at urban markets, and 28.2% of these traders also exported to other countries (Table 21).

Table 21. Grain off-takers' buying and selling preferences at different market points by zone.

Markets	N/Highlands (%)	S/Highlands (%)	Central (%)	Coastal (%)
Bought at farm gate	28.6	50.0	28.2	25.0
Bought at rural market	0.0	25.0	7.8	16.7
Bought at urban market	71.4	25.0	64.0	58.3
Sold at urban market	100.0	100.0	100.0	100.0
Sold at export market	0.0	0.0	28.2	0.0

Further, grain off-takers observed price variations in grain for the season of 2017/2018 (Table 22). About 50.8% of them observed low buying prices from May to June, followed by 41.3% between July and August. High buying price months were mostly around October to December (54.1%) and January to March (38.1%). Low selling prices were observed from May to June (38.9%) and July to August (33.9%), while high selling prices were observed from January to March (45.8%) and around November to December (35.5%).

Table 22. Variations observed in the buying and selling prices of sorghum grain by off-takers for the season of 2017/2018.

Low buying price		High buying price		Low selling price		High selling price	
Month	Off-takers (%)	Month	Off-takers (%)	Month	Off-takers (%)	Month	Off-takers (%)
May-Jun	50.8	Jan-Mar	38.1	May-Jun	38.9	Jan-Mar	45.8
July-Aug	41.3	Apr-Jun	3.1	July-Aug	33.9	Apr-Jun	10.2
Sept-Oct	6.3	July-Sept	4.7	Sept-Oct	15.3	Sept-Oct	8.5
Nov-Dec	1.6	Oct-Dec	54.1	Nov-Dec	11.9	Nov-Dec	35.5
Total	100.0		100.0		100.0		100.0

Price variations were due to different reasons (Table 23). Among those reported by off-takers for low buying prices were high grain availability (54.8%), low market availability (27.4%), the on-season period (9.7%) and poor grain quality (8.1%). Reasons for high buying prices included low grain availability (51.6%), high market availability (30.2%), drought (9.7%) and the off-season period (8.5%).

Table 23. Factors affecting variations in buying and selling prices of grain.

Low buying price	Off-takers (%)	High buying price	Off-takers (%)	Low selling price	Off-takers (%)	High selling price	Off-takers (%)
High grain availability	54.8	Low grain availability	51.6	High grain availability	50.8	Low grain availability	40.7
Low market availability	27.4	High market availability	30.2	Low market availability	35.6	High market availability	40.6
On-season period	9.7	Drought	9.7	On-season period	8.5	Off-season	10.2
Poor grain quality	8.1	Off-season period	8.5	Poor grain quality	5.1	High tariffs imposed	5.1
						High transport costs	3.4
Total	100.0		100.0		100.0		100.0

On the other hand, the reasons for low selling price were high grain availability (50.8%), low market availability (35.6%), the on-season period (8.5%) and poor grain quality (5.1%). Reasons for high selling price were low grain availability (40.7%), high market availability (40.6%), the off-season (10.2%), high tariffs (5.1%) and high transportation costs (3.4%).

4.3.5. Market corridors (channels) and marketing gaps

Grain was sold within and outside the country. In Tanzania it was mostly traded in Dodoma, Singida, Arusha, Kilimanjaro, Tanga, Mwanza, Mara, Dar es Salaam, Mbeya, Shinyanga and Zanzibar. Grain was also sold in Kenya, Uganda, Burundi and Rwanda. Findings show that there were four major marketing channels (Table 24):

- From farmers to traders to processors to end users;
- From farmers to traders to end users;
- From farmers to middlemen to processors and
- From contractual farmers to processors.

Table 24. Market corridors (channels) of sorghum grain sale and trait preferences.

Country	Zone	Preferred type (%)	Market corridor	End user/use	Destination
Tanzania	Central	White (97.2) and red (2.8)	1.Farmers to traders 2. Farmers to middlemen to traders	1. Home consumers (thick and thin porridge and local brewing)	Dodoma, Singida, Arusha, Moshi Tanga, Mwanza, Mara and Zanzibar, Dar es Salaam Kenya, Uganda Burundi, and Rwanda
	Southern Highlands	White (100.0)	1.Farmers to middlemen 2.Farmers to traders	1. Traders 2. Processors	Kilimanjaro, Dar es Salaam, Mbeya and Shinyanga
	Northern Highlands	White (66.5) and red (33.5)	1. Contractual farmers to processors 2. Farmers to middlemen to processors 3. Farmers to middlemen to traders	1. Beverage consumers (Senator lager, Kibo lager, and Eagle beer) 2. Food consumers (thin and thick porridge, baked products)	Dar es Salaam, Arusha and Kenya
	Coastal	White (84.0) and red (16.0)	1.Farmers to traders 2. Farmers to middlemen to traders	1. Home consumers (thin and thick porridge) 2. Breweries and small traders	Dar es Salaam
	Lake	Red (81.7) and tan (9.3)	1.Farmers to middlemen to traders	1.Home consumers 2. Breweries	Mara, Mwanza, Burundi and Rwanda
Destination Country		Preferred trait (%)	Market corridor	End user	
Kenya		White (86.0) and tan (14.0)	1.Farmers to middlemen to traders 2. Farmers to traders	1. Breweries 2. Home consumers 3. Humanitarian agencies	
Uganda		White (80.0) and tan (20.0)	1. Farmers to middlemen to traders 2. Farmers to traders	1. Breweries 2. Home consumers	
Rwanda		Red (72.7) white (18.2) and tan (9.1)	1. Farmers to middlemen to traders 2. Farmers to traders	1. Breweries 2. Home consumers	
Burundi		Red (100.0)	1.Farmers to middlemen to traders	1. Breweries 2. Home consumers	
UAE		White (100.0)	1. Farmers to traders	1. Home consumers	

Grain-off takers revealed that most of the grain required was of low quality (71.4%) and only few off-takers (28.6%) did not face any quality gap (Table 25). Regarding the quantity gap, it was reported that there was high availability of sorghum grain (84.1%). Also, 92.1% of grain off-takers had information about the market.

Table 25. Marketing gaps experienced by grain off-takers.

Quality	Off-takers (%)	Quantity	Off-takers (%)	Information	Off-takers (%)
Yes	71.4	Yes	15.9	Yes	7.9
No	28.6	No	84.1	No	92.1
Total	100.0		100.0		100.0

4.3.6. Policies framework: Sorghum marketing regulations

The study observed both favourable and limiting regulations in the sorghum grain market. Some off-takers (16.0%) felt it had lately been easy to obtain grain business permits (Figure 5). For instance, the Tanzania Medicines and Medical Authority (TMDA) no longer issues business permits with tax deducted at source. About 13.0% reported easy access to export permits because of reduced tax at the borders of EAC and SADC member countries. About 55.0% stated that information such as grain market location and price and the presence of the international grain market in Kibaigwa, Dodoma was available to both off-takers and farmers. However, 16.0% of off-takers were unaware of any favourable regulations (Figure 5).

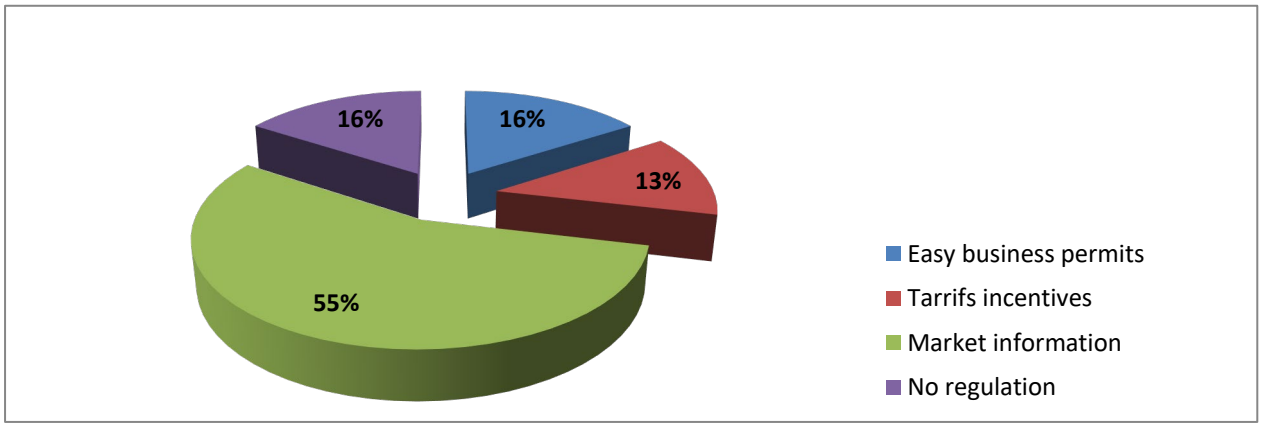

Figure 5. Policies favouring grain marketing.

Some of the limiting regulations reported include high tariffs charged among off-takers (48.0%) and lack of business contracts between grain buyers and sellers (32.0%) (Figure 6). Nonetheless, there were a few off-takers (20.0%) who were unaware of limiting market regulations.

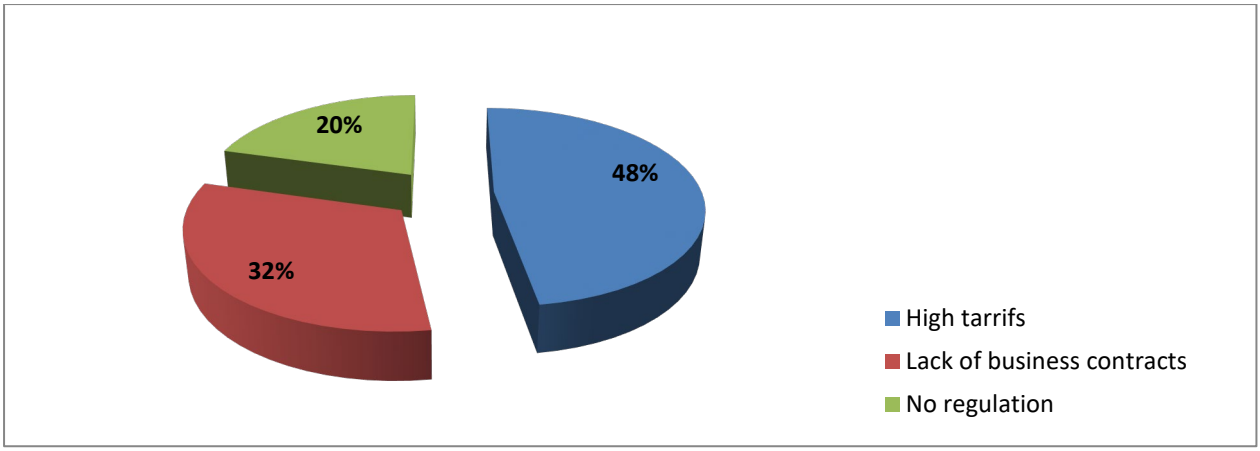

Figure 6. Policies limiting grain marketing.

4.3.7. Off-takers' challenges in grain marketing and interventions suggested

Most off-takers face market unreliability (36.3%), low quality grain (24.8%), high tariffs (10.6%), and lack of grain storage facilities during surplus periods (6.2%). Some off-takers also reported grain nonavailability (5.3%), varying tariffs imposed across districts (4.4%), high transportation cost (3.5%), price fluctuations (1.8%) and lack of capital (1.8%) (Table 26).

Table 26. Ranking of challenges faced by off-takers in the grain market.

Rank	Challenge	Off-takers (%)
1	Market unreliability	36.3
2	Low grain quality	24.8
3	High tariffs	10.6
4	Lack of storage facilities	6.2
5	Low grain price	5.3
6	Nonavailability of grain	5.3
7	Different tariffs imposed across districts	4.4
8	High transportation costs	3.5
9	Price fluctuations	1.8
10	Lack of capital	1.8
	Total	100.0

Off-takers proposed interventions through the government and NGOs. The most obvious interventions were the provision of direct market linkages (34.9%), post-harvest knowledge to farmers to help them obtain quality grain (22.2%), low tariffs (14.3%) and the provision of storage facilities to farmers to maintain the quality of surplus grain (Table 27).

Table 27 . Interventions suggested by off-takers.

Intervention	Off-takers (%)
Direct market linkage	34.9
Post-harvest knowledge	22.2
Low tariffs	14.3
Storage facilities	11.1
Increase grain production	6.3
Emphasis on multiple grain use	4.8
Fair pricing	3.2
Uniform tariffs	1.6
Loan provision	1.6
Total	100.0

4.4. Improved sorghum varieties and their yield potential

4.4.1. Improved varieties released and their traits

Improved sorghum varieties have been developed and released in Tanzania since the 1970s. They include Serena, Tegemeo, Pato, Macia, Wahi, Hakika, Sila, NACO Mtama 1 and PAC (Appendix 3) and possess important traits like early maturity, high yield and tolerance to drought and Striga. Tegemeo, Pato, Macia and NACO Mtama 1 were noted to have high starch content and are highly desirable for brewing. Pato also possesses popping characteristics desirable for making confectionery, while Wahi, Hakika, Sila and PAC possess high palatability suitable for making food products. Wahi and Hakika have tolerance to Striga compared to other varieties.

4.4.2. Nutrient content of improved varieties

Sorghum is reported to have a high starch composition which is a good source of energy as well as higher protein levels than maize. Table 28 shows the nutrient composition of some of these varieties. Macia had higher starch content compared to other improved varieties and lower tannin making it suitable for poultry feed. Macia, NACO Mtama 1 and Tegemeo are used in brewing opaque beer and distilled alcohol due to low tannin. These beverages contain a good proportion of starch, protein, fats, minerals and vitamins.

Table 28. Proximate analysis of improved sorghum varieties.

Variety	MC%	Ash%	CP%	CF%	EE%	CHO%
Hakika	11.47	1.60	11.97	2.07	2.42	70.47
Wahi	11.90	1.32	11.18	2.74	2.25	70.47
Macia	11.83	1.30	10.41	2.47	2.10	71.89
Pato	11.17	1.40	9.96	3.30	2.30	71.87
Tegemeo	11.94	1.16	9.71	3.02	3.1	71.05

MC: Moisture Content, CP: Crude Protein, CF: Crude Fibre, EE: Ether Extract (crude fat) and CHO: Carbohydrates.

Source: Hombolo Research Institute, 2019 (HOPE I project).

4.5. Farmer adoption of improved sorghum varieties

4.5.1. Current adoption rate

According to a farmers' survey and households interviewed, 39.2% adopted improved varieties while 60.8% were non-adopters in the 2017/2018 farming season. The highly adopted varieties were NACO Mtama 1 (17.0 %) and Macia (9.0%). Table 29 summarizes the adoption rates of the different varieties.

Table 29. Adoption rates of different improved varieties.

Varieties	Adoption rate (%)
NACO Mtama 1	17.0
Macia	9.0
Tegemeo	6.6
Pato	4.2
Hakika	0.9
Pato and Tegemeo	0.5
Pato and Macia	0.5
Macia and Tegemeo	0.5
Total	39.2

Higher adoption rates were observed among farmers in the intervention districts (30.7%) compared to non-intervention districts (8.5%) (Table 30). Among all the intervention districts, Singida DC and Songwe had higher adoption rates of 9.0% and 8.1%, respectively. However, a higher adoption rate was observed in the non-intervention district of Kongwa (8.0%), while Tarime district had the lowest adoption rate of 0.5% (Table 30).

Table 30. Adoption rates of improved sorghum varieties among farmers in intervention and non-intervention districts.

Non-intervention district	Adoption rate (%)	Intervention district	Adoption rate (%)
Kongwa	8.0	Singida DC	9.0
Tarime	0.5	Songwe	8.1
		Mkalama	4.7
		Rombo	4.2
		Iramba	3.3
		Ikungi	1.4
Total	8.5	Total	30.7

Farmers had different reasons for using seed of improved varieties (Table 31). Most farmers were motivated to do so because of high yields (54.3%), early maturity (18.1%) and drought resistance

(10.8%). Other motivating factors included the availability of free seed (8.4%), palatability (4.8%) and extension advice (3.6%).

Table 31. Reasons why farmers used seed of improved varieties.

Motivation	Farmers (%)
High yield	54.3
Early maturity	18.1
Drought resistance	10.8
Availability of free seed	8.4
Highly palatable	4.8
Extension advice	3.6
Total	100.0

Varietal replacement was reported by adopters (Figure 7). About 70.0% of the adopters replaced seed with another variety's seed while 30.0% reported replacing it with seed of the same variety. Farmers replaced seeds either by buying or exchange.

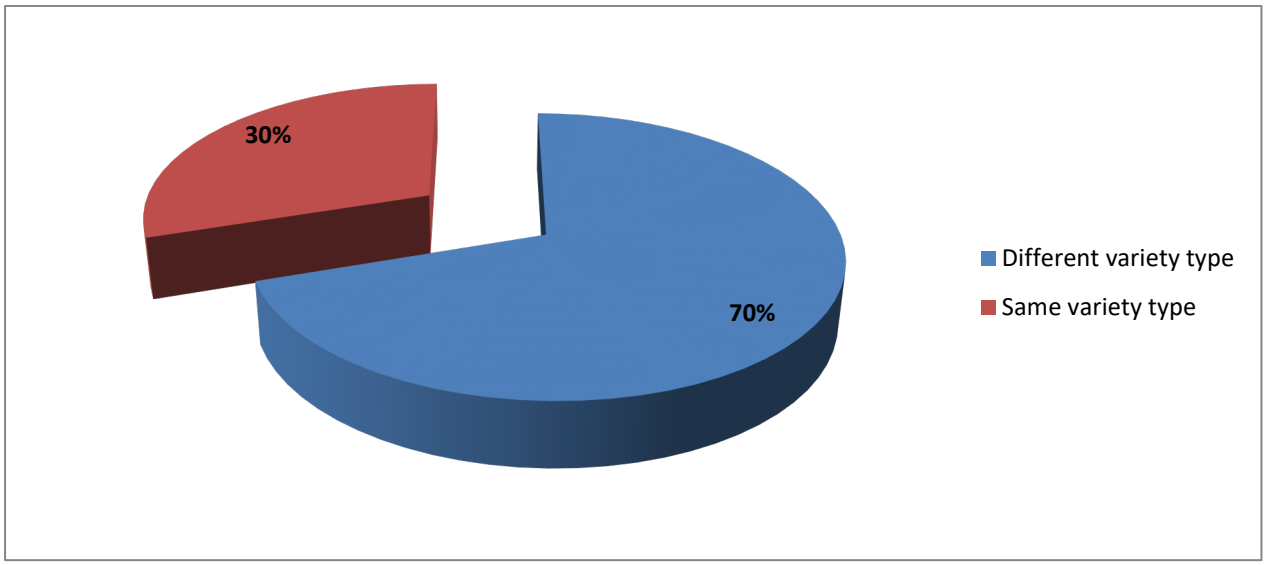

Figure 7. Two modes of varietal replacement adopted by farmers.

The number of years farmers took to replace varieties by buying new seeds ranged from 2 to 36 years (Table 32). About 45.7% of the adopters replaced seeds by buying new seeds while 54.3% did so without buying new seeds.

Table 32. Number of years adopters took to replace seed.

Number of years	Adopters (%)
2-10	28.9
11-20	8.4
21-30	4.8
31-36	3.6
Total	45.7

4.5.2. Socio-economic factors influencing adoption

A probit model was used to identify factors influencing adoption of improved sorghum varieties among farmers. A multicollinearity test was performed whereby tolerance values were greater than 0.2 as the Variance Inflation Factor (VIF) of these variables was less than 10, indicating no multicollinearity. Adopters were categorized into farmers who used at least one of the improved varieties in the 2017/2018 planting season. The estimated results of the model are presented in Table 33. Empirical estimations were done by maximum likelihood model, with the model being highly significant at 1% (chi^2=87.15; p <0.0000). This explains why the model had strong explanatory power. Results showed that the number of years spent in school, farmers' group membership, free seed availability, grain market accessibility and seed accessibility were the only significant factors.

Table 33. Results of a probit model identifying factors influencing farmer adoption of improved sorghum varieties.

Variables	Coefficient	Std.error	P|z|	Marginal effect
Age	0.0034	0.0901	0.706	
Gender (1=male, 0=female)	-0.1392	0.2162	0.520	
Number of years spent in school	0.7672	0.4481	0.087	0.198857*
Group membership (1=yes, 0=no)	0.3856	0.2185	0.078	0.099961*
Production purpose (1=subsistence and commercial, 0=subsistence)	0.4883	0.3341	0.144	
Farm size	0.0842	0.0883	0.340	
Seed price	0.00006	0.0001	0.569	
Free seeds (1=yes, 0=no)	1.0224	0.5066	0.044	0.265004**
Market accessibility (1=yes, 0=no)	-0.8189	0.4177	0.050	0.21227**
Seed accessibility (1=yes, 0=no)	1.7792	0.3675	0.000	0.46114***
Constant	-1.8048	0.6415	0.005	
LR chi^2	87.15			
Prob<chi^2	0.0000			
Pseudo R^2	0.3071			

*** Significant at 1% level, ** significant at 5% level, * significant at 10% level.

The number of years spent in school positively influenced adoption decision among farmers. An increase in one year in school by a farmer was found to have increased the probability of the

adoption decision by 19.8%. Group membership increased the probability of a farmer deciding to adopt an improved variety by 9.9%. Free seed availability from different sources such as the government through extension officers and international organizations like ICRISAT, International Institute of Tropical Agriculture (IITA) and World Food Programme (WFP) showed a positive relationship to farmers' adoption decision. A unit (kg) increase in free seeds increased the probability of adoption of an improved variety by 26.5%. Further, a unit increase in grain market accessibility increased the probability of farmers' adoption by 21.2%. Seed accessibility had a positive effect on adoption whereby a unit increase hiked adoption probability of farmers by 46.11%. This implies that in high accessible areas, most farmers highly adopted an improved variety compared to in less accessible areas.

4.5.3. Farmer awareness of improved varieties

Farmers reported having knowledge of improved varieties that are drought tolerant (37.3%), disease resistant (29.3%) and highly preferred in the market (24.9%). Some of them (8.5%) reported improved varieties being the most expensive (Table 34).

Table 34. Farmers' awareness of improved sorghum varieties.

Knowledge	Farmers (%)
Drought resistance	37.3
Diseases resistance	29.3
Market preference	24.9
Most expensive	8.5
Total	100.0

Farmers also reported on future challenges they anticipate with improved varieties, which included an unreliable markets (11.8%), low production (7.1%), pest infestation (5.1%), excessive drought (4.3%) and bird attacks (0.5%) (Table 35). However, 71.2% of the farmers saw no challenges arising from improved varieties.

Table 35. Challenges farmers foresee with improved varieties.

Challenges	Farmers (%)
Unreliable markets	11.8
Low production	7.1
Pest infestation	5.1
Excessive drought	4.3
Bird attacks	0.5
No challenges	71.2
Total	100.0

4.5.4. Farmers' trait preferences

Farmers reported reasons for preferring different improved varieties, the main ones being disease resistance, drought resistance and market preferences (Table 36). Among all the improved varieties, farmers preferred NACO Mtama 1 for its disease resistance (14.2%), drought resistance (17.5%) and being the most preferred one in the market (16.0%).

Table 36. Reasons for farmers' preference for improved varieties.

Disease resistance	Farmers (%)	Drought resistance	Farmers (%)	Market preference	Farmers (%)
NACO Mtama 1	14.2	NACO Mtama 1	17.5	NACO Mtama 1	16.0
Macia	7.1	Pato	8.5	Macia	4.2
Pato	4.7	Macia	7.1	Tegemeo	4.2
Tegemeo	2.4	Tegemeo	3.3	Hakika	0.5
Hakika	0.9	Hakika	0.9	None	75.1
None	70.7	None	62.7		
Total	100.0	Total	100.0	Total	100.0

4.5.5. Agronomic practices followed by adopters

The study shows that among all the adopters, 26.5% used insecticides, 16.8% used inorganic fertilizers, while 7.2% followed the recommended planting seed rate. About 49.5% did not follow any other agronomic practice except the use of improved varieties; instead, they used traditional methods such as broadcasting, wood ash to control insect pests and organic manure for fertilizer (Table 37).

Table 37. Adoption of recommended agronomic practices by farmers.

Recommended practices	Farmers (%)
Pesticide application	26.5
Inorganic fertilizer application	16.8
Seed rate (7.5-8.7 kg/ha)	7.2
No other recommended practice	49.5
Total	100.0

4.5.6. Challenges faced by adopters of improved varieties and possible interventions

Farmers reported challenges with improved varieties. These were insect infestation (34.9%), bird attacks (12.2%), seed inaccessibility (15.6%), heavy rainfall (9.6%), unreliable grain markets (3.6%) and excessive drought (3.6%) (Table 38).

Table 38. Challenges faced by adopters of improved varieties.

Challenges	Adopters (%)
Insect infestation	34.9
Seed inaccessibility	15.6
Bird attacks	12.2
Heavy rainfall	9.6
Unreliable grain market	3.6
Excessive drought	3.6
No challenges	20.5
Total	100.0

To circumvent these challenges, farmers suggested several interventions (Table 39), among which were accessibility to seeds, especially during planting seasons (38.6%), trainings and demonstration using experimental plots that engage many farmers (36.1%), linking farmers to reliable grain markets (10.9%), favourable seed prices (7.2%) and low-cost subsidized inputs (7.2%).

Table 39. Interventions suggested by farmers to overcome challenges.

Interventions	Adopters (%)
Seed accessibility	38.6
Trainings and demonstrations	36.1
Reliable market links	10.9
Favourable seed prices	7.2
Low-cost subsidized inputs	7.2
Total	100.0

4.6. Seed requirement vs grain demand

4.6.1. Seed source and accessibility of improved varieties and farmer willingness to pay

The study observed that farmers obtained seeds from six different sources (Table 40). Most farmers obtained seeds by recycling their own seeds (48.2%), from the government through extension and research services (25.3%), from NGOs (13.3%), neighbours (9.6%), QDS producers (2.4%) and agro-dealers (1.2%).

Table 40. Different sources of seeds used by farmers.

Seed sources	Farmers (%)
Own recycled	48.2
Government	25.3
NGOs	13.3
Neighbours	9.6
QDS producers	2.4
Agro-dealers	1.2
Total	100.0

Farmers were willing to purchase seeds at different prices. About 46.2% of them were willing to buy seeds at TZS 500-1,000/kg, 40.1% at TZS 1,200-1,500/kg, 11.3% at TZS 2,000-4,000/kg and 2.4 % at TZS 5,000-10,000/kg (Table 41).

Table 41. The price farmers were willing to pay to buy seeds.

Seed price (TZS/kg)	Farmers (%)
500-1,000	46.2
1,200-1,500	40.1
2,000-4,000	11.3
5,000-10,000	2.4
Total	100.0

4.6.2. Seed production and early generation seed

4.6.2.1. Sources of EGS for different categories of seed producers

Different classes of seed (pre-basic, basic, certified and QDS) are produced by different seed producers. In Tanzania, pre-basic seeds of sorghum are produced by research institutes, mainly TARI Ilonga. Basic and certified seeds are produced and multiplied by ASA, research institutes and private seed companies. QDS is produced by farmers in their respective districts. Seed producers are given certification and permission by TOSCI.

4.6.2.2. Challenges of handling seed demand, coping strategies and interventions

In the case of research institutes, the main constraints faced were the weak link with private seed producers and insufficient funds to produce EGS. Seed multipliers found obtaining basic seeds as well as the lower profits of seed producers, especially QDS producers, most challenging. QDS producers complained that many farmers could not buy seeds due to their high price. Some QDS producers were not certified to sell seeds they produced since they failed to meet standards.

Communication between the research institute and QDS producers through District Agricultural Irrigation and Cooperation Officers (DAICOs) and extension officers occurred mostly during seed shortages. Seed producers suggested the need to improve the link between private seed companies and seed producers within local areas in order to create profitable investments along the seed value chain while maintaining high production and accessibility of seeds. The government ought to provide input subsidies to farmers and regulate seed prices so that they can afford new varieties. Support to community-level seed multipliers (QDS producers) needs to be in the form of ensuring that QDS is sold and marketed beyond district boundaries to increase their profits.

4.6.2.3. Cost benefit analysis of seed production

A cost benefit analysis of seed production was done for the research institute, private companies and QDS producers (Table 42). Gross benefits obtained by the research institute were negative because they were not selling produced seeds. The institute was disseminating free seeds to farmers mainly through extension officers. It incurred high production costs; yet it did not sell the seeds.

Private seed companies accrued average positive gross benefits because they sold seeds to farmers, mostly through agro-dealers, private companies and sometimes directly to farmers. The average

selling price for private seed companies was TZS 3000/kg. This goes to show that despite higher production costs incurred by the companies, they were compensated by the average benefits obtained. Among QDS producers, variety Macia showed a higher positive gross benefit followed by NACO Mtama 1 and Wahi. This was due to low production costs since these farmers didn't incur costs on fertilizers, herbicides and pesticides.

Table 42. Cost benefit analysis of seed production by variety.

Seed class	Producer	Variety	Cost (TZS/ha)	Revenue (TZS/ha)	Gross benefit (TZS/ha)
Pre-basic	Research institute	Hakika	704,590	0	704,590
		NACO Mtama 1	706,590	0	706,590
		Wahi	704,590	0	704,590
Certified	Private seed companies	Macia	6,064,186	11,250,000	5,185,814
QDS	QDS producers	NACO Mtama 1	390,285	3,980,000	3,589,716
		Macia	447,507	4,200,000	3,752,493
		Wahi	451,508	3,360,000	2,908,493

Average prices: Certified seed = TZS 3000/kg and QDS = TZS 1200-2000/kg.

4.6.2.4. Estimating seed requirement

Our study showed that the amount of grain bought by off-takers differed by zone, with Central zone being the largest producer and accounting for a large amount of grain traded (Table 43). The relationship between the minimum amount of grain bought and quantity of seed required to reach farmers in all producing zones indicates that a good quantity of seed was accessible to farmers. Also, this depended on the variety that was highly adopted by farmers in the zone during the 2017/18 season.

Table 43. Minimum quantity of grain bought by traders by zone.

Zone	Quantity bought (t)
Coastal	7,869
Northern Highlands	23860
Central	241,233
Southern Highlands	71,350
Total	344,312

To meet the minimum amount traded by off-takers, seeds should be accessible to farmers, especially in the largest producing zones (Table 44). Since there are far more off-takers than the ones interviewed in this study, there is no limit to the quantity of seed required in each zone.

Table 44. Estimated seed required by farmers by zone and the area required for its cultivation.

Zone	Variety	Minimum seed required (t)	Area required for cultivation (ha)
Northern Highlands	Macia	57.26	47,720
	NACO Mtama 1	57.26	47,720
Central	NACO Mtama 1	578.77	482,305
	Macia	578.77	482,305
	Hakika	694.97	579,138
		578.77	482,305
Southern Highlands	Macia	171.24	142,700
	Hakika	205.62	171,348
	Pato	171.24	142,700
	Tegemeo	171.24	142,700

4.7. Institutional linkages, policies and role of the private sector

4.7.1. Institutions involved in seed system activities

In Tanzania, TARI, TASTA, TOSCI, ASA, NGOs, farmer organizations/groups, universities and private seed companies are involved in seed system activities. These institutions have different roles (Table 45) and are linked along the seed value chain.

Table 45. Roles of different actors in the sorghum seed value chain.

Actors	Roles
TASTA	Represents the interests of private seed companies to the government; works with the government and other stakeholders in formulating and reviewing seed policies; represents the interests of the seed sector locally and internationally; ensures the seed industry conforms to regulatory requirements and promotes seed quality among seed stakeholders.
TOSCI	Policy regulator; ensures compliance of quality standards; enforces rules and regulations; conducts national performance trials; recommends varieties for release; reviews rules and regulations; registers seed dealers; provides import and export permits; provides seed certification and produces and sells seed tags.
TARI	Conducts research (to produce and maintain breeder seeds and to develop improved varieties); develops agronomic packages; produces foundation seed; protects and registers varieties; licenses varieties to the private sector and promotes varieties.
ASA	Produces and promotes foundation and certified seeds; markets seed; provides seed production land to the private sector; provides seed processing facilities and provides advisory services to seed stakeholders.
NGOs and FBOs	Collaborates with TARI to mobilize farmers; creates awareness; disseminates seed of improved varieties and builds the capacity of farmers to produce QDS.

Actors	Roles
Private seed companies	Conducts research activities (developing new varieties, production and maintenance of breeder seeds); ensures compliance with seed regulations; produces and markets certified seeds; promotes seeds; provides advisory services to farmers and stakeholders; ensures variety utilization and promotes land use and management.
Universities [Sokoine University of Agriculture (SUA)]	Research and consultancy in seed development, and promotes and markets seeds.
Farmer groups	Produces and promotes QDS for other farmers to use seeds of improved varieties.

4.7.2. National and regional seed policies

The seed policies consist of national and regional [East African Community (EAC) and Southern African Development Community (SADC)] seed policies. These policies have brought some positive and negative aspects in the seed sector, as reported by the interviewed seed producers. While QDS producers were not aware of any of these policies, the research institute and all private companies interviewed were aware of them (Table 46).

Table 46. Seed producers' knowledge of seed policies.

Seed producer category	Knowledge of seed policies
Public research institute	Yes
Private seed companies	Yes
QDS producers	No

Among the positive aspects of seed policies mentioned by the research institute and seed companies were increased seed production, availability of breeder rights, quality control, harmonization of investment and improved linkages among researchers in the seed value chain, both domestic and international (Table 47). Other aspects included the simplification of the seed business since Tanzania as a SADC member country is accredited for seed exports. Seed companies reported that EAC cooperation had fast-tracked regional varietal release, and upon registration the variety could be used by any member country.

Table 47. Pros and cons of national and regional seed policies.

Positive aspects		Negative aspects	
National	Increased seed production		Poor management
	Breeder rights available		Private producers' unreliability
	Quality control		
Regional	Harmonized business investment		Greater business competition
	Simplified import and export		
	Variety use by member countries		

Among the negative aspects reported were poor management which led to failure to impose proper restrictions, private companies' unreliability and increased business competition brought on by regional cooperation that might limit the profit-making opportunities of producers.

4.7.3. Policy incentives influencing grain off-taker's use of sorghum

Grain off-takers (12.8%) suggested increasing consumer awareness about the use of sorghum for food since it is among the healthiest crops. Some (6.3%) also suggested government interventions to enhance sorghum production, especially in leading producing regions. Unfortunately, most grain off-takers (80.9%) were not aware of any incentive that could influence greater use of the crop (Table 48).

Table 48. Off-takers' awareness of policies enhancing the use of sorghum grain.

Policy incentives	Off-takers (%)
Health promotion	12.8
Production promotion	6.3
No knowledge	80.9
Total	100.0

4.7.4. Awareness and roles of the private sector

Farmers were asked about their awareness of institutions, including the private sector and their role in agricultural production. Most farmers (88.0%) didn't know about the institutions. About 12.0% of the farmers knew of institutions such as ICRISAT (6.0%), IITA (3.0%) and WFP (1.0%); however, some respondents (2.0%) could not recall names of institution (Figure 8).

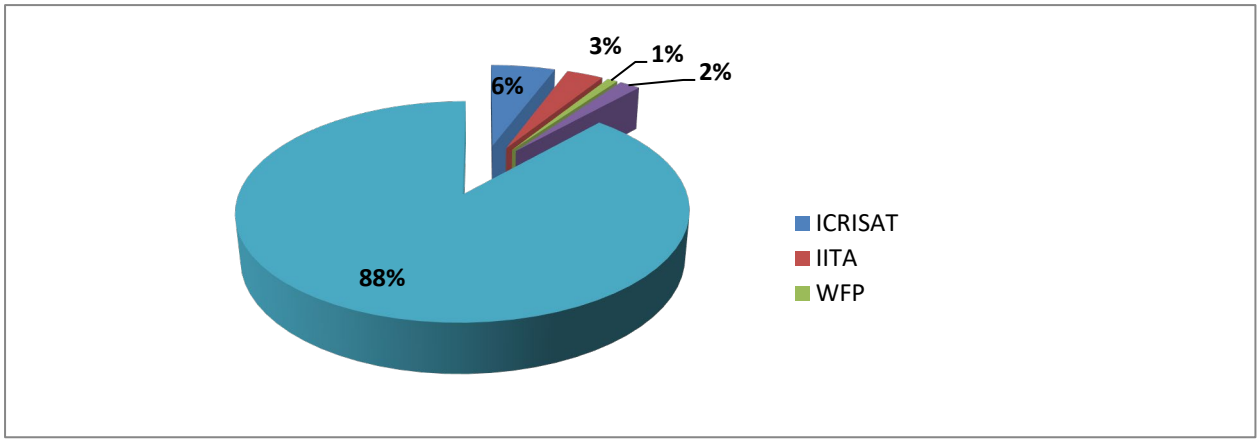

Figure 8. Farmers' awareness of different institutions involved in agricultural production.

Farmer awareness of private institutions and the roles they played are given in Figure 9. Farmers said that these institutions provided free seeds (47%), training (41%) and free fertilizer (12%).

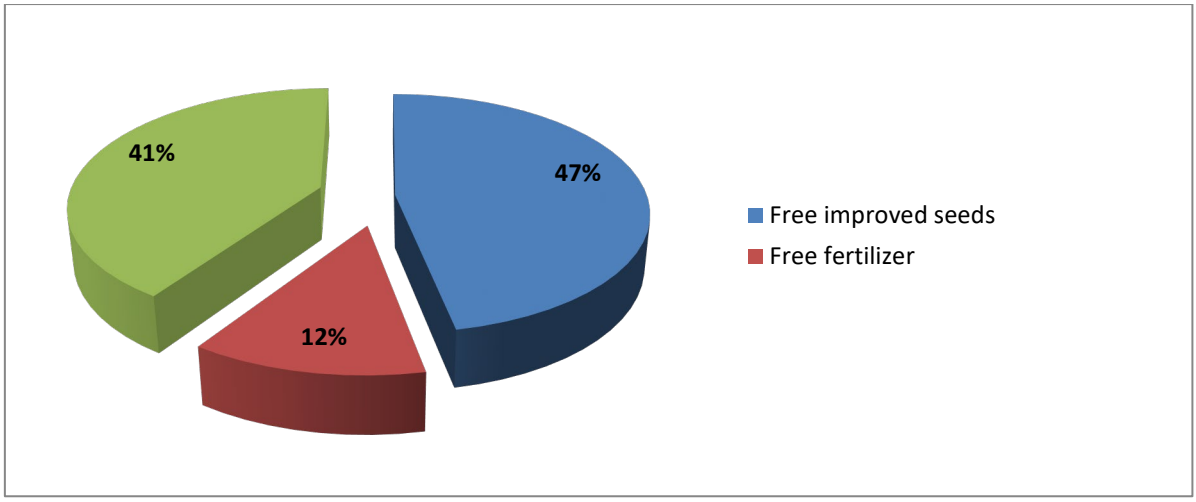

Figure 9. Farmer awareness of the roles played by the private sector.

Grain off-takers acknowledged the different roles of the private sector (Figure 10). Most off-takers mentioned roles such as agro-food processing (41.0%), awareness creation about multiple uses of sorghum grain (32.0%), market creation (19.0%) and inputs supply (8.0%).

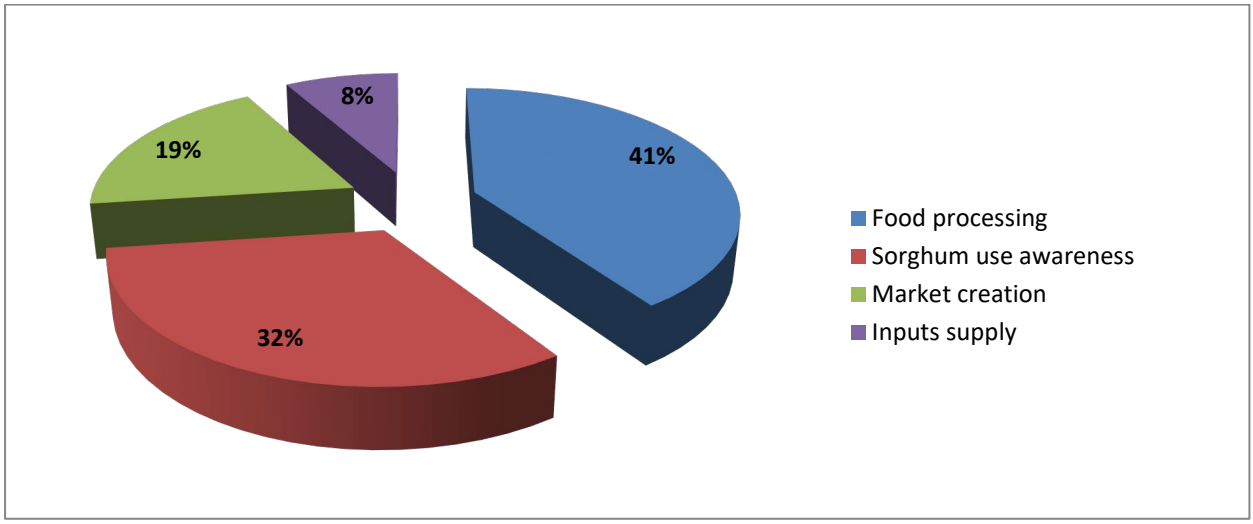

Figure 10. Off-takers' awareness of the roles played by the private sector.

4.7.5. Policy gaps in enhancing sorghum seed and grain businesses

The key policy gaps reported by the research institute was lack of research funds and laboratory facilities and failure of the extension department to deliver information on different technologies to farmers. Grain off-takers reported gaps such as high marketing tariffs during transportation (27.0%), weak market links (28.6%) and inadequate sorghum promotion (20.6%) (Table 49).

Table 49. Policy gaps observed in enhancing sorghum grain marketing.

Policy gaps	Off-takers (%)
High tariffs	27.0
Weak marketing links	28.6
Inadequate promotion	20.6
None	23.8
Total	100.0

5. DISCUSSION

5.1. Production of sorghum grain and its main uses in Tanzania

Sorghum production is mostly done in the semi-arid regions of the country that include Central, Lake and Western zones which have similar agro-ecological conditions. Most of the production is by smallholder farmers. The national sorghum farm size was 1.4 ha in 2017 (NBS 2017). Sorghum is mainly grown by smallholder farmers operating at subsistence level (Mitaru et al. (2012).

During production, farmers either use improved or old varieties or both. Some of these varieties have similar traits while others differed in terms of yield, colour, taste and resistance to diseases and pests. Farmer choice of these varieties depended on preferred traits. The grain yield of a variety depended on factors such as its high yielding trait, ability to tolerate drought, disease and pests and farmers' choice of agronomic practices (fertilizer and pesticide use and seed rate). Old varieties occupied the largest area of 110 ha and yielded 122,476 kg, which may have been because most farmers use local varieties. According to Msongaleli et al. (2017), most households plant old sorghum varieties, sometimes together with improved varieties.

Sorghum was mostly used for consumption (90.6%) and/or commercial purposes (9.4%). The low commercialization may have been due to lack of ready markets and low price. As a result, this has created a gap in commercial production (Mitaru et al. 2012).

Farmers faced production and marketing challenges that prevented high yields and higher financial benefits. For instance, failure to obtain inputs forced farmers to use local inputs such as old varieties. Lack of access to seeds has been reported either because farmers revert to old varieties or quit production (Simtowe and Mausch 2019). High input costs stopped farmers from purchasing them; hence they continued using local inputs such as manure and traditional methods such as ash to mitigate pests and insects. Mundia et al. (2019) report that high cost of inputs force farmers to engage in production using ineffective local inputs. Climate change events like excessive rainfall and drought were shown to have immense effect on sorghum production. Farmers also experienced weed infestation that constrained high yields. Peerzada et al. (2017) report of weeds causing 15-97% losses in sorghum yield and growth. The most common market challenge reported was inaccessibility which served as a disincentive for farmers to grow the crop. Unreliable grain markets and low prices can limit farmers' interest in producing and managing sorghum (Rohrbach and Kiriwaggulu 2007).

5.2. Adoption and profitability of improved sorghum varieties

Factors that support farmers' decision to adopt an improved variety could influence profitability levels. Educated farmers are likely to be less ignorant and less conservative when it comes to trying new technologies. Teferi et al. (2015) noted that educated farmers are more likely to adopt innovations more easily than uneducated ones.

Farmer groups simplify accessibility of improved technologies such as improved variety of seeds, knowledge, and other extension services. In areas with high seed accessibility, farmers easily adopt improved varieties (Elsheikh et al. 2018). Further, farmers are easily motivated when seeds are freely available because many of them can't afford current seed prices. In most cases, farmers obtained seed of improved varieties from the government through research and extension officers. It is highly imperative to improve seed accessibility of farmers, especially close to planting season. Grain market accessibility acts as an incentive to adopt improved varieties. This implies that farmers take production risks by incurring an extra cost since they are sure of a market.

Although many farmers had used old varieties, their margins were very low compared to farmers who had used improved varieties. Old varieties have late maturity and are less stress tolerant leading to low grain yield (Mwamahonje and Maseta 2018). This demonstrates that farmers have a better chance of obtaining higher financial benefits with the use of improved varieties than from using old varieties. Simtowe and Mausch (2019) noted that farmers' preference of improved varieties is tied to early maturity, high yield and high stress tolerance.

5.3. Commercialization of sorghum grain

Sorghum grain was traded across the country, mostly in the Central zone. This is because most of the grain production is undertaken in this zone, which also happens to be the main area of sorghum trade (Rohrbach and Kiriwaggulu 2007). Other East African countries import grain from Tanzania as it is the leading producer in East Africa (Orr et al. 2016).

Market drivers were based on uses of the grain, its quality and price. The white variety was highly preferred for food due to its high palatability, and for brewing due to low tannin content. Red and tan varieties are preferred due to their prominent bird resistance trait and for food, especially by those with diabetes and also for brewing due to their high tannin composition (FEWSNET 2018). A range of food products such as thin and thick porridge flour, powder drinks, bread and cakes are made from both white and red sorghum to give consumers choices. However, red varieties are used less for brewing because they leave a bitter taste. Furthermore, clean grain with a moisture content of about 2-4% is highly preferred by individual buyers and breweries [Tanzania Breweries Limited (TBL) and SBL] for quality and machine safety.

Major off-takers tend to change their preferences depending on market forces. Rhodes (2014) reports that the sorghum grain market is anticipated to increase due to a rise in demand for its health benefits since it is gluten-free and good for diabetics. Grain demand is also expected to rise due to an increase in demand from the brewing industry (American Sorghum 2016). Increase in grain demand creates an incentive for farmers to shift into profitable commercial production.

Sorghum grain price is market driven, implying that its price increases when demand increases (Mundia et al. 2019). Furthermore, among all market levels, the urban market offered higher prices due to the extra costs incurred on transportation, packaging, cleaning and standardization.

Indirect market linkages discouraged most farmers since middlemen tend to offer low prices and make high profits. Farmers mostly preferred market channels from farmers to off-takers and then to consumers since farmers could sell grain at a reasonable price compared to when middlemen are

involved. The other preferred channel was from farmers to processors. This was easy for farmers who had contracts with brewery companies. Contract farming was not a common channel because off-takers experienced quality and quantity gaps. While grain off-takers had market information, the only gap was a direct link between actors in the value chain.

Off-takers also faced market unreliability. Geoffrey (2010) noted that poor quality grain offered to off-takers gives them a hard time in competing in the market. Also, high tariffs imposed on them cause traders to increase grain price that leads to fewer buyers in the market.

5.4 Policy framework: Seed policy in Tanzania

The Government of Tanzania regulates the release of improved varieties, drives certification and phytosanitary measures. Regulation is done through the Seed Act (2003), Protection of New Plant Varieties Act (2002) and Plant Breeders Right (No 222, 2002). This allows for the co-existence of public and private institutions and an emphasis on strong linkages. The policy aims to support both local and international bodies in participating in breeding, seed production and multiplication in a harmonized manner (ASARECA/KIT 2014). Specifically, public organizations in the agricultural value chain are primarily involved in developing seed varieties while private institutions are involved in producing and marketing seed varieties. At the regional level, Tanzania has harmonized seed regulations within EAC and SADC regions which allow the introduction of new improved varieties within the member countries. Since the establishment of a National Seed Committee (NSC) by the Seed Act (2003), sub-committees have been formed on testing, evaluating and recommending candidates for seed release (Rutger 2012). The Seed Act also recognizes the roles of TOSCI and QDS production since it actively encourages seed dissemination and accessibility at the local level. The Protection of New Plant Varieties Act of 2002 was reviewed in 2013 to comply with the International Union for the Protection of New Varieties of Plants (UPOV) 1991 regulations and renamed the Plant Breeders Rights Act (2013). The Act focuses on promoting all breeding activities fairly by observing all breeders' rights while facilitating and improving seed development in the country (Sullivan et al. 2012).

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

Recently, the production of and area under sorghum have been increasing, indicating possible increase in its demand within and outside the country. Tanzania has been exporting more sorghum grain to neighbouring countries, confirming its place as the leading producer in East Africa. In Tanzania, white sorghum was highly preferred in the Southern Highlands zone while red and tan varieties were highly preferred in Lake zone. The Northern Highlands, Central and Coastal zones highly preferred white and red varieties. White sorghum was mostly preferred in Kenya, Uganda and UAE, while red sorghum was highly preferred in Burundi and Rwanda. Tan sorghum was preferred by fewer off-takers in Uganda, Kenya and Rwanda.

The adoption rate by sorghum farmers was low (39.2%), and the most adopted varieties were NACO Mtama 1 (17.0%), Macia (9.0%), Tegemeo (6.6%) and Pato (4.2%). Results from the probit analysis show that socio-economic factors like the number of years in school, group membership, availability of free seed, seed accessibility and grain market accessibility positively influenced farmers' adoption decision. The cost benefit analyses of seed and grain production showed positive gross benefits, demonstrating that farmers and seed producers can invest in improved sorghum seeds and obtain high financial benefits. The study also showed that farmers preferred seeds with desirable production and marketing traits. It demonstrated the weak linkage among value chain actors that needs to be strengthened by addressing constraints within the value chain. The private sector has played a role in the value chain in the areas of seed production, marketing and consumption, despite obstacles such as high tariffs, taxes and unreliable markets, to name a few.

6.2. Recommendations

1. There are opportunities for agro-dealers, research institutes, private seed companies and NGOs to invest in the distribution of seed of improved varieties in order that they reach a majority of farmers with no access to them.
2. Seeds produced by institutions, seed companies and QDS producers need to be accessible to farmers for more quality grain to be produced, creating a market for seed producers. This can be done through the mobilization, promotion and advertisement of improved varieties.
3. There is a clear business opportunity for farmers to invest in producing sorghum grain. However, they need to be encouraged to use other improved technologies apart from seed of improved sorghum varieties in order to increase benefits.
4. The government needs to review policies and subsidize farm inputs for sorghum to lower production costs in order to encourage farmers to use them.
5. There is a need to invest in breeding and post-harvest technologies to obtain seeds with desirable traits and to ensure grain quality.
6. It is important to enhance market links, market intelligence, quality assurance and reduce the tax levied throughout the value chain.
7. Greater awareness needs to be built among all value chain actors such as farmers, traders, processors and final consumers about the multiple uses of sorghum through more training, promotion and advertisements. This will enhance sorghum seed and grain production, marketing and create a profitable business environment.

REFERENCES

Agriculture for Impact. (2018). Agricultural value chains. http//disrupt-africa.com/agrinnovating-for-africa-2018/. Visited on 02/02/2019.

AGRA (Alliance for a Green Revolution in Africa). (2016). Africa agriculture status report. Progress towards agricultural transformation in Sub-Saharan Africa. Nairobi, Kenya. Issue No. 4. 284 pp.

American Sorghum. (2016). Sorghum sees research breakthroughs and new markets. United Sorghum Check off Program. http://www.sorghumcheckoff.com. Visited on 17/12/2019.

Anderson L, Gaffney A, McKee C, Slakie E and Gugerty K. (2013). Tanzania national panel survey LSMS-ISA: sorghum and millet. Evans school policy and research (EPAR). The University of Washington. 9 pp.

ASARECA/KIT. (2014). Tanzania seed sector assessment: A participatory national seed sector assessment for the development of an Integrated Seed Sector Development (ISSD) programme in Tanzania. Entebbe, Uganda. 169 pp.

Awotide B, Abdoulaye T, Alene A and Manyong M. (2014). Assessing the extent and determinants of adoption of improved cassava varieties in south-western Nigeria. Journal of development and agricultural economics 6 (9): 376–385. Academic journals. https://doi.org/10.5897/jdae2014.0559

Balie J, Angelucci F, Gourichon H, MasAparisi A and Witwer M. (2013). Monitoring and analyzing food and agricultural policies in Africa. MAFAP Synthesis Report 2013. MAFAP Synthesis Report Series. FAO: Rome, Italy. 156 pp.

Brown D. (2013). Contribution of sorghum production towards food household food security in Tanzania. A case study of Singida region. Dissertation for Award of Master's degree at Sokoine University of Agriculture, Morogoro, Tanzania. 88 pp.

Chiona S. (2012). Technical and allocative efficiency of smallholder maize farmers in Zambia. Unpublished MSc Thesis, University of Zambia, Lusaka, Zambia. 54 pp.

Das B. (2014). ICTs adoption for accessing agricultural information: Evidence from Indian agriculture. Agricultural Economics Research Review27 (2):199–208.

Dera J. (2017). Sorghum and millet processed products availability in retail supermarkets: Bulawayo, Zimbabwe, MAYFEB. Journal of Agricultural Science 2:18–27.

Djamen P. (2016). Developing the seed sector to increase agricultural productivity in West and Central Africa. Key interventions areas and guiding principles. Policy brief. Conseil Ouest et Centre African pour la Recherche et le Development Agricoles (CORAF)/West and Central African Council for Agricultural Research and Development (WECARD): Dakar, Senegal. 11 pp. 10.13140/RG.2.2.25936.81921.

Doss R. (2003). Understanding farm technology adoption: lessons learned from CIMMYT's Micro Surveys in Eastern Africa. CIMMYT Economics working paper 03-07. Mexico, D.F: CIMMYT. 20 pp.

EABL (East Africa Breweries Limited). (2017). EABL'S New demand for sorghum growers. http://www.foodbusinessafrica.com.

Elsheikh S, Hashim A, Faki H and Elamin E. (2018). Factors affecting adoption of improved varieties of Sorghum, millet, groundnut, and sesame in North Kordofan State. Agricultural Research and Technology: Open Access Journal 13(4): 1–8.

Erbaugh M, Mbiha R, Kilima T, Hamukwala P, Tembo G and Larson W. (2010). Market development in support of sorghum and millet farmers in Tanzania and Zambia, International Sorghum and Millet Collaborative Research Support Program (INTSORMIL CRSP). Presentations 22. https://digitalcommons.unl.edu/intsormilpresent/22. Visited on 30/08/2020.

ESAFF. (2013). Seeds and agriculture research processes in Tanzania: The case of small scale farmers' participation in setting research agenda participation. 42 pp.

FAOSTAT. (2014). Food and Agriculture Organization, Statistics Division. Rome, Italy.

FAOSTAT. (2017). Food and Agriculture Organization, Statistics Division. Rome, Italy.

FAOSTAT. (2018). Food and Agriculture Organization, Statistics Division. Rome, Italy.

FAOSTAT. (2019). Food and Agriculture Organization, Statistics Division. Rome, Italy.

FEWSNET (Famine Early Warning Systems Network). (2018). Tanzania market fundamentals summary. Agriculture/Food and Nutrition. URT.

Geoffrey M. (2010). Evaluating factors affecting marketing of sorghum in Mwingi district. Thesis paper. College of Agriculture and Veterinary Sciences. University of Nairobi.

Gujarati D. (2004). Basic Econometrics. 4th ed., McGraw-Hill, New York. 1001 pp.

Hall B and Khan B. (2003). Adoption of new technology. National Bureau of Economic Research Working Paper, Working Paper 9730. Massachusetts Avenue, Cambridge. 19 pp.

Hamukwala P, Tembo G, Larson D and Erbaugh M. (2010). Sorghum and pearl millet improved seed value chain in Zambia: Challenges and opportunities for smallholder farmers. INTSORMIL Scientific Publications. University of Nebraska- Lincoln. 44 pp.

Isham J. (2002). The effect of social capital on fertilizer adoption: Evidence from rural Tanzania. Journal of African Economies11 (1):39–60.

Jatoe J, Al-Hassan R and Abatania L. (2005). Factors affecting the adoption of improved sorghum varieties among farm households in the Northwest Ghana: A Probit analysis. Ghana Journal of Development Studies 2 (1):37–50.

Kaliba R, Mazvimavi K and Ghebreyesus S. (2017). Economic profitability and risk analyses of improved sorghum varieties in Tanzania. Journal of Development and Agricultural Economics 9(9):251–268.

Kaliba AR, Mazvimavi K, Geoffrey T, Mgonja F and Mgonja M. (2018). Factors affecting adoption of improved sorghum varieties in Tanzania under information and capital constraints. Agric. Econ. 6 (8):1–21.

Kilimo Trust. (2017). Mapping study of food-grain value chains in Eastern Africa. CTA discussion paper. Wageningen, Netherlands. 46 pp. https://cgspace.cgiar.org/handle/10568/100815?show=full.Visited on 30/08/2021.

Kimaro P. (2016). Niche market opportunities for Sorghum smallholder farmers Tanzania. Paper presented at Innovative Agriculture Research Initiative (IAGRI) Graduate Researcher Workshop, Morogoro, Tanzania, 5-6 May 2016.

Kinfe H and Tesfaye A. (2018). Yield performance and adoption of released sorghum varieties in Ethiopia. Edelweiss Applied Science and Technology 46–55. 10.33805/2576.8484.115.

Kothari CR. (2004). Research methodology: Methods and techniques: Second Revised Edition ed. New Age International. 418 pp.

Kumar V, Bahukhandi D and Wasnik V. (2017). An economic analysis of sorghum seed production: A profitable enterprise for farmers. Agro Economist - An International Journal, 4(1): 11–14.

Macauley H and Ramadjita T. (2015). Cereal crops: Rice, maize, millet, sorghum, wheat. Feeding Africa. 36 pp.

Meinzen-Dick R, Adato M, Haddad L and Hazell P. (2004). Science and poverty: An interdisciplinary assessment of the impact of agricultural research. Food Policy Report. Washington, D.C: International Food Policy Research Institute. 22 pp.

Miklyaev M, Afra S, Schultz M and Awantang A. (2017). Cost benefit analysis of Mali's sorghum and millet value chains. Development discussion paper. EDIRC Kingston. 39 pp. https://cri-world.com/publications/qed_dp_300.pdf . Visited on 30/08/2021.

Mitaru N, Mgonja A, Rwomushana I and Opio F. (eds.) (2012). Integrated sorghum and millet sector for increased economic growth and improved livelihoods in Eastern and Central Africa. Proceedings of the ECARSAM Stakeholders Conference, 20–22 November 2006, Dar es Salaam, Tanzania. ASARECA (Association for Strengthening Agricultural Research in Eastern and Central Africa), Entebbe. 168 pp.

Monyo S, Mgonja A, Ngereza A and Rohrbach D. (2002). Adoption of improved sorghum and pearl millet varieties in Tanzania. International Sorghum Millets Newsletter 43:12–14.

Mpangwa M. (2011). Adoption and economic impacts of improved sorghum varieties in semi-arid areas of Tanzania: A case of Singida rural district. MSc. Thesis, Agricultural Economics of Sokoine University of Agriculture, Morogoro, Tanzania.

Mrema E, Shimelis H, Laing M and Bucheyeki T. (2017). Farmers' perceptions of sorghum production constraints and Striga control practices in semi-arid areas of Tanzania. International Journal of Pest Management 63(2): 146–156.

Msongaleli S, Kihupi N and Rwehumbiza F. (2017). Performance of sorghum varieties under variable rainfall in Central Tanzania. International Scholarly Research Notices, 2506946:1-10.

Mundia C, Secchi S, Akamani K and Wang G. (2019). A regional comparison of factors affecting global sorghum production: The case of North America, Asia and Africa's Sahel. Sustainability 11(7):2135. https://doi.org/10.3390/su11072135

Mwamahonje A and Maseta Z. (2018). Evaluation of yield performance of sorghum (*Sorghum bicolor* L. Moench) varieties in Central Tanzania. International Journal of Agronomy and Agricultural Research 13, (2):8–14.

NBS (National Bureau of Statistics). (2013). The 2012 Population and housing census, Population distribution by administrative area. Dar es Salaam, Tanzania. https://www.nbs.go.tz/index.php/en/census-surveys/population-and-housing-census/162-2012-phcpopulation-distribution-by-administrative-areas.Visited on 10/07/2019.

NBS (National Bureau of Statistics). (2017). Annual agriculture sample survey crop and livestock report. Dar es Salaam, Tanzania. https://www.nbs.go.tz/nbs/takwimu/Agriculture/2016-17_AASS%20Report%20_Final.pdf . Visited on 10/07/2019.

NBS (National Bureau of Statistics). 2018. Consumption and Commercialization trends of sorghum (unpublished data). Dar es Salaam, Tanzania.

Nicholson W and Snyder C. (2008). Microeconomic theory: Basic principles and extensions. Mason, Ohio: Thomson/South-Western. 740 pp.

Ogunyemi A and Ojo S. (2014). Analysis of factors influencing the adoption of improved cassava production technology in Ekiti state, Nigeria. International journal of Agricultural Sciences and Natural Resources 1(3): 40–44.

Oladeji OO, Okoruwa VO, Ojehomon VET, Diagne A and Obasoro OA. (2015). Determinants of awareness and adoption of improved rice varieties in North Central, Nigeria. Rice Genomics and Genetics 6 (7): 1–10.

Orr A, Gierend A and Choudary D. (2017). Value chain for sorghum and millet in Eastern and Southern Africa: Priorities for CGIAR Research Program for Dryland Cereals. ICRISAT Socio-economic Discussion Paper Series No. 42, 81 pp.

Orr A, Mwema C, Gierend A and Nedumaran S. (2016). Sorghum and millets in Eastern and Southern Africa. Facts, trends and outlook. Working paper series No. 62. ICRISAT research program, market, institutions and policies. Patancheru 502 324, Telangana, India: International Crops Research Institute for the Semi-Arid Tropics. 76 pp. http://oar.icrisat.org/9441/2016-062%20WPS%2062%20S%26M%20ESA.pdf. Visited on 26/05/2020.

Peerzada A, Ali H and Chauhan B. (2017). Weed management in sorghum [*Sorghum bicolor* (L.) Moench] using crop competition: A review. Crop Protection 95: 74–80.

Prasad V and Staggenborg S. (2011). Growth and production of sorghum and millets, in soils, plant growth and crop production (Willy H, Ed.). Encyclopedia of life support systems (EOLSS). Oxford, UK. 27 pp.

Rao B. (2010). Nutrition and health benefits of sorghum and millets. Pages 26-31 *in* Research and development in millets: Present status and future strategies. Ed (1). Directorate of sorghum Research. file:///C:/Users/EAkpo/AppData/Local/Temp/Nutritionalandhealthbenefitsofsorghumandmillets.pdf .Visited on 30/08/2021.

Rao B, Mukherjee D, Devi Y and Vilas T. (2017). An economic analysis of improved rabi sorghum cultivars in rain fed situation of Maharashtra, India. International Journal of Current Microbiology and Applied Sciences. Special issue: 7–15.

Rhodes D. (2014). Diversity, genetics and health benefits of sorghum grain. Doctoral dissertation. Retrieved from https://scholarcommons.sc.edu/etd/3005. Visited on 03/09/2019.

Rogers M. (1995). Diffusion of innovations. 4thEdition. The Free Press, New York. 519 pp.

Rohrbach D and Kiriwaggulu B. (2007). Commercialization prospects for sorghum and pearl millet in Tanzania. Journal of SAT Agricultural Research 3(1): 1–25.

Rutger P. (2012). Tanzania seed sector status 2012. SVALOF. http://q.datakultur.se/~svalofco/wpcontent/uploads/2012/12/Tanzania-SeedSector-StatusPaper.

Schipmann-Schwarze C, Muange E, Orr A and Mafuru M. (2011). Dry land cereals and household food security in Tanzania: Potential and constraints of improved sorghum cultivars. Presented at the

conference, 18-24 August 2012, Foz do Iguacu, Brazil (No. 126232). International Association of Agricultural Economists. 25 pp.

Simtowe F and Mausch K. (2019). Who is quitting? An analysis of the dis-adoption of climate smart sorghum varieties in Tanzania. International Journal of Climate Change Strategies and Management 11 (3):341–357.

Sullivan A, Mwamakamba S, Mumba A, Hachigonta S and Sibanda L. (2012). Climate smart agriculture: more than technologies are needed to move smallholder farmers toward resilient and sustainable livelihoods. FANRPAN policy brief. Issue no.2: Volume XIII. 4 pp.

Teferi A, Philip AY and Jaleta M. (2015). Factors that affect the adoption of improved maize varieties by smallholder farmers in Central Oromia Ethiopia. Developing Country Studies 5(15):50–59.

Timu AG, Mulwa R, Okello J and Kamau M. (2014). The role of varietal attributes on adoption of improved seed varieties: the case of sorghum in Kenya. Agric. and Food Security 3 (9):1–7. https://doi.org/10.1186/2048-7010-3-9.

Xiong Y, Zhang P, Warner R and Fang Z. (2019). Sorghum grain: From genotype, nutrition and phenolic profile to its health benefits and food applications. Comprehensive Reviews in Food Science and Food Safety 18 (1): 2025–2046.

Yates L. (2001). Applying diffusion theory: Adoption of media literacy programs in schools. Paper presented at the International Communication Association Conference, Washington, DC. 29 pp.

APPENDICES

Appendix 1. Area and production of major crops grown in different agro-ecological zones of Tanzania.

Zone	Region	Maize (ha)	Maize (t)	Sorghum (ha)	Sorghum (ha)	Simsim (ha)	Simsim (t)	Cashew (ha)	Cashew (t)	Cassava (ha)	Cassava (t)
Southern	Mtwara	143,566	95,519	11,309	2,749	21,301	2,709	220,883	133,489	75,250	228,431
	Lindi	199,483	92,243	54,769	36,035	267,532	77,489	157,707	41,220	19,875	19,044
	Total	343,049	187,762	66,078	38,784	288,833	80,198	378,590	174,709	95,125	247,475
Southern Highlands		Maize (ha)	Maize (t)	Paddy (ha)	Paddy (t)	Irish potato (ha)	Irish potato (t)	Simsim (ha)	Simsim (t)	Groundnut (ha)	Groundnut (t)
	Mbeya	356,563	539,726	124,734	132,540	25,362	88,341	34,072	31,445	97,242	45,393
	Iringa	237,770	442,584	820	4,014	2,601	9,857	3,059	118	7,943	4,220
	Njombe	128,192	204,367	50	8	19,465	35,226	0	0	1,419	1,093
	Rukwa	248,595	465,138	37,230	35,468	0	0	13,437	4,472	9,204	10,997
	Ruvuma	173,822	172,480	25,408	21,748	0	0	0	0	0	0
	Songwe	0	0	0	0	0	0	0	0	0	0
	Katavi	150,420	187,762	39,504	77,318	0	0	34,017	6,076	24,805	35,136
	Total	1,295,362	2,012,057	227,746	271,096	47,428	133,424	84,585	42,111	140,613	96,839
Central		Maize (ha)	Maize (t)	Sorghum (ha)	Sorghum (t)	Sunflower (ha)	Sunflower (t),	Groundnut (ha)	Groundnut (t)	Simsim (ha)	Simsim (t)
	Dodoma	438,149	164,803	176,346	81,854	185,906	62487	41,040	20,034	134,832	21,746
	Singida	367,072	197,324	112,963	48,688	139,662	67,682	21,261	9,422	3,684	664
	Total	805,221	362,127	289,309	130,542	325,568	130,169	62,301	29,456	138,516	22,410
Eastern		Maize (ha)	Maize (t)	Sweet potato (ha)	Sweet potato (t)	Paddy (ha)	Paddy (t)	Sugarcane (ha)	Sugarcane (t)	Simsim (ha)	Simsim (t)
	Dar es Salaam	143	673	4,598	12,001	3,623	3,834	0	0	0	0
	Morogoro	193,561	204,059	542,207	325	158,296	197,931	390,421	37,187	13,591	8,116
	Coast	147,190	95,885	3,615	3137	90,481	79,561	0	0	14,267	2,575
	Total	340,894	300,617	550,420	15,463	252,400	281,326	390,421	37,187	27,858	10,691
		Maize (ha)	Maize (t)	Wheat (ha)	Wheat (t)	Sorghum (ha)	Sorghum (t)	Beans (ha)	Beans (t)		
Northern Highlands	Arusha	221,935	131,585	14,687	15,886	10,066	9,846	76,019	25,956		
	Kilimanjaro	149,983	194,855	20,642	15,692	457	650	59,595	44,674		
	Manyara	391,826	308,688	11,082	9752	15,486	5,359	2,850	6,031		
	Tanga	547,082	587,042	146	0	1,422	420	76,019	47,229		
	Total	1,310,826	1,222,170	46,557	41,330	27,431	16,275	214,483	123,890		

Lake		Cotton (ha)	Cotton (t)	Maize (ha)	Maize (t)	Paddy (ha)	Paddy (t)	Sunflower (ha)	Sunflower (t)	Sorghum (ha)	Sorghum (t)
	Mwanza	32,735	24,285	378,894	260,451	155,785	196,825	0	0	24,770	13,385
	Kagera	0	0	178,744	190,867	20,996	36,915	3,580	4,424	9,264	5,801
	Geita	40,974	72,613	399,948	546,836	174,201	72,6490	4,958	3,109	5,893	3,099
	Shinyanga	82,932	194,194	409,518	362,882	284,522	392,549	6,082	7,034	41,819	17,986
	Simiyu	214,003	112,396	448,251	274,610	45,355	30,609	17,559	8798	58,399	34,214
	Mara	21,843	48,457	304,927	351,302	6,681	6,626	0	0	92,928	107,463
	Total	392,487	451,945	2,120,282	1,986,948	687,540	1,390,014	32,179	23,365	233,073	181,948
Western		Maize (ha)	Maize (t)	Beans (ha)	Beans (t)	Bulrush (ha)	Bulrush (t)	Tobacco (ha)	Tobacco (t)	Groundnut (ha)	Groundnut (t)
	Kigoma	814,104	703,769	3,563	627	34,139	14,283	72,402	98,608	108,826	94623
	Tabora	359,464	423,823	110,897	92,527	4,038	4,648	4,698	12,607	87,739	38,112
	Total	1,173,568	1,127,592	114,460	93,154	38,177	18,931	77,100	111,215	196,565	132,735

Source: NBS (2017) crop census.

Appendix 2. Purchasing capacity of grain off-takers in different regions.

Regions	Purchasing capacity (t)
Arusha	60
Arusha	180
Arusha	1,000
Arusha	14,000
Arusha	4,000
Arusha	120
Dar es Salaam	80
Dar es Salaam	50
Dar es Salaam	50
Dar es Salaam	2,000
Dar es Salaam	1,000
Dar es Salaam	2,000
Dar es Salaam	645
Dar es Salaam	1,050
Dar es Salaam	1,000
Dar es Salaam	60
Dar es Salaam	3
Dar es Salaam	10
Dar es Salaam	1
Dodoma	300
Dodoma	5
Dodoma	28
Dodoma	5

Dodoma	7,000
Dodoma	20
Dodoma	2
Dodoma	2,000
Dodoma	100,000
Dodoma	240
Dodoma	100
Dodoma	300
Dodoma	30
Dodoma	120
Dodoma	5
Dodoma	216
Dodoma	350
Dodoma	1,500
Dodoma	100
Dodoma	700
Dodoma	500
Dodoma	300
Dodoma	113,000
Dodoma	1,300
Dodoma	5,000
Dodoma	500
Dodoma	3,800
Dodoma	330
Dodoma	1,300
Kilimanjaro	4,500
Mbeya	30,000
Mbeya	40,000
Mbeya	300
Mbeya	1,050
Singida	100
Singida	60
Singida	60
Singida	90
Singida	1,500
Singida	60
Singida	200
Singida	25
Singida	5
Singida	2
Total	344,312

Appendix 3. Sorghum varieties released in Tanzania and their yields, agronomic and market traits.

Varieties	Year	Developer	Organization	Yield (t/ha)	Agronomic traits	Marketing traits
Serena	1970	EAC	EAC	3.0-3.5	Recommended for altitudes below 1500 m above sea level (asl), high yield, drought resistant, brown, medium-sized grains and takes about 105-115 days to maturity.	Palatable for food
Tegemeo	1983	ARI Ilonga	Public	3.0-3.5	Recommended for altitudes from 0-1300 m asl, 500-1200 mm rainfall, white grains, high yield and takes about 120 days to maturity.	High starch content suitable for beer making
Pato	1997	ARI Ilonga	Public	3.0-3.5	Recommended for altitudes from 0-1300 m asl, 500-1200 mm rainfall, white grains, tolerant to leaf spot but susceptible to leaf blight, high yield and takes about 120 days to maturity.	Popping characteristics and high starch content suitable for beer making
Macia	2000	ARI Ilonga	Public	3.5-4.0	Recommended for altitudes from 0-1300 m, 500-1200 mm rainfall, grows in light, fertile and well drained soils, white grains, tolerant to leaf blight, high yield and takes about 120 days to maturity.	High starch content suitable for beer making
Wahi	2002	ARI Ilonga	Public	2.0-2.5	Recommended for altitudes from 0-1500 m asl, 200-500 mm rainfall, tolerant to leaf blight and striga, white grains, high yield and takes about 100 days to maturity.	Highly palatable
Hakika	2002	ARI Ilonga	Public	2.5 - 3.0	Recommended for altitudes from 0-1500 m asl, 200-500 mm rainfall, tolerant to leaf blight and striga, white grains, high yield and takes about 105 days to maturity.	Highly palatable
SILA	2005	SEEDCO	Public international	3.5	Recommended for altitudes from 0-1200 m asl, drought tolerant, tolerant to leaf blight, white grains, and takes about 110-130 days of maturity.	Suitable for food
NACO Mtama 1	2012	Namburi Seed Company	Private local	3.0-3.5	Recommended for altitudes from 0-1300 m asl, white grains, high yield and takes about 120 days to maturity.	High starch content suitable for beer making
NACOSH 1	2013	Namburi Seed Company	Private local	4.5-5.5	Recommended for altitudes from 1-1300 m asl, white big grains, high yield, grows in light fertile soils and takes about 120 days to maturity.	High starch content suitable for beer making
NACOSH 2	2013	Namburi Seed Company	Private local	3.0-3.5	Recommended for altitudes from 1-1300 m asl, white big grains, high yield, grows in light fertile soils and takes about 120 days to maturity.	High starch content suitable for beer making
PAC 537	2014	Advanta Seed Company	Private international	3.8	High yield and pearl white grain	Suitable for food and feed
PAC 501	2014	Advanta Seed Company	Private international	3.7	High yield and pearl white grain	Suitable for food and feed

This work was undertaken as part of, and funded by the CGIAR Research Program on Grain Legumes and Dryland Cereals (GLDC) and supported by CGIAR Fund Donors.
https://www.cgiar.org/funders/

About CRP-GLDC

The CGIAR Research Program on Grain Legumes and Dryland Cereals (CRP-GLDC) brings together research on seven legumes (chickpea, cowpea, pigeonpea, groundnut, lentil, soybean and common bean) and three cereals (pearl millet, finger millet and sorghum) to deliver improved livelihoods and nutrition by prioritizing demand driven innovations to increase production and market opportunities along value chains.
http://gldc.cgiar.org

About the CGIAR

CGIAR is a global research partnership for a food-secure future. CGIAR science is dedicated to reducing poverty, enhancing food and nutrition security, and improving natural resources and ecosystem services. Fifteen CGIAR Centers in close collaboration with hundreds of partners, including national and regional research institutes, civil society organizations, academia, development organizations, and the private sector carry out its research.
http://www.cgiar.org

CGIAR RESEARCH PROGRAM ON Grain Legumes and Dryland Cereals

ICRISAT INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS · IITA Research to Nourish Africa · ICARDA Science for resilient livelihoods in dry areas · World Agroforestry

Alliance

ILRI INTERNATIONAL LIVESTOCK RESEARCH INSTITUTE · Bioversity International · CIAT International Center for Tropical Agriculture Since 1967 Science to cultivate change · CSIRO · IRD Institut de Recherche pour le Développement FRANCE · cirad