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DIGITALIZATION OF MULTI-STAKEHOLDER STRUCTURES ALONG SORGHUM VALUE CHAIN IN SIAYA COUNTY

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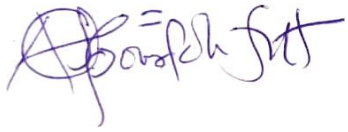
DECLARATION

I, Joackim Omedo Apondo, declare that this research project report is my original work and has not been submitted for the award of a degree in this or any other University.



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This research project report has been submitted for examination with my approval as the University Supervisor**s.**

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DEDICATION

I

dedicate this research

work to the fond memories of

my son and friend Jay Allen Omedo and dear parents;

the late Mama Lorna Omedo and Mzee Joseph L. Apondo.

To my friend 'ninjalito', you were special and we loved you much;

To my dear parents, a big 'thank you' for sacrificing beyond your means

to ensure that I get fine education. Your selfless legacy lives on.

Rest in peace my beloved Son, Mom and Dad.

ABSTRACT

Detailed knowledge of specific agricultural value chain stakeholders is a key element for quality and profitable food production (Makini et al. 2013). While there are attempts to organize agricultural stakeholders in innovation structures that allow them to access agricultural resources and information, little attempts have been made to digitalize these structures for enhanced information flow and decision making necessary for timely interventions and greater productivity. The inadequacies in digitalization of the multi-stakeholder structures limits the systematic sharing; dissemination; and application of improved technologies and also restricts the uptake of innovations, and management practices that helps to attain greater impact and benefits to value chain stakeholders (Misiko 2019). Such insufficiency of information has affected the sorghum value chain in Kenya, characterized by small-scale production and minimum access to critical resources. These limitations are further compounded by the unavailability of technologies that would bridge the gaps. (Burnham et al. 2015) portend that a proper strategy to enhance knowledge and innovation in agriculture is that which would turn farmers into a potentially valuable source of information. These strategies are currently domiciled in public and private extension services which are largely manual, slow, and ineffective. This study assesses the efficacy of a digitalized data management model on information flow and decision support among sorghum value chain actors in Siaya County through a multi-stakeholder structure. Structured KII and FGD checklists were used to obtain qualitative data and information relevant to the study while a simple survey was used to validate the resultant value chain model. The study found out that the sorghum value chain in Siaya County did not function optimally with farmers' decisions being influenced by other stakeholders. Subsequently, the existing multi-stakeholder structures are marred with misgivings among members thus threatening efficiency in information flow along the value chain. The study recommends a robust digitalized multi-stakeholder structure that utilizes web and mobile based applications to enhance decision making and improve information flow among Sorghum Value actors in Siaya County.

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ABBREVIATIONS

ODK - Open Data Kit

ADSS - Agricultural Decision Support System

ICT – Information Communication Technology

USAID - United States Agency for International Development

ICRISAT -International Crops Research Institute for Semi-Arid Tropics

KALRO – Kenya Agricultural & Livestock Research Organization

KEMRI - Kenya Medical Research Institute

KBL - Kenya Breweries Limited

GAPs - Good Agricultural Practices

KII- Key Informant Interview

FGD- Focus Group Discussion

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1.0. CHAPTER 1: INTRODUCTION

1.1. Background of the study

Detailed knowledge of specific agricultural value chain stakeholders is a key element for quality and profitable food production (Makini et al. 2013). However, precise agricultural data to augment that knowledge, which in turn may inform decisions by the stakeholders, is scanty and or generally unavailable. Critical strategies to gather the vital data to perform these essential functions in agriculture will, therefore, require a combined action of stakeholders. (Burnham et al. 2015) portend that a proper strategy to enhance knowledge and innovation in agriculture is that which would turn farmers into a potentially valuable source of information. (Burnham et al. 2015) emphasize that such information should be accurate and organized from the point of collection to its retrieval.

According to the Technical Centre for Agricultural and Rural Cooperation (CTA 2020), there is an exponential growth in data accompanying the digitization of agriculture through remote sensing technologies, mobile technology, and computing capabilities, among others. (Szövetség 2017) notes that the effective management of these data is bound to open up new opportunities to improve smallholder farmers' livelihoods and lives by reducing information asymmetries and lowering production costs. Site-specific agricultural data and a deep understanding of farmers' spatial characteristics, data gathering processes, data needs, and stakeholders' functions are therefore essential to support informed, evidence-based policy, and decision making.

Traditionally, data collection and management have been performed with paper and pen, making them difficult to conduct on large scales. This was also expensive and prone to error, thereby hindering empirical decision- making in agriculture (Data Scope 2019). However, various applications have since been developed to support the collection and management of digital agricultural data. These include Open Data Kit (ODK- Collect), Survey CTO, Kobo Collect, and many more. This study will leverage these digital solutions to digitalize the information flow among the existing structures in the sorghum value chain in Siaya County.

1.2. Problem statement

Sorghum production in Kenya has relatively stagnated over the years (Upadhyaya et al. 2017). The crop is mostly produced by small-scale subsistence farmers, and being poor in resources, most of them have only minimum access to timely and actionable interventions, production inputs and improved credit facilities for their purchase (Makini, & Hayden, 2013). The factors like low profitability of sorghum, less demand as a food grain has not dithered its importance. These limitations are further compounded by unavailability of technologies that would bridge the resource allocation and information asymmetries. According to (Muyanga, Jayne 2013), where technologies are relevant and available, smallholder farmers sometimes have no access to them. Besides, access to changing agricultural technologies also require that farmers are made aware of how those technologies work.

These inadequacies can also be realized in input supplier and distribution systems. Kenya (Market Trust 2019) reports that public sector has dominated the distribution of fertilizer and other inputs in Kenya. Since it is more profitable for input suppliers to serve large agribusiness operations, the distributions tend to expend very little effort interacting with the downstream consumers such as agro-dealers and farmers. As a result, market actors lower down the chain tend to deploy short-term, transactional business models, premised in high margin sales at the expense of long-term agricultural production growth at the farm levels (Market Trust 2019). (Okello et al. 2019) note that smallholder farmers' participation in agricultural input and output markets continue to be constrained by lack of market information. Most markets operate under conditions of information asymmetry which locks out smallholder farmers.

According to (Okello et al. 2019), it is important to address these information imbalance and attempts to address them are currently domiciled in the use of ICT technologies to provide linkages and market information. Such importance has necessitated efforts of consolidating stakeholders' efforts into a multi-stakeholder structure, a platform through which farmers, traders, researchers, processors, input suppliers, policy makers and other value chain actors come together to determine efficiency along the sorghum value chain. While there are attempts to organize farmers and other agricultural stakeholders in innovation structures that allow them to access agricultural resources and information (Misiko 2019), little attempts have been made to digitalize these multi-stakeholder structures to efficiently collect, manage and disseminate information for timely and actionable interventions. Also, empirical studies that have investigated digitalization of

multi-stakeholder structures in Kenya are rare and the influence of a digitalized information hub on commercialization of sorghum value chain remains unknown.

Studies express a range of benefits and diverse opportunities to farmers when this information is organized. They include the enhancement of access to affordable agricultural resources such as inputs, fertilizers, seeds, agrochemicals, breeds, feeds and services (Tolno 2015). According to (Wortmann-Kolundzija 2019), information organization helps in improving farmers' uptake of better technologies, innovations and information. (Wortmann-Kolundzija 2019) adds that such organization ensures remunerative linkages to markets for their farm produce through collective or contract marketing. This is done with the aim of upgrading farmers' agricultural value chains through aggregation and value addition. (Tolno 2015), notes that farmers' advocacy can be strengthened for favorable agricultural policies only when there are organized in structures.

According to (Misiko 2019), the inadequacies in the digitalization of the multi-stakeholders' structures limits the systematic sharing; dissemination; and application of improved technologies and also restricts the uptake of innovations and management practices that helps to attain greater impact and benefits to value chain stakeholders. (Misiko 2019) adds that a digitalized structure will boost the structures' efficiency and expand and replicate it while bringing extra actors to promote the value chains.

1.3 Objective of the study

This study's broad objective was to assess the effectiveness of a digitalized multi-stakeholder data management structure on information flow among sorghum value chain actors in Siaya County.

1.3.1 Specific Objectives

The study will endeavor to achieve the following specific objectives:

i. To analyze the sorghum value chain actors who are members of a multi-stakeholder structure in Siaya county.
ii. To design a digital multi-stakeholder value chain model for sorghum in Siaya county.
iii. To develop a Siaya county sorghum value chain multi-stakeholder prototype.
iv. To test, evaluate and validate the multi-stakeholder value chain model.

1.3.2 Research Questions

In order to achieve the above objectives, this study will be guided by the following research questions:

(a) What is the structure of sorghum value chain in Siaya county?

(b) How can we design a multi-stakeholder value chain model that enables improved information flow and decision making in Siaya county?

(c) How can we design a digital prototype for the enhanced communication and decision making among the sorghum value-chain actors?

(d) How can we validate the multi-stakeholder value-chain model?

1.3.3 Significance of the Study

This study will contribute to several changes likely to trigger a paradigm shift in information flow in the sorghum value chain in particular and agriculture in general. Specifics include:

i. Timely dissemination of accurate and actionable interventions among the sorghum value chain players for improved productivity and profitability.

ii. Enhancement of the accurate planning and prediction of sorghum farmers' capacity in Kenya, thus maximizing production and profitability.

iii. Determination of the impact of climate-smart initiatives in agriculture through spatial analysis to derive site-specific interventions.

2.0. CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter presents a literature review and considers both theoretical and empirical literature relevant to digitalization in agriculture. The chapter concludes by delineating the boundaries existing in the current setup of multi-stakeholder structures in agriculture and proposes a robust digitalized infrastructure that leverages modern-day technologies and best practices to remedy the inefficiencies while improving productivity and profitability at different points of the sorghum value chain.

2.1.1 Agricultural value chains in Siaya County

Siaya County is situated in Western Kenya. It is one of the six counties that form the Nyanza region. The county neighbours Vihiga and Kakamega Counties to the North-East, Kisumu County to the South-East, Busia County to the North and Homa Bay County across the Winam Gulf. (Kenya County Climate Risk Profile Series 2017). It has a land surface area of 253,000 ha and a water surface area of 100,500 ha. The water surface forms part of Lake Victoria. Siaya County's arable land is 200,000 ha, representing about 80% of the total County area. The area under food crops is 150,300 ha while that under cash crops is only 2,500 ha (75.2% and 1.25% of the total agricultural land respectively (ASDSP 2017).

There is a broad diversity of agricultural production systems in Siaya County. The main food crops include: maize, beans, sorghum, millet, cowpeas, sweet potatoes and groundnuts while the main cash crops include; cotton, rice, sugarcane, and groundnuts (ASDSP 2017). Various value chains have been prioritized for development interventions by different government organizations and programmes, such as the ASDSP, the Kenya Agricultural and Livestock Research Organization (KALRO) and University of Nairobi survey, and the Kenya Agricultural Productivity Programme (KAPP) (Kenya County Climate Risk Profile Series 2017). The priority value chain in the county include; indigenous chicken, maize, beans, mango, and sorghum. While these value chains have been prioritized in the county, farmers face fair share of challenges with them. Maize production for examples is always affected by droughts and intense rainfall (ASDSP 2017). This affects the key stages of the value chain especially input supply and on farm activities. Mango

value chain is one of the resilient sub sectors in the county. Previously, it was a neglected crop but gradually there has been increased interest in the crop due to the potential it holds in the transforming the economic livelihoods of the residents of the county. Establishment of mango value chain has now expanded with many homesteads expanding their plantations (ASDSP 2017).

Like any other value chain, sorghum equally faces its own challenge. It is a drought-tolerant crop which has steadily been grown in Siaya County, replacing maize in some places (ASDSP 2017). The crop requires less water and this makes it susceptible to intense rainfall. Challenges faced by sorghum encompasses full range of activities and services required from production to sale in the markets. In Siaya County, sorghum value chain actors are diverse and include input suppliers, producers, middlemen, traders, transporters, wholesalers, retailers, processors and consumers. Some of the strategies that have been adopted by the actors is anchored on the appreciation that solutions to the challenges are not obviously technical rather they could be institutional, social, economic and policy oriented in nature. ASDSP (2017) refers to this approach as a systems approach. In Siaya County, systems approach is operationalized through multi-stakeholder structures, where value chain players jointly identify bottlenecks and opportunities that pertain to production, marketing, policy and institutional frameworks.

2.2 Information Systems and Decision Support in Agriculture

There are four essential requirements in agricultural production: allocating resources reasonably, increasing productivity, avoiding food wastage, and mitigating the effects of climate change. These requirements have been levelled for optimum production by advanced information systems and internet technologies in agriculture such as meteorological information, marketing demands, soil conditions, and land uses. (Klerkx et al. 2019) refers to this as digitalization in agriculture. Digitalization in agriculture is the introduction of digital technology innovations into existing institutional, industrial, and societal systems in such a way that transforms how those systems operate (Fielke 2020).

Applied to agriculture, many of the proposed benefits of digitalization focus on increased efficiency through precise mechanization, automation, and improved decision-making. (Klerkx et al. 2019) portents that digitalization in agriculture is more than simply the adoption of new technologies; it involves the symmetry of technologies, societies, economies, and institutions (Klerkx et al. 2019). This argument is reiterated by (Zhai et al. 2020) who assert that such

digitalization will be grounded on the transparency of agricultural practices and informational interaction between farmers, advisors, agri-businesses, consumers, and regulators. (Zhai et al. 2020) adds that such transparency will largely drive and be driven by connectivity.

In the agricultural sector, several theories have emerged to express different forms of digitalization in the agricultural production system: these include Smart Farming, Precision Agriculture, and the Agricultural Decision Support Systems (ADSS) (Klerkx et al. 2019). Precision agriculture is the application of modern information technology to provide, process, and analyze multi-source data of high spatial and temporal resolution for decision making. While this would be a general definition for digitalization in agriculture, precision farming optimizes field-level management strategies and tools while other models utilize technology to enhance agricultural advisory. This study followed the digitalization principles as propagated by the theory of agricultural decision support system, and integrates it with innovation platform.

An agricultural decision support system (ADSS) can be defined as a human-computer system that utilizes data from various sources, aiming at providing farmers with a basket of advice for supporting their decision making under different circumstances (Zhai et, al. 2020) The data utilized can be collected, analysed, and processed for assisting farmers in making appropriate decisions that would enhance their prospects for obtaining higher returns. For efficiency, ADSS relies on current technologies like the Internet of Things, big data, artificial intelligence, cloud computing, and remote sensing.

While farmers and agricultural stakeholders appreciate that farm decisions grounded on data inform better production, robust management of huge amount of information may be overwhelming and even more challenging to transfer it into practical knowledge. (Zhai et al. 2020) notes that platforms like decision support systems are needed to assist them in making evidence-based and precise decisions. According to (Zhai et al. 2020), one of the most representative characteristics of an ADSS is that it does not give direct instructions or commands to farmers, but leaves room for farmers to make their own decisions.

2.3 Digitalization in Agriculture

Digitalization in agriculture is the introduction of digital technology innovations into existing institutional, industrial, and societal systems in such a way that transforms how those systems operate to enhance profitable production (Fielke 2020). (Nikola et al. 2019) suggest that

achieving the UN Sustainable Development Goal 2 of a "world with zero hunger" will require an efficient, productive, sustainable, and resilient food system. (Nikola et al. 2019) further notes that this kind of system will require a transformation of agrifood structure. A proper intervention for the envisaged transformation will require the integration of modern digital innovations and technologies. Szövetség (2017) points that in the food sub-sector in particular, and agriculture sector in general, the spread of mobile technologies, distributed computing, and remote sensing services are already improving smallholders' access to inputs, information, finances, markets, and training. The argument underscores the position of the United States Agency for International Development (USAID) that digital technologies create new opportunities to bring in smallholders in a digitally-driven agrifood system (Szövetség 2017).

According to Szövetség (2017), digitalization will change every part of agriculture, including smallholders' ability to manage production resources by optimizing and individualizing production intelligently and anticipatorily. This will enable the system to function in real-time while, at the same time, being driven by data. (Nikola et al. 2019) reiterate that with a digitalized system, traceability of production will be enhanced, with all stakeholders coordinating at the most detailed level. Digital agriculture has the potential of creating systems that are highly productive and adaptable to changes, including climate change. This, in turn, could lead to food security and profitability. Additionally, access to digital technology predisposes smallholders to significant advantages in providing links and information to suppliers. This subsequently allows users to tap into workforce talent, access support services, and build strategic partnerships that are mutually beneficial. While digitalization determines how knowledge and information are accessed, there has been limited success in adopting the associated technologies. Baumüller (2015) notes that technology adoption failure can be traced from the design and management of digital systems and its ultimate ability to disseminate information.

There are several entities that have attempted to come up with innovations in agriculture with the aim of digitalizing efficiency in the sector (Agarwal & Panwar 2019). In Kenya, innovations like M-Shamba have endeavored to revolutionize farmer access to information. M-Shamba is a market linkage platform that secures market demand for particular value chains (Walter 2016). It engages and support the smallholder farmers to produce for the secured market adhering to the food safety standards and commodity quality requirements. Thus smallholder

farmers get a ready, and verified markets with stable prices (Walter 2016). The platform deploys innovative digital channels such as interactive voice through the use of mobile phone technology such as USSD and SMS to transfer sustainable agriculture land management content. The M-Shamba innovation focusses on the use of simple phones commonly known as feature phones to deliver vital information to the smallholder farmers even in remote areas. Through the use of an interactive voice response service, push voice services and virtual call center services, it is simpler to effectively deploy new technologies to smallholder farmers, train them on climate change adaptation and building their resilience, give them personalized support through on-demand extension services and build their knowledge base. The platform also offers a menu for more customized services. For instance, if a farmer wants to receive the services of a crop protection specialist instead of a general agronomist, they are able to select through a number of options as they listen to the voice. This platform has been used in Kenya including in Nakuru where M-Shamba has on-boarded 3,985 farmers from Nakuru county on Potato and chicken value chains (Walter 2016).

Other entities like TruTrade, Digital Green, and Astra Aerial, have also introduced models digitalizing agriculture. TruTrade is an online and mobile enabled trading and payment platform for collaborative supply chain management. The platform allows for the capture of all costs, analysis and transaction viability and price setting; registration of farmers and triggering payments; and tracking of produce from collection to delivery. (Agarwal and Panwar 2019) note that the technology has opened up significant new possibilities for farmers and businesses credentialing, which gives global commodity buyers the ability to connect to their smallholder farmer suppliers. Digital Green developed an open-source protocol known as FarmStack. The protocol uses peer to peer connectors and usage policies for the secure transfer of data between organizations and farmers. Agarwal and Panwar (2019) note that the system allows farmers to access customized services through multiple channels, where organizations can then access farmers' feedback and relevant data. Astral aerial uses unmanned aerial vehicles, also known as drones, and connected analytics, which has great potential to support and address some of the most pressing problems faced by agriculture in terms of access to actionable real-time quality data. Goldman Sachs predicts that the agriculture sector will be the second largest user of drone in the world in the next five years.

Acre Africa have also attempted to drive smallholder farmers' sustainability through digital solutions (Agarwal and Panwar 2019). The entity has innovation targeting digital inclusion that leverage on mobile phone technology, automated weather stations and satellite data to design suitable products best suited for smallholder farmers. This has brought together various stakeholders among them farm input companies, mobile technology firms, agronomists, researchers, off takers and insurance companies to offer various services geared towards improving farmers' livelihood. According to this system, farmers access the insurance through village change agents, who train them on risk management solutions.

While these models have been used to enhanced agro-business, there are several aspects of the digitalization that do not address profitability and productivity to agricultural stakeholders. The multi-stakeholder structure as digitized through ADSS provide a wholesome strategy to all players within the value chain. While entities like M-Shamba for instance, provide verified markets, there are salient factors such as cost of production. Understanding the cost of production helps the markets appreciate the recommended pricing for the produce. With focus only on markets, producers are left at the mercy of traders oblivious to the farmers' profitability aspect in the entire value chain. The review of other digitalized frameworks places the farmers' interest outside the framework. Tru-Trade for example has their point of contact with the farmer at the collection and aggregation levels. This is almost at the end of the value chain. At this stage, traders and middlemen have control of the produce. Other players who sustain production such as input suppliers and transporters are not factored in. When such players are not given the opportunity to influence the pricing, sustainable production in hindered. This is the gap that will be sealed by the ADSS as framed from the Multi-stakeholder structures.

2.3.2 Sorghum in Western Kenya and Multi-Stakeholder Structures in Agriculture

Sorghum is an important crop in Kenya's medium and low altitude areas, conditions predominantly experienced in Western Kenya. A unimodal rainfall pattern characterizes the region, and the distribution of rainfall makes it possible to grow sorghum. The sorghum produced is considered to be of great value to local farmers with huge industrial potential and create employment and alleviate poverty. In Siaya County, sorghum production at the farm level is limited by low yielding varieties, lack of appropriate varieties targeted for specific uses, disease

and pest prevalence, poor agronomic practices, and under-developed seed supply systems. Some of these production constraints can be alleviated through efficient and digitalized multi-stakeholder structures.

Since multi-stakeholder structures are always geared towards accounting for different interests that would yield a common solution, the structures have increasingly become common in research and development initiatives (Dubbeling, Zeeuw, & Veenhuizen 2017). However, multi-stakeholder structures can always be difficult to navigate and therefore needs a proper harmonization to cater for the diverse interests (Dubbeling et. al. 2017). There are attributes of multi-stakeholder structures that describes how to ensure their efficiency. Dubbeling et. al. (2017) points out that the most important attribution is that the structure allows for spaces for learning and change. In the structure, different groups of individuals with different backgrounds including agricultural input suppliers, farmers, traders, food processors, researcher come together to develop a common vision and decide on ways through which they can achieve their goals. Members of these structures may design and implement activities as a group or coordinate activities by individual members. Tui et.al. (2013) notes that it is important to understand how multi-stakeholder structures work. They suggest the following steps: First, the structure should begin by *initiation.* According to Tui et.al. (2013), any member within the structure can initiate its formation but this must be grounded on the broad focus area. Secondly, *a decision on the focus area* should be made. This is the stage when members decide what they want to solve. The decisions made should be backed by research findings, current practices, policy guidelines and local knowledge. The third stage is where *options are identified*. Stakeholders decide on what they want to do and for which they can take advantage of the opportunities they have identified. Other stages include the testing and refining of the solution; capacity development; and implementation and scale up. Upon the determination of the success of the solution by the stakeholders, members of the multi-stakeholder structure work hand in hand to ensure that the solution is adopted widely.

Multi-stakeholder structure presents a number of benefits to its members. Tui et.al. (2013) notes that multi-stakeholders' structures facilitate dialogue and understanding among members thus providing them with the opportunity to create a common vision and mutual trust. It also enables stakeholders to identify the bottlenecks hindering innovation. Further, the structure inspire ownership among members, facilitate upward communication and enhance impact.

Multi-stakeholder structures are increasingly becoming an approach to enhance innovation and collaboration within agricultural production, research, and development (Schut et al. 2018). Given their great prospects to improve agricultural productivity and profitability, recent literature has mainly focused on the structures' implementation steps, and how they can be facilitated for desired institutional and technological changes (Makini et al. 2013). Schut et al. (2018) point out that what currently lacks are the discussions on the usefulness of the multi-stakeholder structures in overcoming agricultural challenges. In particular, there are inadequate decision support tools to inspire essential *ex-ante* reflection on when and for what resolve are multi-stakeholder structures a suitable mechanism for achieving development outcomes in agriculture (Schut et al. 2018). Warner (2016) cautions that without adequate tools and models to analyze these structures' impact, there is a risk of simply promoting them as a panacea for research problems in the agricultural sector without any meaningful outcomes. Some entities have attempted to introduce digital version of the this but with little ownership strategies to users. Such entities include the Wefarm. Platforms like Wefarm create opportunities for farmers to connect to each other thus creating an open source stage for the community to unlock better outcomes in agricultural production. Through a mobile phone application, the community can connect online or via SMS, and access a trusted market place of physical retailers.

There is a need therefore, to have models that shape the expectation of the multi-stakeholder structures to more realistic agricultural development outcomes. This should be efficient, timely, and implemented with minimum human and financial resources (Schut et al. 2018). According to Larmers *et al*. (2017), before adopting a multi-stakeholder structure, a careful reflection on the need for the structure and whether they are cost-efficient in meeting the objectives of the stakeholders is essential. Kahan (2013) reiterates that even though multi-stakeholder structures aim to counter weaknesses in agricultural innovation systems by building interactions among varied actors and organizations, technological advancement is needed to bridge the disjunctions between the conception of the ideas of the structure, their implementation, and outcomes.

Multi-stakeholder structures are premised on the understanding that the involved stakeholders can provide various complementary insights about the institutional and technological dimensions of the problem and broaden the knowledge base (Burnham et al 2015). The structure

also enables the stakeholders to negotiate the type of innovation that are culturally, politically and socially acceptable, and are economically viable within the stakeholders' context (Schut et al. 2014). Ultimately, the multi-stakeholder structures will enable the participants to be aware of their different interests, objectives and needs, and to realize their areas of dependencies to meet their objectives.

The increasing desire by projects and communities to lean towards multi-stakeholder structures is prompted by a number of factors. Schut et.al (2014), notes that multi-stakeholder structures always try to harmonize diverse perspectives of persons and organization especially those with different socio-economic interests, backgrounds, and perspectives. The structures also promote synergy particularly in aspects that cannot be addressed individually (Schut et.al 2014), enhance combination of technologies, and promote sharing of resources, risks, benefits and knowledge (Kahan 2013). Wigboldus et al. (2016) portends that multi-stakeholder approach in the agricultural sector can fulfill an important function in the pathway that leads to the scaling out of agricultural innovation. Through the unified efforts, stakeholders are thus able to come up with technically sound solutions affordable for farmers and coherent with the government policies (Wigboldus et al. 2016).

2.3.3 Application of Multi-Stakeholder Structures in Sorghum production in Kenya

Like many other counties in Kenya, Siaya has sorghum as one of the crops promoted in a value chain (ICRISAT 2018). Diverse stakeholders play multiple roles along the sorghum value chain and this determines their position and influence in decision making along all the stages of the value chain. Influential stakeholders can always determine access to information, technical and funding resources and markets of sorghum (Schut et al. 2014). This access makes it easier to upscale, out-scale and to commercialize production among smallholder farmers. When stakeholders work together, sorghum producers are predisposed to easy access to technical support and information from relevant organizations. In Kenya, agricultural research organizations like Kenya Agricultural and Livestock Research Organization (KALRO) in coordination with international research organizations such as International Crops Research Institute for Semi-Arid Tropics (ICRISAT) are always in the forefront. These entities use multi-stakeholder structures to facilitate the adoption of appropriate seed varieties and accompanying technologies. Based on the

interests expressed by farmers, the multi-stakeholder structures are therefore able to stir uptake of better technologies among farmers. The process of production is then backstopped by private sector players including traders, processors such as Kenya Breweries Limited, to boost economic activities.

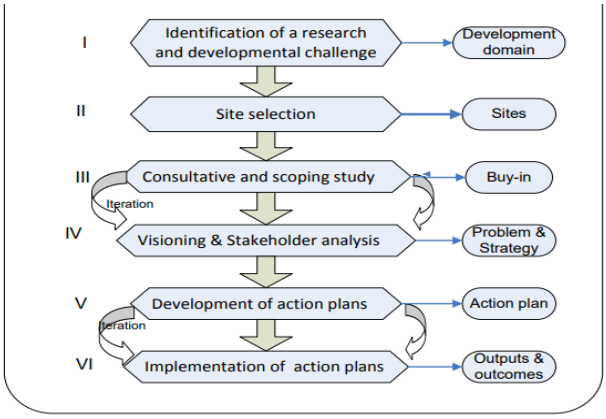
In Siaya County, sorghum production is organized around multi-stakeholder structures, loosely referred to as innovation platforms. These stakeholders have been mapped as research institutions, extension services, farmers, marketers and agricultural input suppliers. The mapping process gives a picture of the level of interaction and the manner of influence the stakeholders hold on sorghum production in the county either as an organization or as other collective actors. The stakeholder's map also gives an understanding on how private actors play a role in fostering optimum sorghum production by providing adapted technological solutions and setting up productive standards. Sorghum famers therefore rely on these multi stakeholders' structures to promote sorghum production in all stages for maximum production and increased profitability (Schut et al. 2014).

2.4 Digitalization of Multi-Stakeholder Structures in Sorghum Production

Various fundamental parameters for agricultural statistics associated with production within geopolitical or administrative units such as counties and wards, have been used in many econometric analyses. However, obtaining reliable data for such analysis has always been a challenge in developing countries. In cases where data is available, this is on the sub-unit scales with substantial data gaps. For a good evaluation of food security, technology potential of production is essential and it is critical to have reliable information on spatial distribution patterns, site-specific location of people, and other environmental components.

In digital mapping for agriculture, focus has always been on soil and other spatial factors that support land-use plans and other geospatial parameters to help with environmental and agricultural policies. Research organizations and projects rely on accurate and rapid digital maps to evaluate soil fertility, precision management of crop inputs, modelling ecological response, environmental threats as well as the estimation of carbon stocks (Burnham et al. 2015). Schut et al. (2014), notes that limited focus has been put on other passive factors such as farmers' relationship, conducive environment for value chain stakeholders and knowledge on the roles of

stakeholders that may enhance productivity and profitability. While these attempts assist farmers in preparing to address the pest problems Schut et al. (2014), reiterates that participatory approaches are never involved, which limits the technology adoption and are devoid of fundamental desires of farmers. The author reiterates that any mapping in agriculture should be premised on the individual value-chain stakeholders' worldview to ascertain productivity and profitability. In practice, the multi-stakeholder approach is relevant to the smallholder agricultural context because the system is defined by a diverse set of players and multiple sources of innovation along the value chain. Klerkx et al. (2008) notes that attempts to improve outcomes along the value chain system must capitalize on the synergies of these diverse players, which is done in a participatory manner.



Steps for Participatory formation of Agricultural Multi-Stakeholder structure- Adopted from Rao et, al. (2018)

Figure 1: Steps for Participatory formation of Agricultural Multi-Stakeholder Structure

2.4.1 Application of Multi-Stakeholder structures on Sorghum production in Siaya County

Like various other counties in Kenya, productivity of sorghum in Siaya County has been in the decline despite sorghum being one of the most important crops to the locals. The yield of sorghum in the county is estimated at 0.85 tonnes per acre. Effort has been put in the past to develop and disseminate disease tolerant varieties as well as yield improving technologies. However, the gap between potential yields and the on-farm yields have remained wide (Upadhyaya et al. 2017). Between 2008 and 2019, the consumption of sorghum in Kenya increased due to the growing demand for Gadam variety by the brewing industry for use in beer production. Sorghum farmers in Siaya County have also taken advantage of the new market and now consider sorghum production more as a cash crop than for subsistence.

To consolidate production and to further minimize costs, traders like Kenya Breweries Limited (KBL) organize farmers in several locations and distribute sorghum seeds for production. Upadhyaya et al. (2017) notes that with the assurance of the markets, many farmers are thus able to invite other stakeholders who can buffer other stages of the value chain such as pest control, and other mechanization related with sorghum production. While this would be the case, there is limited outreach to other sorghum farmers who may not be in production groups. Upadhyaya et al. (2017) notes that such limitations are occasioned by strained networks and inability to access farmers with knowledge at appropriate time. Such bottlenecks witnessed in the sorghum multi-stakeholder structures could be ameliorated were digitalization integrated in the value chain. The literature review alludes to the fact that a well-developed digitalized multi-stakeholder structure, especially among the smallholders, has the potential of creating condition for a digital agriculture and food systems. While there are advances in technology, there is still a digital divide which is occasioned by the inability to access information. The divide has also affected sorghum farmers in Siaya County. Increased interest in data-enabled farming should factor in models that will make data useful, sufficient and are able to foster partnerships needed to transform smallholder farming into viable, sustainable digital businesses. It is important to prioritize technologies with the ability to facilitate the collection of better data, and that can provide viable digital solutions for the smallholder sorghum farmers to increase their productivity and profitability.

2.6 Conceptual Model

The design of the conceptual model was premised on the understanding that members of the innovation platform synergize each other when they are facilitated by an efficient digitalized system (Klerkx et al. 2019). Oluwole (2016) notes that such model has essential elements that will result in the effective flow of knowledge to bring about efficient and increased food production to enhance food security and socio-economic benefits to all the actors involved in the process. Considering the specific objectives and the research questions guiding this study, four possible synergistic areas were identified based on the roles of each category of actors. It follows then that each of the actor groups will likely be influenced differently by different intervening variables:

1: Producers will gain from the interaction and collaboration with other actors through information flow and as such, positively influence the digitalized platform's ability to enhance production. This is linked to objective 1 of this study.

2: Service providers will enjoy partnership not only with the producers but also with other service providers. This will positively influence the function of the information hub to accelerate production and profitability. This relationship contributes to achievement of objective 1 and provide answers for research question 1.

3: Digital mapping of sorghum value chain actors will positively support researchers to disseminate technologies to producers with utmost accuracy in terms of their location needs. This association will be explored in order to achieve objective 2 and provide empirical evidence for research question 2.

4: Information hub will enjoy the institutional support of the extension services based on advantages each location has and as such positively influence production and profitability. The role of institutional support will be established through this empirical relationship in a bid to achieve objective 3 and answer research question 3 of this study.

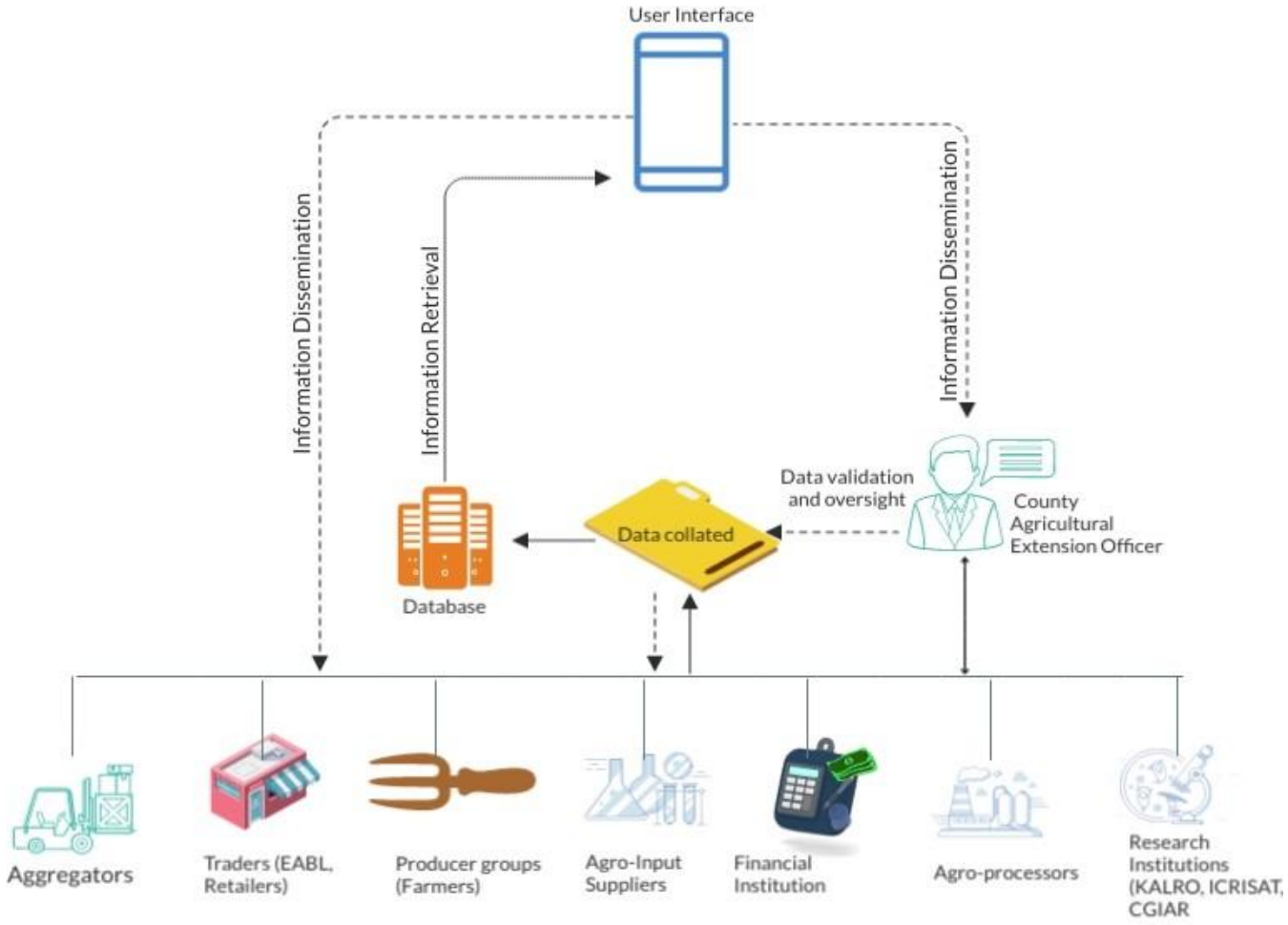


Figure 2: Digital Multi-Stakeholder Value Chain Model for Sorghum in Siaya County (Adopted and modified from ILRI, 2014)

3.0 CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter discusses research design, the population used for the study, sampling frame, sampling technique, determination of the sample size and how the sampling plan was executed. Further, the chapter looked at the data collection methods, research procedures, key ethical considerations and data analysis methods applied.

3.2 Research Design

In their book on Essentials of Research Design and Methodology, Marczyk et al. (2010) broadly define Research Design as the many ways in which research can be conducted to answer the question being asked or simply, the plan used to examine the question of interest. This research employed structured checklists for both Key Informant Interviews (KIIs) and Focus Group Discussions (FGDs) to obtain qualitative data and information relevant to the study. A simple survey capturing key features, both technical and operational, was then used to test, evaluate and validate the multi-stakeholder value chain model.

3.3 Population

The study population comprised sorghum producer groups(farmers), researchers, extension service providers and various other value chain actors such as agro-input suppliers, aggregators, traders, agro-processors and creditors who were members of an existing multi-stakeholder structure in Siaya county.

3.4 Sampling Design

3.4.1 Reconnaissance Survey

A reconnaissance survey was conducted in order to gather basic information about the study area before actual data collection. Information gathered included the prevalence of sorghum value chain activities, number and location of focal sorghum producer groups, researchers, extension service providers, other value chain actors as well as the existing sorghum multi-stakeholder structures in Siaya County. Main source of information was the Ministry of Agriculture, the County Government of Siaya.

3.4.2 Sampling Frame

The sampling frame was based on the sorghum value chain actors from Alego-Usonga, Bondo and Ugenya Sub-counties of the larger Siaya county. The selection of the above mentioned sub-counties for the study was informed by the prevalence of sorghum production and marketing activities. The sampling frame also considered only those sorghum value chain actors who are members of existing multi-stakeholder structures.

3.4.3 Sampling Technique

A multi-stage sampling technique was applied to select representative samples of sorghum value chain actors for this study. In the first stage, three sub-counties were sampled as mentioned above. In the second stage, one ward was sampled in each sub-county based on agro-ecological zonation and predominant sorghum value chain activities. During the third stage of sampling in each sampled ward, existing sorghum multi-stakeholder structures were identified and value chain actor groups and representatives selected. While (Mugenda & Mugenda 2003) observes that 30% of the target population is a good representation, this study realized 100% representation for the producer groups by covering all the producer groups that are members of an existing multi-stakeholder structure from each sampled ward. In the final stage, a representative sample of individual members was drawn from each multi-stakeholder structure to participate in this study. Being a participatory survey that relied on key informant interviews (KIIs) and focus group discussions (FGDs), special attention was placed on selection of representative actors from the sampled multi-stakeholder structures. Each focus group discussion (FGD) consisted of 12 participants (farmers) randomly selected from the sampled producer group currently participating in a multi-stakeholder structure. Purposive sampling was also undertaken to select 7 other sorghum value chain actors in each sub-county who participated as key informants and provided broad insights, perspectives and information on the functioning of the existing multi-stakeholder structures and the performance of sorghum value chain in Siaya County.

3.4.4 Sample Size

A total of six Focus Group Discussions (FGDs) were carried out, two in each of the sub-counties of Alego-Usonga, Bondo and Ugenya. The FGDs made a sample size of 72 farmers and were administered across the sampled sorghum value chain producer groups. In addition, a total of 21 respondents were interviewed as key informants. The 21 Key Informant Interviews (KIIs) were conducted among other key stakeholders through individual interviews and enabled the study to gain in-depth understanding of the sorghum value chain. The Key Informants were purposively identified and distributed proportionately to cover all the other actor groups of researchers, extension service providers, agro-input suppliers, aggregators, traders, agro-processors and creditors who are members of an existing multi-stakeholder structure. The total sample size for this study was 93 respondents.

3.5 Data Collection Methods

The study utilized a combination of one-on-one and telephone meeting channels to reach the selected key informants for in-depth interviews. Interviews took an average of 40-60 minutes and was done by skilled qualitative researchers from KALRO and KEMRI. Data collection took one week within the fore mentioned Sub-counties in Siaya County. Focus group discussions relied on physical meetings with a representative group of farmers. The meetings were conducted while strictly observing the Ministry of Health's COVID-19 prevention protocols. Interview schedules, checklists and audio recorders were used during data collection. The data collection instruments were pre-tested with a smaller group of farmers in non-sampled areas of Siaya County and relevant adjustments done to enhance their reliability and validity in data collection. Six (6) enumerators were identified and trained on how to administer the FGD and KII instruments. Each Focus Group Discussion was conducted by two enumerators, the first enumerator moderated the session while the second enumerator recorded the proceedings while also taking down additional notes. The Key Informant Interviews were conducted by an enumerator interviewing and recording the sessions with the key informants. The data collected included status of decision making along the sorghum value chain, sorghum value chain stakeholder's characteristics and their roles in the multi-stakeholder structure, status of sorghum production (input type and quantities, costs, agronomic practices), marketing (volumes sold, value addition activities, marketing strategies, prices), access to information and services (modes of access, frequency, usefulness, timeliness, affordability) and

the use of ICT tools and related methods in stakeholder interactions. Data quality control was conducted on a daily basis by checking the records of FGD proceedings for completeness and correctness of responses from KIIs. Debrief reports were shared among interviewers daily after data collection for contextual discussions. Whenever anomalies and inconstancies were noted, they were discussed with the relevant enumerator(s) and immediate corrective measures taken, including re-visiting the respondents and call-backs for clarification.

3.7 Ethical Considerations

Various considerations were made to ensure adherence to the relevant ethical provisions during data collection throughout the study. Enumerators were trained on survey ethics and acceptable interview techniques within the target community. They were also sensitized on safety guidelines against COVID-19 to reduce infection risk to themselves and their respondents. In order to minimize movement during the period of administration of the instruments, two enumerators were assigned a specific ward to conduct both the FGDs and KIIs under the guidance of a local administrator or Ward Agricultural Officer. Each sampled respondent for the KII and sampled members of a producer group for the FGD were informed about the purpose of the study and their express consent obtained before actual interview. Communication to the various participants sampled for the study to obtain consent for the interviews was facilitated through the officer in-charge of Crops development, the department of Agriculture at the County Government of Siaya. Confidentiality and security of the data provided by the respondents was emphasized to them.

3.8 Data Analysis and Presentation of Results

At the end of data collection, interviews were transcribed verbatim and translated as appropriate by various members of the data collection team. Each audio recording was transcribed into a Microsoft Word transcript and translated into English capturing the entire interview session. The transcription and translation exercise lasted 4 days. The team then sat down, brainstormed and generated a consolidated list of themes as noted from each transcript processed. Subsequently, the team generated a codebook to categorize the key themes and sub-themes from the transcripts.

4.0 CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents and discusses the process of data analysis, results obtained from content analysis of summaries with coded segments report generated. The chapter presents key findings under three main areas that covered the sorghum value chain (prevalence, decision making, information sharing and marketing) activities, the multi-stakeholder structures along the sorghum value chain, their formation, operationalization, information sharing and collaboration among stakeholder groups, and the status of integration of ICTs tools in the sorghum value chain.

4.2 Process of Data Analysis

Table 1: Initial List of Themes generated by the Data Collection team from the Transcripts

Theme	***Weighted Score*** *(number of members who identified the theme from transcripts)*
Sorghum Value chain Performance	6
Effects of Devolution on Agriculture and Sorghum	1
Birds Menace in Sorghum Production	4
Multi-stake holder structures	6
Innovation Platforms	3
Decision making	6
Challenges in the Multi-stake holder structures	5
Marketing in Sorghum value chain	6
Integration of ICT in the multi-stake holder structures.	6
Erratic Weather and Sorghum Production	5
Market Monopoly in Sorghum	5
Lack of Oversight and Quality Assurance of Structures	4

Table 2: Codebook generated from the Key Themes identified

Key Theme	Code	Sub-Code	Definition of Codes
Sorghum Value Chain	Prevalence	Prevalence of sorghum	This code describes areas where sorghum value chain is prevalent, with reasons why. Including areas where it is not.
	Performance	Performance of Sorghum value chain	This code describes the performance of sorghum value chain both positive and negative aspects
	Decision Making	Status of Decision making along the Sorghum Value Chain	Refers to how decisions are made in the sorghum value chain (when to plant, where to plant, market, inputs) e.g. stakeholders and farmers. -Includes if modes of decision making are working optimally.
Multi-Stakeholder Structures			Describes the existing multi-stakeholder structures involved in the sorghum value chain.
	Structure Formation	Considerations for structure formation	Refers to considerations made during formation of multi-stakeholder structure
		Viability of the multi-stake holder structures	Description of whether the multi-stakeholder structures work optimally or not. -including reasons why.
		Improvement of the multi-stakeholder structures	Suggestions to improve the multi-stake holder structure to work optimally.
	Communication	Stakeholder Communication	Communication platforms and information exchange among stakeholders. e.g. phones, physical meetings
	Roles	Stakeholder roles	Roles played by the various stakeholders in the structure
	Interactions	Stakeholder interactions	Involves how stakeholders interact among themselves and among different stakeholder groups. N/B (To bring out differentiation among the stakeholder interactions)
	Challenges	Challenges in the Multi-stake holder structures	Refers to the challenges in the multi-stake holder structures in the production, marketing, communication etc.
		Production	Refers to the production challenges e.g. inputs,
		Post-harvest	Experienced challenges in post harvesting and production aggregators.
		Marketing	Refers to the marketing challenges e.g. control of prices
		Communication	Challenges in communication e.g. distance (access), phone. etc.
	Marketing in sorghum value chain		Describes marketing in the sorghum value chain both commercial and subsistence.
		Market Monopoly	Description of cases of monopoly by specific stakeholder(s) (Transu and EBL)

		Marketing Outlets	Description of marketing outlets (two-staged or EBL directly)
		Market Improvement	Suggestions to improve marketing in the sorghum value chain.
Integration of ICTs in the operations of the Multi-Stakeholder Structures.			Refers to how agricultural information is shared across multi-stakeholder structures and possible integration of ICTs tools
	Information Sharing	Methods of information sharing	Describes methods used to share agricultural information both ICT and Non-ICT
	Limitations	Limitations of ICT tools in Sorghum value chain	Mentioned limitations to the use of ICT tools in the sorghum value chain
	Influence	Influence of ICT tools in sorghum value chain	Describes how ICT tools could help attain benefits to the value chain stakeholders
	Adoption	Adoption of ICT in the Sorghum value chain	Describes willingness or lack thereof to the use of ICT tools in sorghum value chain
	Digitalization	Digitalized platforms for information flow in multi-stakeholder structures	Discussed possible use of ICT tools to improve information flow among stakeholders in sorghum value chain
Parking lot code			This code describes areas not mentioned in the key themes
Exemplary Quotes			

4.2.1 Data Analysis using the MAXQDA analysis software (pro 2020)

After generation of the codebook, transcripts were coded using the agreed codebook assisted by MAXQDA analysis software (pro 2020). Inductive and deductive analysis approaches were used to summarize and condense data to extract meaning, coupled with illustrative quotes. Main results were summarized and presented in figures, using maps, illustrative quotes and narratives. The Figure 3 below shows the interface of the MAXQDA analysis software (pro 2020).

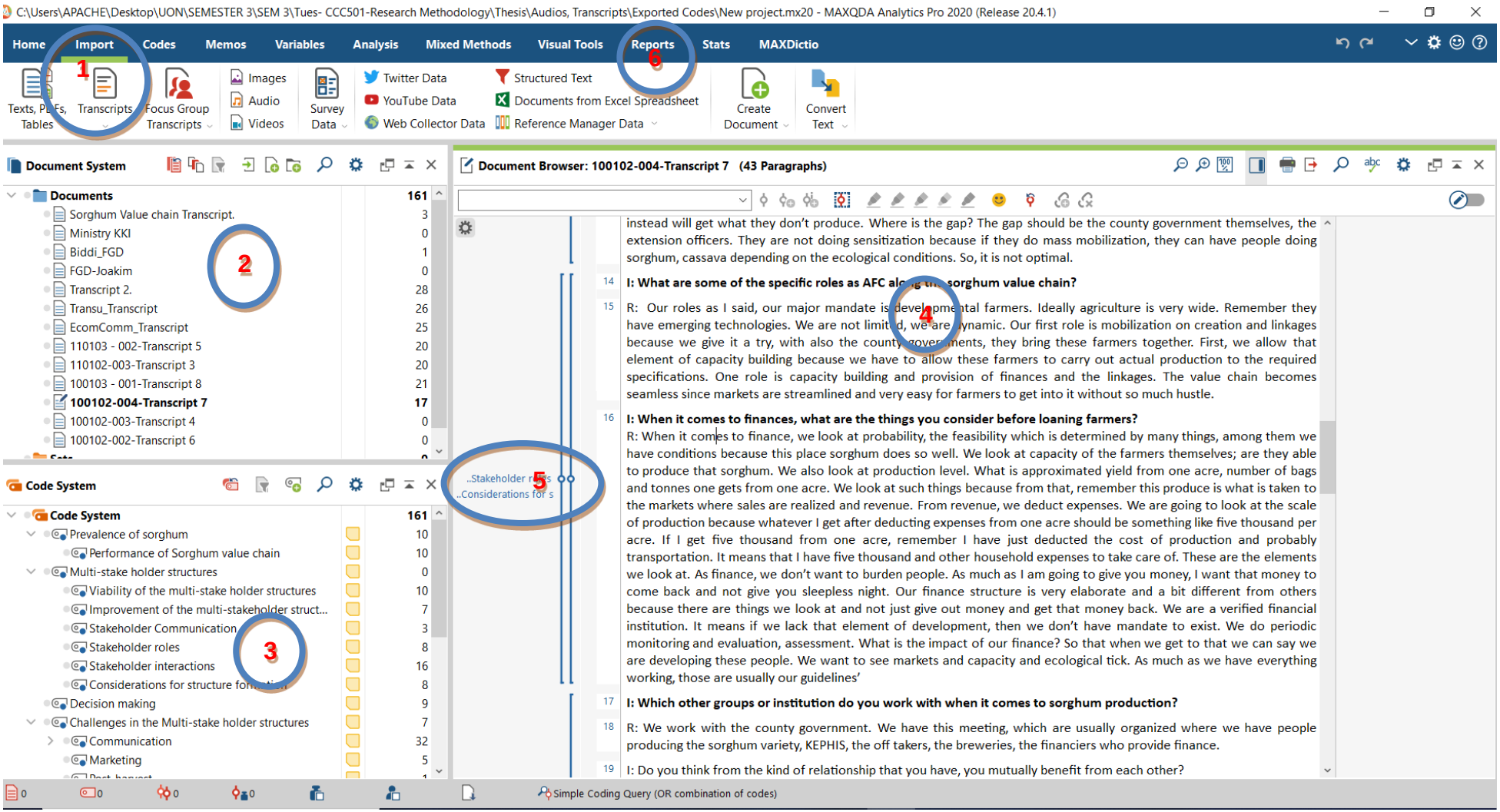


Figure 3: MAXQDA analysis software (pro 2020) interface

After launching the MAXQDA analysis software (pro 2020) as seen above, the following steps were followed in the coding and analysis process:

1. The import feature (**1**) was used to import all transcripts generated for analysis;
2. The transcripts were successfully imported into the document area (**2**);
3. Using the codebook as seen in *Table 2* above, the code system (**3**) was developed with the relevant codes and sub-codes;
4. Each transcript was then launched; the relevant transcript being coded opened in the document browser area (**4**);
5. For all the different sections of the transcripts, key themes were identified and coded. Sections could be double (**5**), triple coded depending on the prevalence of a particular theme within a transcript;
6. After coding all the transcripts and categorizing the themes, a report was generated from the reports (**6**) feature containing summaries with coded segments

Summaries with Coded Segments - New project.mx20

Code	Coded segments	Summary
Prevalence of sorghum	**I: It is exactly 9:40am and we are with [Mentions name of participant] who is the case sub county coordinator. This interview is taken at Siaya case sub county offices conducted by [mentions name of interviewer]. We have three sections, section A that talks about sorghum value chain in Siaya county as is, section B that talks about the characteristics of the multi stake holder structures and then section C will be looking at integration of ICTs in multi-stake holder structures. So, I will go to the first question, where in Siaya in your opinion is sorghum value chain activities prevalent. Briefly describe the prevalence.** **R**: I think I would say that sorghum is grown in the whole of Siaya county but now what matters is the carriages. You will find that within the southern part where the land is still valuable then you will find that they are more in sorghum than those people from the area in northern part that is bordering Mumias areas. Southern	

Figure 4: Summaries with Coded Segments used for Content Analysis

4.3 Findings and Discussions

4.3.1 Prevalence of Sorghum Value Chain Activities in Siaya County

Most respondents reported that sorghum was mostly prevalent in Ugenya sub-county, this was attributed to the availability of favourable weather as it was reported to receive fairly more rainfall compared to other sub-counties within the County. Other sub-counties that were also mentioned to do fairly well with sorghum included, Bondo, and Alego-Usonga. Prevalence was associated with the traditional nature of the crop 'native food' that acted as a source of livelihoods to the residents. The study found that tolerability of the sorghum crop, known nutritional benefits, health benefits, availability of ready market from KBL, and the fact that it took shorter time of approximately 3 months before it is harvested and ready for the market boosted its prevalence.

Illustrative Quote:

"*Okay! it has been a native crop; that is one. Another thing is that because some people now have known that there are good nutrients in sorghum, most families are producing sorghum though not in a very large scale but in a small scale. So, you will find that in all those sub counties at least every household is producing some small quantities of sorghum. So, is one of a staple food in Siaya County." (Key Informant, East Comm)*

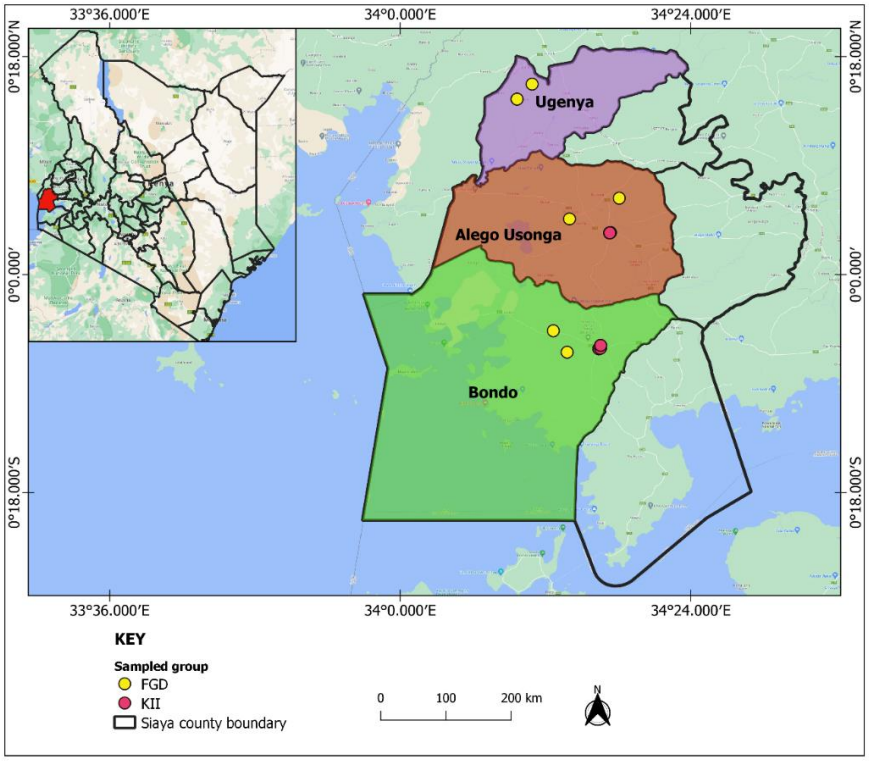


Figure 5: Map showing the study sites and the distribution of interviewed sorghum

Further, Rarieda sub-county was reported to be lagging behind in sorghum production due to the differences in weather patterns, poor topography, inadequate market and slow uptake of technology that limited production. Urbanization has also seen a number of younger workforce migrate to nearby towns thus limiting sorghum value chain activities and prevalence as it was reported that young people did not want to engage in agriculture related activities.

Illustrative Quote:

"*Another thing, Rarieda sub-county is largely dry despite being in Siaya County. The weather still remains unpredictable in the sub-county adding to other challenges like the lack of tractors to plough and the black cotton soil. However, Ugenya Sub-county receives more rainfall…in fact when I came here, sorghum production was low because of market issues. By the time we collaborated with the Ministry of Agriculture and started promoting sorghum, Ugenya Sub-county was not largely involved in Sorghum value chain. Since now there is availability of market and adequate rainfall, the sub-county now champions sorghum value chain activities in Siaya County." (KII)*

4.3.2 Performance of Sorghum Value Chain

Most key informants reported that the sorghum value chain was not functioning optimally and that much still needed to be done. Challenges varied from low production as majority of the farmers had not taken up sorghum production citing reduced sorghum consumption, on-farm losses mainly attributed to birds that ate the produce leading to low yields. Low quality seed production was also a contributing factor to the non-performance. Subsequently, traditional production methods were seen to lead to low production attributable to slow adoption of improved sorghum production technologies. Marketing was also cited as a challenge especially controlled pricing that ensured sorghum prices remained low long periods of time.

Illustrative Quote

"*Definitely, the sorghum value chain is not performing optimally. It is not working optimally because of a lack of stable outlets for the produce. There is also little motivation for producers to produce besides what they may require for their domestic consumption. The operation of the value chain is not close to optimal it's still far down from the optimal" (KII).*

Stakeholders suggested some of the ways to remedy the various challenges encumbering the sorghum value chain from achieving optimal performance. The suggestions included capacity building of the farmers on improved technologies to enhance uptake and out scaling of production, mechanization of land preparation and adoption of advanced technology such as the use text messages in the provision of advisories to farmers. Additionally, they pointed out the need to review every area in the value chain to enhance effective interactions thus enhancing performance. The bird menace which was a major threat to sorghum production needed combined efforts of various stakeholders for farmers to realize high yields.

4.3.3 Decision Making in the Sorghum Value Chain

The respondents were asked to comment on the status of decision making along the sorghum value chain with regards to planting time, varieties planted, inputs access, marketing and decisions related to technological innovations and management practices. Most key informants reported that decisions were made primarily by the farmers, but with a great influence from other stakeholders like the Cereal Growers Association (CGA), Aggregator groups like Transu, the department of meteorology, Siaya County and other agro-inputs suppliers who were members of the existing

multi-stakeholder structures. CGA was reported to work with various actor groups along the value chain in capacity building, information sharing and dissemination of advisories as well as facilitating stakeholder meetings and linkages. These technical service providers also worked closely with the national government through the Ministry of Agriculture to give information to respective stakeholders. For instance, Agro-dealers interviewed reported to make decisions on the type of seed to supply to farmers based on the market demand and advice from other technical service providers and research organizations. This information was then shared with various farmer groups. Decisions on innovations and technology uptake were largely made by the organizations promoting the said innovations and improved technologies although uptake of such was also limited due to unstructured way of interactions and information sharing within the multi-stakeholder structure. Other views captured indicated that all value chain actors were involved in the decision making process.

Illustrative Quote:

"So, it still relies entirely on farmers themselves" (KII)

"*We have a platform initiated by the Ministry of Agriculture which is the backbone of Agriculture in the County. So, we came together and formed a platform where all stakeholders are participating in terms of airing their views and coming up with a decision and we also usually meet once in a month as stakeholders to exchange views" (KII)*

This information from the key informants mirrored reports from the focus group discussants. Farmer groups reported to make decisions at the group level but these decisions were hardly considered by other actor groups especially in the area of input provision and pricing. For instance, discussants reported being supplied with a sorghum seed variety different from what they had ordered because of agro-input supplier preference. It was also reported in the groups that seed variety supplied to the farmer groups was highly dependent on the main market outlet which was the KBL.

Illustrative Quote

"We always agree in a meeting, but there was a time we had a variety we wanted to plant and we agreed with them and when they came, we were telling them we want to plant KARI Mtama One but they were insisting that they just want us to plant Silla. We knew that Silla took longer to mature but they brought us what they liked and they left what we wrote. (FGD farmer group)

"The seeds they gave us depended on the market which is KBL. KBL decides on the variety which is Silla, Gaddam or KARI Mtama One." (FGD farmer group)

Both in the key informant interviews and the focus group discussions, the respondents indicated that the current status of decision making along the sorghum value chain was not optimal. They cited the need to have a structured platform that could enhance decision making by enabling transparency in information sharing and stakeholder interactions. Other stakeholders involved in the sorghum value chain reported that the decision making process was not optimal due to the marketing system for sorghum that was being dictated by a monopoly company, KBL. There was need therefore for farmers and farmer groups to work closely and in an organized way to enable them enjoy improved productivity and enhanced advocacy for fair pricing through economies of scale.

Illustrative Quotes:

"We do not participate in price making. The white sorghum, the company that proposes the price or that constitute the price do not consult the stakeholders in the value chain. They always come up with their prices and that is the EABL…because it is like a monopoly company producing sorghum in Kenya"

"Decision making in sorghum value chain is not structured I would say so because every player particularly producers except for the other few who are already attached to some market like east African breweries which will guide them on which kind of variety to produce" (KII)

4.4 Multi-Stakeholder Structures along the Sorghum Value Chain in Siaya County

This theme highlighted the multi-stakeholder structures involved in the sorghum value chain, their formation, operationalization, viability, stakeholder roles, interactions and communication channels including suggestions for improvement.

The results of the study confirmed the existence of multi-stakeholder structures which were mostly referred to as innovation platforms by the respondents. The existing structures bringing together various actors along the Sorghum Value Chain in Siaya County were largely amorphous. This has led to mistrust and misgivings among actor groups thus threatening interactions within the existing structures. The other actors in a multi-stakeholder structure included Financial Service Providers, Agro-Input Suppliers, Technical Service Providers, Agro-Processors, Aggregators and Traders/Buyers. Various representatives of these stakeholder groups were interviewed either as key informants or as members of a focus group discussions. Several respondents reported that there was no definite platform that brought together all the stakeholders and that stakeholder groups only came together on a need basis. Few reported an existing structure that lacked a structured way of communication hence impacted its effectiveness. Further, in both KIIs and FGDs, the relationship among stakeholders was reported to be mutually beneficial as every stakeholder's need was met. Concerns on how farmer groups could be adequately involved were mentioned.

Illustrative Quote:

"Mutually beneficial it is but unfortunately it is not structured to achieve that if the linkages between those actors was streamlined then the overall output would be profitable returns from the sorghum value chain to particularly producers but as it is they are fairly disjointed their operations and hence we don't have the energy to propel optimal benefits from their engagement" (KII)

4.4.1 Considerations during formation of the Multi-Stakeholder Structures

Among the key informants and focus group discussants, considerations to be involved in the multi-stakeholder structure included organization capacity and availability of personnel, financial capability, ability to communicate to farmer groups, honesty and integrity. When asked about an ideal multi-stake holder structure, reviews gave descriptions summarized as indicated *Figure 5*.

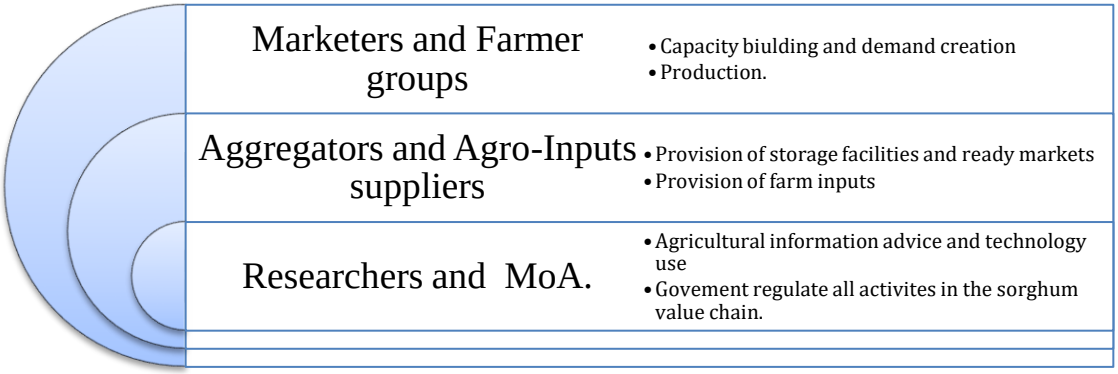


Figure 6: Ideal composition of a multi-stakeholder structure

Illustrative Quotes:

"Capacity building which goes hand in hand with civic education. The group can be capacity built then they take civic education to other community members. I request that the capacity building be regular do that you can assess the progress whether positive or negative" (FGD-Farmer group)

"*First, we consider the personnel because if you don't have the right personnel, then we cannot call you a stakeholder …yeah because some of them are just pocket company's where one person is the director, is the CEO and is the field officer, so we cannot qualify you to be called a stakeholder. So, we consider the personnel and the capacity of that organization" (KII)*

"*I think the Ministry of Agriculture, researchers, Agricultural NGO's, farmers on the ground and representatives who can represent farmers" (KII)*

4.4.2 Stakeholder Roles

All stakeholders appeared to understand their roles within the multi-stakeholder structure. Specific roles mentioned by different actors and actor groups included: Organization of farmers into cluster producer groups, promotion of stakeholder linkages, preparation of demo plots to allow exchange visits of farmers and farmer groups from different areas, technical support provision, training

farmer groups on new innovations and technologies, grants issuance to farmer groups, strengthening of associations like the marketing groups to improve information flow.

Illustrative Quote:

"*Our roles as I said, our major mandate is development of farmers. Ideally agriculture is very wide. Remember they have emerging technologies. We are not limited, we are dynamic. Our first role is mobilization on creation and linkages because we give it a try, with also the county governments, they bring these farmers together. First, we allow that element of capacity building because we have to allow these farmers to carry out actual production to the required specifications. One role is capacity building and provision of finances and the linkages. The value chain becomes seamless since markets are streamlined and very easy for farmers to get into it without so much hustle". (KII)*

4.4.3 Interactions in the Multi-Stakeholder Structure

Interactions within the multi-stakeholder structure occurred among different actor groups and at different levels. Inter-farmer group interactions involved farmer groups working with other farmer groups to gain more knowledge and information. Inter-stakeholder interactions involved different stakeholders and stakeholder groups working together to improve productivity, profitability and to create efficiency along the sorghum value chain. With the producer groups(farmers) playing a central role, various other actors have had contractual agreements with these producer groups and in some instances with other actor groups as well. Subsequently, the aforementioned contractual agreements have been breached from one actor group to another due to mistrust and a lack of transparency between parties involved. The other factor that has largely contributed to the breach is a lack of oversight and quality assurance which could guarantee that either party in a contractual agreement is bound by the obligations of the contract and could suffer losses in the event of a breach. Both in the KIIs and the FGDs, stakeholder interactions were facilitated through physical meetings. Phone calls, text messages and WhatsApp group interactions were also mentioned by some respondents. In summary, the interactions in the sorghum value chain were described in a pyramid by a stake holder as below:

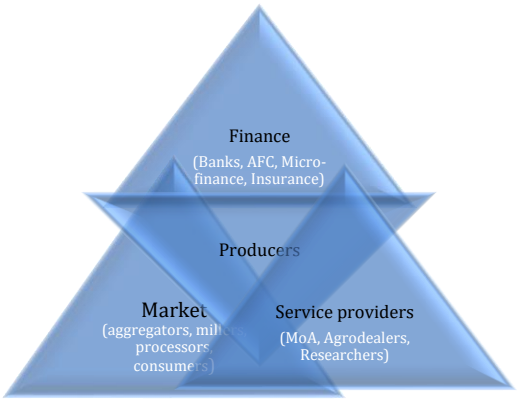


Figure 7: Pyramid showing sorghum multi-stakeholder interactions

Illustrative Quote:

"*As per now we can improve the networking because sometimes the famers get different information from the agriculture officers. You find that officers from Transu can train farmers on issues like GAPs but when an officer from a different company comes in, the information will be a different one, so the farmers get confused. So, the issue of networking should be harmonized so that when a company or when the Ministry of Agriculture is training a group, other groups should also know that today, they have trained on this topic so that when you come, you don't repeat the same topic and confuse the farmer" (KII).*

"We should have a system that is much better in the sense that if there are meetings that have taken place at the high level of the county government, the discussions should be passed down to the farmers on the ground. (KII)

4.5 Integration of ICT in the sorghum value chain

This theme analyzed how agricultural information was shared within the multi-stakeholder structures, methods of information sharing that were both ICT and Non-ICT, including limitations and willingness to integrate ICT into the sorghum value chain.

4.5.1 Methods of information sharing

Information was exchanged manually or by use of mobile technology such as cell phones. Physical meetings were on need basis and were coordinated through the Ministry of Agriculture in Siaya County. Various respondents raised concerns with the physical meetings bringing together the various stakeholders like walking very long distances to get to the venue of the meetings. Coupled

with the outbreak of the coronavirus, it was becoming increasingly difficult to convene these physical meetings. Mobile phones were also used to disseminate weather information to farmers and farmer groups though the advisories were reported to be inconsistent and inaccurate. Other stakeholders and stakeholder groups reported to have WhatsApp groups where they shared information especially while scheduling physical meetings. Other methods of information sharing reported were the use of fliers and brochures which were largely ineffective in reaching all actor groups within the multi-stakeholder structure in short notices.

Illustrative Quote:

At the moment we don't have that one… we don't have any…in fact we are do not have ICT, no, we have not invested into that. It is only fliers and brochures, that is all we have. (KII)

In the focus group discussions, discussants reported that they got relevant information from their chairpersons who attended multi-stakeholder meetings and carried the responsibility of relaying the concerns of the groups to the other actor groups and sharing relevant information with the members. Other media reported for information sharing were barazzas convened by chiefs.

4.5.2 Adoption of ICT for information sharing in the Multi-Stakeholder Structures

Both the key informants and the group discussants expressed willingness to embrace the integration of ICT in the multi-stakeholder structures. Their preferences varied with level of proficiency and exposure to the use of ICT tools in information sharing. Among key informants, ICT was perceived as important in sharing information to a wide coverage, giving accurate and relevant information on time and allowing quick exchange of information. The information would include; weather information, availability of market and market pricing as well as availability of farm inputs and credit facilities. With all this information available in one platform, information flow and decision making would be enhanced.

Illustrative Quotes:

"Once there is ICT…there is a platform, it will really help in information dissemination because most farmers now can access information through their phones whenever they are, maybe through emails and internet access…and all that. So, ICT is very important if that one can be used in the platform" (KII)

"The absence of digitalization will mean slow flow of information and probably also limited access to available technology information so it will hinder first of all availability of such information and the dissemination" (KII)

Focus group discussants echoed the need to incorporate ICT tools in the multi-stakeholder structures so they could have direct access to information. They also reported the need for ICT to consider the semi-literate and the illiterate in the new technologies and embrace text messages sent in a language they understood or Voice-overs for those who could not read.

Illustrative Quote:
"Just to add on that the text messages are good than the WhatsApp because not everyone has the smart phone some of us have feature phone like mine so the messages are good and easy to access" (FGD, farmer groups).

A few key informants reported working with ICT innovations and platforms that allowed the sharing of technical agricultural information with farmers and farmer groups. The technology however was on general agricultural production enterprises including crops and livestock and therefore could not serve a specific enterprise like sorghum effectively. The respondents expressed a need for the development of an integrated digital platform which could streamline information sharing, enhance stakeholder interactions and help realize greater benefits to all value chain stakeholders in the sorghum multi-stakeholder structures.

4.6 Testing, Evaluation and Validation of the Multi-Stakeholder Value Chain model

A prototype was designed and developed based on the model in *Figure 2* above. Subsequently, 27 respondents mainly from the producer groups earlier identified were randomly selected, contacted by phone, sensitized and allowed to interact with the system. Through the developed system, most of the users were able to create accounts, sign-in and share information. A mini survey was conducted using a structured questionnaire to gather respondent views about various features and functionalities of the system like content, design, personalization and community as seen below. The data obtained was analyzed and key observations discussed in the results section.

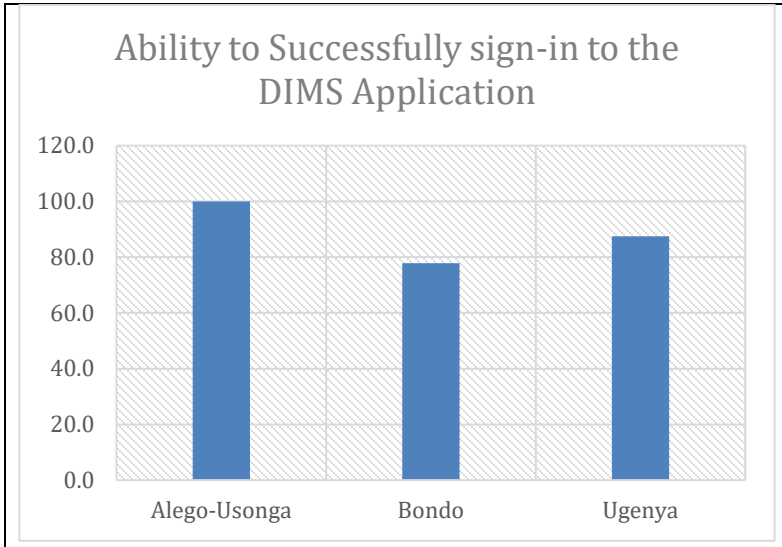
4.6.1 Model Validation Findings and Discussion

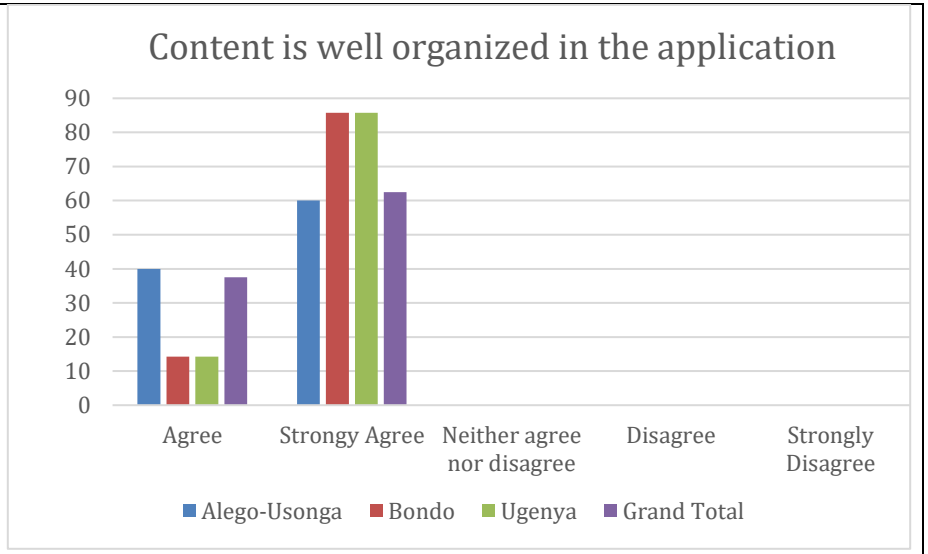
The model validation results showed the following:

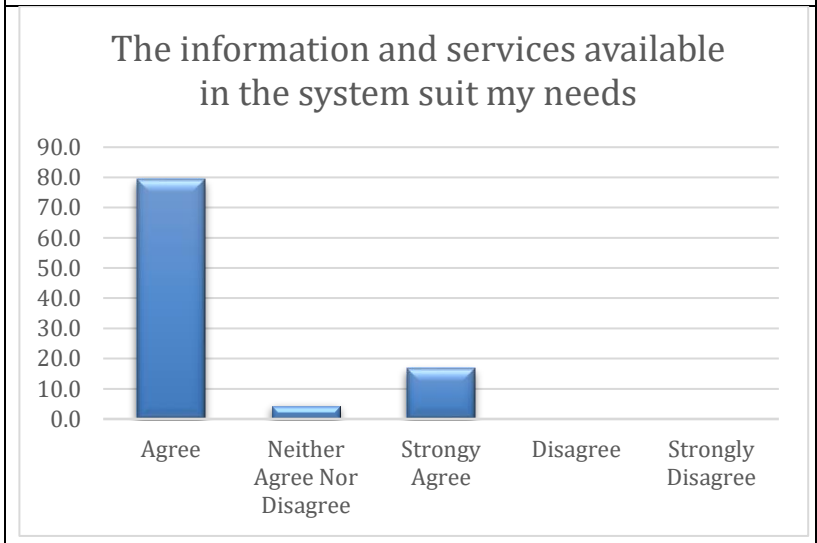
i. That 88 percent of the respondents managed to successfully create accounts and signed into the system;
ii. That 60 percent of the respondents from Alego-Usonga Strongly agreed that Content was well organized in the application as well as 85 percent of respondents from Ugenya and Bondo respectively;
iii. That 79 percent of all the respondents across the 3 Sub-Counties Agreed that the information and services available in the system suited my needs;
iv. That 33 percent of the respondents Agreed that clarity, focus and language made the application useful and;

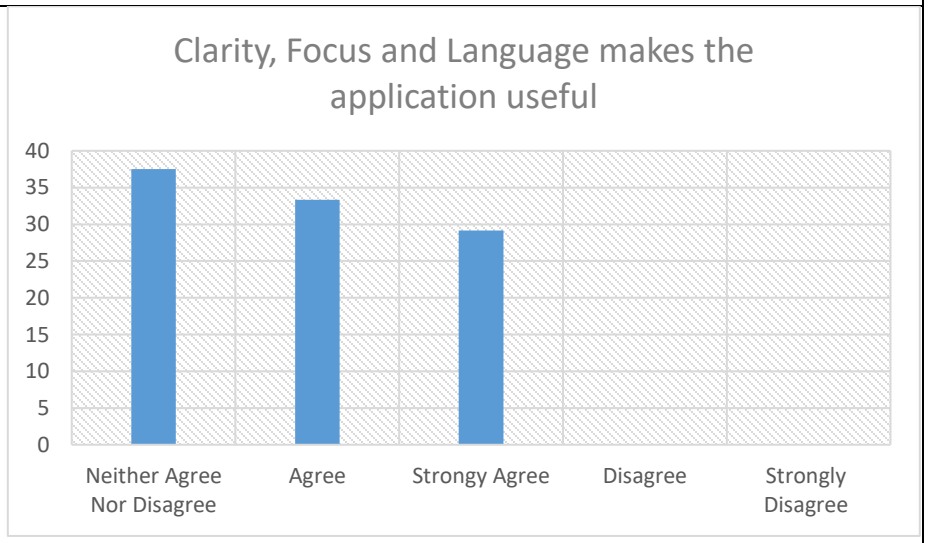
The results therefore from the 27 respondents proved that the model as designed in ***Figure 2*** above was a great fit for the data earlier collected from the various sorghum value chain actors and actor groups.

Table 3: Test, Evaluation and Validation Results for the Model









5.0 CHAPTER 5: SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter summarizes the key findings of the study and recommends a digitalized multi-stakeholder value chain model for sorghum that could improve stakeholder interactions and improve information flow within the multi-stakeholder structure.

5.2 Summary

The study found out that the sorghum value chain in Siaya County does not function optimally with farmers' decisions being influenced by other stakeholders. The results also confirmed the existence of multi-stakeholder structures bringing together various actors along the Sorghum Value Chain in Siaya County. However, there was not a structured platform that could allow smooth flow of information among all the value chain actors. Subsequently, the existing multi-stakeholder structures were marred with misgivings among members thus threatening efficiency in information flow along the value chain.

5.3 Conclusions

While the use of ICT related platforms in information sharing within the multi-stakeholder structures remained low, all the sorghum value chain stakeholders interviewed expressed willingness to embrace the integration of ICT in the structures as a way of streamlining information flow and enhancing access to timely and actionable interventions. Their preferences varied with level of proficiency and exposure to the use of ICT tools in information sharing. Among key informants, ICT was perceived as important in sharing information to a wide coverage, giving accurate and relevant information on time and allowing quick exchange of information. The information would include; weather information, availability of market and market pricing as well as availability of farm inputs and credit facilities. With all this information available in one platform, information flow and decision making would be enhanced resulting in efficiency at different points of the sorghum value chain.

5.4 Recommendation(s)

1. This study recommends a robust digitalized multi-stakeholder structure that utilizes web and mobile based applications to enhance decision making and improve information flow among Sorghum Value actors in Siaya County.
2. The study also recommends a digitalized multi-stakeholder structure that leverages blockchain technology to enhance security and transparency in online contractual transactions between various value chain actors. This could remedy disagreements arising from breach of contracts as observed during the research while also helping stakeholders to access credit facilities based on authentic electronic contracts.

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Appendices

Appendix 1: Value Chain Actors in Existing Multi-Stakeholder Structures in Siaya County

Sub-County	FINANCIAL SERVICS	INPUT SUPPLIERS	TECHNICAL SERVICE PROVIDERS	PRODUCER GROUPS	AGRO-PROCESSORS	AGGREGATORS	BUYERS
Alego-Usonga	Equity Bank AFC – Siaya Branch	1. Avepo Agrovet Contact person: Julius Okoth-0722976171 2.Patricia Oyugi Agrovet Contact person: 0727690734	1. Department of agriculture Contact: 0723150931 2.Cereal Grain Association (CGA) Contact person: Philip Ndenga- 0726643700	1. Bidii Farmers Group. Contact person: Elizabeth Owiti-0718807650 2. Nyiego CBO Contact person: Mathlida Juma - 0715824604	1.ATDC – Siaya Contact person: Mr. Mulielie 0723795900 2. Nyiego CBO Contact person: Mathlida Juma - 0715824604	1.Linet Otieno– 0725903914 2.Transu Contact person: Humphery-0711927942	1. East African Breweries Limited. Contact person: Victor Onyango-0706440407
Ugenya	Agriwallet Equity bank		1. Department of agriculture Contact: 0723150931 2.Cereal Grain Association (CGA) Contact person: Brian Etemesi 0720057516	1. Ndenga CBO Contact: FRANCIS Onyango 0724538013 2. NOWUEG CBO Contact: 0708170751	Eastcom Foods Contact: Charles Oloo 0726543106	1. Transu Contact person: Humphery-0711927942 2. Ndenga CBO Contact: FRANCIS Onyango 0724538013 3. NOWUEG CBO Contact: 0708170751	1. Eastcom Foods Contact: Charles Oloo 0726543106 2. East African Malting Company Contact: Victor Onyango 0706440407
Bondo	Equity Bank AFC – Siaya Branch	Zilmac Agrovet 0713704965	1. Department of agriculture Contact: 0723150931 2. KCSAP 0726543106	1. Usire Smallcale Group 0714318499 2. New Ujwanga 0711438642		Transu 0751302004	Transu 0751302004

Appendix 2: Focused Group Discussion (FGD) Checklist

Objectives:

1. To find out the processes involved in the exchange of agricultural information among stakeholders along the sorghum value chain in Siaya County;
2. To examine the current status of decision-making in Sorghum production
3. To find out the characteristics or features of a multi-stakeholder structure along the sorghum value chain in Siaya County;

Definitions

Multi-Stakeholder Structure: a platform through which farmers, traders, researchers, processors, input suppliers, policy makers and other value chain actors come together to determine efficiency along the sorghum value chain. Its goal is to boost information flow among stakeholders for improved commercialization of the sorghum value chain in Siaya County

BACKGROUND INFORMATION

a) Name of your Organization/Group:

b) Organization/Group Type

c) Ward:

d) Total Members:

e) Female**:**

f) Male

SECTION A: Sorghum Value Chain in Siaya County

1. Where in Siaya county is sorghum production activities prevalent?
   What would you attribute this prevalence to?
2. What is the current status of Sorghum production in Siaya county?
   Hint: Frequency out of every 10 farmers, how many are engaged in sorghum production? Main input types used in the production of Sorghum, source(s) of inputs, average quantities, costs of inputs used in the production of Sorghum, average yield/acre?
3. What agronomic practices are prevalent in the production of Sorghum?
4. Do you think the sorghum value chain is working optimally? Discuss
5. What is the current status of decision-making in Sorghum production?
   Hint: decisions on when, varieties to plant, where to access inputs, where to sell and related TIMPs?
6. Is decision making as presently happening in sorghum production effective?
   a. If Yes, briefly explain how
   b. If No, please explain what is needed to make it effective
7. Do you think your group/institution faces any challenge(s) in accessing or sharing relevant agricultural information with the members of other multi-stakeholder structures along the sorghum value chain?
   a. If **Yes**, what are these challenges? How can these challenges be addressed?
   b. If **No**, how has your organization managed to cope with the competing information needs to ensure effective information flow among stakeholders?
8. What do you think should be done to improve levels of interaction and access to relevant, timely and actionable advisories on Sorghum?
9. What marketing activities do you undertake for Sorghum?
   Hint: Marketing outlets, arrangements, pricing. How can your income from sorghum be improved?

SECTION B: Characteristics (features) of Multi-Stakeholder Structures

1. What are the main considerations during the formation of your structure?
2. What specific roles does your group/structure play along the Sorghum Value Chain? What can be done for your group to play these roles even better?
3. Within your structure, how is information exchanged?
    a. In your opinion, are these modes of information exchange effective in accessing and disseminating information from and in the structure?
        i. If Yes, briefly explain how
        ii. If No, what are the challenges encountered with the fore mentioned modes of information exchange within the structure?
        iii. How can the challenges in (ii) above be overcome?
4. How would you describe the information/advisories/service received in terms of: *accessibility, usefulness, timeliness, affordability, accuracy?*
5. What role does your structure play in reference to:
    a. Innovation; and
    b. Collaboration within agricultural production, research, and development?
6. Is your structure working optimally?
    a. If Yes, briefly explain how
    b. If No, please explain why they are not working optimally.
7. What should be done to ensure that your structure work optimally to enable benefits that lead to greater impact for the stakeholders?

SECTION C: Integration of ICTs in Multi-Stakeholder Structures

1. How do you think modern information and communication tools can influence Sorghum production and marketing?
2. How do you think these ICT tools can be integrated in multi-stakeholder structures to facilitate information sharing?

Appendix 3: Key Informant Interview Checklist

Objectives:

1. To find out the processes involved in the exchange of agricultural information among stakeholders along the sorghum value chain in Siaya County;
2. To examine the current status of decision-making in the sorghum value chain?
3. To find out the characteristics or features of a multi-stakeholder structure along the sorghum value chain in Siaya County;

Definitions:

Multi-Stakeholder Structure: a platform through which farmers, traders, researchers, processors, input suppliers, policy makers and other value chain actors come together to determine efficiency along the sorghum value chain. Its goal is to boost information flow among stakeholders for improved commercialization of the sorghum value chain in Siaya County?

Digitalization in agriculture refers to the introduction of digital technology innovations into existing institutional, industrial, and societal systems in such a way that transforms how those systems operate to enhance profitable production (Fielke, 2020).

BACKGROUND INFORMATION

1.Please kindly provide your brief personal details

a. Your Full Name:

b. Your Title:

c. Name of your Organization/Group:

d. Your main role in the organization

e. Number of years you served in the organiza

f. County:

g. Ward:

h. Sex: ◯ Male ◯ Female

i. Age bracket: ◯ 18-35 years ◯ 36-55 years ◯ Above 55 years

SECTION A: Sorghum Value Chain in Siaya County

1. Where in Siaya county is sorghum value chain activities prevalent? Briefly describe this prevalence
2. In your opinion, how does the Sorghum value chain perform presently in Siaya county?
3. Do you think the sorghum value chain is working optimally?
    a. If Yes, briefly explain how: -
    b. If No, please explain why it is not working optimally and who/what else should be included in the value chain to enable it work optimally-challenges
4. What is the current status of decision-making in the sorghum value chain?
   Hint: decisions on when, varieties to plant, where to access inputs, where to sell and related TIMPs?
5. In your opinion, is decision making as presently happening in the value chain optimal? Hint
    a. If Yes, briefly explain how
    b. If No, please explain what is needed to make it optimal
6. What specific roles does your group/institution play along the Sorghum Value Chain?
7. In your opinion, how can your group/institution play the said roles in (6) even better?
8. Which other groups/institutions do you work with in the production of Sorghum?
9. Do you think the relationship among actors in the sorghum value chain is mutually beneficial?
    a. If **Yes**, in which ways do you benefit each other?
    b. If **No**, how can the relationship be made mutually beneficial?
10. Briefly describe how multi-stakeholder structures in the sorghum value chain interact?
    Hint: their location, average distance between them (in km), how often they link up, is the interaction structured or ad hoc and how is it facilitated?
11. What do you think should be done to improve levels of interaction and access to relevant, timely and actionable advisories on Sorghum?
12. Do you think your organization faces any challenge(s) in accessing or sharing relevant agricultural information with the members of other multi-stakeholder structures along the sorghum value chain?
    a. If **Yes**, what are these challenges? How can these challenges be addressed?
    b. If **No**, how has your organization managed to cope with the competing information needs to ensure effective information flow among stakeholders?

SECTION B: Characteristics (features) of Multi-Stakeholder Structures

1. In your opinion, what are the main considerations during the formation of the multi-stakeholder structure in relation to:

a. who should be on the multi-stakeholder structure; b) how the multi-stakeholder structure should look like; and c) how the multi-stakeholder structure should work?

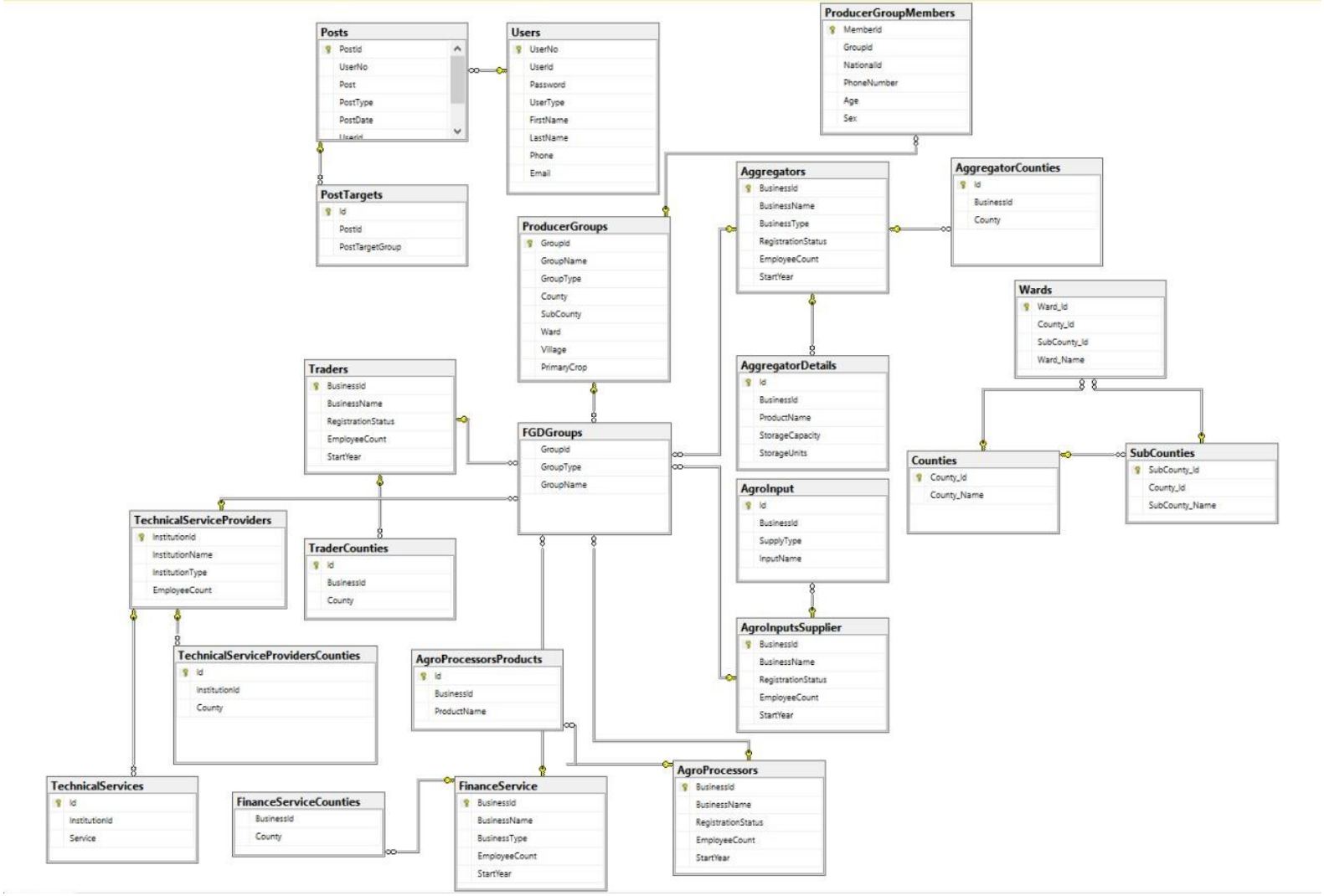
2. Within the multi-stakeholder structure, how is information exchanged?
   a. In your opinion, are these modes of information exchange effective in accessing and disseminating information from and in the structure?
      i. If Yes, briefly explain how
      ii. If No, what are the challenges encountered with the fore mentioned modes of information exchange within the structure?
      iii. In your opinion, how can the challenges in (ii) above be overcome?
3. What role do the multi-stakeholder structures play in reference to:
   a. Innovation; and
   b. Collaboration within agricultural production, research, and development
4. How do you think the multi-stakeholder structures can influence;
   a. the systematic sharing of information among value chain stakeholders
   b. the dissemination of advisories
   c. application of information technologies, innovations and management practices that helps to attain greater impact and benefits to value chain stakeholders
5. Do you think the multi-stakeholder structures are working optimally?
   a. If Yes, briefly explain how
   b. If No, please explain why they are not working optimally.
6. What in your opinion should be done to ensure that the multi-stakeholder structures work optimally to enable benefits that lead to greater impact for the stakeholders?

SECTION C: Integration of ICTs in Multi-Stakeholder Structures

1. What are the tools or methods (formal and informal/ICT based and Non-ICT based) used in your organization to ensure that agricultural information shared across other multi-stakeholders' structures is accessible, useful, timely, affordable and accurate?
2. In your view, how might the use of ICTs tools in the multi-stakeholder structures help to attain benefits (and greater impact) to the value chain stakeholders?
3. What role do you think modern information and communication tools can play in improving access to valuable information on Sorghum production and marketing?
4. In your opinion, in what way(s) could the digitalization of multi-stakeholder structures affect;
   a. sharing of information among value chain stakeholders, b. dissemination of advisories and c. uptake of agricultural innovations and management practices

Appendix 4: Picture of an Audio Recorder used for the FGD and KII interviews

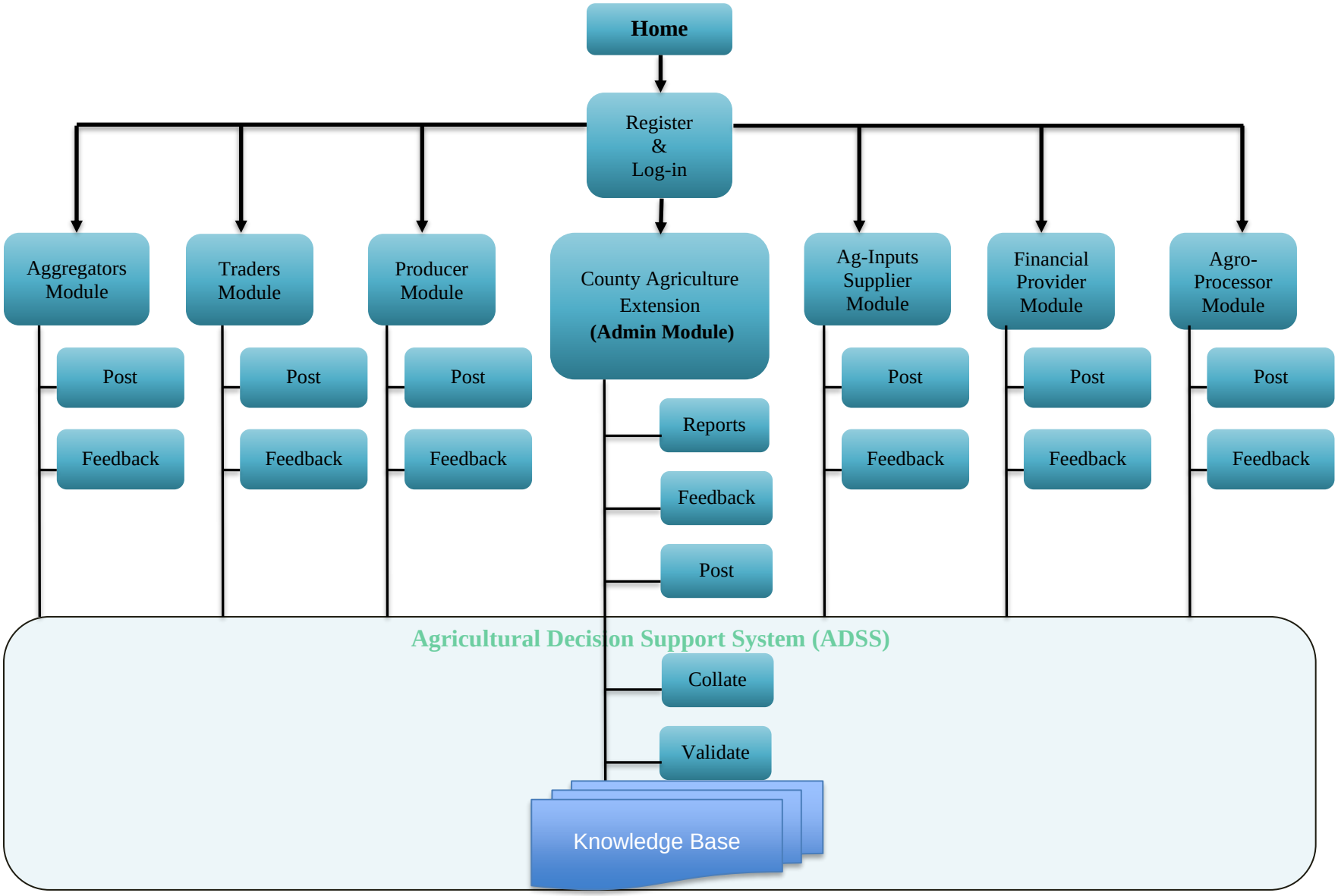
Appendix 5: Design of the Prototype



Appendix 6: Table showing required fields for registration in the Siaya county sorghum value chain multi-stakeholder prototype

FINANCIAL SERVICS Banks, AFC, Development Partners – GiZ, USAID, World Bank, JICA	**AGRO-INPUT SUPPLIERS**	**TECHNICAL SERVICE PROVIDERS** MoA, Agro-dealers, Research Organizations(KALRO, ICRISAT etc.)	**PRODUCER GROUPS** Farmers	**AGRO-PROCESSORS**	**AGGREGATORS**	**TRADERS** EABL, Consumers
• Business Name • Business Type • Registration Status • Number of Employees • Start Year of Operations • County(ies) of Operations	• Business Name • Business Type • Registration Status • Number of Employees • Start Year of Operations • Agro Supply Products • Agro Input Services • County(ies) of Operations	• Institution Name • Institution Type (Govt/Private/NGO) • Service Types • Number of Employees • County(ies) of Operations	Registration Module: • Name of Farmer • ID Number • Phone Number • Age • Sex (M/F) • Group Type • Group Name • County • Sub-County • Ward • Village • Primary Crop	• Business Name • Business Type • Registration Status • Number of Employees • Start Year of Operations • Agro Processor Products • County(ies) of Operations	• Business Name • Business Type • Registration Status • Number of Employees • Start Year of Operations • Aggregator Products • Storage Capacity • Storage Units • County(ies) of Operations	• Business Name • Business Type • Registration Status • Number of Employees • Start Year of Operations • Licenses • County(ies) of Operations

Appendix 7: Sitemap of the Prototype



Appendix 8: Multi-Stakeholder Model and the Prototype; The Nexus

The model in *Figure 2* was used to structure the prototype as shown in the above sitemap. The sitemap depicts information flow, decision support and interactions among the various sorghum value chain actors in a digitalized multi-stakeholder structure. From the sitemap:

i. All sorghum actor groups and individuals register in the platform with the details listed in the table appearing under *appendix 6* above. Each individual registered in the platform must belong to a particular module as shown. The modules are: Aggregators module, Traders module, Producers module, Agro-Inputs Supplier module, Financial Service Provider module, Agro-Processors module, Research Institutions module and the County Agriculture Extension module; the Admin Module.

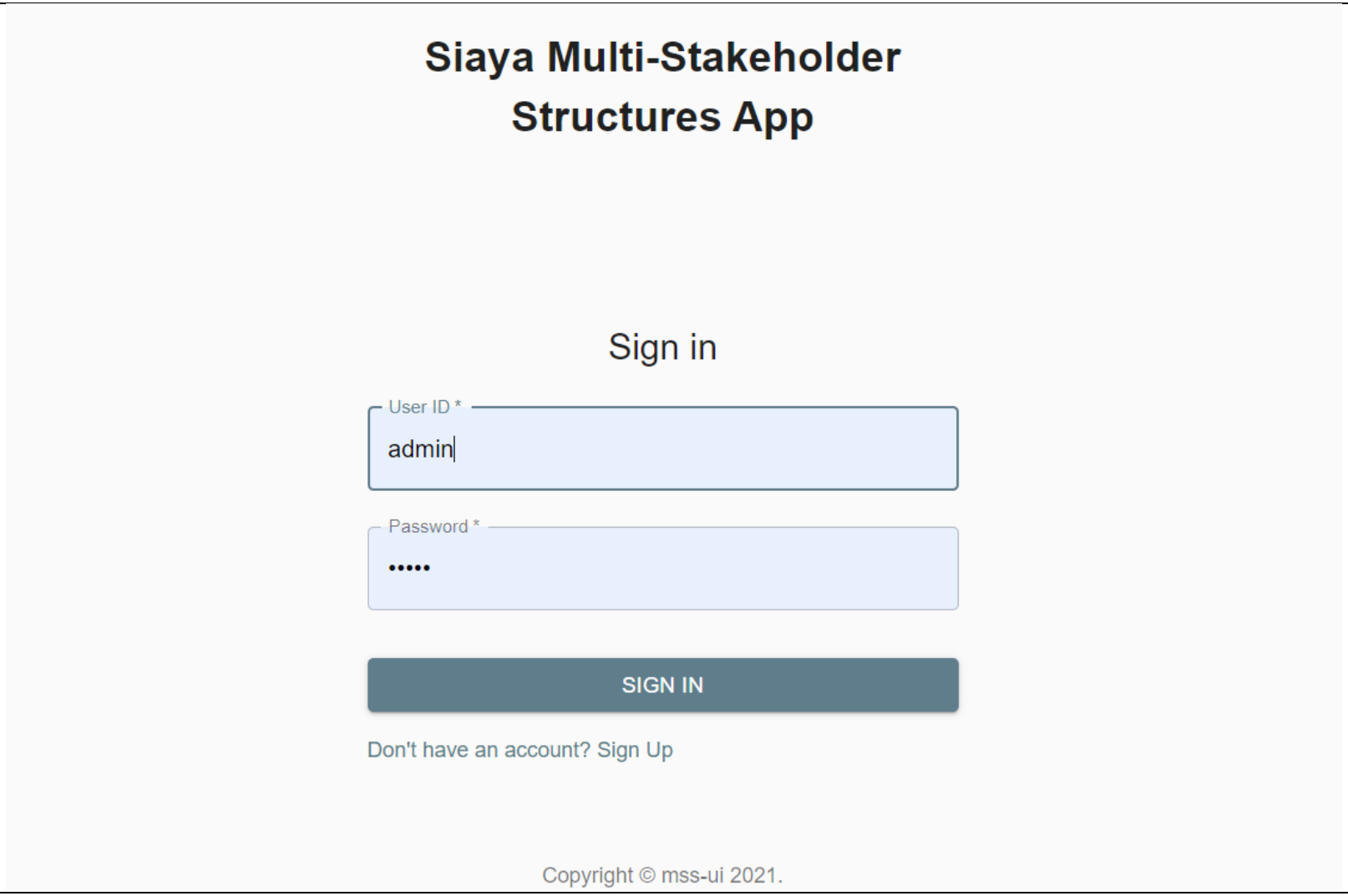
ii. After successful registration and log-in, the user is able to see all posts by him/her and information shared to their group by any other user in their timeline. This may include feedback, advisories, warning, general information;

iii. All the data and information exchanged on the digitalized platform go through the County Agricultural Extension Officer (admin) for validation and oversight. This forms the central module for collation, validation, decision support and information sharing in the multi-stakeholder structure;

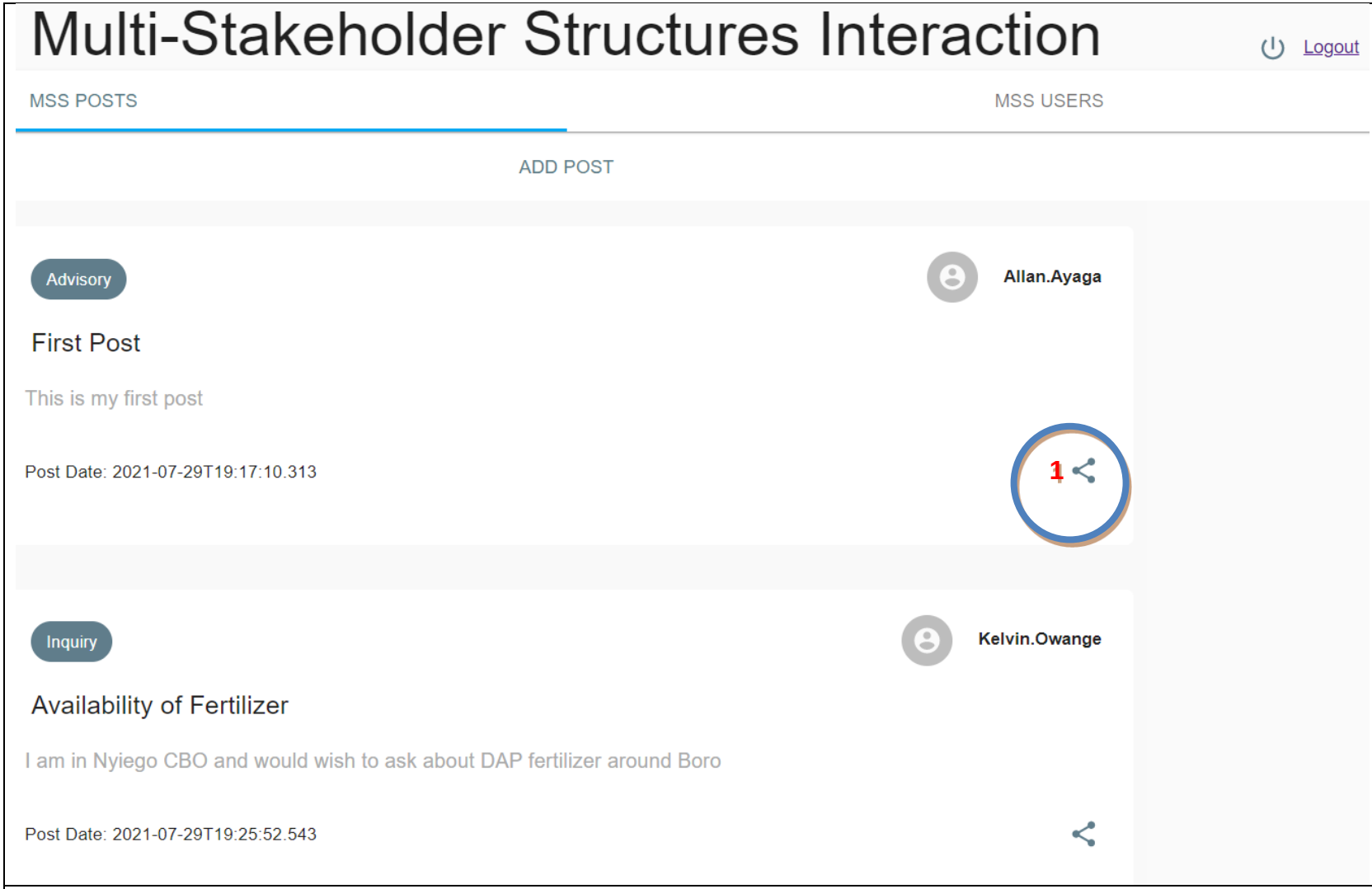
iv. When information is shared at the platform, the admin will select the intended recipient groups and broadcast the information which should be available on the timelines of all the intended recipients;

v. Every stakeholder group will have technology champions capacity built to the required proficiency levels to retrieve and disseminate information from the platform for sharing with the other members of the group by way of SMSs and phone calls

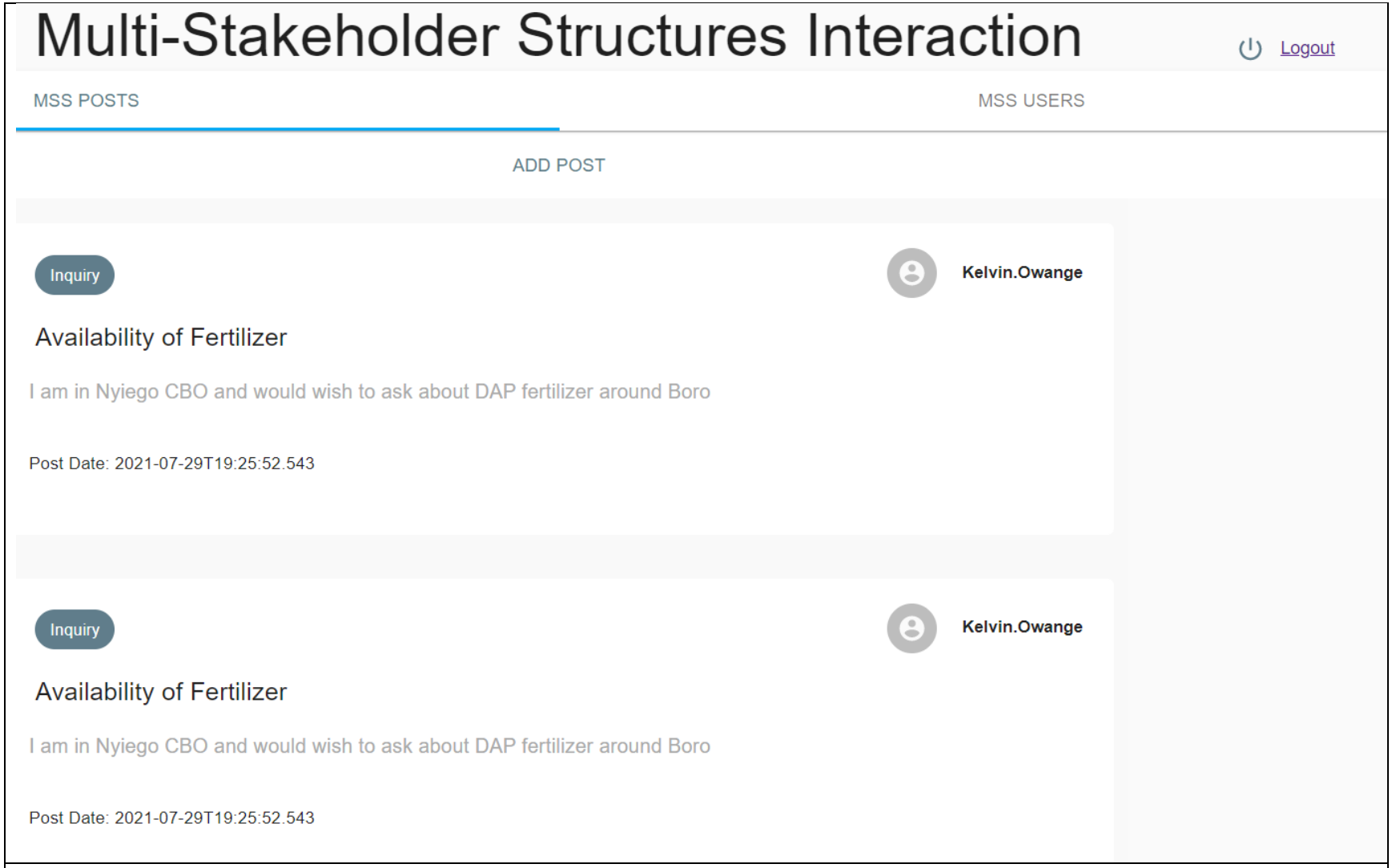
Appendix 9: Prototype Screenshots



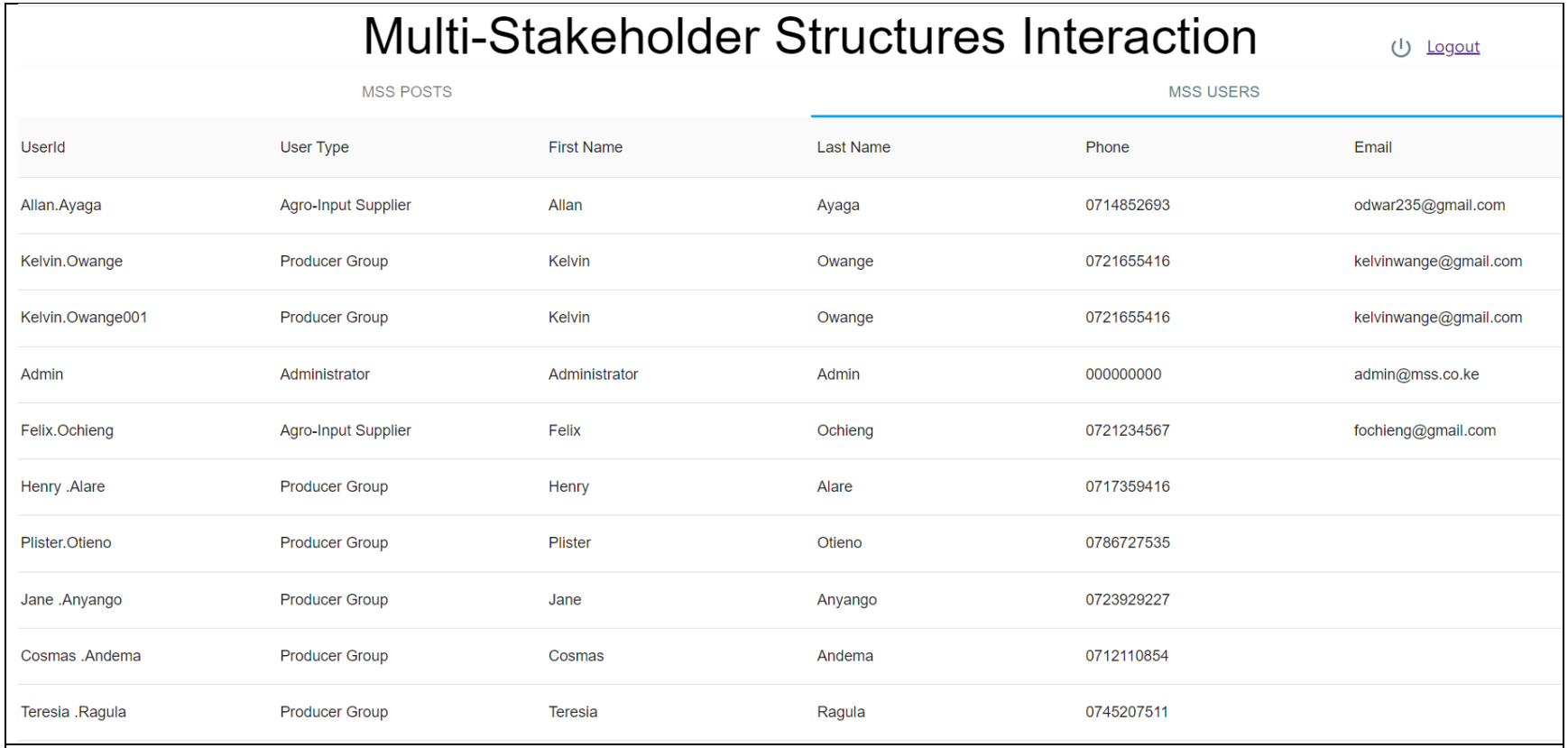
1. **log-in screen**



2. **admin interface, the circled area allows the admin to broadcast/post information to other registered users**



3. **standard user interface**



4. registered users by **user** type (module)