An Appraisal of Selected Innovation Cases in the Livestock Sector in Kenya

March 2020

Lawrence Mose, Geoffrey Kamau, Wellington Mulinge, Felister Makini, Stella Makokha, Elkana Nyambati, Beatrice Salasya and Elias Thuranira

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Forum for Agricultural Research in Africa
12 Anmeda Street, Roman Ridge
PMB CT 173, Accra, Ghana
Tel: +233 302772823 / 302779421
Fax: +233 302773676
Email: info@faraafrica.org
Website: www.faraafrica.org

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Acronyms and Abbreviations

AI	Artificial Insemination
ASAL	Arid and Semi-Arid Lands
ASFs	Animal Sourced Foods
CBBP	Community Based Breeding Programme
DESA	Department of Economic and Social Affairs
ECA	United Nations Economic Commission for Africa
E-data	Electronic data
FAO	Food and Agriculture Organization of the United Nations
GHGs	Greenhouse gases
GoK	Government of Kenya
IIH	Induced Innovation Hypothesis
ILRI	International Livestock Research Institute
IPPC	Inter-Governmental Panel on Climate Change
KALRO	Kenya Agricultural and Livestock Research Organization
KLBA	Kenya Livestock Breeders Association
KNBS	Kenya National Bureau of Statistics
MOA	Ministry of Agriculture
MOH	Ministry of Health
MSc	Master of Science
NSS	National Sahiwal Stud
PhD	Doctor of Philosophy
SEAZ	Small East African Zebu
SSA	Sub Saharan Africa
TMR	Total Mixed Ration
WB	World Bank

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Executive Summary

The demand for livestock products is on the rise and farmers, policy makers, state and non-state actors are making efforts to ensure that the demand is met. However, a number of challenges affect the sub-sector and these include shortage of grazing land and forages, low milk and egg production, low rates of growth and input/output market information asymmetry among others. With a view to addressing some of the above mentioned challenges, a number of initiatives have been launched in Kenya. An assessment of four identified innovation initiatives was conducted and the findings are herein reported.

The broad objective of the study was to carry out a brief overview of the national livestock sector and its recent developments, including the evolution of the policy environment and a description of major innovations. The specific objectives were to: Select novel and scalable innovations for the study; Carry out in-depth analysis of major factors contributing to the success of the innovations in the selected platforms; Identify potential for further development and scaling; Draw lessons for other countries potentially desiring to initiate similar initiatives. The assessment followed the theory of induced innovations as the theoretical framework to identify and understand the dynamics of the various initiatives.

The methodology involved a joint learning and planning workshop in Nairobi to develop a consensus on successful innovations in the livestock sector in four countries Benin, Ethiopia, Kenya and Mali. The workshop shared learning around the scaling up of proven innovations to enhance agricultural productivity with a view to improve food security and natural resource management in Africa. Initial selection of initiatives was made during this workshop and affirmed through a Skype conference. For Kenya, the selected innovation case studies included:

1) Development of hay and crop residues, 2) Community based genetic improvement of Sahiwal cattle breed. 3). Development and upscaling of improved indigenous chicken 4) Market integration in pigs: The case of Farmers' Choice. The information on the innovation case studies was collected through desktop studies, expert consultations and Key Informant Interviews. The information collected was validated through a Stakeholder/Expert Consultation Workshop in Nakuru, Kenya and the results were synthesized and presented in form of narratives, tables and charts.

Assessment of the hay and crop residue system in Kenya revealed that the increasing population continues to exert pressure on the already scarce land and especially in the country's 20% high potential areas. This has led to opening up of Arid and Semi-Arid Land (ASAL) areas for crop and livestock production and the overall effect of this is competition for grazing land and sources of livestock feeds. Currently, the ASAL counties produce about 20 million bales/year against over 35 million bales required to cover a 4-month annual feed deficit meaning that the unexploited potential for hay production in ASAL counties remain enormous. Maize, wheat and rice crop residues used to be left in the field to be fed on by livestock as standing hay. Increased demand has however led to commercialization of the residues. However, the low levels of nitrogen and carbohydrates limit microbial activity and the high levels of fiber hinder their palatability and digestibility.

To improve these residues, urea treatment has been introduced as well as preparation of mineral blocks using molasses, urea and are further improved through inclusion of de-wormers. This value addition increases intake and improves the rumen ecosystem to facilitate absorption. Chopping and grinding of the straw is also practiced using locally fabricated machinery and this has created employment for the informal or 'jua kali' artisans while motorbike operators take the machinery from one field to the other providing stover processing services. The rice straw hay processors have organized themselves into women and youth self-help groups for baling and marketing the hay. In periods when there is no hay, they harvest grass growing in between the fields and dry it for baling and selling to livestock keepers.

Rhodes grass, Lucerne and range grasses hay have attracted a growing number of farmers to invest in commercial hay production. Private farmers in different parts of the country have invested in hay production while some have developed businesses in providing mechanized services on contract basis to other farmers.

The farmers have organized themselves into hay growers' associations with an example being Rift Valley Hay Growers Association who came together in 2015 to grow and market hay. Membership is spread out in seven counties and besides production and marketing of hay, they lobby the national and county governments on various issues such as standardization of hay production, storage, marketing and distribution. A key reason for the success of the hay value chain is the partnership between the farmers, private sector entities such as the New Kenya Cooperative Creameries (KCC), Technoserve, Kenya Seed Company and various commercial banks, management advisers and the county governments. Range grass hay production was initiated through selection and domestication of wild grasses at KALRO, Kiboko in response to deteriorating rangeland pastures and the frequent droughts which led to immense livestock losses. This practice of growing grasses instead of the common practice of transhumance has resulted in the emergence of secondary innovations such as adoption of collective action for mechanical baling and selling of hay in addition to grass seed business, milling for TMR formulations and water harvesting for reseeding. The cultivated hay and crop residue production is a good example of adaptation to climate change where prolonged drought and reduced natural pasture production triggered various innovations to respond to the increasing demand for livestock feed.

Sahiwal breed genetic improvement is a strategy that was introduced to unlock the potential of the Kenyan ASAL areas. The Sahiwal cattle breed imported from Pakistan is a large dual purpose cattle breed and plays a role in food and nutrition security and also serves as a source of income. The process involves maintenance of a National Sahiwal Stud herd in KALRO, Naivasha and multiplication centres in a few well managed commercial ranches in the ASAL areas. Selected breeding bulls from these sources are availed to the individual ranches and farmers while semen is also extracted for use in AI programmes by commercial farmers. Once the superior bulls are availed to the farmers, they cross breed with the local cattle and the resultant superior progenies produce high milk yield, grow fast and tolerate the adverse climatic conditions in the ASALs.

This breeding system is based on a pyramidal management of the Sahiwal population with the breeders of nucleus herds at the top and participating herds at the lower levels. Currently, it is estimated that about 900,000 Sahiwal genetic resources of varying gene combinations are with over 20,000 pastoral households who derive their main livelihoods from them.

This has resulted from the annual dissemination of 3,000 breeding bulls to lower tier pastoral herds from the Sahiwal nucleus herds. The Sahiwal genetic resources now account for about 85 million litres of milk out of a total national production of 5.2 billion litres per year. At household level, milk production has increased from 3 litres per cow to about 5.8 litres per cow per day.

Poultry and particularly indigenous chicken are a popular enterprise among Kenyan small-scale farmers owing to low starting capital requirements and thus making it an easy farm enterprise to start. In 2016, under the EU funded ASAL-APRP, a long term IC breeding programme was initiated with an aim of developing an improved IC line for meat and egg production for the tropical environment. This initiative involved utilizing chicken genetic resources maintained at KALRO, Naivasha; which was further expanded through introgression of foreign blood lines. In this collaborative effort two intermediate IC breed lines were produced and referred to as KALRO Chicken (KC) with high egg production and enhanced growth rates. The two breed lines which comprised a spotted and a black one had undergone selection as distinct lines as good meat and egg producers.

They mature early and lay at 18 weeks while the cocks weigh two kilogrammes at the same age. The KC was distributed to farmers in form of day and month old chicks and fertile eggs are also sold. The annual distribution of DOC increased rapidly from 8,686 chicks in 2010 to 169,744 in 2015 and peaked in 2018 at 181,680. The sales of MOC also increased from 15,439 in year 2010 to 28,481 in 2016. KALRO has developed an efficient structure to efficiently scale up KC which involves three breeding and production tiers as well as various actors in the chicken value chain.

The pig value chain is ideal for people with limited access to land and offers many opportunities for investors such as feed processors and pig products processors. However, smallholders face many challenges such as expensive feeds, most of which are imported, inadequate specialized government extension services and marketing. It is in this regard that Farmer's Choice Limited embarked on a contract pig farming arrangement with farmers as an innovative way of supplying quality pigs to the factory. The contract involves the acquisition of superior breeding sows from the company's farm or recommended farmers and also supply of highly subsidized pig feed from the company's factory thus ensuring good quality feeds and access. The farmer also receives free technical advice on pig husbandry practices, and does not have to worry about marketing as the company buys the pigs as per the agreement. This has motivated farmers to embrace pig production. Currently Farmer's Choice Limited gets 50% of its supply from contracted farmers and 50% from the nucleus farms.

Among the many benefits to the farmers is timely payment for their pigs. Collectively, the 1,000 contracted farmers dispersed across the country obtain about Ksh. 19.0 million (190,000 USD) monthly. The model if extended to other value chains can minimize losses in the agricultural sector. Local butcheries and eateries have emerged throughout major cities and towns in Kenya in response to the increasing local demand for pork and this has changed the marketing frontier, from the conventional tourist hotels and supermarkets.

In conclusion, it is apparent that the production and consumption of livestock products and especially meat is still low but this situation is, expected to change leading to improved nutrition. There is therefore need for productivity to be enhanced through improved management practices at a lower cost for the sector to grow and be competitive. The various innovations assessed are intended to enhance the efficiency, and improve productivity of the livestock sector. Various secondary technical and social-organizational innovations have emerged aimed at adding value to the original innovations. These have enhanced the nutritional, genetic and marketing efficiencies in the four initiatives assessed. County governments have played key roles in for example the hay Sahiwal and KALRO chicken cases but more needs to be done to enhance the efficiency of these cases. The pig industry even though demonstrating great potential has not however received as much support from the county governments. The pig vertical integration is an interesting model which has kept pig production in the country vibrant but as the demand for pork escalates, the factory may not be able to meet the demand.

The four innovations clusters have generated important innovations that are helping to keep the livestock sector vibrant and also creating employment. They have also helped to avert livestock deaths as has been witnessed in the past. Some county governments have already formulated institutional innovations in form of the Strategic Feed Reserves (SFR) legislation. In all of them, there is a clear illustration of the importance of collective action such as hay growers' association, participatory breeding, multiplication of IC and the pig farmers served by the technical staff of Farmer's Choice Limited. Such collective approaches are useful in utilizing economies of scale that reduce transaction costs of service delivery.
The low usage of ICT tools is of concern and this needs to be increased in order to further reduce the transaction costs and also reduce the intermediation by brokers within the value chains.

In all cases, the role of the national and county governments is not apparent in the area of quality management for the hay products, facilitation of access to necessary ingredients, formulation of necessary regulations and diversification of strategic food and feed reserve regulations.

Arising out of these conclusions, the study recommends the following:

- There is need for development of policy and regulations on straw and stover markets for its sustained use and to avoid conflicts. Studies are also needed on the effect of removing straw and stover from the farm on soil nutrients and organic matter depletion and subsequently on crop production.
- There is need to strengthen collaboration among all fodder value chain actors including national and county governments, private sector especially MFIs, farmers and research institutions to synergize efforts towards curbing national fodder deficits.
- There is need to support fabrication of affordable tools and research on Molasses Urea Mineral Blocks (MUMBs) and TMRs that farmers can use to improve on straw and stover quality.
- There is the need to create an organization to champion, regulate, develop and promote Sahiwal beef industry by tapping into possibilities/opportunities in other ASALs in Kenya and beyond.
- There is need to enhance government (national and county) investments such as livestock insurance schemes, infrastructure such as abattoirs and livestock markets as potential drivers for upscaling of the innovation.
- Support and increase investment on the KALRO Chicken (KC) production and distribution of breeding stock to farmers as the demand is currently much higher than the supply.
- Create a Pig Task-Force which should come up with a functional strategy to improve the pig sub-sector
- Quality standard is needed for the various forage and crop residues feed sources to ensure production of good quality hay and products and to discourage unfair competition in the market. Seed production of the cultivated fodders need to be enhanced in order to expand on hectarage under these forages.

CHAPTER 1

Background Information

1.1 Background to the Study

In Sub-Saharan Africa (SSA), the agricultural sector employs more than half of the total workforce, and is the primary source of livelihood for 10% to 25% of urban households (Yeboah and Jayne, 2015). In addition, it contributes on average,15% of the total GDP (OECD/FAO, 2016) while the livestock sub-sector contributes 40% of the global value of agricultural output and supports the livelihoods and food security of about 1.3 billion people (FAO, 2018).

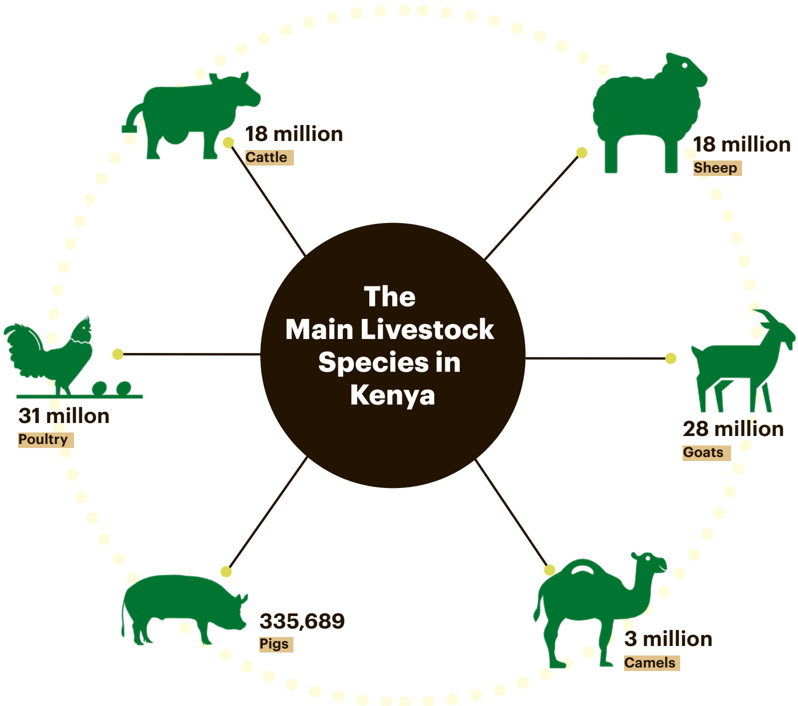
Livestock production intersects a wide range of broad societal issues ranging from environmental to economic and social issues which includes its contribution to Green House Gas (GHG) emission and climate change; food safety; livelihoods; youth employment; its role in nutrient cycling and biomass use; health issues and dependence on international trade (FAO, 2018). These interactions clearly imply a need to take a broader view of innovations and investments in the livestock sub-sector.

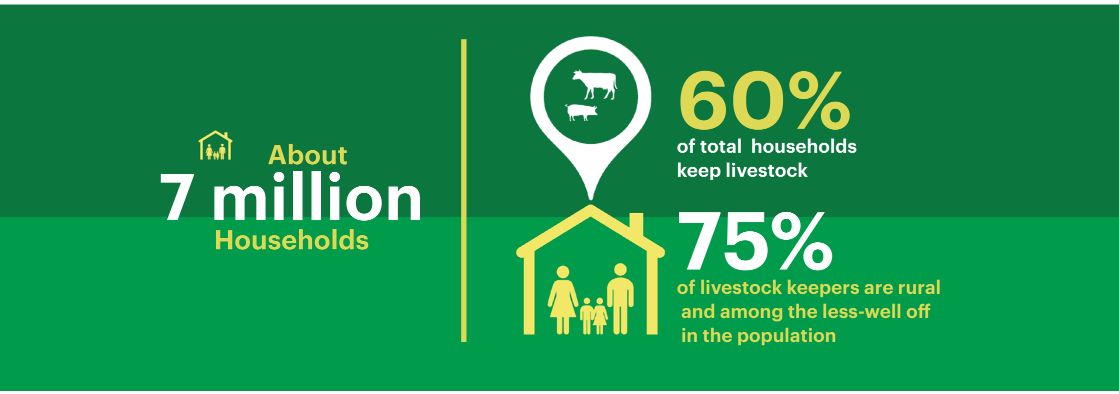
This sub-sector requires a significant amount of natural resources and is responsible for about 14.5% of total anthropogenic GHG emissions (Gerber et al., 2013; Grossi et. al., 2019). These emissions are exacerbated by the increasing demand for livestock products.

On the other hand, the UN estimates that 237 million people in SSA are suffering from chronic under-nutrition, derailing the gains made in the past years (FAO and ECA, 2018). The cause of this worsening situation is difficult global economic conditions and, in many countries, conflict and adverse climate conditions affecting production and productivity of livestock. About 340 million hectares of grazing land are degraded with yield degradation rates of 48% (FAO, 2017a). Kwon et. al. (2014) reported that within SSA, Eastern Africa experienced the most severe grazing biomass degradation with 65% of livestock grazing on degraded grasslands. To adapt and cope with the loss in biomass and rangeland degradation, pastoralists have changed herd structure from cattle to camels, sheep and goats (Ogutu et. al., 2016).

1.2 Importance of Livestock Sub-Sector in Kenya

Although the livestock sub-sector contributes about 12% to Kenya's GDP and 40% of agricultural GDP (FAO, 2017), its importance has often been underestimated (Behnke and David, 2011) probably due to poor data availability.





The sub-sector employs 50% of the agricultural labor force and also supports the livestock industry such as feed manufacturing, veterinary, farm equipment and value addition (processing meat, milk and leather). Over 10 million Kenyans living in the ASALs derive their livelihoods largely from livestock and have about 60% of Kenya's livestock herd which constitutes about 82% of the country livestock enterprise (Agriculture Policy, 2014). The other 40% is found in high rainfall areas under intensive production systems whose main feature is the cattle dairy enterprise, followed by poultry and pig production. In the ASALs, the sub-sector contributes 95% of the family income. Figure 1 shows the trends of livestock population from 1961 to 2017. Pigs and camels had the highest increase which was 9.6 and 9.5 fold, respectively, followed by chicken having increased six fold with cattle having the least increase that was only 2.5 fold.

Figure 1: Livestock population trends from 1961 to 2017

Source: FAO, 2019a

Currently,

1.8 million

urban and peri-urban households keeping livestock (dairy, pigs and poultry) do not adopt adequate

Bio-security

Waste management practices.

The tradeoffs associated with increased livestock production in Kenya includes negative consequences such as biodiversity loss due to overgrazing, surface water eutrophication, groundwater contamination, reduced soil fertility, emerging infectious diseases, antimicrobial resistance, and rural impoverishment. Unregulated growth of livestock in Kenya could thus be catastrophic on the impoverished soils and weak health systems. Highlights of the negative impacts as reported in FAO (2018) includes:

- Currently, 1.8 million urban and peri-urban households keeping livestock (dairy, pigs and poultry) do not adopt adequate bio-security and waste management practices. This number is expected to increase to over 6 million households in 2050, exponentially increasing public health and environmental threats.
- GHG emissions are likely to increase from 32 MtCO2e in 2010 to 39 MtCO2e in 2030, largely driven by livestock methane emissions and land use change (GoK, 2015).
- Currently, the livestock sector is estimated to use 255 million litres of water per year. Extrapolation suggests that nearly 650 million litres of water will be used by livestock systems in 2050 (FAO, 2017c). Bearing in mind that Kenya has a water deficit, serious actions would need to be taken to meet the rising water demand.
- Generation of major negative effects on public health due to zoonotic diseases for example, there were at least 255 000 human cases of brucellosis between 2012 and 2016 (GoK, 2016).
- Despite the negative impacts, Kenya like other countries needs to strategize on how to bridge the gap between supply and the anticipated increased demand

1.3 Challenges in Livestock Production and SWOT Analysis

The livestock industry has a high degree of vertical linkages with upstream and downstream industries. It is a significant user of feeds, drugs, vaccines and equipment from the different manufacturing industries, and a major provider of raw materials for agro-processing industries. Therefore, any shock in the industry will affect the supply chain. For example, in pastoral and agro-pastoral areas, inadequate supply of good quality feed during drought limits the efficiency of livestock production, and affects human health and economic benefits derived from livestock.

In addition, the marketing of some of the industry's products in Kenya (e.g. meat) is informal, fragmented and dominated by middlemen with few organized producer organizations or processors who buy directly from livestock producers. Nairobi and Mombasa cities remain the key terminal markets accounting for 75% of the country's meat consumption. Table 1 presents the SWOT analysis of the livestock sub-sector.

Table 1: SWOT Analysis of Livestock Sub-Sector in Kenya

Strengths	Weaknesses
Large grassland areas for extensive cattle production with experienced livestock keepers at a low cost Diverse agro-ecological zones, breeds and farming systems, thus spreading climate and marketing risks Increasing demand for beef at both national and regional level Supply and demand easily balanced through porous borders	Low livestock productivity in many systems due to: poor husbandry practices; diseases; poor feeds and feeding; inappropriate and uncontrolled breeding Poor financial services Weak extension services Unreliable data and information management Increasing transport costs Poor marketing and slaughtering infrastructure

Threats:	Opportunities:
Climate change	Development of better supplementary feeding programmes for the dry season and during prolonged drought
Limited supply of quality fodder and feed	
Limited capacity to control/ prevent trans-boundary animal diseases	Establishment of strong public–private partnerships for the control/prevention of trans-boundary animal diseases which are exacerbated by the increased movement of livestock
Unregulated large numbers of livestock from neighbouring countries thus lowering prices	The growing middle class has created demand for more price differentiation for different meat qualities thus providing more markets for livestock products
Inter tribe/clan livestock thefts and clashes	Growing consumer demands and preferences is creating niche markets, demanding more slaughterhouses, better transport, water supply, and reduced overhead costs
	Climate change has led to more conservation of feed e.g. through hay making

1.4 PARI Livestock Cluster – Possible Contributor to Solve the Challenge

The PARI Livestock Cluster study starts from the premise that demand for foods of animal origin will be high in Africa. This study seeks to provide guidance to policy makers, private and public investors on promising innovations in the livestock value chains in Africa with a view to transforming the livestock economy, taking into account its multiple trade-offs and co-benefits. An in-depth analysis of success stories in selected countries to encourage wider lesson-learning and knowledge-sharing was therefore undertaken, although a global comprehensive review of livestock innovations was beyond the scope of this study. However, the Kenya study is similar to studies conducted in other countries in Africa.

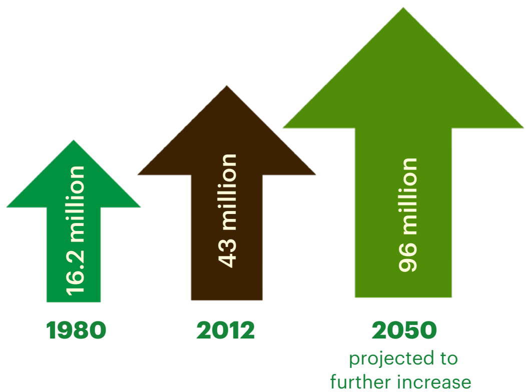
CHAPTER 2

Conceptual Framework

2.1 Demand for Livestock Products

Kenya has an annual supply deficit of livestock products of approximately 300,000 metric tons (Bergevoet and Engelen, 2014). The main factors driving demand are population growth, urbanization, and income rise in developing countries (UN, 2019).

According to FAO 2018
the population of Kenya increased from



GDP Per Capita — WILL INCREASE

FROM **USD 1,200 in 2012**

TO **USD 2,700 in the year 2050**

15.6% of the population was in the urban areas in the year **1980**

24.4% in the year **2012**

46.3% Expected to increase to **2050**

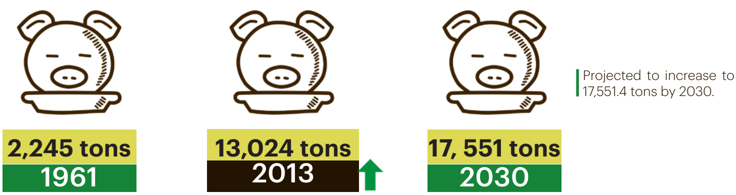
The growing, increasingly affluent and urbanized Kenyan population is expected to consume more high value food products, in particular animal source foods such as meat, milk and eggs. Currently per capita consumption of meat is low, averaging no more than 10 kg for any type of meat per year. The expected increase in consumption will improve nutrition, without any envisaged negative impact on human health due to over consumption (GoK, 2005/6).

Figure 2 shows a general increase in the demand and projected demand for selected livestock products up to the year 2030 in Kenya. The projected demand for milk will increase from 5.9 million tons in 2018 to 7.5 million tons in 2030, while the consumption of red meat (beef, mutton and goat) increased from 104,674 and 30,436 tons in 1961 to 423,035 and 82,411 in 2013 respectively, it is projected to increase to 538,186 and 103,293 tons in 2030.

Fresh water fish and egg consumption steadily increased from 10,032 and 9,282 tons in 1961 to 166,022 and 43,181 tons in 1990, respectively where fresh water fish peaked at 172,236 tons in 2000 and dropped to 115,434 tons in 2005.

The drop was due to declining fish from Lake Victoria due to pollution and water hyacinth infestation. This necessitated the government to introduce the stimulus programme to boost fish production, which increased demand to 182,689 tons in 2013, and is projected to increase to 244,073 tons in 2030. Demand for poultry increased from 7,228 tons in 1961 to 32,222 tons in 1980 and peaked at 40,905 in 1985, but dropped to 17,867 tons by 1990 due to disease outbreak and high feed cost. The demand then increased to 16,818 tons in 2000; 19,819 tons in 2005 and 20,868 in 2013, and is projected to increase to 24,316 by 2030.

Demand for pork has also increased



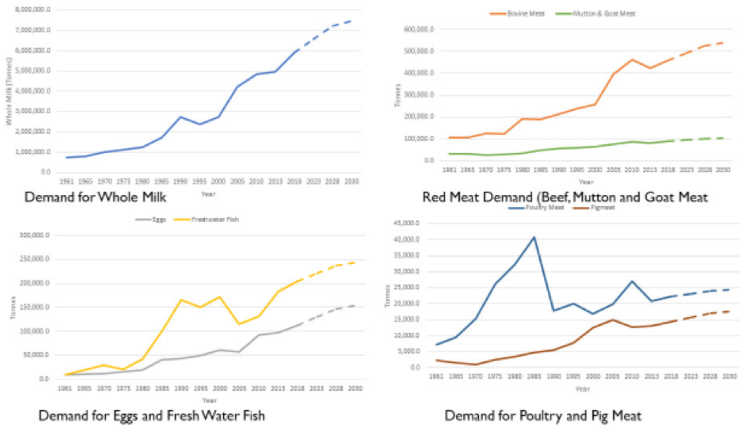


Figure 2: Domestic demand for livestock products

Source: FAO, 2019b

Despite the increased demand, there has been a steady decline in the average per capita agricultural land, cropped land and land under pasture since 1961 (Figure 3). Cropped land per capita declined from 0.408 ha in the 1960s to 0.136 ha in 2011-2017. The reduced land sizes increased competition for livestock fodder/hay production and crop production.

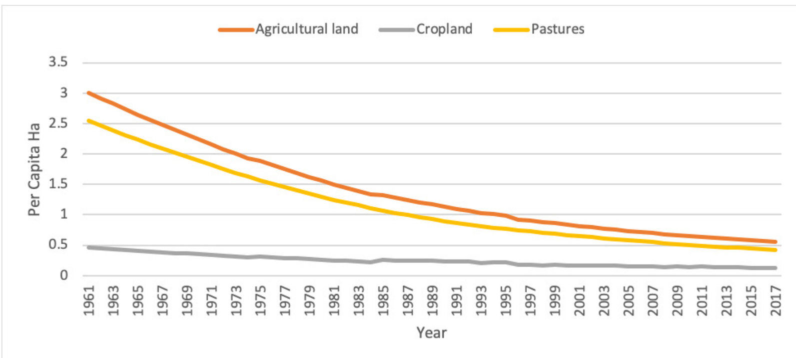


Figure 3: Per capita agricultural land, cropped land and land under pasture

Source: FAO, 2019c

As a response to the growing demand and declining land sizes per capita, productivity-enhancing practices need to be adopted, hence the study on selected innovations in Kenya with a view to upscaling them for increased productivity.

2.2 Induced Innovation in Agriculture

Development of agriculture is a fundamental part of the world economic growth. Being able to meet the demand of an exponentially growing population can be a challenging task, especially if we consider that one of the most important factors, land, remains fixed (Ehrlich and Holdren, 1971). Agricultural production more than tripled between 1960 and 2015, owing in part to productivity-enhancing Green Revolution technologies and a significant expansion in the use of land, water and other natural resources for agricultural purposes (FAO, 2017).

The theory of price-induced innovation has been particularly important in focusing attention of economists on technological innovation (Lichtenberg, 1986). This theory asserts that changes in relative prices of factors are expected to induce development and implementation of new technology to save the relatively more expensive factors (Kako, 1978). The theory first proposed by Hicks in 1932 has been empirically examined during the past four decades.

Using the microeconomic foundations of induced innovation theory proposed by Ahmad (1966), Hayami and Ruttan (1970) conducted the first formal test of the induced innovation hypothesis (IIH) and concluded that the evolution of relative factor demand "represents a process of dynamic factor substitutions accompanying changes in the production function induced by changes in relative factor prices". Since that time it has been tested in a wide variety of countries and industries using various analytical tools and data.

To best explain how Hick's macroeconomic theory works, consider a situation in which the demand for agricultural derived products such as livestock products increase as a result of either population growth or increased income.

The theory states that in such a situation, prices of inputs for which supply is inelastic will rise relative to prices of more elastic inputs. Similarly, if the supply of a particular input (input x) increases at a faster rate than the supply of other inputs, the price of input x will decline relative to the price of the other inputs used (Hayami and Ruttan, 1970). Ideally then, farmers would want to replace/use less of the more inelastic (less responsive) inputs since they are more expensive to use. Therefore, technical innovations that replace such inputs would guarantee less costs and hence more profits. In other words, when demand for their products increases, farmers are lured by changes in relative prices to seek for technological alternatives (innovations) that substitute the increasingly scarce factors of production (Ehrlich and Holdren, 1971).

Under these conditions, researchers or the farming community seek for best solutions to this problem and respond by making the appropriate technical developments such that producers can efficiently substitute the abundant inputs for the increasingly scarce factors. Ultimately, this will lead to a reduction of farmer's unit costs in the best possible way (Hayami, 1971).

In line with the above theory, the four livestock cases considered in this study were triggered by certain changes of circumstances in various production cost factors. Two of the cases (Sahiwal and the KALRO Improved Chicken (KIC) were in response to the inefficient local breeds. The case of hay is in response to feed shortage and high cost of feeds during the dry season, while the pig production and marketing case is in response to lack of information on production and marketing. In all the cases, the farmers were in search of innovations that would address the 'inelastic' production factors with a view to reducing the associated costs and increase their profits.

The introduction of the Sahiwal by the government in the 1960s was in response to the low yielding local cows in the ASALs. The Sahiwal would for the same amount of feeds yield more in terms of milk, grow faster and increase the farmers' social standing. The KIC with their high growth rate and high egg production were introduced in response to the inefficient local chicken whose maturity period was long (26-34 weeks) and egg production was half that of KIC (100-180 eggs in a year). In the case of hay, decreasing land sizes as well as increasing livestock numbers led to a reduction of feed resources during the dry season for the dairy farmers.

This necessitated an innovation which came in the form of growing of grasses such as Rhodes, Lucerne, baling of cereal crop residues and range grasses. The innovation has led to others in the form of policies in some counties where Strategic Feed Reserves (SFR) are maintained to be used during periods of feed scarcity. The pig production and marketing case was in response to the shortage of information on pig management as well as market outlet for the pigs. Farmer's Choice Limited devised a contract farming arrangement where farmers were to adhere to recommended pig management practices which were partially facilitated by the company. In return, the company bought the pigs from farmers with prompt payment.

2.3 The Objectives of the Study

The broad objective of the study was to carry out an overview of the national livestock sector and its recent development, including the evolution of the policy environment and a description of major innovations. The specific objectives were to:

1. Select novel and scalable innovations for the study;
2. Carry out in-depth analysis of major factors contributing to the success of the innovations in the selected platforms;
3. Identify potential for further development and scaling;
4. Draw lessons for other countries potentially wishing to initiate similar platforms.

CHAPTER 3

Methodology

3.1 Rationale for choice of selected case studies

3.1.1 Multi-Country Joint Learning and Planning Workshop

As a first step toward the development of a consensus on successful innovations in the livestock sector, a multi-country joint learning and planning workshop was held on October 7 and 8, 2019 at the KALRO Headquarters Campus, Nairobi, Kenya. The workshop convened jointly by FARA and ZEF representatives brought together scientists from four countries Benin, Ethiopia, Kenya and Mali to share learning around the scaling up of proven innovations to enhance agricultural productivity with a view to improve food security and natural resource management in Africa. Specifically, the meeting aimed at discussing and developing a strategy on how to operationalize the ideas contained in the earlier prepared and circulated Livestock Cluster Concept Note. The deliberation was expected to ultimately prepare policy briefs and documentation necessary for stakeholders, among the donors, policy makers in various governments, private sector and any other interested parties in livestock related work in the four selected countries for planning purposes.

The broad objectives of the joint learning workshop were to:

- Identify mechanisms for ongoing joint learning that facilitate collaboration to address country/regional challenges facing livestock production, and develop a series of next steps for continued joint learning;
- Develop consensus on the use of case study approach to document the scalable innovations from the four countries as well as consensus on methodology (selection of cases, data collection and analysis, write-up) of the proposed case studies;
- Identify proven livestock innovations in the four countries representing tipping points in the sub sector and share these success stories with a view to replicate/upscale them beyond the four countries.

The workshop spanned 2 days and provided participants the opportunity to share and learn from one another and engage in in-depth learning around a handful of specific technical issues surrounding scalable innovations in the livestock sector. The workshop leveraged on a range of learning modalities (e.g. from group presentations and discussions to small working groups, issue-focused country/regional challenges and innovations aimed at mitigation against them) to maximize participant engagement and learning.

The country teams were clustered into two groups based on common challenges and geographical location. Kenya was paired with Ethiopia representing Eastern Africa while Benin was paired with Mali representing West Africa. The Eastern Africa team considered the following broad areas based on the challenges in the region for purposes of identifying relevant innovations:

a) Feeds: Development of hay and crop residue value chain in Kenya and Ethiopia;
b) Genetics: Community based genetic improvement in livestock (Sahiwal, Indigenous Chicken and Small ruminants) in Kenya and Ethiopia;
c) Market integration: Pig (Kenya) and beef (Ethiopia) value chains.

It was agreed that each country team would further fine-tune the issues through broad country consultations and report during a scheduled Skype conference.

3.1.2 Skype conference

The Skype conference was held on 13th November, 2019 starting at 2:00 pm. The conference participants were Patrice Adegbola (INRAB), Alpha Kerga (IER), Lawrence Mose, Wellington Mulinge and Geoffrey Kamau (KALRO), Azage Tegegne and Getachew Legese Feye (ILRI), Oluwole Fatunbi (FARA) and Carlos Sere (ZEF).

The aim of the conference was to develop consensus on selected innovations and methodology as well as eliciting progress and timelines. A deadline for submission of advanced draft country reports was agreed to be 2nd December, 2019. The Kenyan team affirmed that it would now settle on the innovation case studies highlighted in the next section.

3.2 Contextualizing the Case Studies

3.2.1 Feeds: Development of hay and crop residue value chains in Kenya

Feeding constitutes a substantial proportion of the cost components of a livestock production system (Kahi et. al., 2006). This means attention towards ensuring a sufficient supply of feed resources of adequate quality is required (Gueye, 2002). Smallholder farmers in Kenya practice livestock farming under conditions of feed scarcity because of competition for land that restricts access to adequate grazing pastures and fodder production.

The available on-farm feed is estimated at less than 5 Kg dry matter per head per day (Potter, 1988). This quantity cannot support maintenance requirements of a cow producing 10 litres of milk a day. This reflects feed scarcity which worsens during the dry season when the feed available in abundance are the residues of crops, although farmers underutilize this feed resource because they face challenges in improving the nutritive value. Crop residues include all inedible (by humans) phyto-mass of agricultural production: cereal and legume straws; leaves, stalks, and tops of vegetable, sugar, oil, and tuber crops; and the litter and prunings of nut and fruit trees.

There are several approaches to improve the nutritive value of crop residues for dairy cattle feeding including improved handling and processing to increase palatability, voluntary intake, and digestibility to release nutrients to animals (Kashongwe et al., 2017). Addition of yeast culture (Saccharomyces cerevisiae) and treatment of straw with urea are viable for improving the nutritive value of crop residues, but farmers are yet to adopt their utilization (Plata et. al., 1994). The innovations under pasture and crop residues will include the following;

Maize Stover: Shredding, grinding and treatment with Urea and Molasses Urea Mineral Blocks (MUMBs);

- Wheat Straw: Treatment with Urea and Baling;
- Rice Straw: Baling;
- Rhodes/Lucerne Grass: Grinding and Baling;
- Range Grass: Baling.

3.2.2 Genetic Improvement: Community based genetic improvement in livestock for Sahiwal

Generally, the Small East African Zebu (SEAZ) cow is a low milk producer (Nyariki et al., 2009). On average, the number of milked cows per a typical ASAL pastoralist household per day is 12, out of 23 cows that have calves. The average amount of milk produced was 4.3 litres per household per day during the dry season. With 12 cows being milked, this translates to about 0.2 - 0.4 litres per cow per day. However, during the rains, the amount of milk produced per cow more than doubles to approximately 1-2 litres a day. The low productivity of the SEAZ calls for genetic improvement in order to effectively utilize the ASAL. The innovations in the case study will highlight the mechanisms and systems used for rapid multiplication of Sahiwal genetic superiority over SEAZ to improve production and productivity.

3.2.3 Genetic Improvement: Community based genetic improvement in Indigenous Chicken (IC)

Indigenous chickens in Kenya are about 22 million and are kept by 90% of the rural communities in small flocks of up to 30 birds mainly under free range system (Kingori et al., 2010). Demand for IC and their products is ever increasing due to urbanization, increasing human population, decreasing agricultural land, consumer preference and changes in human eating habits. Despite the increasing demand, production output from the IC value chain is still low, hence limiting their contribution to development. The case study under IC describes how its genetic resource was enhanced to ensure increase in production and productivity through the KALRO Improved Chicken.

3.2.4 Market integration in pigs: The case of Farmers' Choice documented

The initial demand for pigs was mainly from the tourism sector and the rich in the society. However, there has been a recent increase in demand for pork by local people. This was due to the changing tastes and health concerns which favored pork over beef. This led to the emergence of unstructured and costly marketing system comprising of small butcheries, eateries and slaughter houses in Kenya's major towns such as Nairobi, Thika, Nyeri, and Nakuru which has increased the market for pork. The case study will demonstrate how a more organized pig production based on contracting and a sophisticated marketing system and strategy can be used to meet the rising demand and supply gap in Kenya.

3.3 Data Collection and Analysis Procedures

3.3.1 Literature review

Specifically, secondary data were collected from various published reports, papers and other relevant documents. The data included production, marketing and consumption trends and patterns as well as issues surrounding the innovations in order to establish gaps that require to be filled.

3.3.2 Consultations and Key Informant Interviews

Consultations with subject matter specialists on each of the selected innovations targeted the following stakeholders: Ministry of Agriculture and Livestock officers, Nairobi; Ministry of Agriculture and Livestock county officers in Nakuru, Kirinyaga, Trans Nzoia, Narok and Nakuru counties; CEO, Farmers' Choice; agricultural mechanization officers in Nakuru, Kirinyaga, Trans Nzoia, Narok and Nakuru counties; livestock scientists and socio-economists in KALRO Centres (Naivasha, Mwea, Njoro and Kitale); Select animal feeds manufacturers; select supermarkets; representative of Kenya National Farmers' Federation (KENAFF) and the representative of Kenya National Bureau of Standards (KeBS).
Due to logistical challenges, a few of the stakeholders were consulted through telephone interviews. They gave insights on the content of the study and also on possible sites where more and detailed data and information could be obtained. Consequently, a template was developed to gather the information from secondary and primary sources. The template was designed to elicit information including: description of the innovation and its context (significant scale wise and not of necessity new); technical and socioeconomic analyses; adoption and impact; inclusivity (women/youth involvement etc.) of the innovation; trade-off analysis; environmental issues (positive and negative); potential for scaling up and Lessons Learnt. Ten (10) stakeholders were requested to provide the information,

3.3.3 Stakeholder/Expert Consultation Workshop Nakuru, Kenya

A one (1) day stakeholders' workshop was held on 28th November, 2019. The purpose of the workshop was to identify gaps in the four identified value chains. The specific objectives were:

- Present highlights of the 4 value chain innovations;
- Validate and discuss gaps in the 4 value chain innovations;
- Participants/stakeholders to share their experiences with regards to challenges, effectiveness, upscaling;
- Provide information and suggest possible other sources of missing information.
- The stakeholders' workshop was very successful and yielded very useful information and appreciation.

3.3.4 Data Analysis and Report Writing

Once the validated information was obtained, it was collated and inspected for completeness. Where possible, missing gaps were filled in the data through further discussion with the information providers, contact with key informants and /or mailed template. The data and information collected were synthesized and presented in form of narratives, tables and charts.

CHAPTER 4

Case Study Results

4.1 Hay and Crop Residue Innovation for Ruminants

4.1.1 Why the Hay and Crop Residue Innovation?

A major challenge that confronts livestock and particularly ruminant farmers in Kenya is lack of access to high quality feeds and information related to feeds and animal health (Technoserve, 2016). The increasing population continues to exert pressure on the already scarce land and especially in the country's 20% high potential areas. This has led to opening up of arid and semi-arid areas for crop and livestock production leading to competition for grazing land and sources of livestock feeds.

Majority of smallholder dairy farmers produce milk under conditions of feed and fodder scarcity with available on-farm feed estimated at less than 5 Kg dry matter per head per day, (Njarui et al. 2016). Feed is an important part of cattle health and has substantial impact on yield while poor access to concentrate feed and fodder, as well as poor feeding regimens mean that most cattle are not reaching their highest productivity potential (Technoserve, 2016).

It has been estimated that **KENYA** has a large **UNMET AND EXPANDING DEMAND** of fodder amounting to **50-90%** annual feed deficit which translates to **53 - 57 million** tons of dry matter,

which is projected to double by 2035. Increasingly, livestock producers are therefore relying on crop residues and hay for feeding their animals particularly in times of feed shortage when massive losses in livestock is experienced (Alila and Atieno, 2006).

The common crop residues whose innovations are considered in this write up are maize stover, wheat and rice straw. Similarly, innovations in hay production considered are based on Rhodes grass, Lucerne and range grasses. Below is an explanation on why the innovations are a necessity, discussed under three sub sections; Crop residues (Maize, Wheat, Rice), Hay from Rhodes grass and Lucerne, and hay from ranges grasses

i) Crop residues

Maize is a crop that is extensively grown in Kenya with an estimated production of 3.4 million tons in 2019, which was a drop from the 4 million tons produced in 2018 (USDA, 2019). It is a staple crop for majority of Kenyans with a per capita consumption of 85kg per year.

Maize stover, the residue that remains after grain is harvested consists of

Stalks	(40 - 60%)
Leaves	(20 -30%)
Husks	(10 - 15%)
Cobs	(15 - 20%)

and is a common livestock feed wherever maize is grown (Lizotte et. al., 2015)

At an estimated grain to stover ratio of 2:1 (FAO, 1978), the stover yield from the 2019 maize production is estimated at **1.7 million tons.**

The stover is used by an estimated 1.8 million small holder farmers in Kenya who produce 4 billion litres of milk per day comprising 80% of the total milk produced in the country. The abundant maize stover harvested from the maize growing zones if properly managed can contribute to considerable positive impact on the overall livestock productivity. In Trans Nzoia, Uasin Gishu, West Pokot and Bungoma Counties, due to the large acreage of maize crop, maize stover is a common livestock feed.

However, maize stover even though considered the best crop residue among cereals, has low levels of nitrogen and carbohydrates, which limit microbial activity and has high levels of fiber or lignin that hinders palatability and digestibility.

It is recommended that the stover is harvested and stored as soon as possible after grain harvest because leaves at harvest tend to be dry and brittle and are easily lost when rains start. They also deteriorate through microbial attack and decomposition. Where the stover gets wet, it is supposed to be sundried prior to storage. In all cases, efforts are required to avoid post-harvest losses (Feedpedia, Methu et al. 2011).

The other crop residues are from wheat, whose production has been estimated at 320,000 tons in 2019/20 and is a source of abundant straw material (USDA, 2019).

Wheat straw, which comprises over half the harvestable vegetation of the crop, consists of dry stems and leaves left after the grain is harvested.
They are coarse and highly fibrous and play an important role as an additional option for feeding livestock (Kashongwe et al. 2014). At small-scale and subsistence farming, importance of straw has been magnified by the decreasing access to free grazing and for their utilization as livestock fodder and livestock bedding.

Rice straw is also an important livestock feed. Rice is the third most important cereal crop in Kenya after maize and wheat (Emongor et al.., 2009, Republic of Kenya, 2013). Annual rice consumption is approximated at 550,000 metric tons against an annual production of 150,000 metric tons from 25,000 hectares (Kenya Bureau of Statistics, 2016; Ministry of Agriculture, 2008). Rice consumption is projected to rise with increasing population and changes in eating habits (Atera et al., 2011). An important by product of the rice value chain is the rice straw which is obtained after harvesting the rice and removing the grain and is the only organic material that is available in significant quantities for the rice farmer (Dobermann and Fairhurst, 2002). Initially the farmers used to burn or leave the rice straw on the farms and livestock could graze freely in the fields after harvesting. However, with the growing need for livestock feed, it became a source of feed, and hence the need for innovation on how to utilize it better.

Despite the shortage of livestock feed and therefore high demand for crop (maize. wheat, rice) residues, their potential as livestock feed in Kenya has not been fully exploited as earlier stated. In some cases, the maize stover is usually fed as whole stalk and leaves without chopping or grinding resulting in high wastage and very low intake. Similarly, in some cases, livestock are grazed directly on wheat and rice straw on farms, which is not efficient. This inefficient utilization of these crop residues led to the need for innovations that are more efficient and less wasteful.

Besides utilization of crop residues in feeding animals, some farmers incorporate them in the field for maintenance of soil organic matter, soil moisture, erosion control and ensuring the long-term productivity of the soil. Whereas feeding the crop residues to animals may appear to take nutrients away from the field, the manure from the animals when applied to the same fields leads to efficient nutrient recycling (Lusweti et al., 2013). The crop residues are also used as fuel and for fencing. It is usually the farmer's prerogative to determine the best use of these residues that will give him/her the most economic returns (Rangoma, 2018).

ii). Hay (Rhodes Grass, Lucerne)

Similar to the crop residues, development of pasture and fodder crops production and conservation systems help smooth out feed and energy requirements of livestock throughout the year. Provision of advice to farmers on feed rations and balancing has great potential to increase farm productivity, reduce livestock mortality in the dry season and increase farm incomes.

This huge potential on feed conservation has attracted a growing number of farmers to invest in commercial hay production while others have invested in provision of mechanized services on contract basis to other farmers (BLGG, 2013). However, despite these developments, the hay business in the country remains unstructured and uncoordinated. This is despite the fact that areas such as the Rift Valley region have favorable volcanic soils with pH ranging from 6 - 7, which are ideal for Lucerne and Rhodes grass production which in turn suitable for hay making. The altitude which is more than 1800 m above sea level is an added advantage as well as proximity to the local and regional markets, and adequate land for commercial production. The common varieties of Rhodes grass include Boma Rhodes, Elmba Rhodes and Ex Tosi whereas Lucerne varieties include Hairy Peruvian, Cuf-101, Hunters River, Aurora hibred from Australia, SA Standard, WL625HQ, KK59595 and WL414. These varieties of Lucerne grow in an altitude range of 1800-2200 m a.s.l., and require a minimum annual precipitation of 800 mm (SNV, 2013)

Full exploitation of the existing hay market is limited by lack of quality/certified seeds, limited knowledge of good forage agronomic practices and lack of machinery and storage facilities. In addition, there has been a failure by businesses to recognize the market opportunity for innovations that would address the needs of small-scale dairy farmers (Technoserve, 2016). Financial institutions have also not been willing to provide credit to hay producers to finance required investments on machinery and storage (Van Dijk, et al. 2018; Nangole, et al. 2011). Competition with food crops is also an issue that hinders widespread hay production. Conversely, larger commercial farmers have been growing hay for their own consumption with occasional limited sales of excess hay to cooperatives and small holder farmers (Technoserve, 2016). From the above background, Technoserve's Kenya Market Assistance Programme started a pilot initiative in 2012 with two companies on commercial hay production and marketing and since then various advances have been and still continue being made towards developing hay production and marketing.

iii. Range Grasses Hay Value Chain

Farmers initially migrated from higher potential zones where crop farming was viable to agro-ecological zone V, which is described as semi-arid area mainly suitable for pastoralism and wildlife. However, on arrival they continued with their crop farming although the zone was unsuitable for such enterprises. This has led to frequent crop failures due to inadequate rainfall which on average is about 500mm per annum. This is exacerbated by frequent droughts and prolonged dry seasons due to climate change (Nzau, 2003; Herrero et al., 2010). This notwithstanding, farmers have continued with crop farming because of small land sizes per household (Njoka et. al., 2016). They also rear livestock using extensive production systems where animals are continuously grazed on natural pasture in the field and then confined in an enclosure for the night (Kidake et. al., 2016; Mnene et. al., 2004). This has led to the collapse of traditional land management practices due to changing land use dynamics, climate change and socio-economic factors (Kassahun et al. 2008).

In response to the above development, the Range Grass Seed System innovation was conceived by KALRO, Kiboko and was actualized through projects with financial support from the EU and GOK. The project selected a variety of range grasses with desirable characteristics and upon successful testing, seeds were produced and distributed to farmers for livestock feeding instead of depending on grazing their animals on natural pasture in the field (Kidake et. al., 2016). The farmers adopted the community based seeds system approach for Common Interest Groups (CIGs) for range pasture seed technologies. The Range Grass Seed System and expanded hay production in the ASAL is shown in Figure 4.

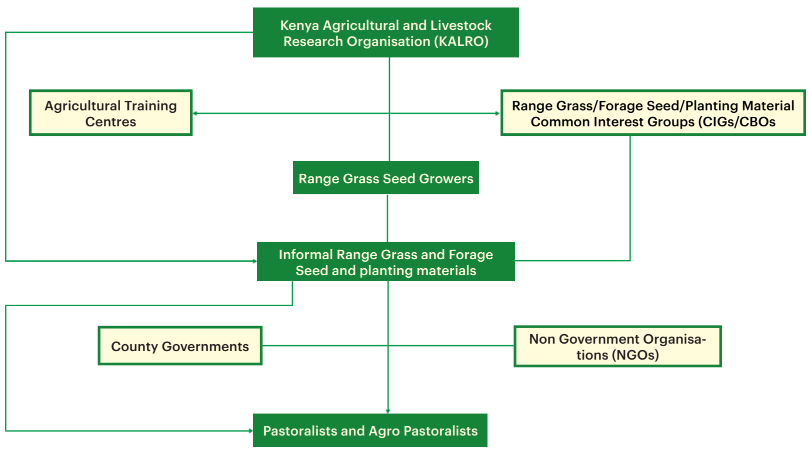


Figure 4: Range grass seed system as conceptualized by the study team

Farmers started pasture production on a small scale but due to increasing scale of production and availability of machinery, mechanized pasture production is increasing where tractors and ox plough are used for seedbed preparation.

4.1.2 Brief description of the innovation

This section provides highlights on hay and crop residue innovations. Specifically, the highlights focus on innovations in crop residues (maize stover, wheat and rice straw) and hay from Lucerne, Rhodes grass and range grasses.

i) Use of maize stover in situ or through cut and carry systems have been used by mixed farmers for many years. However, with increasing demand for livestock products and declining prices for cereals especially in North Rift Region (the grain basket) of Kenya, shredding of stover and cobs for use by livestock during the dry season (December-March) has become a common practice among livestock farmers. The shredding of stover and other crop residue is undertaken by motorized equipment connected to tractor PTO or motor cycle for use in production of total mixed rations (TMR). The shredders conveniently move from one farm to another and are thus revolutionizing maize stover business. The ground feeds are easy to store and are also easily consumed by the animals. Huge amounts of maize stover can now be shredded and stored using the motorized equipment. The activity costs about one US Dollar per 90kg bag.

However, due to low palatability and low nutrient levels of the stover, secondary innovations have arisen. These includes: stover treatment with urea fertilizer which improves the nitrogen status of the maize stover leading to high productivity of cattle during the dry season (Syomiti et. al., 2011; Sarwar et. al., 2006); fortification of maize stover to enhance nutrition by adding nutrients to milled/chopped stover and making blocks by adding a binder (Syomiti et. al., 2011). This product is called Molasses Urea Mineral Blocks (MUMBs) and when a de-wormer is further added, they are called Medicated Molasses Mineral Blocks (MMMBs) (Syomiti et. al., 2011). Molasses-urea blocks have been found ideal in the improvement of ruminant feeding. They improve the rumen ecosystem thus favoring the growth of young animals and milk production and may also affect conception rates and size of new born animals. The blocks are easily packaged making them easy to transport and use by smallholder farmers. Use of blocks is a relatively cheap and safe way of supplying urea, sulphur, trace minerals and macro elements for rumen microbes and amino acids, B-Vitamins and other growth factors.

ii) A major challenge of feeding livestock with wheat straw is the high indigestible fibre due to increased lignification of cellulose and deficiency in fermentable energy and protein which impairs intake and rumen functions thus reducing productivity (Kashongwe et al., 2014; Jabbar et. al. 2009). Mitigation of this led to the introduction of a new innovation through wheat straw treatment with fertilizer grade urea and yeast culture. The innovation involves soaking of wheat straw in a solution of urea and yeast culture thus improving the quality of the straw and making it available for use by livestock. Its use by livestock producers has been on the increase and its widespread adoption has led to increased productivity of the livestock during the dry spells as well as for maintenance.

iii) From the establishment of the Mwea Irrigation Scheme up to 2012, the rice crop used to be hand harvested and the straw gleaned and afterwards burnt or left in the field. Animals would graze freely on the straw lying in the field while individual farmers could sell the straw along the highways. However, with the introduction of combine harvesting, huge amounts of straw are now generated during harvest. Lately, the occurrence of an acute drought in the arid and semi-arid counties of Marsabit, Moyale, Garissa, Isiolo and Kajiado increased the demand for the feed. Some farmers started baling the straw, using tractor operated balers sourced from wheat growing areas. Youth and women groups were formed for the purpose of baling and marketing and this collective action led to increased supply and demand for the baled rice straw.

A secondary innovation is baling by the roadside also doubling as points for marketing the hay. Rice is harvested in June/July and November/December thus leaving the other eight months with nothing to bale. Instead of keeping the baling machines idle, youths started making hay from the grasses which grow alongside the canals in the irrigation scheme. Laborers cut grass and sold it at Ksh 50 (0.5 USD) per bag which is then dried and baled. This grass straw normally fetches 20% higher prices than the rice straw bale since it is softer. In this hay case, the actors are mainly male and female youth who in the case of rice straw, collect the rice straw after grain is threshed which they deliver to the aggregation centers using donkey carts. The straw is dried to a suitable moisture content which they assess based on experience, and then arranged in rows ready for baling. Once it is baled, it is displayed for the customers. The innovation has employed many youth and the livestock keepers are assured of year round hay availability. The hay makers encounter a number of challenges in the course of baling and marketing the hay. These includes the lack of quality standards like what is the best moisture content or how long after cutting should the hay be baled. There is also a problem of selling the hay through brokers who offer relatively low prices and sell to end users at a higher price.

iv) Rhodes hay production was a preserve of some individual large scale dairy or beef farms until 2012 when Technoserve identified two partners to pilot hay production as a commercially viable venture. The two early adopters were two dairy cooperatives which partnered to form a company (HN'F Ltd) in Nyandarua and a commercial farm (Sochon Ltd) in Nakuru. Beyond identifying the market opportunity, Technoserve provided technical advisory support and facilitated market linkages. Technoserve also provided an enabling environment for hay production through an arrangement with several support service providers to develop tailored attractive products for companies venturing into commercial hay production. The products were tailored to be commercially viable for subsequent hay producers (Technoserve, 2016).

Following the pilot phase, Technoserve shifted its role from working with the early adopters to showcasing the success of the pilot to the industry to attract other players into commercial hay production. An official launch event was organized in 2015 which was attended by other potential hay farmers, support service companies, the government etc.

Through working with partners and showcasing the success of the early adopters led to increased hectarage for hay production, commercial banks have also become involved by providing credit to hay growers. Rift Valley Hay Growers Association was then formed with an initial membership of 406 members. The association lobbies the government through the Ministry of Agriculture for concessions on inputs, including fertilizer. It is also working with laboratories to standardize hay production in addition to coordinating efforts to market and distribute the hay. The association is also promoting land leasing, establishment of storage facilities, farmer training, contract farming and establishment of hay growers' platform with a targeted number of 60,000 hay farmers.

In the meantime, Technoserve continues to provide support to the growth of the commercial hay market through working with news outlets and radio programmes to spread the word on hay production. The company also continues to provide linkages between hay-sector companies and prospective clients. As commercial hay production continues, several other innovations are emerging such as introduction of small scale machinery for cutting and packaging hay, milling/grinding of hay to constitute Total Mixed Rations (TMRs) in which the grinding breaks the bulky materials which allows ease of transportation and storage.

v) Over the years, frequent droughts, increased human population and livestock pressure necessitated the need for livestock feeds in the southern rangelands. In order to restore the declining vegetation-cover in the rangelands, KALRO, Kiboko started domesticating adaptable grass species. Seeds were multiplied and availed to farmers for planting in their fields. Fields with water conservation structures such as zai pits were used to plant the grasses in order to enhance their establishment and survival. The production of grass for livestock instead of the common practice of transhumance has resulted in the emergence of secondary innovations such as collective action for mechanical baling and selling of hay in addition to grass seed. The major players in the innovation structure are machine operators i.e. tractor owners, drivers, equipment owners, producers (farmers), traders (businessmen, middlemen), extension officers, consumers (farmers-beef and dairy producers) and researchers.

4.1.3 Benefits of the innovations

i) Crop residues

Impacts of the use of stover/straw and their derivatives as livestock feed is mixed. About 95% of the households in maize growing counties (about 53,000 households in Trans Nzoia County alone) use dry maize stover as feed, where about 10% of whom use the innovation of shredding and fortifying the stover. Use of maize stover alone during the dry season enables the dairy animals to produce at least two litres of milk per day (Methu, 1998).

> **Farmers also sell standing stover at a cost of KES 2,500 - 5,000 per hectare *(250 – 500 USD per ha).***

The innovation offers employment opportunities to youth who chop and grind maize stover. For example, in Trans Nzoia County two youths are employed in each of the 25 Wards. Besides the farmers, some traders buy and shred maize stover into small pieces and transport to ASAL counties where feed shortage is a major problem.

The innovation of combining molasses and urea to wheat straw softens it, making it easy for livestock to chew and digest, thus increasing livestock productivity. According to BLGG Research (2013), increasing fodder supply and improvements in feed ration balancing are important measures to increase on-farm productivity and enhance milk production in the dry season, and hence farmers' income. A study carried out in Holleta, Ethiopia by Mesfin and Ktaw (2010) found that cows fed on urea-treated wheat straw consumed higher concentrate (4.22 kg) than those fed on untreated wheat straw based diets (4.03 kg). In addition, cows fed on urea-treated wheat straw had a milk yield of 9 litres/cow/day compared to the ones fed on untreated wheat straw with 8 litres/cow/day. Oosting (1993) also found that wheat straw treated with urea increased feed intake and digestion in sheep and cattle. From the PARI Livestock Cluster Case Studies reports of 2019, the gross margins for producing wheat straw was KES 7,692.5 per acre (Ksh 3496.6/ha or 35 USD per ha). The average price of a bale of wheat straw is Ksh 80 or 0.8 USD and on average there are 200 bales per acre (500 bales per ha). The innovations on crop residues also has the benefit of reducing GHG emission intensity of dairy production.

From one hectare of rice, 480 bales of hay are made. About 5 million bales of hay are produced from about 26,000 acres (10,400 ha) under rice in the Mwea scheme. The hay making business takes place from November – January from the main crop and February-April from the ratoon crop. It costs Ksh 3.50 to sun dry one bale-equivalent of grass and another Ksh 25 for the baling. The hay buyers come from drought-prone and/or high rainfall counties where dairy or beef production are major economic activities. These counties include: Kirinyaga, Marsabit, Isiolo, Meru, Embu and in the recent past Kiambu, Muran'ga and Kajiado. The buyers mainly transport the hay using lorries and pickups. Depending on season, the price of each bale of rice straw ranges from Ksh. 100 to Ksh. 300 (1 – 3 USD). On the average, the price of grass hay is 20% higher than that of hay from rice straw. The mode of payment is mainly cash or through mobile money payment (M-Pesa).

Hay making from rice is considered a profitable venture because even in low demand periods, a trader in rice straw hay obtains revenue about doubled the business investment cost. There are about 100 traders (youth, men and women) involved in the hay business. Men are mainly involved in transportation activities, removing the straw from the farms to the drying/baling points; and the women dry the straw or grass and sell the hay; while the youth are involved in both transportation and drying. The men are also the main actors in the baling process whereby they use the tractor driven machines. Once the straw is baled, it is transported to the market using small trucks and pickups. However, people involved in the business face certain challenges from some farmers especially the relatively large scale farmers. For example, a farmer who has harvested 5 acres (2 ha) of rice can choose to dry the straw, bale and sell at a lower price than the major players in the business.

Other benefits of crop residues, particularly wheat straw and possibly, rice straw includes their use as a substrate for growing mushrooms and also for making fuel briquettes (Wamukonya and Jenkins, 1995; Wenjie Yang et al., 2013). The straw is also used for building houses (Standard Digital, 2013). Direct removal of rice straw avoids labor intensive incorporation of large amounts of straw and buildup of diseases and pests. Straw has slow decomposition rate and burning it causes atmospheric pollution and results in nutrient loss.

Various other actors in the crop residue innovation includes transporters of stover/straw and the shredded product; those involved in drying; the transporters; the Jua kali artisans involved in the repair and modification of stover/straw chopping machines; and the hay stockists. The increased number of available baling machines and traders/selling points by the roadside are a pointer to wide adoption of the rice straw innovation. The straw business has impacted positively on the income of the players, translating to improvement in their standards of living.
In addition, this is a gender inclusive innovation where youth benefit by earning income from chopping of the crop residues and from transportation; the jua kali artisans benefit from selling and repairing crop residues chopping equipment/machinery and women benefit from crop processing, particularly dehusking of maize.

ii) Rhodes Grass and Lucerne

Rhodes grass readily establishes, needs little water and matures early - in less than 4 months (Heuzé, 2016). The grass has high productivity per hectare and imparts several other benefits on the soil. There is good income in hay farming as reported by a farmer who sells a bale of hay at 2 USD and harvests 50,000 bales of hay every year. It costs about KES 60 (0.6 USD) to produce a bale of Boma Rhodes grass hay" (Smart Farm 2018.). This means that the farmer gets KES 7 million (70,000 USD) per year. Rhodes grass has also increased employment for various players in the value chain. In the Rift Valley, the youth have formed a Rift Valley Hay Growers Association whose members offer farmer training, storage facilities and a platform for hay growers (Van Dijk et al., 2018). In Bomet County, women in Kaparuso village participate in commercial hay production through Shirikisho Community Development Group. The group has 34 members who are part of the 7,000 smallholder dairy farmers who harvest 180-200 bales of hay/acre (450 to 500 bales per ha) and sell at KES 300 (3 USD) per bale (Joyce Mutua, personal communication).
Lucerne (Medicago sativa) is a forage legume that contains high quality and digestible protein that is beneficial to dairy cows. It increases milk and enhances reproduction in dairy cows (Bolt, 2018). It has higher proportion of ruminal undegradable protein (RUP)/bypass protein (25% - 35%) than grass hays and has a higher concentration of phosphorus, calcium, potassium, sulfur, magnesium, iron, selenium and zinc than grass hay. It contains metabolizable energy (ME) ranging from 8 to 11MJ/kg DM (Rangoma, 2018). Dairy farmers can therefore minimize the costs of protein feeding by using farm grown sources of protein such as Lucerne.

iii) Range grasses

At KALRO,Kiboko, hay is not sold but is used to complement the scarce pasture for KALRO livestock during drought periods. However, grass seed which is produced alongside the hay is sold to farmers and institutions like county governments and non-governmental organizations. Information on seed availability and pricing is obtained through promotions during field days and agricultural shows. Payments for seed is made electronically through M-PESA/Pay Bill or by cheque.

Figure 5 shows impact of pasture production on livelihood change where a farmer who lived in a traditional hut has been able to build a stone house using proceeds from hay and seed sales. The farmer was trained on pasture production by KALRO, Kiboko.

Former pasture seed farmer's home *Current home*

Figure 5: Livelihood change of a farmer who adopted range grass seed and hay production

Two cases below demonstrate the impacts of the innovation on farmer groups.

Case 1: Kavatini Pasture and Livestock Improvement Group (KAPALIG)

The Kavatini Pasture and Livestock Improvement Group (KAPALIG) located in Kibwezi, West Sub-County of Makueni County is a community based organization which is involved in pasture and livestock improvement. The group was formed to respond to challenges of feed shortage and feed quality. Due to increased demand for the range grasses the group started seed production and produced 8,465 kg of pasture seed, which they sold to various individual and groups at an average price of KES 800 (8 USD) and earned KES 6,664,000 (66,640 USD).

At 2.5kg per acre, the 8,465 kg of seeds were used to establish 3,386 acres (1,354.4 hectares) of pasture. At an average dry matter yield of 2,500 kg/ha, the 8,465 kg of seed produced about 3,386,000 kg of dry matter equivalent to about 225,733 bales of 15 kg each. At an average price of KES 200 (2 USD) per bale the grass is worth approximately KES. 45.1 million (451,000 USD). Given that the cost of producing one acre of hay is KES 5,159 (51.6 USD), the cost of producing 3,386 acres is KES 17,437,900 (174,379 USD). The net returns from the investment is thus KES 27,662,100 (276,621 USD), showing that production of hay is a viable investment.

Box 1: Story by chairperson of KAPALIG on benefits arising from growing range grass

Summing the benefits of the innovation, the chairman of the group said

"Due to frequent droughts, we stopped planting crops and instead increased the acreage under pasture. Consequently, between 2001-2009, the colour of our land changed from brown to green through increased pastures. The cost of one acre of land has since increased from KES. 40,000 (400 USD) to KES. 100,000 (1000 USD). Milk production has increased 100% e.g. goats producing ½ litre of milk now produce 1 litre; local cows producing 2 litres of milk increased to 4 litres, exotic cows increased milk production from 10 to 20 litres a day. There was also a change in body live weight of livestock; from 10 to 20 kg for goats; from 200 kg to 400 kg for cows and bulls from 250 kg to 500 kg. Due to increased body size, livestock market prices went up by 50%. Despite the successes, we are still not able to satisfy the demand for pasture (hay) and pasture seeds

Other farmers from the area started coming to buy hay for their animals and seeds for planting.

Group members now rely on sales from pastures and pasture seed to buy food, pay bills and meet other domestic needs. Bees find plenty of forage thus we keep them for honey. Now, pasture acreage ranges from 15 to 85 acres (6 – 34 ha) per farmer in the region. One acre produces about 200 bales of fodder weighing 16 - 17 kg and 150-200 kg of seeds. The main market for fodder and seeds is other farmers, groups and NGOs. The group cannot meet the high market demand for pasture and pasture seeds, estimated at 5 tons per year. People are always asking for seeds and we never have enough".

Case 2: Sultan Estate

Hay and grass seed production farm in Sultan Estate measures approximately 100 acres (40 ha). In 2017 the farm produced 12,703 bales of hay and 1,500kg of seed out of which 1,300kg were sold. The unsold 200kg was used for reseeding the farm. With a selling price of KES 1,000 per kg (10 USD), the farm generated KES 1,500,000 (15,000 USD) from seed alone. Most of hay and seed produced by Sultan Estate were bought by farmers from Kajiado, Makueni, Machakos, Nairobi, Kitui, Kiambu, Nyandarua and Narok Counties, some of these locations are more than 300km away, which implied growing demand, and hence the need for scaling up the innovation.

4.1.4 Other benefits from hay *(from Rhodes grass, Lucerne, Range grasses)*

The perennial nature of forages grown for hay making reduces the frequency of soil disturbance by heavy machinery (tractors, ploughs and harrows). Furthermore, use of Lucerne as a legume for hay reduces the use of nitrogenous fertilizer and hence considered as a climate smart practice in terms of nitrous oxide emission. Other actors benefitting from the hay making processes includes machinery (tractors, mowers, balers, trailers) operators, manual grass cutters, and those who dry and bale grasses. All these actors directly earn their livelihoods from this innovation. Community members benefit from hiring out farm equipment like plough and harrow. Traders get involved in hay and also seed marketing because they buy from the producers and then transport to sell elsewhere. Transporters are also involved since they are hired by buyers to transport the hay as well as seed to various destinations.

This is a gender inclusive innovation where men operate the tractors and the production/baling equipment. They are also involved in bush clearing while preparing land for pasture production. Women are mainly involved in harvesting and processing grass seed and the youth harvest and process the grass seeds. Women and youth earn income when employed to harvest and process seed and income earned is used to buy food for the family.

4.1.5 Negative impacts from hay (Rhodes, Lucerne, Range grass)

Some of the farmers involved in commercial hay production do not have access to information about Good Agricultural Practices (GAP), to enhance pasture and fodder production (Kidane et al., 2016). As such, they practice continuous pasture cultivation on the same farm without adding fertilizer/manure which mines soil nutrients and eventually render the land unproductive and vulnerable to erosion. This is especially so in the ASALs where farmers rarely use fertilizer/manure.

4.1.6 Hay: a potential solution to livestock losses due to drought

Kenya has in the past recorded deficits of food due to drought resulting from shortfall in rainfall in various periods starting from 1928 to 2009. About 28 ASAL districts in Kenya, Laikipia District included, have been placed under Emergency Operation Programme (EMOP) due to the heightening food insecurity caused by droughts (Huho et al., 2010). Table 2 provides the spread and effects of some drought incidences in Kenya.

Table 2: Recent Drought Incidences in Kenya

YEAR	Region	Effects
1974-76	Most parts of Kenya	About 80% Maasai cattle lost
1980	Eastern, Central, Western Coast Provinces	Crop production paralyzed and water shortages in towns
1981	Eastern Province	Crop failure causing famine in the province
1983	Country wide	Migration of people and livestock in search of food and water shortages
1984-85	Central, Rift valley, Eastern and Northeastern Prov-inces	Large food deficits leading to consumption of yellow maize and large food queues in the supermarkets
1987	Eastern and Central Provinces	Severe food shortages in Eastern Province, less in Central Province
1991-92	Northeastern, Eastern, Rift valley and Central Provinces	Large food deficits causing relief food imports
1999-2000	Countrywide	4.7 million people became dependent on relief food Water shortages
2004-06	Most parts of Kenya	Acute food shortages in pastoral and agro-pastoral areas, 4.4 million people affected. Most parts of Kenya 2.6 million people were at risk of starvation. Up to 70% loss of livestock in some pastoral communities
2008-2009	Most parts of Kenya	Acute food and water shortages in pastoral and agro-pastoral areas. About 3.8 million people urgently required food aid and about 6.2 million were at risk of starvation; Loss of wildlife animals - 40 elephants died

Source: UNEP, 2000, Ngaira, 2004; KRCS, 2005; OCHA,2009

Climate change is already affecting Kenya, causing pastoralists to migrate into new areas. Violent outbreaks have been triggered as a result of diminishing natural resources in extreme dry months and prolonged rains at other times, causing havoc across the country.

Livestock accounted for over 70 per cent of the total USD 12 billion damages caused as a result of drought experienced between 2008-2011. Further, these estimates are likely to be an underestimation of the full costs of drought. As stated previously, the 2008-2011 drought cost Kenya an estimated USD 12.1 billion in damages and losses combined which slowed GDP by an average of 2.8 per cent per annum (NDMA, 2012).

4.1.7 Potential for scalability and sustainability

The demand for livestock feed is growing partly because of factors such as climate change, increased human population leading to declining per unit farm size and increased livestock population. For instance, the long and unpredictable droughts in livestock rearing counties and in the Arid and Semi-Arid Lands have resulted in scarcity of natural pasture prompting livestock keepers to look for alternative feeds for their livestock, thus increasing demand for hay. Consequently, the situation has partially led to the innovative ways of baling crop residue, mainly from maize stover, wheat and rice straw. Considering that the ASAL counties currently produce about 20 million bales/year against over 35 million bales required to cover a 4-month annual feed deficit in ASALs of Kenya, the unexploited potential for hay production in ASALs remain enormous. This is indicative of a big potential for scaling of hay production.

Equally, demand for seed for reseeding the rangelands has fueled the increased production of hay, a complementary enterprise to grass seed cultivation in the southern rangelands of Kenya. Figure 6 shows seeds for pasture being sold and distributed.

Figure 6: Pasture seed from Kiboko loaded to a van destined for Samburu County for reseeding

In high rainfall areas where land sizes have declined over time, the amount of pasture grown per unit of land has also declined. Zero grazing has taken centre stage necessitating farmers to buy feed for livestock. Given the declining gross margins from production of major cereals in these areas, pasture production (Lucerne and Rhodes grass) and hay making have become an alternative profitable enterprise.

Furthermore, the conversion of potentially less valuable but abundant crop residue into a feed resource; an input into beef and dairy production has generated business interest among farmers and innovative actors along the hay value chain. The availability of sufficient quantities of the straw and grass also acts as a potential driver for scaling up the innovation. Besides, options for mechanization through availability of tractors and small-scale equipment/machines attached to and powered by motor-bikes for baling, shredding and grinding of residue has made it easy to preserve crop residues and transport same over long distances for use in demand sites and when it is most desired.

Collective action among actors in the various crop residue and hay innovations has increased awareness of the need to supply and also demand for hay. An example is the formation of the 1,000-member strong Rift Valley Hay Association which operates at both local and regional level across seven counties and keeps expanding its operations (van Dijk et al., 2018).

Creation of awareness on the use of ICT (mobile telephone communication, emails, WhatsApp etc.) to promote the innovation is a potential driver for scaling up the innovation. This has been achieved in the case of upscaling of MUMBS, MMMBS, and providing information on markets for the shredded stover. In addition, the potential for sustainability exists if regulatory mechanisms are put in place and innovations that minimize nutrient mining during production of wheat straw as hay are adopted. Some counties have held discussions on legislation to establish Strategic Feed Reserves (SFR). Lastly the potential for sustainability exists if farmers' awareness level is increased for the need to produce enriched wheat straw and maintain good quality.

4.1.8 Lessons Learnt

• An innovation with a high demand will trigger secondary innovations to address the changing innovation dynamics.

Hay production innovations are an example of adaptation to negative climate change effects manifested in prolonged drought and reduced natural pasture production. This triggered various secondary innovations in hay production to respond to the high demand for adequate and high quality livestock feed. Examples includes the high demand for rice straw hay which has led to a secondary innovation in the form of rice field boundary grass hay; low value maize and wheat straw residues which have given rise to urea treatment and molasses urea blocks in addition to stay green maize varieties. In the rangelands, the quest for grass for baling has given rise to a thriving seed sale business.

• An innovation may start in a simple and spontaneous manner but its positive impacts may end up spreading far and wide.

Making hay from rice straw started in a simple way where rice growers were initially not interested in the straw until the livestock keepers expressed need for it to keep their animals alive. Rhodes grass and the range grass started in a similar manner with demand being low but increased demand led to creation of employment for all genders not only in the hay production areas but beyond in the livestock production areas where hay sheds are all over. Hay has developed backward linkages far from its original counties where livestock keepers buying rice straw can sell livestock products to other counties. Production of hay has become part of the livestock value chain in counties far from where it is produced, thereby creating backward linkages in the value chain, which may initiate economic growth in different places.

• Innovation in one sector can trigger innovation in a different sector

Use of crop residues started with farmers letting their animals graze on the standing crop residues. Reduction in land size coupled with occasional droughts led to harvesting and even selling of the previously ignored resources. Drudgery in chopping, shredding and milling of cobs triggered the jua kali (informal artisans) to fabricate small scale machinery to mechanize activities that were carried out manually at the initial stage.

This has now created employment for the artisans who make machinery for harvesting, chopping and baling for both cultivated forages and crop residues' hay.

• Lack of developments of quality standards and their enforcement may compromise the expected output from an innovation
Hay production is being done without adherence to any set standards and hence risking production of sub-standard products and unfair competition in the market. In this case, unethical practices like selling hay that is not adequately dried can pave way for contamination and hence risking the output from the animals. Farmers are also likely to lose money from underweight hay bales whose price will be based on the standard bale weights. Unfair transactions could result from cases of hay from rice being sold at the same price as cultivated grass hay which have higher costs of production than rice straw hay. Limited information on the nutritional content of fodder and; on proper utilization of the same may also lead to improper utilization. Standards formulating and enforcement bodies ought to note and address this gap.

• Ease of value addition in the hay innovation seems to determine the level of commercialization and this occurs at different times
Buying and selling of hay, especially crop residue was through informal marketing, where buyers and sellers negotiated to arrive at a price. Rice and wheat straw hay which is easily baled and hence value added; easily transported and marketed seemed to be more commercialized than maize stover which is not easy to bale. Some farmers who needed maize stover could collect it for free or at a small fee through informal relationships/linkages. This situation is likely to change if some entrepreneur starts selling urea-treated maize stover as it is been done with molasses urea blocks.
• There is need to pay attention to tradeoffs in innovations to avoid short time gains at the expense of long term loss
The question of sustainability of hay production needs to be thought through because both cultivated fodder and crop residues carry significant portion of nutrients mined from soil and fed to livestock. This challenge is especially acute in rice, wheat and maize straw residues. In the cultivated forages, use of fertilizers only, may be a temporary reprieve which will lead to depletion of important micronutrients and other agents in the soil. These challenges may need attention to be paid to nutrient monitoring in the concerned areas. Another area of tradeoff is the long term effect of replacement of food crop with fodder on cultivatable land which may call for ratios to be worked out to stem food insecurity disaster in the future.

4.2 Sahiwal Genetic Improvement

4.2.1 Why the Innovation?

The Arid and Semi-Arid Lands (ASALs) of Kenya constitute 89% of the country, a population of about 16 million people and approximately 70% of the national livestock herd (Njoka et al., 2016). The area experiences periodic cycles of drought and famine which diminish the sources of livelihood for the inhabitants. The livestock breeds traditionally kept by the ASAL communities were Zebu cattle strains, but these have now been undergoing upgrading through crossing with Sahiwal cattle breed. Sahiwal is large dual purpose cattle breed whose production plays a major role in food and nutrition security as well as a source of income. The breed constitutes around five per cent of the 18 million cattle in Kenya which translates to 900,000 heads. The breed's characteristics includes high milk yield, high growth rate under natural pastures and good reproductive ability among others (Ilatsia et al., 2007). They have a mature weight of up to 500kg and a daily weight gain of 511g and 470g has been reported for males and females, respectively (Muhuyi et al.,1999).

4.2.2 Brief Description of the Innovation

The importation of Sahiwal from Pakistan by the Kenya Government was as a result of the need to avail a hardy animal that was more productive than the local Zebu cattle and that would be adaptable to the extensive Kenyan rangelands. After importation, there was need to improve and conserve the genetic performance in response to changing land use and increasing population pressure. The technical innovation in form of the introduction of the Sahiwal has continued to replace the less efficient Zebu and hence guarantees less costs and more profits. The improvement and conservation efforts have been led by KALRO and partners through a Community Based Breeding Programme (CBBP) in which both pure and cross breeding strategies are utilized. The pure breeding strategy is used in the nucleus herds where proper pedigree and performance records are maintained. These records are organized into a database that forms the basis of a coordinated joint selection programme among the nucleus herds. The genetic gain generated from the nucleus herds is transferred to the pastoral herds through supply of superior breeding bulls which cross breed with the local cattle producing improved progenies. To a limited extent, artificial insemination is used for the commercial farms. The resultant superior progenies have high milk yield, grow fast and tolerate the adverse climatic conditions in the ASALs. This breeding system is based on a pyramidal management of the Sahiwal population with the breeders of nucleus herds at the top and participating herds at the lower levels (Figure 7).

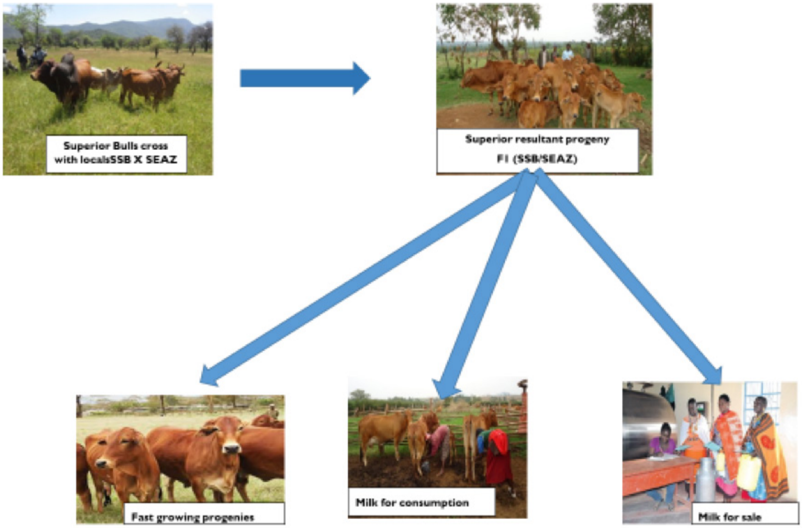
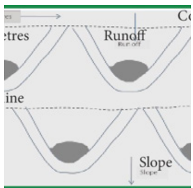


Figure 7: Crossing local breeds with Sahiwal breed to enhance performance in ASALS.

In addition to genetic improvement of the Sahiwal, KALRO introduced superior high yielding range grasses for use in feeding the animals. The grasses produce high biomass and hence ensure that the improved animals are well fed. The grass is baled into hay by some entrepreneurs for dry season feeding. Water harvesting and grass reseeding programmes have also been introduced in which various techniques such as semi-circular bunds, zai pits and negarims are used (Figure 8).

Zai Pits

Semi-Circular bunds



Negarims

Figure 8: Water harvesting and grass reseeding techniques in ASALS

Feed lots have also been introduced in the ASALS for fattening of Sahiwal bulls. Animal health management practices have also been introduced to safeguard cattle against diseases and pests. Community animal health workers have been trained to address the animal health needs. These and other practices make the Sahiwal to perform well in the harsh environmental conditions of the ASAL areas.

4.2.3 Benefits of the Innovation

Currently, it is estimated that about 900,000 Sahiwal genetic resources of varying gene combinations are with over 20,000 pastoral households who derive their main livelihoods from them. This has resulted from the annual dissemination of 3,000 breeding bulls to lower tier pastoral herds from the Sahiwal nucleus herds. The bulls are used to up-grade the indigenous herds for improved milk and growth performance mainly under pastoral systems. Cumulative increase in growth performance has been witnessed in the past 25-30 years with birth weights, weaning weights, mature sale live weights increasing from 17kg to 23kg, 105kg to 170 kg at 240 days and 270kg to 400kg, respectively (Ilatsia, 2011). There has also been a reduction in average age at first service from 23 to 21 months. Reduction in age at first calving results in increased number of calves and therefore increased offtake while high birth and weaning weights lead to hastened maturity.

The Sahiwal genetic resources now account for about 85 million litres of milk out of a total national production of 5.2 billion litres per year. At household level, milk production has increased from three litres per cow to the current 5.8 litres per cow per day. On the average, the production translates into 3,920 litres of milk per household per year. Subsistence requirement (home consumption) per household is 2,190 litres per year leaving a surplus of 1,730 litres for disposal (Ilatsia, 2011). In addition, keeping a Sahiwal bull confers the owner with higher socio-cultural standing (personal communication during stakeholders' meeting). Such a person is considered admissible to address a village or community baraza (meeting). The Sahiwal genetic resources have a direct implication on the welfare of pastoral communities, affecting their livelihood strategies and influencing their decision for keeping Sahiwal genetic resources. Besides the community, meat traders, dairy value chain actors, especially forage producers, milk transporters, traders, and aggregators/traders and processors have benefited from increased milk production. Employment opportunities for pastoralists including youth and women have arisen in both upstream and downstream segments of the milk value chain, making the innovation socially inclusive.

The consumers of Sahiwal dairy and meat products have access to, and consume safer and more affordable products. Additionally, environmentalist and the general public will benefit from better managed rangeland with fewer, more efficient animals. This translates to less rangeland degradation, increased diversity, and enhanced/sustainable environmental health and services.

At community level, keeping of the Sahiwal, is the best livelihood alternative in rangelands over other livestock species, given their ability to utilize low quality feed resources to produce milk and meat without exacerbating the fragile environmental conditions of the ASALs. Besides, keeping Sahiwal leads to reduced stocking rates since fewer animals are needed relative to specific breeds for either milk or beef under the ASAL ecosystem. This reduces the amount of GHG (methane etc.) produced. Despite the benefits accruing from this innovation, with the introduction of Sahiwal cattle breed in Kenya, there has been an indiscriminate crossbreeding with the Small East African Zebu (SEAZ). The SEAZ is more tolerant to heat stress and diseases as compared to Sahiwal cattle breed although they perform poorly in other performance traits such as milk production and growth. They are therefore the most adaptable cattle breeds hence most important in the wake of adverse climate change. The indiscriminate crossbreeding is a threat to SEAZ genetic resources which is an indigenous breed in Kenya. Besides, the demand for Sahiwal breeding bulls outstrips supply leading to inbreeding depression as reported on some performance traits in Sahiwal cattle populations in Kenya (Mwangi et al., 2016).

As the human population grows and people become wealthier, the demand for animal products will increase leading to the need to keep more cattle; a cost to the environment due to increased greenhouse gases emissions. Further, there is a negative danger of destroying the ASAL environment arising from increased Sahiwal population.

4.2.4 Potential for Scalability and Sustainability

Kajiado, Trans Mara and Narok are the three geographical areas in Kenya (Figure 9) with the highest populations of the Sahiwal genetic resources (Ilatsia et al., 2011a). Kajiado area was the first one to receive the initial stock of Sahiwal bulls while Trans Mara received theirs in the late 1980s through a collaborative project between the Government of Kenya and GIZ (Ilatsia, 2011b). Narok acquired bulls from the National Sahiwal Stud (NSS), Naivasha and the neighboring Kajiado county.

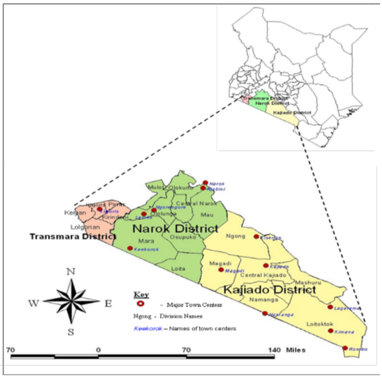


Figure 9: Geographical areas in Kenya with the highest populations of the Sahiwal genetic resources

Source; Ilatsia et al., 2011a

The innovation has potential to be up-scaled for greater socio-economic benefits to more people. This could be achieved through functional efficiency through accelerated multiplication using estrus synchronization and artificial insemination technologies. The high demand for this genetic resource creates market and the high prices that the Sahiwal fetches offer a good market niche compared to other breeds. This drives the demand for the improvement and distribution of the breed. Currently, there are plans underway to apply digital and genomic technologies for data capture and evaluation of animals and communicating with participating famers. Proven emerging reproductive technologies will be used to deliver the desired genetics adaptable for climate change.

Government has been actively promoting the establishment of large scale ranches in the rangelands and expansion of feed lots in order to increase meat offtake. Government (National and Counties) investments such as livestock insurance scheme, infrastructure such as abattoirs and livestock markets are potential drivers for up-scaling of the innovation.

The E-data platform at ILRI has just been adapted by inputting customized information on performance of Sahiwal cattle genetic resources in data capture tools and analytical procedures and feedback modules from 5,000 households, mainly from the Maasai Counties - Narok and Kajiado. The platform has been deployed to capture data on animal and herd performance to identify superior animal genotypes, and support real time on-farm decision making processes. Community-chosen animal recording agents and breeder farms have been trained on breeding management and data collection using the digital devices. Subsequently, data on animals' reproductive, milk production, growth performance and pedigree data is captured and then transmitted electronically to the ILRI digital data platform (with back-up at KALRO, Naivasha and Kenya Livestock Breeders' Association {KLBA}) and analyzed. The results of various genetic and phenotypic parameters are then relayed back to source for decision making at the National Sahiwal Stud. Once fully operational, this faster and reliable approach will add value to the innovation by hastening the process of availing Sahiwal breeding bulls for wider dissemination – making it easy for the innovation to be scaled.

Increased demand for Sahiwal cattle beyond Kenya is a potential driver for scalability. In recent years, there have been requests for Sahiwal cattle from Uganda, Rwanda, Ethiopia and as far as Sri Lanka. This offers an opportunity for scaling across Africa.

4.2.5 Lessons Learnt

• For adoption of an innovation, the innovator should work with other partners to address issues that enhance adoption.

The breed multiplication and dissemination model of the Sahiwal, owes its success to the partnership created between KALRO and other organizations who provided other services to facilitate the sustenance of the breed.

• An innovation with a positive cultural attribute that lead to recognition of the dominant gender has a high acceptability chance.

The Maasai value animal size (prestige), milk (for food) and fast growth rate which are attributes that the Sahiwal has. These attributes improve the owners social standing where ''Only men with Sahiwal bulls can stand and address people in a baraza' (Personal communication – David, Trans Mara County).

• Good record keeping and feedback from beneficiaries are important aspects for continuous improvement of an innovation.

While some recipients such as the ranches have been keeping good records, individual farmers do not. However, KALRO should address feedback such as the issue of inbreeding with urgency.

• Scientists should work closely with farmers to understand 'secondary innovations' and give technical support.

Such secondary innovations are for example the crossing of the Sahiwal with the Ayrshire which farmers said was superior to the Friesian is feedback that should not be ignored by scientists since this depicts the direction that farmers want the innovation to take.

• An innovation with superior socioeconomic benefit and demand has a higher chance of acceptability.

The Sahiwal has high and positive socioeconomic benefits and its demand is within and outside the national boundaries. A Sahiwal bull less than one-year old fetches up to KES 300,000 (3,000 USD) while a mature bull will fetch up to KES 200,000 (2,000 USD).

4.3 KALRO Indigenous Chicken

4.3.1 Why the innovation?

Poultry, particularly indigenous chicken are a popular enterprise among Kenyan small-scale farmers owing to low starting capital requirements thus making it an easy farm enterprise to start. Hybrid chickens are superior in productivity but their high maintenance cost discourages farmers. The IC are highly adapted to the harsh scavenging conditions, poor nutrition and disease and/or parasite challenges and are tastier.

The poultry population in Kenya is estimated to be 42 million birds out of which 34 million (83%) are categorized as Indigenous Chickens (IC), which consist of mixed sub-populations with heterogeneous features such as plumage color and body sizes. They contribute over 40% and 60% of the chicken eggs and meat produced in the country, respectively (MoALF, 2015). In 2006, IC accounted for 11,400 MT of meat and 570 million eggs making a total contribution of KES 1.0 billion into the national economy (MOLD, 2008). Demand for IC and their products is ever increasing due to urbanization, increasing human population, decreasing agricultural land, consumer preference and changes in human eating habits.

Despite the increasing demand of IC, their production potential has not been optimized and hence their contribution to the country's development has not been realized. This is due to constraints in their production environment, low genetic potential, seasonal fluctuation in quality and quantity of feeds, high disease and parasite prevalence, climatic variability, policies and infrastructure (Okitoi and Mukisira, 2001). There is however enormous potential to up-grade the IC rearing to commercial status through strategic research and technology innovations. With the foregoing in mind, a long term breeding program for indigenous chicken was initiated in KALRO, Naivasha with the main aim of improving production and reproduction traits of IC.

4.3.2 Brief description of the innovation

In 2016, under the EU funded Arid and Semi-arid lands Agricultural Productivity Research Project (ASAL-APRP), a long term IC breeding programme was initiated with the aim of developing an improved IC line for meat and egg production for the tropical environment (Ilatsia et al., 2018). This was also an impetus to address the increasing challenges of reduced production and reproduction traits of IC together with conserving different ecotypes available in Kenya. This initiative involved utilizing chicken genetic resources maintained at KALRO, Naivasha; which was further expanded through introgression of foreign blood lines. In this collaborative effort, a team of scientists and other stakeholders developed two intermediate IC breed lines {referred to as KALRO Chicken, (KC)} with high egg production and enhanced growth rates. The two breed lines (Figure 10) have been undergoing selection as distinct lines termed KC1 - spotted hens and cocks for both meat and egg production and KC2 - black hens and cocks for egg and meat production.

Both KC lines are highly adaptable to the varied production environments and tropical agro-ecological conditions. The birds mature early; giving first egg at 18 weeks of age, the same age that cocks get to 2 kg weight.

Figure 10: KALRO improved indigenous chicken (KC1 and KC2) produced and distributed from KALRO, Naivasha

The KALRO improved Kienyeji chicken is a more productive indigenous breed which lays more eggs than ordinary indigenous breeds. An exotic breed such as the Leghorn can lay up to 300 eggs in a year, but under good management, the improved indigenous breed from KALRO can produce 220 – 250 eggs under good management. As a dual-purpose breed, KALRO improved indigenous chicken matures at five and a half months. Managed as layers, they will lay between 15-25 eggs per month. On average cocks weigh between 2.0 to 2.2 kg while hens weigh between 1.5 to 1.8 kg at maturity. The chickens have high disease resistance as compared to commercial breed and other improved Kienyeji, thus reducing the cost on medication and losses due to mortalities. As good grazers, these chickens supplement their feeding thereby reducing the cost of feeding. Thus, they can thrive and produce with irregular supply of feed and water and with minimum healthcare.

4.3.3 Benefits of the innovation

The genetic materials of KC are an important aspect in poverty alleviation as they have a direct implication on the economic and social status of particularly small scale farmers. The KC has been adopted in over 95% of the country, giving an indication of different production systems in which the breed lines are being reared. The trend of distribution of Day Old Chicks (DOC) and Month Old Chicks (MOC), and fertile eggs (FE) is presented in Figure 11. The annual distribution of DOC increased rapidly from 8,686 chicks in 2010 to 169,186 and 169,744 in 2014 and 2015, respectively, and peaked in 2018 at 181,680. The rapid increase of DOC distribution is attributed to increased demand for the KC by farmers and implementation of online marketing strategies.

The sales of MOC also increased from 15,439 in year 2010 to 47,745 in 2012 when the highest quantity was recorded, then steadily declined to 12,817 in 2014 and increased again to 28,481 in 2016. The fluctuating trend in distribution may be attributed to effects of multipliers as indicated by the sale of Fertile Eggs (FE). Distribution of MOC dropped at the onset of FE sales to multipliers and continued to drop as the FE sales increased. This indicates that the availability of MOC from multipliers close to the farmers led to reduced need for them to purchase the same from KALRO, Naivasha. Distribution of FE decreased sharply from the year 2014 to 2017; attributable to unavailability of the eggs after the capacity of the production facilities were exhausted. Conversely, the decrease of FE sales led to an increase of MOC sales.

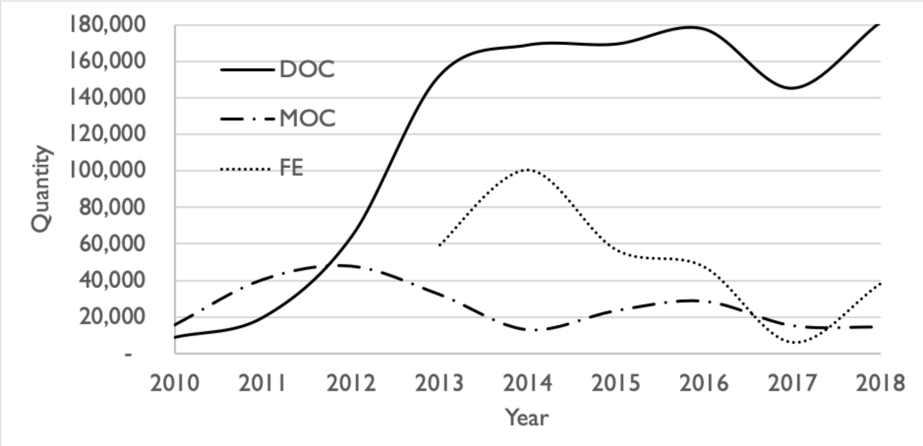


Figure 11: Distribution of KC day old chicks (DOC), month old chicks (MOC) and fertile eggs (FE) in Kenya from the year 2010 to 2018

The distributed KALRO improved Kienyeji chicken have broadly led to the following impacts:

• Adopting KALRO improved Kienyeji chicken has a positive impact on egg productivity and production among the smallholder farmers (Kamau et al., 2018)
• The chickens have vital roles in the rural households as a source of high quality animal protein and emergency cash income and play a significant role in the socio-cultural life of the rural community
• Chicken keeping is gender neutral as most rural women and children generate cash revenue and obtain adequate supply of eggs and meat for their families' diet
Consumers' willingness to pay higher prices, enables sellers to get higher profits for their chicken. This may explain the high number of chicks distributed to Nakuru, Nairobi, Kakamega, Machakos and Kiambu counties.

Chicken generally scavenge around the homestead areas during day time, where they eat kitchen waste, left over cereals such as maize, rice, wheat, pulses, green grass, insects, and other available feed stuff hence, lower cost of production.
Despite the benefits that accrue from adaption of KC, the chicken droppings sometimes contain cecal worms which can be transferred to other terrestrial and aquatic animals. However, in instances where free range production is utilized as is the case in many farms where KC chicken is reared; positive impacts to the environment is recorded, with only minor negative impacts. For example, chicken manure improves soil structure and provides nutrients for plants. Generally, chicken production in quantities that are focused to meet subsistence farming conditions do not have detrimental effects on the environment.
Impact of chicken production to the environment greatly depends on the management practices instituted in a farm. It is necessary to inform farmers of the associated environmental impacts of their productions systems so that they adopt and use economic and environmental friendly options.

4.3.4 Potential for scalability and sustainability

Due to its outstanding performance in terms of fast growth and egg production, the demand for the KC lines has surged and KALRO being the only source of the improved lines can no longer meet the demand. This has resulted in long delays in the delivery of chicks such that farmers have to wait for about six months to get their orders delivered.

The developed KC breed lines thus have a great potential for scaling up; mostly due to the readily available market and their consumer acceptability. Performance recording of the breed lines has heavily relied on computerized databases for data storage and evaluation. Bird registration and characterization utilize applications on the android platform. In addition, marketing and distribution of KC breed lines have taken advantage of social media platforms (Facebook, Twitter, LinkedIn and YouTube). The online platforms have enabled over 500,000 people in various counties of Kenya to be reached; some of whom get in constant communication with the scientists to find solutions to their poultry keeping challenges. A mobile application was also developed to help address aspects of capacity building with respect to chicken farming. Users are able to find standard practices for optimum production on the platform (which runs on Android). Aspects of biosecurity, disease management, breeding and selection, are incorporated in an easy to read format for use in the application. These innovative ways have potential for further upscaling the KC innovation.

Despite these developments, at the moment, the scaling strategy for KC is rudimentary; with multipliers, farmers and end users mainly obtaining chicken and eggs directly from KALRO. Besides, this strategy has limited dissemination capacity due to impersonations by private partners (fake producers of KC) whose bird quality standards are not guaranteed.

To bridge this shortfall in scaling the innovation, KALRO has developed an efficient structure (Figure 12) that will enable efficient scaling up of KC once fully operational. The initiative offers a structured delivery system, product value addition and market access through formation of a systematic commercialization program for improved KC breed lines, involving three breeding and production tiers as well as various actors in the chicken value chain.

In this set-up, KALRO will be the primary source of elite KC parental breeding lines, and will be considered the top tier in the breeding and production of elite KC lines. At the initial stage, 1,200 elite KC lines developed at the KALRO research facility will be multiplied to generate parental stock to be disseminated to the second tier composed of private multiplier and hatchery units. The KALRO will assess partners for consideration as IC scaling partners. The partners to be listed need to have a demonstrated record and capacity in:

i) Production of hatching eggs for multiplication of day old chicks;
ii) Scaling day old chicks beyond one district or ecology;
iii) Established partner with a) an office b) established accounting procedures c) legal registration proof, and d) licensed hatchery;
iv) Partner whose official (registration) mandate is relevant to day-old chicks scaling.
KALRO in conjunction with its main research partners will be involved with continuous genetic improvement of the KC birds through selection and breeding, and formulating husbandry support systems for the improved birds. This will be achieved through;

i) More inter se mating programs to the fifth generation for complete genetic stabilization of the two KC lines;
ii) Strategic introgression of genes from local birds to equip the improved KC lines with some special attributes such as feed efficiency, heat stress tolerance, adaptability to a wide range of climatic variables, disease and parasite tolerance;
iii) Deployment of genome wide techniques and selection;
iv) Systematic crossbreeding programs involving the local adapted ecotypes and KC lines;

In addition, KALRO and its partners will be expected to provide technical support to lower tiers to ensure adherence to the set out breeding objectives and husbandry support systems to maximize on profitability, as well serve as a feedback mechanism from the farmers for continuous technical appraisal of the breeding program.

The second tier will be composed of Multipliers Units/private hatcheries (MUs). The MUs will be the main recipients of certified elite KC breed lines for multiplication purposes. The elite parental stock transferred to the MUs will have identification features for on-farm performance monitoring and registration purposes, and for traceability. The MUs will be selected based on agreed criteria that will ensure geographic dissemination of the KC breed lines in the country and the region. A legal framework will be developed between KALRO and the MUs on how royalties will be paid as compensation for breeding research effort as well as to support future research activities aimed at genetic value addition to the KC lines. The royalties could be paid either through premium price charged on every day old chick supplied to the MUs or commission from every chick sold by the MUs to the lower tier. The MUs will be expected to conduct basic performance data collection as guided by KALRO, as well as consistent inspection and registration of their flocks based on the standards prescribed by the Indigenous Poultry Association of Kenya (IPAK) and Kenya Livestock Breeders' Association (KLBA). This is to ensure consistency in maintaining the KC agreed breed standards and deter non-accredited hatcheries from such dealings.

The lower tier (mainly composed of farmer cooperatives/groups and individual farmers (including women, youth groups, People Living With Disability (PLWD) in the breeding structure will receive resultant progenies of KC breed lines from the MUs for egg and meat production. This tier will be the primary source of eggs, live birds and chicken meat that will enter the market. There will be some form of germplasm exchange within the tier through community based breeding organization. The KALRO is also going to provide technical back stopping with regard to breeding and husbandry support systems. Just like in the middle tier (MUs), members from this tier will be expected to subscribe to the Indigenous Poultry Association of Kenya (IPAK) to ensure consistent breed standards as well as enhanced market linkages. Through IPAK and support from county extension, farmers and farmer groups will be encouraged to form cooperatives for bulk sale of the KC products. The objective is to increase the bargaining power and benefit from economies of scale. Best performing individuals and farmer groups from this tier could be upgraded to MUs once they meet the threshold for incorporation.

The market tier will be composed of, but not limited, to four segments that will be the major outlets of branded KC lines from the individual and farmer groups. Special linkages will be formed for the lower tier to have access to these market outlets for the KC products, mainly live birds, chicken meat from the local abattoirs that will be graded and sold locally or to leading supermarket outlets. Direct sale of KC meat to hospitality industry is also envisaged. Farmer groups and cooperatives will be encouraged to form slaughterhouses (for collective supply of lives birds) which will be dressed and various chicken cuts derived and packaged for sale.

It is important to note that investment in structuring the aforementioned distribution strategy is a noble initiative that would open up a wide range of investment opportunities; including adoption of the innovation by other African countries with chicken and/or other related agricultural value chains.

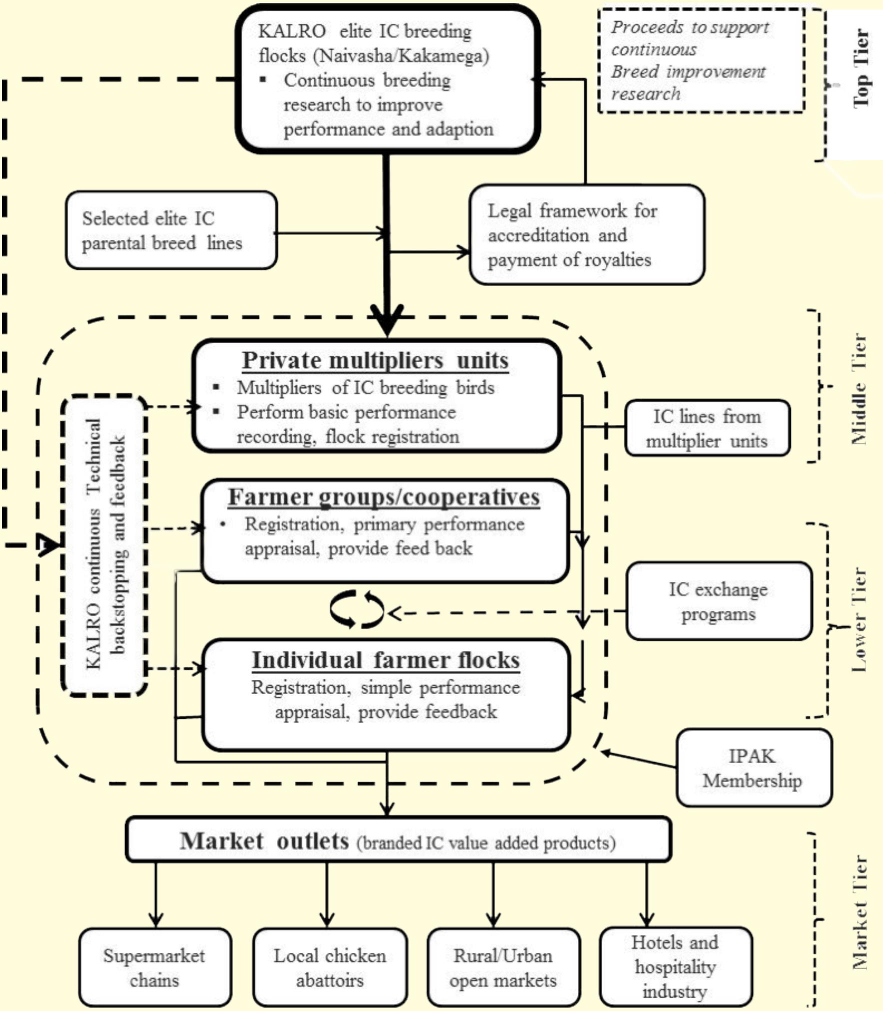


Figure 12: Organizational structure to enhance the role of private sector in KC innovation development and upscaling

4.3.5 Lessons Learnt

- An innovation that builds on an existing one causes minimum conflict and enhances acceptance
- The KALRO improved IC was quite appropriate for the farmers because it only enhanced performance of the already existing indigenous chicken in attributes that elicited high demand for KALRO improved IC.
- Research and development organizations should ride on the popularity of their innovations to come up with other innovations Developing the KALRO improved IC has enabled KALRO to assert its authority in the chicken value chain and can therefore ride on this fact to come up with other innovations in the same value chain. The lessons learnt from development and distribution of the KALRO improved IC can be used to hasten the invention of other innovations.
- There is a risk of 'innovation' hijack if provision to meet demand for a popular innovation is not made by the innovator. The KALRO improved IC innovation needed to be accompanied by an innovative way of distributing breeding stock (fertilized eggs, DOC, MOC). Response by KALRO to the inadequate dissemination model for IC breeding stock was low, which prompted other entities to fill the gap by breeding and distributing low quality breeds. This threatens KALRO's opportunity to reap benefits from this novel product. Large scale farmers started distributing breeding stock, and since there is no regulation, the quality of chicken produced may be compromised. "Farmers wait for long (one year) to get the birds, so they go for other birds, yet KALRO chicken is superior to the others" (personal communication – Chairman Nakuru Indigenous Chicken Farmers Association). The KALRO, Naivasha should explore possibility of satellite centers for wider distribution of IC.
- Development of a successful innovation should spur more research to respond to feedback from the users and consumers. Product consumers have own preferences as demonstrated by preference for yellow flesh and white eggs of the indigenous chicken. As expressed by a farmer, ''Farmers want real characteristics of an indigenous bird, but the skin of KALRO IC is white and the eggs are brown". This has led to some farmers creating yellowness by incorporating food coloring products. Some farmers have initiated their own 'informal breeding' to get the consumers' preferred attributes. These are urgent issues that require response from KALRO, the IC innovator.

• Farmers experiments and their results should not be ignored by researchers

Huge demand for certain attributes may trigger farmers to experiment to address the need. This is illustrated by a farmer who received an order to deliver cocks to a hotel and efforts to meet this demand were futile. Through trial and error, and observations on egg size and physical appearance, she observed patterns in hatching with respect to sex of chicks. A few years down the line she was able to select eggs that will hatch into cocks and those that will hatch into pullets. R&D organizations may need to work with such farmers to verify this innovation and improve on this ability to incorporate it in the chicken management practices.

• A proper innovation proliferation environment will require key practices to be put in place

Accompanying information that is needed for better management of the IC was still wanting. For instance, farmers were handling vaccines themselves instead of seeking the assistance of veterinary officers or para-vets, which compromises vaccine quality. Capacity building is key in providing information for better management.

• Lack of regulation/policy may lead to a compromise in quality through development of quasi- products

The low or lack of quality regulation in the chicken value chain has led to production of sub-standard breeding stock by some 'amateur' breeders. This is not good for the IC innovator and over time, some of these operators may end up registering their innovations as the original IC breed. This may deny KALRO the intellectual property if fast tracking is not done.

• Researchers should pay attention to cultural issues to avoid rejection of 'technically good' but 'culturally unacceptable' innovations

The spotted and black IC lines developed by KALRO have good egg and meat attributes but the spotted is more popular with farmers. Discussion with farmers have revealed that black chicken are culturally associated with witchcraft. Their color is also likened to black cats which are believed to be bad omens. There is need to pay attention to this perception and do further research with a view to retaining beneficial characteristics and get rid of the black color.

4.4 Pig Vertical Marketing Integration
4.4.1 Why the innovation?

The national meat consumption is on an upward trend owing to the rising population and especially the rising middle class. It is estimated that the per capita meat consumption has risen to 16 kgfrom 10.8kg in 2015 (Kenya Market Trust, 2019; FAO 2017, MOALD 2015). Of the total meat consumed, white meat from poultry and pork accounts for about 19% (EPZA, Pork constitutes 2% of the total meat consumed, and in 2016, a total of 262,074 pigs were slaughtered across the Kenyan counties. However, despite the country having an established pig industry, pig production has remained relatively unexploited. In smallholder systems, inadequate feeding, inefficient veterinary care and inbreeding are major impediments hindering pigs from expressing their full performance. Between 2017 and 2019, pig sales increased by 7.8% from 360,100 to 388,200 and this upward trend is expected to continue (Kenya Business Daily, 2019; FAO, 2016). There is therefore an opportunity for the country to address the challenges of food and nutrition insecurity and decreasing levels of poverty through the promotion of the pig industry.

Currently, the pig population in Kenya is estimated at 400,000 and their distribution is in seven main regions namely former Western, Rift Valley, Nyanza, Eastern, Central, North Eastern and Coast regions. Central and Western Kenya (Figure 13) are the leading regions with each having over 80,000 pigs while North Eastern and Coast provinces are emerging pig areas (MOALD, 2010).

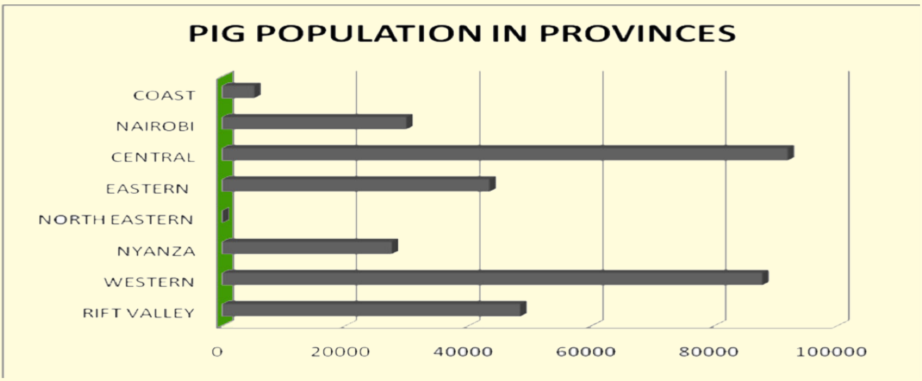


Figure 13: Distribution of pigs in Kenya by 2010

Source: MOALD, 2010

Different types of production systems are used in different parts of Kenya with the main ones being traditional backyard which is predominantly used in Eastern and Nyanza Provinces, and commercial production systems in Central, Eastern and Rift Valley Provinces as well as in major town slums (Mbuthia et al., 2014). The number of pigs range from 1 to 100 for the small scale commercial; 100 – 5,000 for medium commercial; more than 5,000 for large commercial and above 20,000 to 30,000 for the integrated commercial system (FAO, 2012). Pigs are mainly fed on maize germ and wheat bran mixed with soya, and fishmeal, as sources of protein. These feeds are usually enriched with vitamin mixes. Some farmers make their own feeds, which are cheaper and superior in quality compared to the commercial feeds.

When properly housed and fed, pigs have few challenges except two major diseases; African Swine Fever (ASF) and Foot and Mouth Disease (FMD) and gastrointestinal worms. Once pigs are ready for market, there are various outlets which includes Farmers' Choice which slaughters and processes pigs into various products for the local and export market. There are also upcoming local markets in butcheries and pork eateries in cities and towns (FAO, 2012). However, often the farmers do not meet the quality requirements for the main market outlets because of poor production standards emanating from lack of information on pig husbandry practices. The high cost of feed and the lack of organized marketing are other major challenges facing the pig industry.

4.4.2 Brief description of the innovation

In order to handle the challenges of pig production and marketing, Farmer's Choice Limited embarked on a contract pig farming arrangement with farmers as an innovative way of supplying quality pigs to the factory. Contract farming has been defined by various authors as an arrangement which may be written or verbal between a firm and a farmer/client that stipulates production conditions and intentions of the firm to buy the ready products (Prowse, 2013). It is a joint undertaking linking the buyer's business model with the producers' business model (farming system) at the farm supply-firm procurement interface.

Initially, Farmer's Choice sourced 90% of their supply from their nucleus farms in Kiambu, Eldoret, Kamiti and Karen, and 10% from farmers who had to sign a formal contract. Currently, the supply is 50% from the nucleus farms and 50% from farmers. Once a farmer joins the Farmer's Choice production and marketing arrangement, high quality breeding sow is provided to them by the company or from a recommended farmer. The farmer also gets subsidized pig feed which is manufactured at the company's mill. The farmers in the contract are provided with free technical advice by specialized field extension workers on best pig husbandry practices from farrow to finisher stage and also on when to sell the animals. The farmer is issued with a visit report which details the issues covered for future reference. They are also advised on upcoming pig rearing technologies. The company transports th pigs to the slaughterhouse. The transportation cost is recovered from the cost of the delivered pigs. If a farmer uses own transport, they are compensated based on the distance from the farm. The payment to the farmer is normally on the second working day after pigs are slaughtered.

Before delivery of the pigs, the field officers visit the farm to confirm fitness of the pigs for slaughter. The pigs are expected to be properly housed, healthy and fit for consumption on post mortem meat inspection. Pigs must come from disease free zones as per livestock movement policy and farmers delivering pigs must possess relevant animal movement documents from their local District Veterinary Officer. The recommended weight is 90 -100 kg live weight and payment is on the basis of Cold Dressed Weight (CDW) which ranges between 56 to 85 kg. The males must be castrated to eliminate taint in the meat.

The pigs are bought depending on the carcass quality classified from class 1 to 9 based on CDW and fat depth. Class one consist of dressed weight ranging from 60 - 75 kg and fat depth of 0 to 8 mm. Class 2 to 5 consist of 40 to 75 kg dressed weight and all fat levels; class 6 to 8 is dressed weight of 86 to 100kgs and all fat levels; and finally class nine is sows of all weights and fat levels. Pigs below 40kgs and uncastrated boars are not acceptable. All deliveries have to be in before 6pm (Farmer's Choice, 2019).

The production and marketing arrangement between farmers and Farmer's Choice ensures that a market for farmers' pigs is available as long as they ensure that conditions set are adhered to. On the company's part, they are expected to meet their supply quota needs through the 50% portion that is supplied by the contracted farmers.

4.4.3 Benefits of the innovation

The major beneficiaries of the innovation on pig vertical market integration are the contracted farmers and Farmer's Choice (the integrating firm). The contracted farmers derive several benefits arising from the integration as spelt out in the contract. On delivery of the pigs to the factory, the farmers are paid promptly making it easier for them to immediately procure another batch of piglets to ensure continuous production and supply. Collectively, the 1,000 contracted farmers dispersed across the country obtain about KES 19.0 million monthly. One advantage of pig production is their higher stocking density unlike other livestock. They also have a short reproductive cycle and high growth rates (FAO, 2012; Wabacha, 2004).

The integrating firm benefits in that it is able to meet its quota of pigs and have an assured supply of pigs all year round. In addition, it has a ready market for feeds from its factory, and for piglets and boars from the nucleus herd. Furthermore, the manure obtained from the integrating firm is sold to the farming community thus generating extra revenue from the pigs.

Besides the direct benefits to the two players, pig production (including those arising from the innovation) is an inclusive enterprise as illustrated by the following examples:

- In Nyanza, it is believed that keeping pigs in the homestead guards against witchcraft and acts as a security guard. Pork is also thought to boost the immunity of those infected by HIV/AIDS.
- In Central Kenya, some farmers keep pigs for providing farmyard manure, and to make use of crop residues and by-products including kitchen leftovers. In the process they are able to sell the pigs when they mature or when the family needs money.
- The spread of pigs to non-traditional pig keeping areas such as North Eastern Kenya has been associated with a perpetual cultural challenge of cattle rustling. Pigs are not prone to rustling and this coupled with the high demand for pork is helping to encourage many people to rear pigs.

Pig keeping is an all-inclusive enterprise that involves the youths who are otherwise jobless and idle, women and the men. Also, given the compatibility of pig production with the reducing land sizes, it is apparent that this is an industry that has a lot to offer in terms of poverty reduction. The manure from the pigs is also an input used in improving soil fertility.

Pigs present an opportunity where waste and by-products are converted into high value protein. Their production is particularly suitable near institutions and urban market centres where swill and crop residues are abundant. In addition, there is an increasing consumer preference for pork in the market because of health awareness and hence higher demand for white meat.

Despite the many benefits accruing from pig production, they can lead to negative effects. A major negative impact is pollution of the environment through smell emanating from pigsties that are not well maintained. The infected pigs can also be a source of diseases and pests such as swine fever, foot and mouth and Taenia solium. When left to scavenge, pigs can be a nuisance and can spread garbage from dump sites thus increasing the chances of disease and pathogen spread.

4.4.4 Potential for scalability and sustainability

The high demand for pork is a potential driver for scalability, meat preferences have changed and local demand for pork is on an upward trend. The pork eateries and butcheries are emerging in almost every town and shopping centers in the rural areas.

Further, there is high potential for pig production and marketing to be scaled through ICT as demonstrated by the many apps that are being developed. An example is the KALRO app on production and management of pigs. Others are the market sections of Mkulima Young and i-cow. The apps provide valuable information on pig production and marketing that is needed for decision making.

However, wider scalability will require policy support. The draft livestock policy and strategy (MoA&I, 2019) are yet to be finalized. The Pig Task Force is yet to come up with a functional strategy to improve the pig sub sector. All these efforts need to be completed to facilitate scalability of the innovation.

4.4.5 Lessons Learnt

- Consideration of production and marketing issues are bound to enhance attractiveness of innovations adoption. The vertical marketing integration innovation by Farmers Choice has worked well to a great extent and is an appropriate model for timely marketing. If pigs are not sold immediately they mature, the quality of the meat deteriorates fast and the farmer continues to incur production costs. This production - market innovation has succeeded and farmers are assured of the input and output market. Other value chains could adopt the model to minimize losses in the agricultural sector
- The current farm size dynamics should consider popularization of enterprises like pig keeping which are land size neutral and have many unexplored investment opportunities. Pig rearing is ideal for people who have limited access to land, especially the women and youth and it is a profitable venture that can employ many people, especially the youth. The enterprise also offers opportunities for feed manufacturing investors considering that feeds constitute 80% of total costs of pig rearing.
- Interaction between value chains should be explored. One farmer realized that different feeds imparted different tastes to pig meat, pointing to the fact that niche markets can be obtained with innovation. Information on how pig rearing can be integrated with crop value chains is necessary and needs to be generated
- Response to changing consumption patterns should be a trigger to put facilitative mechanisms to increase production in place. Increasing local demand for pork has changed the marketing frontier, from the conventional consumer markets (tourist hotels, supermarkets) to local butcheries thus bringing in new players in the market.
- Information asymmetry should be addressed for enterprises with a potential to immensely impact food security and poverty reduction like the case of the pig industry. It is apparent that information on pig rearing is missing in situations where farmers market individually and did not have information on where to get feeds, and were not assured of the market as opposed to farmers linked to Farmer's Choice, whose input and output markets were well streamlined.

Other market players (brokers and butchers) have the notion that the cost of production was low and therefore offer low prices to farmers. A pig farmer observed that"there is a lot of wrong information out there" (Personal Communication- pig farmer, Nakuru). The initiative by KALRO, Naivasha to start research in the pig value chain will provide the much needed information for the players in this value chain.

- Need for other organized processors to offer more market alternatives to the farmers. The current situation where only one large company is having contracts with farmers may need to be changed to avoid farmer frustration when supply contract is breached and farmers incur unnecessary production costs. Farmers agree to the terms because they lack an alternative market, therefore the industry is exposed to monopoly Another processor should be brought on board to offer competition, thereby benefitting farmers. A study to identify barriers hindering the emergence of new big player needs to be undertaken to address monopoly in the industry.
- County governments to consider helping pig startup businesses in certification to improve local and export markets for pig farmers. Owing to lack of certification, there are pig meat processing opportunities lost as one farmer stated, 'most slaughter houses are not certified, so they cannot export pork'. Regulations and standards should be set for the pig industry and certification fast tracked with the help of county governments to significantly improve income and employment opportunities for the county inhabitants.
- Gross margins for different pig production systems to be computed. Efforts to obtain documented information on pig gross margins were futile. It was not clear if there were differences in revenues earned between the farmers producing pigs under company contract and those operating privately. Gross margin analysis for both market channels would enhance development in this sector
- Collective action by pig producers could improve input-output market . It is documented that marketing groups increase farmers' access to input and output markets. In this case, formation of marketing groups would enable farmers, access to good quality feeds and have bargaining power in the market.

CHAPTER 5

Conclusion and Recommendation

5.1 Conclusions

The aim of this study was to carry out an overview of the livestock sector with a view to identify, analyze and document its development and scalable innovations driving growth and the supportive or necessary policy environment. The key innovations are driven with the backdrop of increasing human population, urbanization and rise in incomes which are factors that are associated with the upward trend in the demand for livestock products and the underperforming sector wrought with low productivity. Implicit in productivity increase is reduced costs which includes deployment of various innovations that enhance productivity. In Kenya, four innovations with potential to increase livestock productivity includes hay and crop residues for ruminant feeding, Sahiwal genetic improvement, KALRO improved chicken and pig production and market integration. Key attributes supporting the successful deployment of the innovations gravitated around digitalization of agriculture, collective action scale of operations, creation of employment opportunities for youth, women and more broadly, rural poor and the importance of government action to regulate markets, set standards, to govern input and output market. While production of these feed materials is picking up, it is noteworthy that ICT tools have not yet been deployed for marketing the products.

It was observed that there were changing patterns of acquisition of information and transactions by farmers through digitalization of agriculture leading to reduced transaction costs, de-intermediation of value chains. Such cases were the creation of awareness on the use of ICT (mobile telephone communication, emails, WhatsApp etc.) to promote innovation which is a potential driver for scaling up the innovation. This has been achieved in the case of upscaling of MUMBS, MMUMBS, and providing information on markets for the shredded stover.

KALRO has made it possible for payments for seed to be made electronically through M-PESA/Pay Bill to enhance pasture and fodder production. Payment through cheque would require two working days to clear to actualize the transaction. Use of M-PESA/ Pay Bill made transactions to be instantaneous. For Sahiwal breeding programme, a platform has been deployed to capture data on animal and herd performance to identify superior animal genotypes, and support real time on-farm decision making processes.
The online platforms have enabled over 500,000 people in various counties of Kenya to be reached; some of whom get in constant communication with the scientists to find solutions to their poultry keeping challenges. A mobile application was also developed to help address aspects of capacity building with respect to chicken farming. In this platform (which runs on android), users are able to find standard practices for optimum production.

However, in some cases there were low usage of ICT tools in situations where it made economic sense to use them to substantially reduce transaction costs. Further, the intermediation by brokers within the value chains was still pervasive. Farmers involved in commercial hay production in some cases do not have access to information about Good Agricultural Practices (GAP). There is limited information on the nutritional content of fodder and on its proper utilization that may also lead to improper usage. In these cases, the potential for sustainability exists if farmers' awareness level is increased for them to make enriched wheat straw and maintain good quality through digitization of the agricultural information and sharing it through a digital platform. Another opportunity for digitalization is through Technoserve's Kenya Market Assistance Programme under its pilot initiative in 2012 where two companies on commercial hay production and marketing were started and since then various advances have been and still continue being made towards developing hay production and marketing. Incorporating digitalization under this initiative would act as a catapult for the initiative to a faster and enhanced development. Digitalization would also link the major players in the innovation structures including the machine operators i.e. tractor owners, drivers, equipment owners, producers (farmers), traders (businessmen, middlemen), extension officers, consumers (farmers-beef and dairy producers) and researchers.

Under the KC innovation aspects of biosecurity, disease management, breeding and selection, are not readily available to producers. There is potential for further up-scaling of the KC innovation using digitalization of this information by incorporating an easy to read format for use in a digital platform. Currently, there are plans underway to apply digital and genomic technologies for data capture and evaluation of animals and communicating with participating famers. KALRO has developed an efficient structure that will enable efficient scaling up of KC once fully operational. The initiative offers a structured delivery system, product value addition and market access through formation of a systematic commercialization program for improved KC breed lines, involving three breeding and production tiers as well as various actors in the chicken value chain. Digitalization of this system will reduce transaction costs and link all the actors.

Under Pig production, it was realized that information asymmetry should be addressed for enterprises with a potential to immensely impact food security and poverty reduction like the case of the pig industry. It is apparent that information on pig rearing is missing in situations where farmers market individually and did not have information on where to get feeds, and were not assured of the market as opposed to farmers linked to Farmer's Choice, whose input and output markets were well streamlined. Other market players (brokers and butchers) imagine that the cost of production was low and therefore offer low prices to farmers. As one farmer said, 'There is a lot of wrong information out there' (Personal Communication- pig farmer, Nakuru). The initiative by KALRO, Naivasha to start research in the pig value chain will provide the much needed information for the players in this value chain. Digitalization is therefore necessary to rapidly enhance this emerging pig production system.

Several cases of collective actions and scale up operations in the innovations were observed. In all of them, there is a clear illustration of the importance of collective action as a useful tool in utilizing economies of scale that reduce transaction costs of service delivery. Collective action among actors in the various crop residue and hay innovations has increased awareness of the need to supply and also demand for hay. Farmers using innovations for improvement of straw and stover have formed hay making self-help groups involved in treatment of the straw and stover using urea to make it digestible, making the practice that was hitherto slowly picking up to accelerate. The formation of the 1000-member strong Rift Valley Hay Association which is operating both at local and regional levels across seven counties and expanding its operations is also promoting land lease, establishment of storage facilities, farmers training, contract farming and establishment of hay growers' platform with a targeted number of 60,000 hay farmers. Under the range seed system, farmers adopted the community based seeds system approach for Common Interest Groups (CIGs) for range pasture seed technologies. One case observed was the formation of Kavatini Pasture and Livestock Improvement Group (KAPALIG) located in Kibwezi West Sub-County of Makueni County which is a community based organization involved in pasture and livestock improvement. The group was formed to respond to challenges of feed shortage and feed quality. The commercialization of fodder which started in Nakuru County has since spread to seven other counties following the formation of the Rift Valley Hay Producers' Association in 2015.

There were cases identified where use of collective action could enhance upscaling/out-scaling of the innovation. For example, there was need for other organized processors to offer more market alternatives to the pig farmers. The current situation where only one large company has contracts agreement with farmers may need to be changed to avoid farmers' frustration when supply contract is breached and farmers incur unnecessary production costs. Farmers agree to the contract terms because they lack alternative and may be exposed to monoply. Another processing company partly owned by farmers should be brought on board to offer competition, thereby benefitting farmers. A study to identify barriers to new entrants as amajor processors need to be undertaken to curb monopoly in the industry

One important characteristic of the innovations was creation of employment opportunities for youth, women and more broadly, rural poor. Hay, stover and straw baling was found to be a gender inclusive innovation where men operate the tractors and the production/baling equipment. They were also involved in bush clearing while preparing land for pasture production. Women and youth were mainly involved in harvesting and processing grass seeds. Production of locally fabricated small scale motorized shredders and millers have been induced by the increased utilization of crop by products. The fabrication, repair and modification of these machines has created employment opportunities for youth in the informal sector, popularly known as jua kali. In the year 2014, 80% of the 800,000 jobs created were in this sector. For the range grass seed systems, large amount of seeds was distributed which became a source of income for ASAL farmers who initially had limited income sources. Women and youth also earned income when employed to harvest and process seed and income earned was used to buy food for the family. Marketing of hay has also led to creation of more employment through selling of hay to farmers all over the country, this is evidenced by the presence of many hay selling points across the country. In Mwea Irrigation Scheme, grass harvested along paths and boundaries in rice fields normally fetches 20% higher price than rice straw bale since it is softer. In this hay case study, the actors are mainly male and female youth who collect the rice straw after grain is threshed, and deliver same to the aggregation centers using donkey carts. Apart from the community involved in Sahiwal breeding, meat traders, dairy value chain actors, especially forage producers, milk transporters, traders, and aggregators/traders and processors have benefited from increased milk production. Employment opportunities involving youth and women have been created in both upstream and downstream segments of the milk and meat value chain, making the innovation socially inclusive. The KC, a novel approach that favours women and youth is bound to open up widespread use of the developed lines to tap into the poverty reduction potential of these birds.

The market integration for pig farmers is organized such that Farmer's Choice gets 50% of its supply from contracted farmers and 50% from the nucleus farms. This has benefited many youths who have taken up pig farming as an employment opportunity. They in turn employ other youth and women.

The high demand for pork has also stimulated emergence of local slaughterhouses and pork eateries which are spread out in all towns in Kenya. This is another area of self - employment for women and youth with knock-on effects on other sectors of the economy.

In all the innovations, the importance of government action to regulate markets, set standards to govern input and output markets was evident. Under hay production, the enterprise operates without adherence to any set standards and hence risking production of sub-standard products and unfair competition in the market. Unethical practices like selling hay that is not adequately dried can pave way for contamination and hence risking the output from the animals. Farmers are also likely to lose money from underweight hay bales whose price may be based on the standard bale weights. Unfair competition could arise from cases of hay rice straw being sold at the same price as cultivated grass hay which normally attracts higher cost price than rice straw-hay. The government therefore needs to step in and develop standards. These standards includes quality standards like moisture content or how long after cutting should the hay be baled. There is also a problem of selling hay through brokers who offer relatively low prices and sell to end users at a higher price. There is also need for the development of legislation to establish Strategic Feed Reserves (SFR). In developing standards for use of crop residue for feed, it is also important to note that the harvesting of crop residues and the growing of fodder has an effect on the nutrient reserves in the soil. The government should institute a study that will lead to the development of quality assurance systems for hays from fodder and crop residues. The role of the national and county governments is also required in the area of quality management for hayand facilitation of access to necessary ingredients.

It is noteworthy however that the indiscriminate improvement of the traditional Zebu is a threat to the indigenous germplasm that may have attributes that introduced breeds may not have. Additionally, the efficiency of the Sahiwal is likely to push cattle production into ASAL areas that were not been utilized before thus posing an environmental risk to these fragile ecosystems. This calls for government legislation and institutions to protect the indigenous Zebu cattle and zoning of areas in ASAL for protection and development of grazing systems for communities. Lastly, there is need for development of quality assured range seed certification to ensure full exploitation of the existing range and hay market since it is limited by lack of quality/ certified seeds.

5.2 Recommendations

- There is need for the government at national and county levels to come up with strategies to address the rapid rise in demand for livestock products.
- Quality standard is needed for the various forage and crop residues feed sources to ensure production of good quality hay and products and to discourage unfair competition in the market.
- Collective action should be encouraged in all the innovation clusters assessed which will not only ease service delivery but will also stimulate ease of access to both input and output markets.
- For the maize stover innovation, there is need for public and private maize breeding programmes to increase development of "stay green" maize varieties that are known to be high in foliage and nutrients compared to the dry stover.
- Research should advise on the trade-offs of crop residues and benefits of removal as feed in its various forms.
- A policy intervention is required for maize stover removal and the management of soil nutrients and organic matter content to create a win-win situation.
- Research on the MUMBs, urea treatment and TMRs should continue to explore ways to reduce the cost of the ingredients and also fabrication of affordable tools that farmers can use to improve on the maize stover quality.
- There is need to strengthen collaboration among all fodder value chain actors including national and county governments, private sector, farmers and research institutions to synergize efforts towards curbing national fodder deficits.
- Seed production of the cultivated fodders need to be enhanced in order to expand on hectarage under these forages.
- Credit should be provided to support producers to make the required investments on machineries and storage facilities.
- There is need for increase in use of ICT tools to enhance the spread of information widely on production practices, marketing and setting up of hay enterprise. This also applies to the Sahiwal breeding, the chicken and pig production, and marketing.
- For Sahiwal cattle, there is need to hasten the multiplication of selected best top genetypes using estrus synchronization and artificial insemination technologies as well as dissemination to wider pastoral areas.

- Farmers should be encouraged to embrace AI services and government should increase the number of inseminators because of high cost of raising bulls.
- There is need to have an organization to champion, regulate, develop and promote Sahiwal beef industry by tapping into possibilities/opportunities in other ASALs in Kenya and beyond.
- Government at both national and county levels needs to increase investments in livestock issues, such as livestock insurance schemes, infrastructure such as abattoirs and livestock markets which are potential drivers for upscaling of the innovation.
- There is need to come up with a strategy to preserve the indigenous cattle breeds such as the Zebu and other livestock types to avoid the risk of extinction and also to avoid pushing the breed into highly fragile areas.
- The KALRO Chicken (KC) needs to be accompanied by an innovative way of producing and distributing breeding stock to farmers as the demand is currently higher than the supply.
- There is need for more financial and physical resources for continuous improvement of the KC, which should spread beyond Kenya. A specific area of focus should be the black bird where research should be conducted to change color to a favorable one.
- A model similar to the one of IC should be extended to cover pig production in the country and the same could be extended to other value chains to minimize losses in the agricultural sector.
- Wider scalability of the pig industry will require a policy to be formulated to guide pig production and marketing and this could be spearheaded by the pig task force.

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Forum for Agricultural Research in Africa
12 Anmeda Street, Roman Ridge
PMB CT 173, Accra, Ghana
Tel: +233 302772823 / 302779421
Fax: +233 302773676
Email: info@faraafrica.org
Website: www.faraafrica.org

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