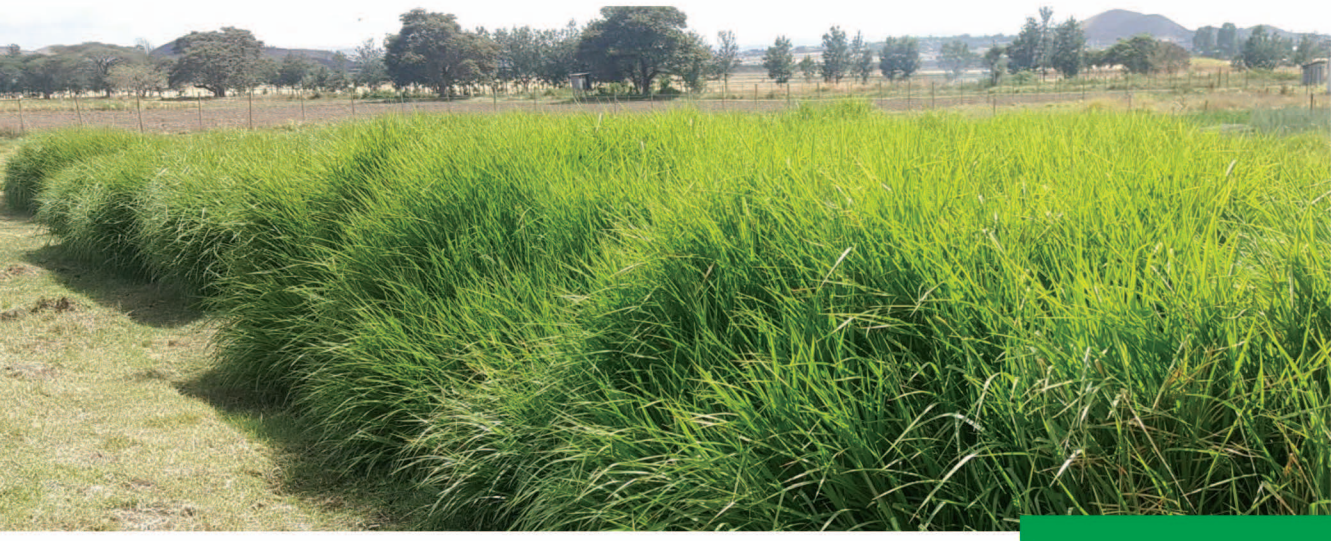
ETHIOPIAN INSTITUTE OF AGRICULTURAL RESEARCH

Livestock Research Strategies

Feeds and Nutrition, Rangelands and Animals Health

(2016-2030)



EIAR

Ethiopian ATA
Agricultural Transformation Agency
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Ethiopian Institute of Agricultural Research

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(2016 – 2030)

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Foreword

In the years ahead agriculture awaits a daunting task of feeding burgeoning population in a resource constraint world and under the influence of climate change while keeping society and environment safe. Agricultural research undoubtedly plays a key role for agriculture to fulfill its objectives. This, however, cannot be addressed through impromptu or with only a short-term research plan. Therefore, while addressing instant problems agricultural research needs to anticipate future needs as today's research will guide tomorrow's solutions and approaches in farming and agri-business. This is especially important in view of lag between conceiving and maturity of research, uptake by users, and ultimate translation into development.

This national program/thematic area-based strategy was therefore drawn within the context and in conformity with the need and evolving national and global emerging trends while taking advantage of the current and emerging opportunities. The strategy is framed in alignment to, among others, Global Sustainable Development Goals (SDGs), the various Ethiopian Ministries Growth and Transformation Plans(GTPIIs), EIAR's GTPII, National Agricultural Research roadmap, Climate Resilient Green Economy strategies and of course under the rubric of the country's medium term vision to become a middle income country by 2025.

While the strategy is lopsided on primary sector (production end) research attempt was also made to establish relevant links to the value networks/chains/ research to the extent it can be stretched.

The strategy development was initiated by and is a special contribution of EIAR to the Ethiopian National Agricultural Research System. As such, the strategy has been developed in close consultations with a wide range of stakeholders. Such a broad-based participation of key stakeholders is thus believed to ensure shared responsibility and ownership of the strategy.

EIAR has a strong conviction that the strategy will serve a vital document that will: specify the contribution of the research program/theme to the overall achievement of the objectives of Ethiopian NARS; serve as a framework to guide the research program planning and implementation; be used to track record of results and as a reference that can be monitored and reviewed and for mobilizing in resources from national and/or

international sources. By having a long-term strategy we specifically aim to focus efforts and fast-track desired outputs as well as achieve research priorities consistency and sequencing.

Indeed, laying down a 15 years plan seems a time too distant to accurately predict. But by scanning and analyzing the national and global trends, and possible future scenarios and signals we believe we have captured at least the coarse portrait of the future. Despite this, however, we by no means claim that it is a complete document. Rather our assumption is that the strategy will serve a live document and remain dynamic to respond to new and emerging problems that can be periodically reviewed and refined in the light of new developments. The full text of the original strategy is much more elaborated than this abridged version and can be retrieved from the EIAR's archive at: http://www. eiar.gov.et

On behalf of EIAR and my own, I would like to extend my sincere thanks to all those who invested their time and energy and, in one way or another, took part in the process of developing the Research Strategy.

Fentahun Mengistu (PhD)
Director General, EIAR

Acknowledgements

These research strategies of feeds and nutrition, rangelands and animal health were prepared by a core team of the different research programs of the Ethiopian Institute of Agricultural Research (EIAR) and researchers from the national research system including the regional research institutes and universities in their respective fields. The strategies were enriched into its current shape taking into account the comments given by stakeholders during two stakeholders' consultation meetings organized by the institute. The financial support of the RESARP project in this process is duly acknowledged.

The following researchers are highly acknowledged for taking the lead and commitment in preparation of the strategies;

1) Adugna Tolera, Solomon Mengistu, Seyoum Bediye, Fekede Feyissa, Gezahegn Kebede, Kidanie Desalgn and Aklilu Mekasha (feeds and nutrition research program)

2) Bedassa Ebba, Berhanu Megerssa, Ashebir Tegegne and Kidanie Desalegn (rangelands research program)

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Feeds and Nutrition Research Strategy

(2016 - 2030)

List of abbreviations and acronyms

ADLI	Agricultural Development Led Industrialization
ASARECA	Association for Strengthening Agricultural Research in Eastern and Central Africa
CAADP	Comprehensive Africa Agriculture Development Program
CGIAR	Consultative Group on International Agricultural Research
CRGE	Climate Resilient Green Economy
CSA	Central Statistical Agency
DM	Dry matter
EIAR	Ethiopian Institute of Agricultural Research
FAO	Food and Agriculture Organization
FDRE	Federal Democratic Republic of Ethiopia
GDP	Gross domestic Product
GIS	Geographic Information System
GoE	Government of Ethiopia
GTP	Growth and Transformation Plan
ICT	Information and Communication Technology
IGAD	Intergovernmental Agency for Development
ILCA	International Livestock Center for Africa
KM	Knowledge Management
LMP	Livestock Master Plan
MoLF	Ministry of Livestock and Fisheries
NIRS	Near-Infrared Spectroscopy
NRM	Natural Resources Management
PEST+	Political, Economic, Socio-cultural, Technological / Technical, and Environmental
SA	South Africa
SNNPR	Southern Nations, Nationalities and Peoples Region
SWOC	Strength, weakness, opportunities and challenges
WBISPP	Woody Biomass Inventory and Strategy Planning Project

Executive summary

1. Introduction

Background: The Ethiopian Institute of Agricultural Research (EIAR) has embarked on preparation of research strategies for the various commodities and research programs. This research strategy on animal feeds and nutrition is prepared to serve as a guide research interventions in animal feeds and nutrition aimed at generating appropriate technologies. Preparation of the strategy was based on review of pertinent literature, assessment of the internal and external environments and lessons learned from the previous Feeds and Nutrition research strategy (EARO, 2000). However, the scope of the current strategy is wider being capable of addressing the research needs of smallholders as well as that of commercial feed and livestock producers. In addition to the main themes of animal feeds and nutrition, the current strategy has given due emphasis to cross-cutting issues such as climate change, socio-economics, knowledge management and ICT, gender and human nutrition. Due attention has also been given to maintaining a fair balance among basic, applied and adaptive research in this strategy.

Rationale: The presence of large and diverse livestock resources, diverse agro-ecologies and different livestock production systems on one hand and the very low productivity of the livestock sector, the high attention given to and the ambitious targets set to benefit from the sector by the Ethiopian Government while building Climate Resilient Green Economy (CRGE) on the other were the rationale up on which preparation of the strategy was based. The strategy will serve as a blue print to guide research directions and priorities in animal feeds and nutrition to avail feed and nutrition technologies and innovations in order to enhance livestock production and productivity during the plan period of 2016 to 2030 guided by the vision, mission, goal, objectives and guiding principles of the research program.

2. Importance of Animal Feeds and Nutrition

This chapter describes the livestock and feed resources base of the country, the effect of animal feed and nutrition on livestock production and productivity and the contribution of animal feeds and nutrition to the macro-economic goals of the country through its effect on livestock production and productivity. It has also considered effects of animal feeds

and nutrition on food security, human nutrition and safety and quality of animal source food as well as animal health and welfare, farm economic viability and the environment.

Livestock and feed resources base: Ethiopia has a large livestock population that requires substantial amounts of good quality feed and appropriate feeding systems for increased productivity, value addition and transformation of the livelihood of livestock keepers. The feed resources potential includes natural pastures, cultivated forages, crop residues and stubble grazing, agro-industrial by-products, grain and grain screenings, compound or formula feeds, and others. The predominant feed resources are crop residues and natural pastures, both of which have low nutritional quality. The availability and supply of good quality feeds (concentrates and cultivated forages) are quite insignificant. There is critical shortage of supplements, premixes and feed additives, posing major challenge to livestock production

Effect of animal feeds and nutrition on livestock production and productivity: This sub-chapter addresses the effect of animal feeds and nutrition on productivity of the livestock sector. Contrary to the livestock resource and agro-ecological potential, the productivity of the livestock sector is very low. Poor feeding and nutrition limits the ability of animals to reach their genetic potential. Nutritional constraint leads to slow growth rate, and low production and reproduction performance. Nutritional problems lead to delayed age of onset of puberty, delayed age at first parturition, long parturition interval, low conception rates, and low overall lifetime reproductive and production performance.

Contribution to macro goals of the country: Livestock provide several benefits including supporting the livelihood as well as food and nutrition security of millions of people. The livestock resource sustains and supports the livelihoods of an estimated 80% of the rural population (FAO, 2004) and contributes 15 to17% of overall GDP, 47% of the agricultural GDP, and 37 to 87% of the household income. The LMP has set ambitious targets to increase meat, milk and egg production by 58%, 83% and 828%, respectively, in 2020 above the 2012/2013 totals. Such increments will not be possible without significant enhancements in feed availability, quality and utilization efficiency as poor feeding is a major impediment to livestock productivity (Shapiro et al., 2015). Improvements in feed quality and feed utilization efficiency will also contribute to the attainment of the

Climate Resilient Green Economy (CRGE) development strategy of GoE (FDRE, 2011).

3. Assessment of External and Internal Environments

The internal and external factors that affect successful accomplishment of the target objectives of a strategic plan at different stages from conception, formulation up to implementation stages were assessed and documented using the SWOC (Strengths, Weaknesses, Opportunities and Challenges) analysis. Assessment of the internal environment pertains to precise identification and articulation of the strengths and weakness of the research program. This includes careful assessment of institutional capacity (status of human, physical and financial resources), technical or technological capacity and organizational capacity which deal with the questions of functional integrations within and between disciplines to forge complementarities and synergies.

The external factors included general and operational external environments. The general external environment dealt with analysis of opportunities and challenges that stem from political, economic, socio-cultural, technological/technical, and environmental (PEST +) dimensions. Analysis of the operational external environment was dealt with analysis of stakeholders, their roles and demands from the research system. In addition, best practices and performances were bench marked to draw lessons from other countries that have advanced levels of research achievements in feed resources and nutrition.

4. Strategic Issues Facing the Feeds and Nutrition Research Program

The strategic issues facing feeds and nutrition were synthesized by filtering out those factors which can be addressed by the research program and for which a strategic planning could be developed. The identified strategic issues have been organized into General (issues that are common across the research program), two major themes (viz. feed resources, and animal nutrition and feeding systems). The issues identified under General theme are mainly related to the human resource, physical and financial capacity required for effective undertaking of research and delivery technologies responsive to the needs of various users. The feed resources theme is further divided into four sub-themes (cultivated forages; natural pastures; agro-industrial by-products, crop residues and other feed resources; and

formula feeds, premixes and feed additives). Moreover, gender, climate change, socio-economics, human nutrition and knowledge management and ICT were presented as a fourth crosscutting theme.

5. Research Themes and Strategic Interventions

Strategic interventions have been designed for each of the strategic issues presented under the different themes and sub-themes for the next fifteen years (2016-2030).

General: The capacity of the feeds and nutrition research program (human resource and research facilities) should be strengthened and the researchers should be equipped with the state of the art techniques and specializations required for a comprehensive and balanced research engagement in basic, strategic, applied and adaptive research. The research program should be equipped with state of the art research facilities (laboratories, experimental houses and facilities, irrigation facilities, seed stores, and facilities for application of modern biotechnology, etc).

Feeds resources

Cultivated forages: Future research in cultivated forages envisions development of varieties suitable for different production environments and refining of production packages as well as generating tangible evidence to show that forages are competitive and better enterprise choices to ensure adoption by various target groups.

Natural pastures: The area of land under natural pasture is shrinking from time to time owning to expansion of arable cropping, urbanization and industrial development all at the expense of grazing land particularly in mixed crop-livestock farming systems. Thus, the main strategic research issues will focus on exhaustive mapping and enhancing effective management and utilization of pastureland available in pocket areas in different parts of the country.

Agro-industrial by-products, crop residues and other feed resources: In views of the expansion crop cultivation and expansion of agro-processing industries, substantial quantities of various by-products of great importance as livestock feed are being produced in Ethiopia. Thus, the potential availability, management and utilization of different agricultural and agro-industrial by-products and interventions needed to ensure their efficient utilization have been identified to be among the focus of subsequent feeds and nutrition research in this strategy.

Formula feeds, premixes and feed additives: Considering increasingly expanding feed processing and commercial livestock production in Ethiopia, availing technological options for developing biologically efficient formula/processed feeds for various classes of animals at the least possible cost have been identified to be taken up as important issues to be addressed by the feeds and nutrition research.

Animal nutrition and feeding system: In view of the sky rocketing prices of animal feeds, most of the strategic issues identified under this theme shall focus on the search for alternative feed resources/ingredients and development of cost effective and biologically efficient feeding packages for the various species and classes of animals. The ultimate target is to contribute to the realization of the country`s ambition of satisfying domestic demand for animal products and generating foreign exchange by increasing production of export quality products.

Crosscutting issues: Determinants of technology adoption encompass characteristics of the technology, features of the farming system, market and policy environments as well as socio-economic characteristics of the decision making unit (household or farmer). Thus, this research strategy has been designed in a manner that takes into account different cross-cutting issues such as gender, climate change, knowledge management and ICT, socio-economic and human nutrition.

6. The next Steps

Preparation of implementation will follow after approval of the strategy by the top management of EIAR. The implementation plan will come out as Volume II of the research strategy and serve as a blueprint to guide the National Feeds and Nutrition Research Program for the next fifteen years (2016-2030). The implementation plan will also include monitoring and evaluation, impact assessment and reassessment plans for the strategy.

Feeds and Nutrition Research Strategy (2016 - 2030)

1. Introduction

1.1. Background

The success of any research organization to improve research performance and deliver good quality and relevant research outputs depends on proper understanding of the drivers of research and development process. Successful research performance and delivery often depends on interactions of many different decisions and choices, including the size and location of research facilities, the division of labor between various groups, the choice of technologies used inside the research organization, the selection of personnel, the allocation of resources, the design of processes for managing projects, and other factors. The performance of a research organization hinges on the coherence between the components. The system may also have some strengths and weaknesses; and could face some challenges and opportunities. A research system needs a research strategy in order to manage trade-offs, overcome its weaknesses, fully exploit its strengths and change its challenges to opportunities, be coherent in its operations and achieve superior performance.

The success of Ethiopian Institute of Agricultural Research (EIAR) and the National Agricultural Research System in strengthening research performance and delivering good quality and relevant research outputs that will contribute to agricultural transformation of the country will depend on the ability of the Institute and the national system to properly understand the drivers of research and development processes and readily respond to urging socio-economic, environmental and policy demands of the country for agricultural technologies, information and knowledge. To this end, the Institute has embarked on preparation of research strategies for the various commodities and research programs guided by its vision, mission and mandate and aligned to the Government's development policy frameworks.

Being well aware of the importance of the livestock sector to the national economy and to the livelihood of millions of Ethiopians who depend on

this sector in one way or another, the Institute has embarked on preparation of research strategies for various livestock commodities under the direction of the Livestock Research Directorate. In addition, considering the role of animal feeds and nutrition in determining livestock production and productivity, the Institute has taken a courageous step of preparing a separate strategy for Animal Feeds and Nutrition Research Program. The strategy will serve as a guide to generate animal feed and nutrition technologies, knowledge and information that will enhance the capacity of the livestock sector in the short-, medium- and long- term timeframes spanning five, ten and fifteen years, respectively.

The draft of this research strategy was prepared by a core team of animal feeds and nutrition researchers of the Institute with the support of a senior expert in the field who was employed for a short term through the Institute's initiative of re-engaging senior researchers. The strategy was drafted based on review of pertinent literature, assessment of the internal (strengths and weaknesses) and external (opportunities and challenges) environments that can influence the performance and research delivery of the Animal Feeds and Nutrition Research Program, and drawing on the experiences of and lessons learned from the first research strategy developed 15 years ago (EARO, 2000). However, the current strategy has widened the scope of focus to address the research needs of various target groups such as commercial feed and livestock producers in addition to the traditional smallholder focus. Efforts have also been made to maintain a fair balance among basic, applied and adaptive research. The strategy has also given due emphasis to cross-cutting issues such as climate change, socio-economic and gender in addition to the disciplinary animal feeds and nutrition. Another point of departure of the current strategy from the previous one is the fact that the current strategy puts more emphasis on generation and transfer of effective animal feed and nutrition technologies that will have a big impact on transforming the livestock sector. It also gives due emphasis to the value chain approach, feed safety and quality issues as well as the linkage of animal nutrition with human nutrition. The strategy was further enriched taking into account the comments given by stakeholders during two stakeholders consultation meetings organized by the Institute.

The strategy is organized in six major chapters. Chapter 1 covers this background section together with descriptions of the rationale, vision, mission, goal, objectives, and guiding principles of the Animal Feeds and

Nutrition Research Program. Chapter 2 provides an overview of the importance of animal feeds and nutrition for the livestock sector development including highlights of the feed resources base, effects of feeds and nutrition on livestock production and productivity, and contribution of the Program to macro- economic goals of the country. Chapter 3 discusses the strengths, weaknesses, opportunities and challenges (SWOC) consolidated from assessments and analyses of internal and external environments influencing the performance and success of research in animal feeds and nutrition. Chapter 4 deals with the critical issues facing the animal feeds and nutrition research that have been identified from assessments of the external and internal environments. Chapter 5 discusses the actual research strategies to be pursued to tackle the critical issues identified. Chapter 6 provides key elements of actions that need to be taken by the EIAR top-management as well as follow up documents that need to be worked out in the next steps for effective implementation of the strategy.

1.1. Rationale for animal feeds and nutrition research strategy

Ethiopia is endowed with a huge livestock population, diverse animal genetic resources and diverse agro-ecologies suitable for different livestock production systems. However, the potential of the livestock sector has not been fully exploited and the contributions achieved so far have been much below the potential because of low productivity. The livestock sector is suffering from low production levels and poor reproductive performance. Ethiopia's livestock production is characterized by poor feed conversion efficiency, poor body weight gain, low milk and meat production level, low off-take rates, low conception and parturition rates, long parturition interval, and high mortality and morbidity losses. The prevailing low productivity level of the livestock sector is the result of several factors, among which shortage of feed supply, low quality of commonly available feed resources and poor nutritional status of the animals play a major role. The high cost and low availability of good quality animal feed is a critical challenge severely limiting livestock productivity. The major sources of feed for livestock are natural pastures, crop residues and other agricultural by-products. The quantity and quality of available forage is critically low during the dry season. The problem is exacerbated by recurrent drought and the pastoralists' loss of key dry

season and drought reserve grazing areas due to increasing population pressure and expansion of crop production into grazing areas.

On the other hand, the Government of Ethiopia (GoE) has set an ambitious target for livestock sector in terms of increasing production and productivity and thereby contributing to poverty reduction, attainment of better food and nutrition security, national income growth and foreign exchange earnings as outlined in the second Growth and Transformation Plan (GTP II) for the period 2015-2020 and Livestock Master Plan (LMP; Shapiro et al., 2015). Overall, there is a huge expectation from the livestock sector to play direct and catalytic roles to make the above indicated contribution to the national development goals of the country while at the same time contributing to climate change mitigation and adaptation as indicated in the Climate Resilient Green Economy (CRGE) development strategy of the country (FDRE, 2011). Furthermore, there is increasing demand for livestock products, which requires proportional increase in livestock production and productivity. The key pillar in achieving these objectives is the issue of improving livestock productivity. In general, livestock and animal feed have moved to the forefront of the priorities of the GoE under GTP II. These targets can only be met through securing year-round supplies of good quality feeds and efficient utilization of the available feed resources through improved feeding management.

The key challenge will be how to attain improvements in productivity when the feed resource base is poor quality crop residues and low quality natural pastures. Moreover, there is substantial loss of energy in the form of enteric methane emission when animals depend on crop residues and other poor quality roughage based diets resulting in reduced efficiency of feed utilization, poor animal performance and higher greenhouse gas emission per unit of product. Feed production and processing industries are not well developed and good quality supplemental feeds are in short supply and very expensive.

Feed formulation or ration balancing is crucial to make the best and most effective use of the available feeds and to supply the necessary nutrients that allow animals to express their genetic potential for growth, development and production (Tedeschi and Muir, 2015). The nutrient (energy, protein, minerals and vitamins) requirements of farm animals have long been known in the developed world. However, lack of information on nutrient requirement of indigenous livestock breeds in sub-

Saharan Africa is one of the challenges limiting the application of ration formulation principles and precision feeding practices to improve animal productivity and enhance overall performance of the sector. Thus, there is a need for more nutritional studies to address issues such as climate smart feed production practices, robust prediction of animal growth, body composition, feed requirements, outputs of waste products from the animal and production costs (Thornton, 2010).

In the past, research works that include cultivated forages, use of multipurpose trees, improvement and utilization of fibrous crop residues and strategic supplementation were carried out with the aim of improving the quality and availability of feed resources. However, the extent/depth and approach of most of the research work was fragmented and could not bring transformation to alleviate nutritional challenges, improve livestock productivity and minimize the negative impacts of livestock on the environment. There is a need for strong research programs dealing with food-feed traits of most crops grown in the crop-livestock mixed farming systems. Similarly, strong and systematic research programs are needed to screen the presence, alleviate the anti-nutritional effects and exploit the beneficial roles of secondary plant metabolites in commonly used herbaceous forages and fodder trees. Moreover, there is a need to create a strong platform where scientists and end users of research outcomes (farmers and the private sector) continuously interact in developing problem solving research agenda, evaluating research findings and designing strategies for wider adoption of promising feed technologies.

The Animal Feeds and Nutrition Research Program will spearhead nutritional studies that will address issues such as robust prediction of animal growth, body composition, feed requirements, improving feed utilization efficiency, reducing enteric greenhouse gas emission, and reducing production costs. In this respect, there is potential for addressing the problems at reasonable cost by identifying alternative feed resources, appropriate feed processing and conservation measures, determining the nutrient requirement of different species and classes of animals, ration formulation and appropriate feeding management. Other areas of high priority for additional exploration, which could potentially have broad implications for livestock production in Ethiopia and Africa at large, include microbial genomics of the rumen to enhance efficiency of utilization of lignocellulosic feeds, livestock-water interaction and

strategies of enhancing livestock water use efficiency, and feed processing and feeding management to improve nutrient absorption.

Availing technological innovations which would support livestock productivity is a key area of intervention in attaining growth and transformation of the livestock sector. Results from a recent sectoral analysis indicates that the current level of feed availability estimated at 81-127 million tons DM should be raised to 202 million tons DM by 2030 indicating a huge task to be accomplished to attain the stretched objectives (Shapiro et al., 2015). As a component of the entire feed supply, the report also recognizes the contribution of cultivated forage towards boosting the productivity of improved family cattle dairy, specialized dairy and improved traditional red meat-milk production sub-systems. It also underlines that if business continues as usual, livestock production will be highly threatened due to lack of feed, let alone achieving the set targets in the road map. Ensuring adequate feed availability would thus require knowledge based interventions for reducing key barriers in the feed sub sector.

Thus, this strategic document of Animal Feeds and Nutrition Research Program has been developed to serve as a blue print to guide research directions and priorities in animal feeds and nutrition to avail feed and nutrition technologies and innovations in order to enhance livestock production and productivity during the plan period of 2016 to 2030. Owing to the fact that constraints, potentials and priorities are influenced by a range of internal and external factors arising through time and space, this strategic document shall be reviewed periodically and adjusted accordingly.

1.2 Vision

The vision of Animal Feeds and Nutrition Program is to be dependable source of scientific information and technological innovations in animal feeds and nutrition to build vibrant animal feed and livestock industry by 2030.

1.3 Mission

The mission of the Program is to avail technological and institutional innovations in animal feeds and nutrition that can improve productivity of

animals and thereby contribute to poverty reduction, nutritional security, economic growth/social transformation and environmental sustainability.

1.4 Goal

The development objective of feeds and nutrition Program is to contribute to the country's macro level economic, social and environmental goals pertaining to (i) ensuring food and nutritional security, (ii) sustainable supply of raw materials for agro-industries and import substitution, (iii) expanding the bases for the country to gain foreign earnings from agricultural exports, and (iv) increasing livelihood resiliency and environmental sustainability while reducing vulnerability to and exacerbation of climate change.

1.5 Objectives

The overall aim of feeds and nutrition research is to facilitate generation and uptake of demand driven animal feeds and nutrition innovations which contribute for increased productivity, product quality, sustainability and competitiveness of the feed and livestock industry in Ethiopia. The specific objectives are to:

(1) To strengthen human and physical capacity of feeds and nutrition research in Ethiopia.

(2) To avail improved feeds and nutrition information and technologies that would contribute to sustainable, rapid and equitable development via promotion of the feed and livestock industry

(3) To coordinate animal feeds and nutrition research across the nation and play key role in creating innovation platforms for research priority setting, effective technology generation and uptake towards growth and transformation of feed and livestock industry.

(4) To undertake participatory demonstration and popularization of biologically and economically feasible, socially acceptable and environmentally sustainable animal feeds and nutrition technologies to support growth of feed and livestock industry along the path of market-led economy and commercialization.

1.6 Guiding principles

The national feeds and nutrition research Program will be guided by the following important and governing principles.

- Alignment with the development policy and plans of the country
- Demonstrating transparency, accountability, inclusiveness, and gender equity
- Enhance competitiveness of the program through capacity building and harnessing application of state-of-the art technology and cutting edge science for effective research engagement in basic, strategic, applied and adaptive research on animal feeds and nutrition
- Capitalize on fundamental knowledge globally available and make good uses of experiences and practices from other countries in the tropical region and move in a catch up approach in availing information and technology to users
- Establishing and sustaining collaborative research relationships with relevant organizations (national and international), sectors (crops, natural resources, social science), inter and intra-disciplines
- Integrating value chain and innovate systems perspectives to biological research for ensuring competitiveness of the feed industry which would serve as spring board for enhancing productivity, product quality and environmental sustainability of livestock sub-sector
- Accountability to clients and users and encouragement of a vibrant public private partnership in animal feed and nutrition research for development
- Establishing innovation platform to support participatory research planning, implementation, and monitoring and effective technology transfer
- Creating favourable research environment and multidisciplinary team approach

2. Importance of animal feeds and nutrition

Sustained availability of the desired type and quantity of animal feed and its feeding is the foundation of livestock production systems. Animal feed availability and animal feeding is a multi-faceted theme. It influences all livestock sub-sectors across production systems. It also has far reaching effects on human nutrition, poverty, food prices and global economy. It impacts almost every sector of the livestock production – from animal reproduction, health and welfare – to farm economic viability, environment, animal product safety and quality (Figure 1).

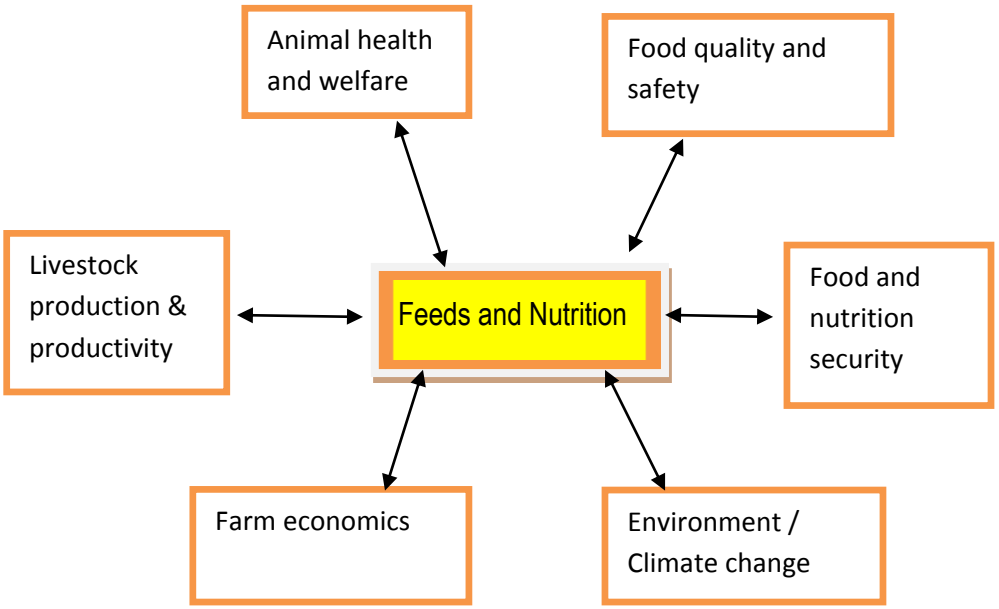

Figure 1. Impact of feed and feeding on various aspects of livestock operation

2.1. Livestock and Feed Resource Base

2.1.1. Livestock resources

Ethiopia has a large livestock population and diverse livestock genetic resources. The CSA (2015) estimate puts the country's livestock population at 56.71 million heads of cattle, 29.33 million sheep, 29.11 million goats, 1.16 million camels and 56.87 million poultry. These estimates are excluding livestock population in the non-sedentary areas of Afar and Somali Regional States. With its huge livestock population and diversity, Ethiopia accounts for 27% (FAO, 2009) of the entire livestock population in the Eastern and Central African countries. Despite the significant importance and immense potential of the livestock sector at national and household levels, the productivity of the livestock sector is much below the potential due to various technical and non-technical constraints. The main technical constraints include inadequate feed supply and inefficient feed management and utilization, widespread diseases and poor health and poor breeding practices. The huge livestock population requires substantial amounts of good quality feed and application of appropriate feeding systems for increased productivity, value addition, sustenance of natural resource base and transformation of farmer's livelihood.

Moreover, the country has diverse agro-ecologies suitable for different kinds of livestock production. There are three major livestock production systems in the country. These are smallholder mixed crop-livestock production, pastoral and agro-pastoral livestock production, and the urban and peri-urban livestock production systems. The mixed crop-livestock system is found in the high and mid altitude areas. The pastoral and agro-pastoral systems are found in the arid and semi-arid lowlands of Afar, Somali, Oromiya, and SNNP Regional States. The urban and peri-urban production system is an emerging component of the livestock sector, which includes smallholder and commercial dairy, feedlot and poultry operations around the major towns.

2.1.2. Feed resources

The national feed resources potential includes natural pastures, cultivated forages, crop residues and stubble grazing, agro-industrial by-products such as grain milling by-products, oilseed cakes, brewery by-products

(brewers grain and yeast), sugar factory by-products (molasses, cane tops and baggasse), abattoir by-products (bone meal, blood meal), fish meal (fish offal), grain and grain screenings (maize, sorghum, oats, soybean, lupin etc.), compound or formula feeds, and other feeds such as foliage and pods of trees and shrubs, fruit and vegetable wastes, foliages and by-products of root and tuber crops, thinning, leaf striping and topping of crops such as maize, sorghum and sugar cane, cactus pear etc. In some localized places there are specific mineral soils and limestone that can be used as mineral supplements. The availability and distribution of these feed resources vary very widely depending on the agro-ecology and production systems.

2.1.2.1. **Cultivated forages and pastures**

Improved forage crops provide useful nutrients especially in the rural areas where availability and accessibility to agro-industrial by-products is a problem.

Multidimensional roles of forages: Improved forage crops have diversified functions and play an important role in sustaining the livelihoods of farmers, mainly as a result of their positive effects on livestock production and contribution to economic and environmental sustainability. Besides producing high amount of better quality forage, they have a number of other benefits in the farming system including improvement of soil fertility through biological N-fixation or when used as mulch (legumes), erosion control when established as conservation structures, fuel wood supply, bee forage and control of weeds, pests and diseases when integrated in crop rotation as break crops. Generally, use of improved forage crops is an important step in supporting and improving livestock productivity while maintaining environmental sustainability in agrarian societies like Ethiopia. Additionally use of cultivated forages reduces pressure on natural resources via zero grazing and supply of high biomass and superior quality feed to ruminant livestock. Forage crops (reach in tannin) also offer a special benefit of huge environmental impact in terms of reducing greenhouse gas emission. Moreover, combined use of cultivated forages with genetically improved animal gives benefits of increasing feed conversion efficiency leading to increased livestock productivity and reduction of greenhouse gas emissions which would serve as a base towards attaining food and nutrition security and climate resilient green economy.

Forage seeds and planting materials: Forage research and existing forage production technologies are focussing mainly on herbage productivity, major agronomic practices and feeding values of the forage crops. Forage seed production has not been given due emphasis both in research and extension. As a result, the available forage seed production is generally scanty. So far only very preliminary research activities have been carried by some research and/or development institutions. Seed production of forage crops is a complex process because different forage crops require different agronomic practices, special techniques of harvesting, threshing, and seed processing.

Improved forage technology transfer and adoption: In spite of the critical shortage and low quality of the available feed resources, the rate of adoption of forage and pasture production and utilization is extremely low in Ethiopia due to various factors, which may include low economic incentives under subsistence production system, limitations in support service delivery and policy and institutional issues. There are many reasons for the poor adoption of improved forage crops (Benin et al., 2003; FAO, 2004). However, the potential for adoption of improved forages could be high when market oriented livestock production is possible and improved animals (crossbred) respond to improved feeding. Farmers may readily accept improved forage production and feeding management if the return from the investment is attractive. Thus, forage production and utilization in feeding systems must go hand in hand with market oriented livestock production and efficient marketing of livestock and livestock products. In evaluation of forage crops, ease of establishment, biomass production, flower setting and seed production potential, persistency for prolonged time, resistance to diseases and pests, forage quality as animal feed, and other complementary benefits such as soil fertility improvement, ability to protect soil erosion, ability to grow on marginal lands and climatic conditions are considered as selection criteria.

2.1.2.2. **Natural pastures**

Traditionally livestock feeding in Ethiopia is based on grazing of natural pastures and fallow lands augmented with crop residues and stubble grazing. However, due to rapidly increasing human population there is expansion of cropping into traditional grazing areas leading to over grazing

and degradation of the remaining grazing lands. Moreover, there is marked seasonal variation in availability and quality of natural pastures following seasonal distribution of rainfall. Thus, appropriate research intervention is needed to devise suitable management strategies to mitigate further degradation of grazing lands and to optimize their utilization as sources of feed and to evaluate the effectiveness and pros and cons of currently implemented strategies such as area closures.

2.1.2.3. **Crop residues, agro-industrial by-products and other feed resources**

Crop residues are becoming increasingly important as sources of roughage feeds for ruminants. These include cereal straws, grain legume haulms, sweet potato and cassava tops and vines, sugarcane tops and *enset* by-products and other feeds derived from different land use systems. However, the nutritive value of crop residues is variable depending upon the species and variety of the crops, time of harvest, handling and storage conditions and other factors. Cereal straws and stovers are generally characterized by relatively low nutrient content, high fiber content, low digestibility, and low voluntary intake (limited consumption) by animals. Most roughage feeds are bulky and of low nutrient density, which makes the transportation cost very expensive relative to the nutritive value of the feeds especially when they are transported over a long distance. Thus, provision of such feeds should be planned based on ease of accessibility of source of supply. Without supplementation, crop residues cannot satisfy even maintenance requirements of animals primarily because of low N, high cell wall and slow digestion leading to a negative N balance, loss of body weight and reduced productivity and death of the animal in critical cases.

Agro-industrial by-products are the by-products of the primary processing of crops. They include flour mill by-products, oilseed cakes, brewery by-products, and molasses. These feed ingredients are the main constituents of concentrate feeds. The production and supply of most agro-industrial by-products is uneven, localized and limited in quantity. Thus, the supply of agro-industrial by-products is not consistent all year round and is not adequate to boost productivity of livestock. The brewery by-products are wet and pose handling, transport and storage problems, which makes it difficult to effectively use them in areas far away from where they are produced.

In order to overcome the prevailing feed shortage and quality problems, it is important to screen a wide range of potential feed resources in order to expand the feed resource base. Such potential feed resources include thinning, leaf stripping and toping from crops such as maize, sorghum and sugar cane; various by-products of root and tuber crops, fruits and vegetables, and foliages and pods of various tree leaves and shrubs, including cactus pear.

2.1.2.4. **Formula feeds, feed supplements and additives**

Two or more feed ingredients that are processed, proportioned and mixed according to specifications are known as compound feeds or formula feeds. Since such feeds are normally processed and mixed in feed mills, they are also known as manufactured feeds. The type of ration to be formulated and mixed could be a complete ration, concentrate mix, supplement and premix depending upon the role the intended ration is expected to play in the animal's diet. Complete feed refers to a nutritionally complete mix of feed ingredients intended to be fed as a sole ration. Such products are common for non-ruminants such as poultry and swine. The same concept also applies to ruminants when they are offered total mixed ration (i.e. a ration produced by mixing all feed ingredients or components including the roughage, concentrate supplements as well as mineral and vitamin supplements). Concentrate refers to a feed or mix of feeds high in energy and/or protein fed with one or more other feeds so as to improve the nutritional balance of the total ration. A supplement is a feed or mix of feed ingredients high in one or more of protein, energy, minerals, vitamins and/or feed additives intended to be fed in limited amounts (often 10% of the diet or less) together with the basal diet so as to improve the nutritional balance of the diet as a whole. A premix refers to a uniform mixture of one or more of micro-ingredients and a carrier used as a means to add nutrients or additives needed in very small amounts to a much larger batch of feed, e.g. a supplement. Micronutrients are usually added to the feeds as vitamin and mineral premixes and they are needed for optimizing growth rate, reproduction, health, immunity and overall performance of animals, esp. non-ruminants.

2.1.2.5. **Feed Resources Availability and Quality**

Estimate of national availability of feed from different sources is shown in Table 1. Cereal, pulse and oilseed crop residues were estimated from crop production data based on CSA data (CSA, 2013) whereas other agricultural by-products were estimated based on 2010/11 crop production data from CSA using conversion factor (FAO, 1987). The amount of feed obtainable from different grazing sources was based on estimations of Woody Biomass Inventory and Strategic Planning Project (WBISPP, 2001). The total annually available feed according to this estimate was 90.8 ton DM, which is higher than the previous estimate of 76.4 million ton DM (Tolera et al., 2012). Cereal crop residues have the highest contribution to the total feed supply at country level. At national level, cereal and pulse crop residues contribute about 50% of the total feed supply followed by grazing (40%), whereas the balance is supplied by other agricultural and agro-industrial by-products (Tolera, 2007). The Ethiopia Livestock Master Plan document by Shapiro et al. (2015) also showed an estimated annual feed supply of 81-145 million ton DM using assumptions based on different scenarios (Table 2). Such variability calls for more comprehensive and rigorous assessment of the feed resource base of the country as a basis for further research on feeds and nutrition to generate appropriate technologies and information for a sound livestock sector development planning.

The predominant feed resources are cereal crop residues and natural pastures (Table 1), both of which are low in nutritional quality. The nutritive value of crop residues is variable depending upon the species and variety of the crops, time of harvest, handling and storage conditions and other factors. Cereal straws and stovers are generally characterized by relatively low nutrient content, high fibre content, low digestibility and low voluntary intake (limited consumption) by animals. The haulms of pulse crops (grain legumes) represent relatively better quality straws with a crude protein content of 5-12%. Most roughage feeds (hays and straws) are bulky and of low nutrient density, which makes the transportation cost very expensive relative to the nutritive value of the feeds especially when they are transported over a long distance. Thus, provision of such feeds should be designed in such a way that they come from easily accessible sources in an economical way. If roughage feeds have to be transported long

distances they have to be dense and highly digestible to keep the price of the feed to a minimum.

Natural pastures are naturally occurring grasses, legumes, herbs, shrubs and tree foliage that are used as animal feed. The availability and quality of natural pastures vary with altitude, rainfall, soil type and cropping intensity. The level and distribution of available soil nutrients and water are the main limiting factors. The quantity and quality of feed obtainable from natural pastures declines as the dry season progresses. The protein content and digestibility of most grass species decline rapidly with advancing physiological maturity of the plants and reaches very low levels during the dry season.

On the other hand, the availability and supply of good quality feed resources such concentrates and cultivated forages are quite insignificant. Concentrate feeds are characterized by high energy and/or protein contents. They mostly include various agro-industrial byproducts and occasional surplus grains and grain byproducts. In addition, there is critical shortage of various feed supplements (mineral and vitamin supplements), premixes and feed additives. Experiences and evidences from other countries show that it would be unrealistic to expect increased productivity and transformation of the livestock sector on feed resources dominated by poor quality natural pastures and crop residues without significant increase and sustainable supply of concentrates and good quality forages as well as mineral, vitamin and limiting amino acid supplements.

Table 1. Quantity of different feeds available in Ethiopia

Feed sources	Quantity (million ton DM/annum)	Percent of total
Cereal straws/stovers[1]	47.1	51.85
Pulse crop haulms[1]	2.75	3.03
Oilseed straws[1]	1.43	1.57
Vegetable wastes[2]	0.102	0.11
Root crop by-products[2]	0.47	0.52
Fruit crop by-products[2]	2.16	2.38
Chat & coffee by-products[2]	0.17	0.19
Sugar cane tops[2]	0.36	0.40
Enset[2]	5.56	6.12
Aftermath grazing[3]	8.12	8.94
Pasture grazing[3]	10.44	11.49
Fallow land grazing[3]	6.56	7.22
Woodland grazing[3]	1.49	1.64
Oilseed cakes [2]	0.14	0.15
Wheat milling by-products[2]	0.34	0.37
Others (5% of total)	3.64	4.01
Total	**90.83**	**100**

**Sources:* [1]CSA (2013); [2]Tolera et al. (2012); [3]WBISPP *(2001)*

Table 2. Feed resources availability (million ton DM/annum) in different livestock production zones of Ethiopia assuming years of good, medium and bad weather conditions (Shapiro et al., 2015)

Livestock zones	Good weather year	Medium weather year	Bad weather year
Lowland grazing and agro-pastoral	68	51	34
Highland mixed crop-livestock, rainfall deficient	28	19	15
Highland mixed crop-livestock, rainfall sufficient	49	38	32
Total	**145**	**108**	**81**

2.2. Effect of Animal Feeds and Nutrition on Livestock Production and Productivity

2.2.1. Effects on production performance of livestock

Poor feeding and nutrition limits the ability of animals to reach their genetic potential. Nutritional constraint leads to slow growth rate in growing animals and low production and reproduction performance. Poorly fed animals give low output of meat and milk and have compromised immune system and ability to fight diseases. Nutritional problems also lead to delayed age of onset of puberty, long parturition intervals, low conception rates, and low overall lifetime productivity. Feed shortage and poor quality of the available feed resources constrain animal output all over the country. Grazing animals subsist mainly on poor quality pastures and crop residues. In some livestock operations, where supplementary feeds are given, the main supplements are protein and energy in the form of agro-industrial by-products such as oilseed cakes and cereal brans. Very often little or no attention is given to the mineral and vitamin contents and nutritional balance of the diets.

In poorly fed animals, feed resources utilization is highly inefficient. In Ethiopian smallholder livestock production system, 85% of the feed intake

is used to meet maintenance requirement of the animal and only 15% is used for production. Poor feed reduces the impacts of other interventions such as estrus synchronization and artificial insemination to boost livestock productivity. Therefore, the feasibility and profitability of livestock enterprises is a function of the type of feed and feeding system. It is estimated that up to five-fold increase in productivity of tropical livestock can be attained if there is optimal feed resources utilization (Yami, 2008). However, the economics of productivity (output/unit time) is different when a feed with low to moderate nutritional value has low/no cost.

In the case of poultry as well, the genetic make-up or breed of chicken, provision of the necessary inputs, nutrition, disease prevention and control and overall management practices influence the production and productivity. In general, the production and productivity of indigenous chicken is very low due to a combination of different factors (nutrition, health, genetics and overall management). Similarly, the performance of high producing exotic lines could not reach their maximum potential due to failure to provide optimum production environment. Overall, shortage and increasing price of feed ingredients and compound feeds and high taxation rate on imported premixes and feed additives are currently posing a significant challenge to the development of the poultry sector in Ethiopia.

Growth rate: Underfeeding and malnutrition lead to low birth weight and sub-optimal growth rates in farm animals. Under poor feeding conditions, animals take too long to reach optimum slaughter weight and the meat produced by such animals may not satisfy the desired quality attributes such as tenderness to satisfy the requirements of the consumers. Hence, the plane of nutrition affects the age at which slaughter animals can be marketed or slaughtered and both the quantity and quality of meat produced when the animals are slaughtered. Slow growth of heifers increases cost of rearing the heifers as they will not be bred and come into production at an early age. Heifers on high plane of nutrition can attain puberty and first calving at an early age, require less number of services per conception, and produce more milk in the first lactation. Hence, proper supplementation of growing heifers would be necessary to achieve rapid growth, early maturity, high subsequent milk production and increased lifetime productivity (Yilma et al., 2000; Gojjam et al., 2011).

Milk production: The average milk yield of local cows under traditional farmers' management is about 1.5 liters per head per day with an average lactation length of about 6 months. However, well-managed Horro cows were reported to produce an average of 4 liters milk at peak lactation, which decreased to 2.2 liters during late lactation (Mekonnen, 2008). The average milk yield of crossbred cows under farmers' management varies from 4 to 6 liters per head per day. On-farm milk production performance of Barka-Friesian and Barka-Jersey crossbred cows at mid-altitude and highland agro-climatic zones around Bako and Holeta Research Centers, respectively, was found to be in the range of 3.9-5.4 liters/head/day (Kumsa, 1995). On the other hand, the crossbred cows produce an average of about 8-12 liters of milk in commercial dairies and government farms. The production gap between farmers' management and commercial producers is a reflection of feeding and management differences. There is seasonal fluctuation in the supply of different feed ingredients even to the commercial producers. Thus, the performance of the crossbred cows even under the commercial setting is suboptimal by the international standards.

Mortality rate: Nutritional stress results in high mortality rate of young and mature animals thereby causing high economic loss to livestock producers. A study conducted over 10 years at Bako Research Center showed a low survival rate of 42% to yearling age for Horro lambs, which represents a major economic loss. The study also further indicated that there is a significant relationship between body weight, which is a function of feeding management and nutritional status of the animals, and survival rate of the lambs (Gojjam et al., 2005). During prolonged dry seasons or droughts, there is massive death of livestock in the pastoral areas due to shortage of feed leading to starvation of the animals (PLI, 2007).

2.2.2. **Effects on reproductive performance**

The reproductive efficiency of breeding animals is determined by factors such age at first mating, age at first parturition, parturition interval, and number of services per conception. Nutritional problems lead to delayed age of onset of puberty, delayed age at first parturition, long parturition interval, low conception rates, and low overall lifetime reproductive performance.

Age at first parturition: Age at puberty and first parturition are important factors that limit productivity of animals. Age at first calving marks the

beginning of the productive life of a cow and influences her lifetime production and reproduction performance. It has a direct influence on the lifetime calf crop and milk production of the cow and an indirect influence on the cost of upbringing the cow. Heritability of age at first calving is low, which indicates that it is highly influenced by environmental factors such as the type and quality of feed supplied and the feeding management. Nutritional stress causes slow growth rate. Hence, heifers attain age at first sexual maturity and at first calving very late. The age at first calving of Boran heifers under pastoral management condition was reported to be 4 years (Coppock, 1994) whereas under improved management at the former Abernossa ranch the heifers reached puberty at 22 months of age (Tegegne, 1989).

A recent study (Gojjam et al., 2011) showed that nutritional manipulation of Friesian-Boran crossbred dairy heifers in the post-weaning period accelerated the growth rate and improved reproductive performance of the heifers. Attainment of puberty at an early age could enhance economic returns and create favorable environment for genetic improvement of the herd as it can enhance selection process. In general, the age at puberty and first calving are related with weight and inversely related with plane of nutrition of replacement heifers. The ultimate goal of heifer rearing is to raise the heifers economically and bring them to proper size and body condition for first service and calving at a reasonable age. Nutrition is a major determinant for attainment of the proper weight at proper time. Protein and energy are the most critical nutrients for the growing young ruminants and should be provided in adequate quantity and quality to support maintenance and growth.

Parturition interval: It is the period between consecutive calving and is a function of the number of days open and gestation length. It has low heritability, which can be improved by proper feeding and other management practices. For optimum economic benefits, it is desirable to have shorter parturition intervals to attain higher lifetime productivity of the female animal. For example, under intensive dairy production systems, it is desirable to have cows calving every year. However, this is not attainable under many conditions. The calving interval of zebu cattle raised under traditional management in Ethiopia is about 26 months or every two years (Perera, 1999).

2.3. Inter-relationships between animal nutrition and human nutrition

Animal source foods (ASF), such as milk, meat and eggs, are rich in energy and also provide a good source of proteins, vitamins and minerals. The consumption of ASF, particularly by the rural poor, can therefore substantially contribute to dietary diversity and household nutritional status, which has implications on household productivity, income levels and ultimately national development. Animal products are critical to the nutrition, food security, livelihoods and resilience of hundreds of millions of people throughout the world. Demand for animal products is set to continue increasing in the next three decades, as is their market price. Animal Source Foods (ASFs) provide high quality protein and a variety of micronutrients that are difficult to obtain in adequate quantities from foods of plant origin alone. Globally, ASF provide 15% of total food energy and 25% total dietary protein. Most significantly, the biological value of animal source protein is 1.4 times more than plant foods. Essential amino acids and micro-nutrients are more bio-available from ASF than from plant foods. Even in small amounts, foods of animal origin can play an important role in improving the nutritional status of low income households by addressing micro- and macronutrient deficiencies, particularly of children and pregnant and lactating women. Available evidence indicates that in the poorest countries, where micronutrient deficiencies are most common, a moderate intake of food of animal origin will improve the nutritional adequacy of diets and improve health outcomes. Small amounts of meat, for example, provide easily absorbable heme iron and help in the absorption of iron from plant foods (Bender, 1992), which helps prevent anaemia arising from iron deficiency. Meat and milk are good sources of vitamin B12, riboflavin and vitamin A. Meat also provides zinc, and milk provides calcium. Adding a small amount of animal source food to the diets of malnourished children can increase their energy and cognitive ability (Neuman *et al.*, 2010).

The availability and quality of ASF is very much dependent on the type and quality of feed available to animals and the feeding management employed. Poor feeding decreases productivity of the animal. A vast array of literature on nutrition-reproduction interactions shows that good feeding increases milk production of lactating animals. It also increases growth rate of meat producing animals, giving more meat.

2.4. Influence of animal feeds and nutrition on food safety and quality

Feed quality and safety also has important implications to food safety and quality. The safety and quality of the food chain can be affected because of the close link between feed and food-borne pathogens such as *Escherichia coli*, *Salmonella* and fatty acids, minerals in animal products, product shelf life). Many of these changes elicit positive effects on human health. Recently, there has been interest in the use of dietary polyunsaturated fatty acids (PUFA), specifically the omega-3 (n-3) fatty acids (FA) α-linolenic acid (ALA), eicosapentaenoic acid (EPA), and docosahexaenoic acid (DHA) to improve sow and piglet performance. Feeding specific n-6 and n-3 FA from either fish (Mateo et al., 2009; Leonard et al., 2010) or flax (Farmer and Petit, 2009) to sows also transfer these fatty acids to their offspring via milk. Feeding cattle with flax-based feeds can increase concentrations of n-3 fatty acids in beef (Drouillard et al., 2004)

2.5. Animal nutrition and the environment

Globally, the livestock sector contributes approximately 14.5% of all anthropogenic greenhouse gas (GHG) emissions (7.1 Gigatonnes of CO2-equivalent per year). The production, processing and transport of feed account for about 45% of the GHG emission from livestock sector. In intensive livestock production systems, which use substantial amount of concentrate feeds, large amount of feed nutrients (70 to 90% of nitrogen and phosphorus) are lost into the environment through manure, which if not managed properly can lead to environmental pollution. Livestock contribute 37% of anthropogenic CH4, mostly from enteric CH4 (FAO. 2009a), which is largely feed dependent. Feed production and use also impact land use and land use change (Gerber et al., 2013), which also leads to loss of sequestered carbon and biodiversity. Both environment and biodiversity degradation have linkage with ecosystem and human health. Smart feeding practices, especially the balanced ration approach i.e. feeding a diet containing nutrients such as protein, carbohydrates and minerals in the right proportion and in an amount that meets the nutrient requirements of animals for achieving the targeted production would decrease nitrogen, phosphorus and methane release in the environment and the biodiversity loss (FAO, 2012a; Garg et al., 2013). Use of locally adapted feed resources is also expected to conserve biodiversity.

2.6. Effect of animal feeds and nutrition on animal health and welfare

Improper nutrition (unbalanced diet, under or over feeding) impacts health adversely directly, and also makes animals more prone to diseases. Furthermore, in case of disease, corrective measures in the form of medicines are less or not effective. Vaccination done during the period of improper nutrition might also properly protect the animals. Correct nutrition can reduce infectious afflictions by enhancing cell-tissue integrity and optimizing defense mechanisms of the immune system (FAO, 2012b). Feeding of balanced ration has been shown to increase immuno-globulin levels in blood, suggesting higher immunity (FAO, 2012a). Supplements such as minerals, antioxidants and amino acids such as methionine also play a role in immune stimulation (Jankowski et al., 2014; Celi et al., 2014). Good nutrition is also a biosecurity measure to control zoonotic and infectious diseases.

Feeding to sustain high production levels, nutrient deficiency or excess can lead to metabolic disorders in ruminants such as acidosis and lameness causing welfare issues; whilst breeding animals of monogastric species which are restrict-fed to optimize health and production may suffer from chronic hunger. A number of welfare problems in ruminants are elicited by the feeding of poor quality or unsafe feeds. A properly balanced diet free of undesirable substances and water supplied in adequate amounts avoid physical and psychological suffering from hunger and thirst; furthermore correct nutrition is crucial for optimal performance and to sustain optimal fitness. Further information on adverse effects of improper animal nutrition on animal welfare and the corrective measures is available in FAO (2012b).

2.7. Influence of animal feeds and nutrition on farm economics

Feed is the single most important cost element of animal production, irrespective of species and production system. Feed cost can account for up to 70% of the total cost of production of an animal product. High feed costs leads to decreased profitability of livestock production operations and in some extreme cases can wipe out a livestock rearing operation. This

was typically what happened to many poultry and dairy farms in Ethiopia during the feed price hike of 2008. The shortage and high cost of feeds results in decreased supply of animal products and increased prices. Optimization of feed use efficiency, i.e. producing more with less feed, decreases feeding costs and increases economic viability of the livestock operation (Makkar and Beever, 2013).

2.8. Overall contribution of animal feeds and nutrition to macro goals of the country

Livestock provide several benefits including supporting the livelihood as well as food and nutrition security of millions of people in Ethiopia. Livestock convert feeds inedible by humans into high quality and nutritious foods such as meat, milk and eggs. Animal source foods (ASF) supply better balanced nutrients needed for growth and development, particularly for cognitive development of children, and for enhancing the immune system. Livestock also provide key crop production inputs such as draft power, manure and cash income (IGAD, 2011). They also play important roles in preservation of ecosystems in the form of grasslands and in nutrient cycling. In Ethiopia, the livestock resource sustains and supports the livelihoods of an estimated 80% of the rural population (FAO, 2004) and contributes 15 to17% of overall GDP, 47% of the agricultural GDP, and 37 to 87% of the household income. Thus, investment in livestock agriculture has the potential to reduce poverty, improve food security and make substantial contribution to GDP growth (Shapiro et al., , 2015).

The government of Ethiopia (GoE) unveiled Agricultural Development Led Industrialization (ADLI) policy about 20 years ago in which it has put the highest emphasis on agriculture and also giving a priority to the transformation of the livestock sector as evidenced in Growth and Transformation Plans I and II (GTP I, 2010-2015; and GTP II, 2015-2020). The livestock sector development is expected to contribute to poverty reduction, food and nutrition security, contribute to national income (GDP) growth and export and foreign exchange earnings (MoLF, 2015; Shapiro et al., 2015). The LMP has set out ambitious targets to increase meat, milk and egg production by 58%, 83% and 828%, respectively, in 2020 above the 2012/2013 totals. Such increments will not be possible without significant enhancements in feed availability, quality and utilization efficiency as poor feeding is a major impediment to livestock productivity

(Shapiro et al., 2015). Improvements in feed quality and feed utilization efficiency will also contribute to the attainment of the Climate Resilient Green Economy (CRGE) development strategy of GoE (FDRE, 2011). The mission of this research strategy aligns well with the above mentioned national policies and strategies, and will also contribute to regional and continental strategies such as the Comprehensive Africa Agriculture Development Program (CAADP) pillar on agricultural research, technology dissemination and adoption (Pillar IV), which aims at achieving accelerated gains in agricultural productivity through enhancing the ability of agricultural research systems to efficiently and effectively generate and adapt technologies needed to increase output and productivity while conserving the environment.

3. Assessment of external and internal environments

Successful accomplishment of the target objectives of a strategic plan depends on various factors which affect the plan at different stages including at conception, formulation and implementation levels. Two categories of such factors (external and internal factors) are recognized and analyzed. The external factors represent those factors that are not under the direct control of the feeds and nutrition research program and thus are outside the institution's domain of jurisdiction; while the internal factors represent those factors that exist and operate within the research system of the institute

The strategic planning tool used by the research team to evaluate and determine the likelihood of success of their research undertaking is the SWOC analysis, which stands for Strengths, Weaknesses, Opportunities and Challenges. The analytical framework is used to gain full awareness of the main external and internal factors with both positive and negative influences that may affect decisions on the strategic planning. While positive influences arising from external factors create opportunities, their negative influences would be regarded as potential challenges. Similarly, the positive influences arising from internal factors constitute strengths whereas their negative influences show the weaknesses of the research Program. The ultimate purpose of performing a SWOC analysis is to identify the internal strengths on which to capitalize and the external opportunities that can be exploited as well as the weaknesses and

challenges to be overcome for successful implementation of the strategic plan.

Since the results from the assessment of the external and internal factors using the SWOC analysis framework are the basis for identifying critical issues that this strategy is formulated to address, brief narrations of the factors are provided hereunder to be followed by a matrix of summarized accounts of the opportunities, challenges, strengths and weaknesses.

3.1. External environment

The external factors, as mentioned above, were analysed using the SWOC framework in conjunction with additional analytic tools such as PEST (Political/Policy/Legal, Economic, Socio-cultural and Technological); and critical considerations of current state of affairs, trends of needs and requirements and best solutions that other countries have adopted to get to their present cutting-edge milieu with respect to feeds and nutrition research and development. Three sub-topics are, therefore, discussed below to provide deeper perspectives. The current state of affairs is discussed under general external environments; trends and needs under operational external environments; and experiences of countries advanced in the research and development of feeds and nutrition are provided under the sub-heading benchmarking. Summaries of the external analyses are then presented in a tabular form at the end of the section (Table 5).

3.1.1. General external environment (Socio-cultural, Economic, Political, Technological, Educational, Environment)

Under the general external environment, analysis was made on opportunities and challenges that stem from political, economic, socio-cultural, technological/technical, and environmental (PEST +) dimensions. Methodical analysis of these factors would help to better understand the big picture of external environments affecting feeds and nutrition either positively or negatively and thus to craft the strategy so that it would make best use of the opportunities created by the positive influences and conversely to be cautious about the negative influences they pose or systematically address the challenges to overcome their impediment.

Political dimension: Assessments were made whether the strategy is aligned with the national, sectorial and institutional policy, strategy and

regulatory/legal frameworks and priorities. Since the adoption of the Agricultural Development Led Industrialization (ADLI) by the GoE, all the policy and strategy frameworks and development programs recognized agriculture to be the pillar of Ethiopia's economic growth and development to promote steady growth of the industrial sector. The current GTP II which provides even greater emphasis to industrialization places utmost priority to those agricultural sub-sectors fostering supply of raw materials for the growing agro-industries and export market. GTP II considers livestock sector a key driver of export led economic growth which cannot be achieved without a due emphasis on ensuring adequate supply of quality feed and development of appropriate feeding system. Therefore, so many opportunities are set forth by the policy environment to promote feeds and nutrition via research and development. The highly ambitious plan set forth for feed development in the recently formulated Livestock Master Plan (LMP) is a clear indication of the attention given to the feed sector. However, despite the development ambitions and favorable policy frameworks put in place, there are also a number of challenges that may surface in due course. Conceivable features of the opportunities to make use of and challenges to be aware of or need to be addressed, from the perspective of the policy dimension, were assessed and sorted out in a matrix of opportunities and challenges presented in Table 6 below.

Economic dimension: The increasingly rising demand for livestock products as a result of increasing population and changing lifestyle create the opportunity for the livestock and feed industries to thrive. Such an increase in the demand side will be the impetus for both the farmers and processing industries to increase outputs. The research has to, therefore, keep pace with the need of the public to increase production mainly through increasing productivity and product quality; while at the same time meeting the demand of the industries for raw materials that are not only sufficient to enable them run in full capacity but also fulfill their requirements of quality standards. The presence of various agro-ecologies and new potential areas to enhance livestock and/or feed production will allow the country to be self-reliant in livestock products and also for supplying to the potential export markets. There are several clusters of agro-industries established in different parts of the country which offer additional opportunity for livestock producers in a much larger scale. The available economic opportunities, however, are not without posing some challenges that the research team needs to be cautious about or address during the coming years. These are again described in Table 6.

Socio-cultural dimension: Ethiopian farmers are closely linked to and have long culture of livestock production. Ethiopia has diverse types and breeds of livestock in various agro-ecologies, and the country in general has strong and traditional culture attached to livestock production and consumption of livestock products. It is thus essential for the feeds and nutrition research team together with its key stakeholders to make best use of these opportunities and strive to make livestock commodities economically feasible, socially acceptable, environmentally sustainable and competent in the global market via supply of state of the art and applicable feed and nutrition technologies. Therefore, the opportunities and challenges related to socio-cultural settings around production; processing/management and utilization of available feed resources are examined and presented as elements of the SWOC analysis.

Technological dimension: Livestock is being considered as the next growth driver by the Ethiopian government. The highly extended targets set for the various livestock commodities in the Livestock Master Plan (LMP) and GTP-II are clear indications of tangible commitments and ambitions to develop the sector. In addition to meeting domestic demand in different livestock products such as dairy products, meat and eggs, ensuring competiveness and penetrating into international markets in meat export are among the focused areas of livestock development. Moreover, major emphasis has been placed on livestock sector as one important potential area for youth employment. Realization of such an extended livestock development plans and expectations will inevitably rely on adequate and sustainable supply of appropriate feeds and nutrition technologies. Accordingly both the potential opportunities and perceived challenges associated with the aforementioned scenarios were assessed and outlined in the SWOC table.

Environmental dimension: Existence of diverse agro-ecologies in Ethiopia suits to grow a wide array of forage and pasture species thereby help to diversify livestock feed options. Besides the potential suitability to various introduced forage species, the country is also the center of genetic diversity for various indigenous grass and browse species of great significance as livestock feed. The massively launched natural resource conservation program and establishment of enclosures in the country also allows regeneration of indigenous forage genetic resources which can serve as hot spot areas both for in-situ conservation and collection,

characterization and variety development of promising indigenous forages. However, there are still a number of climatic and edaphic factors including moisture stress, frost, water logging, soil acidity and salinity, etc which can impose limitations on feed resources research and development. Moreover, diversity of ecological factors and forage crop types may provide a fertile ground for a range of biotic agents such as pathogens, insect pests and weeds. The damages from these biotic factors coupled with climatic and edaphic factors hindering normal growth and full fruition of feed resources are among the primary issues that the research team would target to address. It is, therefore, essential to distinguish what opportunities these environmental factors could offer in order to take advantage of them while at the same time to be prepared to tackle the challenges they may pose on feed resource research and development.

3.1.2. **Operational external environment (Clients, Users, Partners, Competitors)**

Operational external environment is by and large about analysis of stakeholders whereby identification of key stakeholders in the feeds and nutrition value chain, the role they play to strengthen the feed sub-sector and their demands that they would like the research system delivers are elaborated. A list of such stakeholders with different roles and demands were examined. Different as they are the research team recognizes that the tiny bit of the role each of these stakeholders plays is crucially important for successful designing and implementation of the strategy and the outputs and impacts thereof. Therefore assessments were made what opportunities the research Program could make use of and, by the same token, what challenges it should face up to coming from these stakeholders by merely being involved in providing services of agricultural extension, production, processing, trading and research. These stakeholders, for ease of discussion, were grouped as clients, users, processors, partners and competitors and the opportunities and challenges coming from them were analyzed and captured.

Another dimension that has been considered in the analysis was the need for forging closer collaboration and partnership with different domestic and international research, academic and development institutions who can contribute, in one way or another, to the advancement of animal feeds and nutrition research for development.

3.1.3. **Benchmarking**

As pointed out earlier, Ethiopia has a considerable potential for developing its feed industry not only from perspectives of its diverse feed resources and diverse agro-ecologies for feed production but also a number of other factors including macro-economic policy based on market led economy and commercialization. Additionally, the special focus given to livestock sector as a new source of economic growth in the second GTP and beyond with recognition of the feed subsector as a major determinant of growth and transformation of livestock shades green light on possibility of using a fast track approach for availing knowledge, information and technology to remove barriers in the feed sub-sector. The fast track approach can be supported by drawing lessons from other countries that have advanced levels of research achievements in feed resources and nutrition.

Table 3 Productivity levels of cultivated forage (ton DM/ha) in comparison with the countries of the highest record considered as benchmark

Parameter	Ethiopia	Brazil	Productivity target to be attained by 2030
Average productivity of improved annual grass	15	15	17
Average productivity of improved perennial grass	15	20	20
Average productivity of improved annual forage legume	10	15	15
Average productivity of improved tree legume	5	8	8

Table 4. Best practices or approaches in availing information or nutritional interventions in comparison with the countries of the highest record considered as benchmark

Parameter	Current Ethiopian situation	Bench marked country and current status	Stretched target to be attained by 2030
Feed Resource characterization	Non-systematic and limited parameters	**Australia:** Systematic national data base of major feeds and major nutrients	Systematic national data base of major feeds and major nutrients
Nutrient requirement of domestic animals	No information under local situation	**Australia:** Nutrient requirement of ruminant under tropical or sub -tropical situation	Energy, protein and major minerals requirement of cattle and shoats)
Robust and cost effective techniques for feed evaluation	Limited use of NIRS and prediction equation for most feed resources	**Australia, SA and Brazil:** Routine use of NIRS and exploring advanced techniques	Wider and routine use of NIRS for major feeds and major analyses
Technological alternatives for enhancing use of crop residues and AIBP	Limited options	**India:** TMR Balanced diet	Wider options and enhanced utilization of crop residues and AIBP
Feed data base	Non digital grey literature	**Australia;** Digitalized feed composition and recommendation domain of forage	User friendly digitalized feed information
Focus in nutrition research	Intake, digestibility and animal response	**Australia:** Nutritional physiology, biochemistry, methane, genomic approach and product quality	Maintaining balance in applied and basic research

Accordingly, comparisons in terms of productivity of cultivated forages were made between the current positions of the Ethiopian research system with that of Brazil (Table 3). Additionally the current practices and approaches of Ethiopian research system in availing nutritional information and technology were compared against best practices in Brazil, Australia, India and South Africa (Table 4). Stretched objectives in terms of productivity targets and best practices to be attained by 2030 are also set to guide the current strategic directions and goal of national feeds and nutrition research program.

3.2. Internal environment

Assessment of internal environments is a process in which a given research team examines availability of the required capacity within the research program and/or EIAR system and can be readily used by the team to deliver outputs. Such a capacity that is readily available for the team within the research program indicates the strength of the team while the capacity which is required to deliver the outputs but falls short to exist denotes the weakness of the team. Assessment of the internal environment is thus about precise identification and articulation of strengths and weakness of the research program. Capacity in this context encompasses a wide array of topics including institutional capacity which signifies the status of human, physical and financial resources; technical or technological capacity and organizational capacity which deals with the questions of functional integrations within and between disciplines to forge complementarities and synergies. Below are briefly discussed the elements of internal environments examined to synthesize summaries of the Strengths and Weakness of animal feeds and nutrition research described in Table 5.

3.2.1. **Resource availability**

Effectiveness of any research planning, implementation, coordination and administration depends on availability of the required human, physical and financial resources. Accordingly, the status of human resources capacity, financial capacity and the physical resources available and lacking in feeds and nutrition research were assessed and outlined as strengths or weaknesses in the SWOC analysis.

3.2.2. **Technologies**

In more than four decades of concerted research endeavors in feeds and nutrition, about 37 improved forage varieties (16 grasses, 16 herbaceous legumes and 5 browse tree legumes) have been developed and released for different agro-ecological zones of the country with their essential agronomic packages and management practices (Annex 2). Database on nutritional profiles of major feed resources available in the country has been established and livestock feeding system/supplementation strategies based on selected feed resources including promising forage crops have also been developed. Moreover, possible methods of integrating improved forage crops into the farming system, crop residue improvement, natural pasture management and development and use of urea-molasses multi-nutrient blocks as supplementary feeds have been extensively studied and appropriate recommendations provided for wider application. The feeds and nutrition research efforts exerted and the technologies generated thus far have been thoroughly assessed in terms of scope, depth and coverage in view of the perceived development needs in order to capitalize on strengths and identify weaknesses to be addressed in the strategy.

3.2.3. **Organizational setup**

Lack of strong systems and clear operational modalities at different levels imposes a major limit on effectiveness of a research work. Research progress can also be hampered by poor intra- and inter-institutional linkages. In view of these, organizational strengths and weaknesses that would negatively and positively affect the progress of feeds and nutrition research were assessed and described from the program, center-level, institutional level and national level perspectives.

3.2.4. **Inter and intra disciplinary integrations, complementarities and synergies**

Feeds and nutrition research is naturally versatile and requires multi-sectoral integrations for successful and effective delivery of the anticipated outputs. A close working relationship of experts engaged in forage and pasture improvement and animal nutrition is pivotal followed by establishing a binding linkage with the other mainstream disciplines of livestock research such as breeding and genetics, animal production,

animal health and animal product post-harvest processing and product quality. Besides the intra-sectoral linkages, it is equally essential to solicit and realize complementarities and synergies with experts working in other fields like Crops Research (breeding, agronomy, crop protection), Land and Water Resources Management Research, socioeconomics and extension, Agricultural-Biotechnology Research, Agricultural Mechanization Research, Technology Multiplication and Seed Research, Climate and Geospatial and ICT. The status of linkage and synergies of feeds and nutrition research with the aforementioned areas of research were assessed with a due emphasis on the potential role of effective integrations to address livestock and feed related production and productivity issues at system levels, market access and product competitiveness, value addition, sustenance of natural resources and emerging issues such as climate variability.

3.3. Strengths, Weaknesses, Opportunities and Challenges by the Research Themes

Table 5. Summary of the strengths, weaknesses, opportunities and challenges assessed from the perspectives of the external and internal factors

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
Theme 1: General			
➢ EIAR commitment in expansion and support of feeds and nutrition research in unaddressed agro-ecologies and clients. ➢ Modest level of collaboration among stakeholders in planning and implementation of feeds and nutrition research activities. ➢ Experiences in research undertaking	➢ Limited scope, depth and coverage of research undertakings to avail technological options for various users (smallholder farmers, commercial feed and livestock producers, pastoralists). ➢ Lack of innovative approach in research problem identification, technology generation and transfer. ➢ Poor understanding on determinants of feeds and nutrition technology adoption pathway.	➢ Availability of huge livestock resource base, diverse agro-ecologies and production systems. ➢ Favorable government attention to the livestock sector (GTP plan, livestock master plan targets, establishment of Ministry of Livestock and Fisheries). ➢ Increasing demand for livestock products and services.	➢ Loss of indigenous forage genetic resources due to land use change, climate change, and population pressure and land degradation. ➢ Climate change and climate variability. ➢ Dependence of crop production on animal power. ➢ Predominance of non market oriented livestock production.

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
on feeds and nutrition, coordination and availing appropriate technology to users. ➢ Availability of some feeds and nutrition technologies which can serve as a takeoff point to support feed industry along the path of market-led economy and commercialization. ➢ Availability of modest facilities and trained manpower for conducting feeds and nutrition research.	➢ Insufficient critical mass and lack of specialization in some aspects of feeds and nutrition research. ➢ Limited technological options for efficient utilization of available feed resources. ➢ Limited practical feed management and feeding guidelines for addressing seasonal fluctuation in feed supply and quality. ➢ Weak on-farm verification and demonstration of available feed and nutrition technologies. ➢ Limited in-service training and mentoring for researchers.	➢ Increasing interest in market oriented livestock production and growing demand for livestock technologies. ➢ High attention for trained human resource development and expansion of universities in the country. ➢ Some efforts has been underway to develop feed chopper and mixer in the research system	➢ Lack of institutions responsible for multiplication of feed and livestock technologies. ➢ Weak feed and livestock extension delivery system. ➢ The prevailing land use system is not favorable for feed resource and livestock development. ➢ Inadequate budget allocation to feeds and nutrition research. ➢ Inadequate research facilities (lab, field equipment's, store, office, etc.)

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
	➢ Unavailability of research manuals and clear protocols to be used as guidance for junior researchers. ➢ Lack of strong collaboration with relevant international partners (such as CGIAR working on livestock).		➢ Shortage of vehicle for conducting on-farm and field trials and surveys. ➢ Limited capacity and access to apply modern tools and techniques like biotechnology, GIS and remote sensing in feeds and nutrition research. ➢ Limited donors supports for feed and livestock research and development. ➢ High staff turnover and shortage of senior researchers. ➢ Unfavorable organizational setup and frequent restructuring of feeds and nutrition research.

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
			➢ Lack of necessary tools and machineries for feed processing and preservation. ➢ Inability to manage temporal and spatial variability in feed supply. ➢ Low commitment of international partners (such as CGIAR Centers working on livestock) for forging strong collaboration ➢ Lack of clear modality for supporting collaborative research within and among different disciplines. ➢ Lack of clear demarcation and task sharing among research institutions at different level (national and

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
			international research institutions)
Theme 2: Feed resources			
Sub-theme 2.1. Cultivated forage crops			
➢ Adapted and high yielding forage species /varieties/ identified and released for different agro-ecologies and production systems. ➢ Modest production and management packages developed for most released forage varieties/species. ➢ Efforts have been made on demonstration and promotion of recommended/released cultivated forages.	➢ Limited forage varietal options for some environments and different land use and production systems (degraded areas, moisture stress areas, irrigated areas, frost prone highlands, soil salinity and acidity etc.). ➢ Lack of information on opportunity cost of forage production versus other uses of land. ➢ Lack of comprehensive information on determinants of forage adoption and utilization.	➢ Availability of diverse but untapped forage genetic resources. ➢ Increased attention given to natural resource conservation. ➢ Presence of diverse agro-ecologies and production system. ➢ More number of research centers and institutions engaged in forage research.	➢ Narrow genetic base on which variety selection has been carried out. ➢ Lack of facilities for handling and maintenance of forage germ-plasm. ➢ Difficulty of forage seed supply • Lack of strong institutions engaged in forage seed production and supply. • Lack of necessary facilities required for forage seed and germ-

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
➢ Modest effort in multiplication of initial seeds of released forage varieties/species. ➢ Relatively better number of trained human resource engaged in forage research. ➢ Increased attention on identification, characterization and improvement of indigenous forage species.	➢ Weak genetic materials acquisition, handling, conservation/maintenance and exchange. ➢ Inadequate research on indigenous forages. ➢ Absence of research efforts on characterization (genotypic) of forage genetic resources. ➢ Incomplete packages of production and management of forages. ➢ Limited expertise and research effort in the area of forage seed. ➢ Forage improvement works have been limited to conventional selection.	➢ Ambitious plan for forage development in the livestock master plan. ➢ Feed shortage and growing demand for feed options. ➢ Increasing demand and price of livestock products	plasm maintenance (e.g. standard seed store). • Difficulty in acquiring new forage germ-plasm. • Inherent limitation of most forage crops for seed production. • Shortage of land for forage research and seed production ➢ Lack of binding modality for integration/cooperation. ➢ Too ambitious plan for forage development in the livestock master plan.

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
	➢ Lack of compelling evidences regarding potential of different forage crops in improving livestock productivity and farmer livelihood (including biological, socio economic aspects). ➢ Lack of specialization in forage research. ➢ Lack of proper and targeted approach for demonstration and promotion of forage crops. ➢ Limited capacity to avail adequate initial seeds for released forage varieties. ➢ Limited research effort on irrigated forage. ➢ Weak intra and inter disciplinary collaboration. ➢ Lack of focus and specialization in forage research based on		➢ Inadequate attention to forage crops in the curricula of agricultural colleges and universities in the country. ➢ Weak extension service in forage development and utilization. ➢ Inadequate irrigation facilities to support irrigated forage research. ➢ Lack of quality control system and certification of forage seed

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
	potential impact ad agro-ecological suitability of specific forage crops		
Sub-theme 2.2: Natural pasture			
➢ Modest information and recommendation is available on appropriate management practices to improve herbage yield and quality of natural pasture. ➢ Information on nutritional dynamics of natural pasture hay as affected by harvesting stage, storage method and duration studied and documented mainly in the highlands. ➢ Availability of some information on botanical	➢ Limited effort to undertake research on natural pasture (mapping potential areas, management and utilization strategy, control of invasive species and termites, etc). ➢ Limited integration of research efforts with ongoing natural resource and wildlife conservation programs. ➢ Lack of information on hot-spot areas to be targeted for maintenance, conservation and management of indigenous forage genetic resources. ➢ Limited studies on geographical distribution to support collection,	➢ Modest availability of indigenous genetic resource base. ➢ Ongoing NRM (area closure, wet-land management, etc) efforts in the country. ➢ Increased demand and price of natural pasture hay. ➢ Availability of diverse agro-ecologies in the country ➢	➢ Shrinkage of grazing lands due to land use changes (expansion of cropping, floriculture, urbanization and industries) ➢ Over grazing and depletion of desirable species. ➢ Uncontrolled free grazing practices. ➢ Climate change and climate variability. ➢ Encroachment of invasive species.

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
composition of natural pasture	evaluation, characterization, maintenance and utilization as well as provide information for in-situ conservation. ➢ Shortage of compelling evidence on comparative economic advantage of different natural pasture management practices (fertilization, harvesting stage, weed control, resting period, burning, etc). ➢ Lack of appropriate grazing management recommendations for different production and land use systems		➢ Expansion of pests (termite mounds, rodents, etc). ➢ Depletion of indigenous forage genetic resources. ➢ Poor understanding of the pros and cons of different grazing systems by development planners ➢ Tradeoff between plantation/afforestation and survival of indigenous plant genetic resources. ➢ Low attention for conservation and maintenance of indigenous forage genetic resources

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
Sub-theme 2.3: Agro-industrial by-products, crop residues and other feed resources			
➢ Information is available on nutritional profile of major agro-industrial by-products, crop residues, grains, and some non-conventional feed resources (cactus, prosopis pod, enset, etc). ➢ Supplementation strategies and feeding systems developed for different classes of animals based on selected agro-industrial by-products.	➢ Limited research intervention and recommendations on management, conservation, processing and utilization of agro-industrial by-products, crop residues and non-conventional feed resources (eg. Vegetable and fruit by-products). ➢ Lack of research interventions on brewery by-products handling, management and efficient utilization as feed. ➢ Lack of comprehensive information on availability, management, spatial and temporal distribution as well as nutritional profiles of horticultural by-products and other non-conventional feed resources.	➢ Expansion of horticultural crops and agro-processing industries. ➢ Growing interest to use non-conventional feed resources as animal feeds (eg. Weeds from crop field). ➢ Increasing number of new agro-processing industries that produce agro-industrial by-products ➢ Increasing availability of non-conventional feed resources	➢ Perishability and bulkiness of horticultural and some agro-industrial by-products (eg. brewery by-products). ➢ Seasonal availability and skewed spatial distribution of some agro-industrial and horticultural by-products. ➢ Fluctuating market price of commonly used agro-industrial by-products. ➢ Adulteration of some agro-industrial by-products

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
	➢ Lack of context specific feed formulation options (limited consideration of locally available by-products as ingredients for feed formulation) ➢ Limited understanding and documentation of indigenous knowledge on feed processing and utilization practices. ➢ Lack of information on source, background (processing methods) and traceability of agro-industrial by-products used in feeding experiments. ➢ Limited research in the availability and use of herbal plants as feed supplements		

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
Sub-theme 2.4: Formula Feeds, Premixes and Feed Additives			
➢ The presence of ample information about such feeds and feed ingredients locally and internationally	➢ Limited information on nutritional characteristics and high cost of formula feeds ➢ Use of formula feeds limited in urban and peri-urban settings of livestock production ➢ Technical limitations of premixes and feed additives in terms of suitability for local situation	➢ Macro-economic policy supporting investment and commercialization ➢ Emerging trend in decline of grazing land and need for supplements ➢ Emerging trend in intensification of livestock production demanding quality feeds such as formula feed, premixes and feed additives ➢ Commercial interest in availing formula feeds, premixes and feed additives or domestic supply of premixes	➢ Limited technical capability to support production of formula feeds, premixes and feed additives ➢ No local source, heavy reliance on importation and high cost of premixes and feed additives

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
Theme 3: Animal nutrition and feeding systems			
➢ Nutritional profiles of major feed resources available in the country have been documented. ➢ Modest availability of trained human resources. ➢ Availability of information on feed formulation and feeding system for some classes of livestock. ➢ Modest availability of information on improvement of crop residue and other feedstuffs. ➢ Experiences in formulation, production	➢ Lack of robust, cost effective and responsive feed evaluation technique to support the need of feed and livestock industry ➢ Limited technological options for different clients, agro-ecologies and production systems. ➢ Limited alternative feed formulation and feeding system for various classes of livestock. ➢ Inadequate information and intervention options to ensure efficient utilization of available feed resources. ➢ Lack of technical capacity for determining mineral, amino acid and fatty acid contents of various feeds, feed safety parameters as	➢ Expansion of agro-industries that produce byproducts used as animal feed. ➢ Expansion of market oriented livestock production ➢ Increasing demand for nutritional interventions like feed formulation and feeding management. ➢ Increasing number of feed processing plants. ➢ Increasing interest on use of non conventional feed resources. ➢ Increasing availability of crop residues as feed resource.	➢ Inadequate barn facilities for individual animal feeding. ➢ Lack of facilities for determining mineral, amino acid and fatty acid contents of various feeds, feed safety parameters as well as greenhouse gas emissions. ➢ Very old and some non functional lab facilities. ➢ Difficulty of acquiring required inputs for feed analysis (reagents, kits, etc).

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
and utilization of urea-molasses multi-nutrient block. ➢ Availability of modest laboratory facilities and analytical capacity. ➢ Close working relationships with high learning institutes.	well as green house gas emissions. ➢ Inadequate animal response studies on improved forage crops. ➢ Limited alternatives on cost effective and biologically efficient supplementary feeds for different classes of livestock. ➢ Lack of capacity in feed technology (processing) to support the feed industry. ➢ No work on fundamental research issues of animal nutrition such as development of nutrient requirement and supplementation regimes for local animals ➢ Lack of research initiatives on nutrition versus health and genetics interactions	➢ Increasing demand for technology options to reduce feed cost and improve feed efficiency.	➢ Inadequate and intermittent supply of water and electricity. ➢ Lack of qualified lab technician. ➢ Land allocated for forage production is not adequate to produce sufficient forage for animal response trials (especially for large ruminants). ➢ Taxation and VAT on imported feed additives and premixes

4. Strategic issues facing the feeds and nutrition research program

The strategic issues facing feeds and nutrition are synthesized by filtering out those factors which can be addressed by the research program and for which a strategic planning could be developed by the team. Those issues which are important for the success of the research program, but perceived to be outside the technical domain of the team, are not included in this section. It is however felt important to consolidate the issues beyond technical domain of the team and bring them to the attention of concerned top management as decision support tool for promoting the feed sub-sector. The identified strategic issues are organized in one general crosscutting topic, and two pillar disciplinary themes: feed resources and animal nutrition and feeding system themes. The feed resources theme is further divided into four sub-themes *viz.,* cultivated forages; natural pastures; agro-industrial by-products, crop residues and other feed resources; and formula feeds, premixes and feed additives. Moreover, gender, climate change, socio-economics and knowledge management and ICT related issues have been presented as crosscutting themes under the fourth category (Table 6). The strategic issues/gaps that are common to most of the other themes/sub-themes have been addressed under the general theme. The issues identified under this theme are mainly related to the human resource, physical and financial capacity required for effective undertaking of research and delivery of feeds and nutrition technologies responsive to the needs of various users. The other detail strategic issues have been identified and described under the respective research themes/sub-themes as shown in Table 6.

Table 6:- Strategic issues facing the feeds and nutrition research commodity and their relevance in the short, medium and long terms

1. General
1.1. Expanding the scope, depth, coverage and capacity for research undertakings to avail technological options for various users • Balancing research engagement in basic, strategic, applied and adaptive research to avail basic information and state- of- the art technology
1.2. Applying innovative and holistic approach in research problem identification, planning, technology development and transfer.
Theme 2. Feed resources
Sub-theme 2.1. Cultivated forages
2.1.1.Expanding forage varietal options for various production environments and land use systems (degraded areas, moisture stress areas, frost prone highlands, drought prone areas, soil salinity and acidity, irrigated systems) • Increasing research engagement on indigenous forages • Strengthen genetic materials acquisition, handling, conservation/maintenance and exchange
2.1.2. Avail complete packages of production and management of forages • Increasing information and technology on forage seed and innovative approach for enhancing forage seed supply • Availing information on incidence and control measures of pests and diseases of forages
Sub-theme 2.2. Natural pasture
2.2.1.Initiate more research undertaking on natural pasture: • Produce compelling evidence on biological, economic and environmental benefits of different natural pasture management practices (fertilization, harvesting stage, weed control, resting period, burning, grazing management etc) • Increased integration of research efforts with ongoing natural resource and wildlife conservation programs • Availing information on long term trends in botanical composition, productivity and quality of natural pasture
Sub-theme 2.3. Agro-industrial by-products, crop residues and other feed resources
2.3.1.Initiate research interventions on selected agro-industrial by-products (brewery by-products, sugarcane by-products, abattoir by-products etc) handling, management and efficient utilization as feed

2.3.2.Availing comprehensive information and technology on optimal use of horticultural by-products, herbal plants, indigenous browse species and other non-conventional feed resources
2.3.3.Enhancing understanding and documentation of indigenous feed processing and utilization practices
2.3.4. Investigating the availability and use of herbal plants and indigenous browses as feed supplements
2.3.5. Widening technology options for improving use of crop residues in ruminant nutrition
Sub-theme 2.4. Formula Feeds, Premixes and Feed Additives
2.4.1. Enhancing availability of information on nutritional characteristics, high cost and limited use of formula feeds
2.4.2. Availing technologies for domestic production and affordable supply of premixes, mineral supplements and feed additives
Theme 3. Animal nutrition and feeding system
3.1. Developing and/or availing cost effective, robust and responsive feed evaluation technique to support the need of feed and livestock industry
3.2. Increasing research interventions and technological options for different agro-ecologies and production systems. • Expanding options for alternative feed formulation and feeding system for various classes of livestock • Generate more information and intervention options to ensure efficient utilization of available feed resources. • Demonstrating the value of improved forage crops through targeted animal response studies. • Widening base of supplementary feeds for different classes of livestock. • Availing basic information and technology to improve nutrition of free ranging ruminants
3.3. Undertaking fundamental animal nutrition research such as development of nutrient requirement with emphasis on local animals
3.4. Investigating interactions of nutrition with health and genetics
Theme 4. Cross cutting issues
4.1. Gender
4.2. Climate change
4.3. Knowledge management and ICT
4.4. Socio-economics
4.5. Human nutrition

5. Research themes and strategic interventions

The livestock sector is expected to contribute much towards the country`s goal of agricultural development led economic growth and industrialization. The livestock sector is also being considered to play a catalytic role in job creation and social transformation. Contribution of livestock towards the stated macroeconomic goals will inevitably rely on adequate supply of better quality feeds and development of biologically efficient and economically feasible feeding systems for various classes of animals. Feeds and nutrition program is naturally versatile and most of the research agendas require multi-institutional, multi-sectoral, multidisciplinary, multi-thematic and participatory engagements, and need to be implemented in collaboration with farmers, extensionists and a wide range of other partners involved in the whole spectrum of the feed and livestock industry. Aligned with the missions, goals and priorities of EIAR and guided by the current GTP II framework and Livestock Master Plan, this research strategy is believed to benefit smallholder farmers, commercial farmers, pastoralists, agro-pastoralists, agro-processors, traders and other stakeholders involved in the feed and livestock value chains. The research themes are built on five key areas (encompassing the four sub-themes under feed resources) and animal nutrition and feeding systems as briefly discussed hereunder. The strategic interventions designed for each of the strategic issues described under section 4 above and spanning the short-, medium- and long-terms of fifteen years (2016-2030) are presented in Table 7.

5.1 Research Themes

5.1.1 General

The second five-year Growth and Transformation Plan (GTP II) of Ethiopia projects that the livestock sector will play a key role in driving towards economic and social transformation. Achievement of these goals basically requires use of improved feeds and nutrition technologies along the value chain of key livestock commodities. Thus it is vital to have a far sighted national feeds and nutrition research strategy to support effective delivery of the set targets for enhancing supply of livestock commodities to ensure self-sufficiency and also generation of substantial foreign

revenue through export. In order to respond to such an important agenda of national urgency, the feeds and nutrition research program should focus on two important capability areas: (i) the feeds and nutrition research program should be strengthened in terms human resources (i.e., the researchers engaged in feeds and nutrition research should be equipped with the state of the art techniques and specializations required for a comprehensive and balanced research engagement in basic, strategic , applied and adaptive research to avail basic information and state- of- the art technology on feed resources and animal nutrition to properly address the needs of various target groups, (ii) the research program should be equipped with state of the art research facilities (i.e. nutrition laboratories, experimental houses, irrigation facilities, breeding facilities, seed stores, and facilities required to apply modern biotechnological tools, etc).

5.1.2 Feeds resources

Under this theme, four sub-themes which deserve strategic research interventions to improve the overall feed supply and quality have been identified, and briefly stated below.

5.1.2.1 Cultivated forages

Cultivated forage crops (both exotic and indigenous) are important feed resources though their potential is yet untapped under Ethiopian context. Substantial number of high yielding forage species and varieties have been identified and recommended for potential areas in different agro-ecologies. However, limited forage varietal options are available for some specific production environments and land use systems (degraded areas, moisture stress areas, frost prone highlands, drought prone areas, soil salinity and acidity, and irrigated systems). Hence, subsequent research in cultivated forages envisions development of varieties suitable for such marginal production environments. Refinement of production packages including the seed aspect and promotion of proven forage species/varieties will be equally emphasized while generating tangible evidence indicating that forages are competitive and best enterprise choices in order to ensure sound adoption by various target groups.

5.1.2.2 Natural pastures

Natural pasture is another important source of livestock feed in Ethiopia though grazing land area is shrinking from time to time owning to expansion of arable cropping, urbanization and industrial development all at the expense of available grazing land particularly in the mid- to highland mixed crop-livestock farming systems. On account of this, different strategic research issues targeting at exhaustive mapping and enhancing effective management and utilization of pasture land available in pocket areas in different parts of the country have been identified and outlined in the strategy.

5.1.2.3 Agro-industrial by-products, crop residues and other feed resources

In views of the expansion in area and diversity of crops grown, and the corresponding expansion of agro-processing industries, substantial quantities of various by-products of great importance as livestock feed are being produced in Ethiopia. Potential availability, management and utilization of different emerging by-products have not been properly understood and there have been limited research intervention to enhance their utilization as feed. Therefore, different strategic issues which deserve intervention to ensure efficient utilization of available by-product feed resources have been identified to be among the forefront agenda in subsequent feeds and nutrition for transformation of the livestock sector in the country.

5.1.2.4 Formula feeds, premixes and feed additives

This sub-theme is perceived essential to address strategic issues of great relevance to the flourishing feed processing industries and commercial livestock production in Ethiopia. Availing technological options for developing biologically efficient formula/processed feeds for various classes of animals at the least possible cost is identified to be taken up as an important issue to be addressed by the feeds and nutrition research team.

5.1.3 Animal nutrition and feeding system

The various feed resources described above are intermediate products which are used as important ingredients/raw materials for the production

of high value animal products via applications of appropriate animal nutrition and feeding systems. Under this theme, different strategic issues have been identified all aiming at development of feeding packages suited to various species and classes of animals. In view of the sky rocketing prices of animal feeds, most of the strategic issues identified under this research theme shall focus on the search for alternative feed resources/ingredients and development of cost effective and biologically efficient feeding packages for the various categories of animals. In addition to dealing with the nutrition and feeding management of ruminants and monogastric animals, this strategy also assumes a collaboration and close working relationship between the Animal Feeds and Nutrition team and the Fisheries Research team in identifying alternative feed resources and formulation of alternative diets using locally available feed resources to address the nutritional needs of the farmed fish at reasonable cost. The ultimate target of the animal nutrition and feeding interventions is to contribute to the realization of the country`s ambition not only to satisfy domestic demand, but also generate substantial foreign exchange via export of livestock products.

5.1.4 Crosscutting Issues

Determinants of technology adoption encompass characteristics of the technology, features of the farming system, market and policy environments as well as socio-economic characteristics of the decision making unit (household or farmer). Available evidences show that major improvements in livestock productivity are possible if appropriate technologies can be generated and adopted by farmers. Problems faced by farmers and livestock producers vary according to existing agro-ecological and socio-economic circumstances. Thus ensuring favorable social, economic and environmental impacts is an important element of a successful research strategy (ILCA, 1992). Appropriate animal feeds and nutrition research and development strategy should ensure adequate economic returns to livestock producers, maintenance of natural resources, minimal adverse effects on the environment, optimal production with external inputs, and satisfaction of human food and income needs, as well as social needs of rural families (Fitzhugh et al., 1992). In addition to being mainstreamed in animal feeds and nutrition research, the cross-cutting issues (gender, climate change, knowledge management and ICT, socio-economics and human nutrition) could also be considered as researchable areas in their own right to generate appropriate technologies.

Gender: Feed production and livestock feeding management are naturally routine and labor intensive ventures demanding active participation of different social groups along the value chain. In this regard, women and youth groups play a crucial role as they contribute over 70% of farm labor required for the various activities. Thus, the national feeds and nutrition strategy considers integration of gender aspects while setting research problems, technology development, extension, and evaluation frameworks to ensure equitable economic and social transformation in livestock production systems.

Climate change: Feed supply in particular and livestock production in general are highly liable to climate change with the consequent direct negative impact on different communities (pastoralists, agro-pastoralists and farmers) whose livelihoods are closely linked to livestock and the nation at large. On the other hand, livestock production and feeding systems may also contribute to greenhouse emissions depending upon the type of production system and intensity pursued. Therefore, the feeds and nutrition research strategy will place due emphasis to avail suitable technological options for effective adaptation to and/or mitigation of the inevitable climate change.

Knowledge management (ICT): Knowledge management interventions aided by modern information technologies would help to facilitate dissemination of up-to-date information to various stakeholders/clients including smallholder farmers thereby enable them to improve their farm productivity and competitive ability. Cognizant of this, issues related to KM will be given a due consideration to ensure effective and wider application of feeds and nutrition technologies while also capturing important feedbacks for the formulation of subsequent research problems.

Socio-economics: Feeds and nutrition research has so far been limited to bio-physical aspects and the economic/social dimension has largely remained unaddressed. Thus, this strategy demands a concerted engagement of social scientists to properly address aspects of economics, anthropology and extension in feeds and nutrition research program. Under this theme, research issues pertaining to economics of feed production, opportunity costs of feed production versus other agricultural land uses, adoption and impact studies of feeds and nutrition technologies, etc will be focused in the years to come.

Human nutrition: Animal feeds and nutrition has significant effect on livestock productivity and availability of livestock products. On the other hand, livestock systems influence human livelihoods on multiple levels, with several influential factors contributing to human nutrition outcomes (Randolph et al., 2007). Animal source foods are an excellent source of nutrition. On the other hand, the safety and quality of animal feed affects human food safety and quality. Thus, a study on the causal relationship between animal feeds and nutrition and human nutrition under different livestock production systems would be of vital importance.

5.2 Strategic interventions

Table 7. Strategic interventions planned to address critical issues facing the feeds and nutrition research program in the short-, medium- and long- terms

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
Theme 1. General			
1.1. Expand the scope, depth, coverage and capacity of research undertakings to avail technological options for various users	• Undertake human resource development plan for critical specialization (feed technology, ruminant and mono gastric nutrition, micro biology, physiology, forage breeding, agronomy, protection, seed technology, etc). • Fill critical human resource gaps through recruitment and training. • Forge research collaboration with national and international research institutes and universities.	• Reassess gaps and design research interventions to respond to dynamism of technological needs. • Strengthen human resource and physical facilities. • Continue facilitation and supporting short term skill development trainings for researchers and technicians.	• Reassess gaps and design research interventions to respond to dynamism of technological needs. • Reassess and strengthen human resource and physical capacity which would enable to generate state of the art technology for various target groups. • Continue facilitation and supporting short term skill development trainings for

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
	• Facilitate and support short term skill development trainings for researchers and technicians. • Effect long term specialized training for researchers • Experience sharing locally and internationally	• Continue effecting long term specialized training for researchers	researchers and technicians. • Continue staff development program to provide replacement for staff members leaving the system due to various reasons
• Balancing research engagement in basic, strategic , applied and adaptive research to avail basic information and state- of- the art technology on feed resources and animal nutrition	• Collating basic information on nutritional characteristics of tropical feeds resources and nutrient requirement of animals under tropical situation. • Identification of rapid and cost effective feed evaluation techniques for generation of basic information towards better understanding of unique characteristics of tropical feed resources	• Engaging in nutritional bio-chemistry, phyto-chemistry, rumen ecology, methanogenesis and nutritional physiology (nutrient partitioning and requirement) to generate fundamental information at feed, microbes and host animal level under tropical situation.	• Continue engaging in basic and strategic research to avail state of the art information and technology. • Application of knowledge and commercialization of products at industry level

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
1.2. Applying innovative and holistic approach in research problem identification, planning, technology development and transfer.	• Establish innovation platforms composed of different stakeholders towards participatory research planning, execution, evaluation, technology transfer and adoption. • Moving from piece meal approach towards nationally coordinated research engagements	• Strengthen innovation platforms	• Ensure sustainability and effectiveness of innovation platforms
Expected Outputs of the Strategic Interventions on general issues: • Desired human and physical capacity built to ensure effective delivery of technology and information by improving scope, depth and coverage of research undertakings in animal feeds and nutrition. • Innovation platform composed of key stakeholders and partners created and strengthened to support feeds and livestock sector development.			
Theme 2. Feed resources			
Sub-theme 2.1. Cultivated forage crops			
2.1.1. Expanding forage varietal options for various production environments and land use systems (degraded areas, moisture stress areas, frost prone highlands, drought prone areas, soil	• Broaden forage genetic bases through collection and acquisition from local and global sources. • Evaluation of different forage germ-plasms in different agro-ecologies and production systems.	• Varietal development of improved forage crops targeting various production environments and land use systems.	• Participatory evaluation, demonstration and scaling up/out of promising forage varieties targeted for various production environments and land use systems.

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	Medium-term (6-10 years)	Long-term (11-15 years)
salinity and acidity, irrigated systems)	• Identify adaptable forage genetic materials in various production environments and land use systems	• Germplasm enhancement and development of drought tolerant forage crops using conventional and biotechnological tools	• Continue germplasm enhancement and development of drought tolerant forage crops using conventional and biotechnological tools
• Strengthening genetic materials acquisition, handling, conservation/maintenance and exchange	• Build the necessary facilities (cold room, seed processing shed, etc) targeted for assembling genetic material, handling, conservation, regeneration and exchange	• Engaging in medium scale maintenance of selected forage germplasms at specified locations in the national research system	• Strengthen medium scale maintenance of selected forage germplasms
• Increasing research engagement on indigenous forages	• Assessment and identification of hot-spot areas for collection, maintenance, in-situ and ex-situ conservation, management, improvement and utilization of indigenous forage genetic resources	• Collection and characterization of selected indigenous forage germplasm for phenotypic and genotypic traits. • Undertake improvement and varietal development of potential indigenous forage genetic resources	• Continue improvement and varietal development of potential indigenous forage genetic resources. • Development of appropriate rhizobia inoculums for indigenous forage legumes

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
2.1.2. Availing complete packages of production and management of forages	• Refine existing production packages (fertilizer, seeding rate, spacing, harvesting stage, conservation, cropping system, irrigation time and frequency etc) and develop environment specific recommendations for selected forage crops	• Continue refinement and development of production packages. • Participatory evaluation and demonstration of production packages for selected forage crops	• Continue participatory evaluation and demonstration of production packages for selected forage crops
• Increasing information and technology on forage seed and innovative approach for enhancing forage seed supply	• Design and implement research projects aiming at improving seed productivity and quality for selected forage crops. • Identification and delineation of responsibilities among centers engaged in forage research towards specialization on forage seed research and multiplication. • Identification and mapping of niche environments suitable for forage seed production within selected agro-ecologies	• Development of forage seed production packages under different agro-ecologies and production systems. • Participatory evaluation and demonstration of forage seed production packages. • Evaluation of innovative approaches and options for enhancing forage seed supply (informal seed system, commercialization etc)	• Continue development of forage seed production packages under different agro-ecologies and production systems. • Continue participatory evaluation and demonstration of forage seed production packages. • Strengthen innovative approaches and options for enhancing forage seed supply

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
• Availing information on incidence and control measures of pests and diseases of forages	• Assess occurrence and distribution of pests and diseases of forage crops. • Study effect of climate change on incidence of pests and diseases in forage crops	• Development of organized and systematic pest control strategies that involve genetic selection for resistance, biological and chemical control, cultural practices and cropping systems	• Participatory evaluation of controlling practices and development of integrated pest management practices in forage crops
Expected Outputs of the Strategic Interventions on cultivated forage crops: • Forage varieties suited to various production environments and land use systems developed and availed to users. • System and capacity for effective acquisition, handling, conservation/maintenance and exchange of forage crop genetic materials established. • Potential indigenous forage genetic resources with desired phenotypic and genotypic traits identified and developed for different production environments • Desired phenotypic and genotypic traits of indigenous forage genetic resources identified for improvement and varietal development • Environment and production system specific production packages developed for selected forage crops • Suitable forage seed production packages and seed system developed. • Major pests and diseases of forage crops identified and control measures developed.			
Sub-theme 2.2. Natural pasture			
2.2.1. Increasing research engagement on natural pasture	• Understanding dynamics of land use changes with respect to natural pasture. • Design research projects for mapping of potential areas.	• Continue implementation of research activities on proper management and utilization of available grazing lands.	• Participatory evaluation and demonstration of promising interventions on the management and utilization of natural pastures

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	Medium-term (6-10 years)	Long-term (11-15 years)
	• Designing client oriented participatory research projects to develop improvement and proper management and utilization strategies. • Design research projects on the control of invasive species and termites	• Continue implementation of research activities on the control of invasive species and termites	
• Integrating of research efforts with ongoing natural resource and wildlife conservation programs	• Understanding the inter relationships of natural resource revitalization development efforts with availability and quality of natural pasture for livestock production. • Identification of research needs to integrate livestock feed production with natural resources and wildlife management initiatives	• Design and implement development oriented adaptive research in livestock feed production and natural resource management. • Participatory evaluation and demonstration of promising interventions in feed production and natural resources management	• Continue implementation of development oriented adaptive research in livestock feed production and natural resource management. • Continue participatory evaluation and demonstration of promising interventions in feed production and natural resources management

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
• Producing compelling evidence on biological, economic and environmental benefits of different natural pasture management practices (fertilization, harvesting stage, weed control, resting period, burning, grazing management etc)	• Conduct contemporary studies on biological, economic and environmental benefits of different pasture improvement and management practices	• Participatory evaluation of potential interventions to improve biological, economic and environmental benefits of natural pasture	• Continue participatory evaluation of potential interventions to improve biological, economic and environmental benefits of natural pasture
• Availing information on long term trends in botanical composition, productivity and quality of natural pasture	• Establish permanent plots and monitor long term bio-physical and climatic effects on dynamics of botanical composition, productivity and quality of pasture at selected sites of different agro-ecologies	• Continue monitoring long term bio-physical and climatic effects on dynamics of botanical composition, productivity and quality of pasture	• Design conservation strategies and policy advice for ensuring species redistribution, ecological sustainability and habitat connectivity in the face of changing climate

Expected Outputs of the Strategic Interventions on natural pasture:

- Context specific recommendations for proper management and utilization of natural pastures developed.
- Information on interaction of feed production and natural resource management generated and modalities developed for effective integration of feed production with NRM initiatives
- Information on biological, economic and environmental benefits of different pasture improvement and management practices generated and policy briefs developed.
- Temporal and spatial dynamism in botanical composition, productivity and quality of natural pasture understood to guide sustainable use of natural pasture under changing climate.

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
Sub-theme 2.3. Agro-industrial by-products, crop residues and other feed resources			
2.3.1. Increasing research interventions on selected agro-industrial by-products (brewery by-products, sugarcane by-products, abattoir by-products, local brewery byproducts etc) handling, management and efficient utilization as feed.	• Establish innovation platform involving representatives of selected agro-industrial by-product producers, distributors, users and regulators for participatory identification of researchable problems. • Assess and map spatial and temporal distribution of major agro industrial by products as livestock feed. • Undertake participatory planning and implementation of research activities to address identified research problems along the value-chain of brewery by-products • Undertake research on determination of mycotoxin/aflatoxin status of various agro-industrial by-products (e.g. oilseed cakes) and mitigation measures	• Continue implementation and participatory monitoring of progresses. • Develop appropriate management and utilization interventions based on selected agro-industrial by-products	• Participatory demonstration and evaluation of potential interventions to enhance use of agro-industrial by-products in livestock feed

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
2.3.2. Availing comprehensive information and technology on optimal use of horticultural by-products and other non-conventional feed resources	• Conduct assessment to document availability, spatial and temporal distribution and management of horticultural by-products and other non-conventional feed resources. • Characterize nutritional profiles of these feed resources	• Conduct studies on improvement of handling, storage and utilization of horticultural by-products and other non-conventional feeds	• Participatory evaluation of best-bet practices on handling, storage and utilization of horticultural by-products and other non-conventional feeds
2.3.3. Enhancing understanding and documentation of indigenous feed processing and utilization practices	• Assess and document indigenous knowledge on feed processing and utilization practices in the country. • Conduct on-station and on-farm participatory evaluation of the impact of indigenous feed processing practices on nutritive value of feeds	• Conduct on-station and on-farm animal response studies on the impact of indigenous feed processing practices	• Participatory demonstration of best-bet lessons from indigenous feed processing practices
2.3.4. Investigating the availability and use of herbal plants and indigenous browses as feed supplements	• Assess and catalogue herbal plants that have potential values as feed supplements and additives. • Study on phyto-chemistry profile of selected herbal plants	• Conduct toxicology studies on pilot animals. • Conduct animal response trials to elucidate effects on bio-chemical profiles, productivity and product quality on selected herbal	• Demonstration of proven interventions in optimizing use of herbal plants and indigenous browse species as livestock feed

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
	• Identification of active ingredients in collaboration with researchers engaged in phyto-chemistry	plants and indigenous browse species for potential use as feed ingredient in livestock diet	
2.3.5. Widening technology options for improving use of crop residues in ruminant nutrition	• Forging collaborative research with crop breeders in indentifying varieties with combining ability of food –feed traits. • Investigation on application of TMR in improving uses of crop residues in ruminant diet. • Investigation of new options (chemical, use of supplements) for enhancing use of crop residues as livestock feed	• Continue investigation on varietal, treatment and supplementary options for optimizing use of crop residues in ruminant diet. • Participatory evaluation of promising options	• Mapping geographic areas where improvement of crop residue would lead to a bigger impact and popularization of promising options for wider use

Expected Outputs of the Strategic Interventions on agro-industrial by-products, crop residues and other feed resources

- Spatial and temporal distribution of major agro industrial by products mapped and potential intervention suggested to enhance their utilization as livestock feed
- Best-bet practices on handling, storage and utilization of horticultural by-products and other non-conventional feeds established and availed for wider use.
- Available indigenous knowledge on feed processing and utilization practices documented, best-bet lessons identified and validated for wider application.
- Potential herbal plants and indigenous browses identified and their phyto-chemistry profile documented.
- Best-bet practices on the use of herbal plants and indigenous browses as feed ingredients in livestock diets developed and recommended for use.

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
• Options for enhancing use of crop residues as livestock feed identified and geographic areas where improvement of crop residues would lead to a bigger impact mapped.			
Sub-theme 2.4. Formula Feeds, Premixes and Feed Additives			
2.4.1. Enhancing availability of information on nutritional characteristics, high cost and limited use of formula feeds	• Assessment of nutritional profile of major formula feeds. • Search for alternative feed ingredient and development of best cost ration. • Animal response trial of selected best cost formula feeds	• Animal response studies on alternative formula feeds using different classes of animals, level of productivity and physiological status	• Forging research for development collaboration in testing and promotion of formula feeds, premixes, feed additives and mineral supplements in commercial livestock production
2.4.2. Availing technologies for domestic production and affordable supply of premixes, mineral supplements and feed additives	• Acquisition of local mineral supplements and characterization of their mineral profile	• Animal response studies on local mineral supplements. • Animal evaluation of premixes and feed additives on productivity and product quality. • Public-private partnership on local production of premixes and feed additives	• Forging research for development collaboration in on-farm testing and promotion of premixes, feed additives and mineral supplements in commercial livestock production

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
Expected Outputs of the Strategic Interventions on formula feeds, premixes and feed additives • Effective collaboration of feed industry with national research system created to support commercialization of formula feeds. • Public-private partnership on local production of mineral supplements, premixes and feed additives created			
Theme 3. Animal nutrition and feeding systems			
3.1. Developing and/or availing cost effective, robust and responsive feed evaluation technique to support the need of feed and livestock industry	• Development of calibration equation for various parameters and feed categories for wider application of NIRS technology in evaluation of local feed resources, varietal choices in crop residues and rapid screening of forage germ plasm and varietal development.	Continue development of calibration equation, validation and application for wider parameters and feed categories	• Forge industry wide research for development collaboration for wider use of NIRS technique through ring test and networking
3.2. Improving technological options for different agro-ecologies and production systems.	• Identify research gaps and technology needs of feed and livestock producers in different agro-ecologies and production systems. • Assess available technologies and their suitability to different agro ecologies and production systems. • Refine and promote available technologies where applicable	• Continue assessment, refinement and promotion of suitable technologies	• Testing and verification of technologies suited to different production systems. • Continue refinement and promotion of proven technologies

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
	• Design and implement animal nutrition research activities responsive to the needs of smallholder farmers, pastoralists, commercial livestock producers, feed producers, etc		
• Expanding options for alternative feed formulation and feeding system for various species and classes of animals (ruminants, monogastric animal animals and fishes)	• Design research projects geared towards determination of nutrient requirement of different classes of animals. • Map locally available feed ingredients, determine and/or compile their nutritional profile. • Create national feed and nutritional profile database and review available information • Develop context specific, alternative feed formulations using selected and locally available feed ingredients	• Continue determination of nutrient requirement of different classes of animals. • Evaluate alternative feed ingredients for developing biologically and economically efficient feed formulations for different classes of animals. • Demonstration and promotion of alternative feed formulation approaches and applications	• Continue determination of nutrient requirement for unaddressed classes of animals. • Continue evaluating alternative feed ingredients for developing biologically and economically efficient feed formulations for unaddressed classes of animals. • Continue refinement, demonstration and promotion of alternative feed formulation approaches and applications

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
• Generating the necessary information and intervention options to ensure efficient utilization of available feed resources.	• Assess and quantify the extent of losses of feed resources along the feed value chain. • Assess potential availability, management and utilization of some unaddressed feed resources (such as horticultural by-products). • Design and develop appropriate interventions to minimize wastage and enhance utilization of available feed resources (crop residues, AIBPs like brewery by-products, horticultural by-products, etc) in the process of production, processing, transportation, storage and utilization. • Asses safety and quality of AIBPs for efficient incorporation into feeding systems for various categories of animals.	• Undertake animal evaluation using selected byproducts and develop feeding system for various categories of animals.	• Undertake on farm evaluation of nutritional interventions based on selected byproducts.

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
	• Develop guidelines and demonstrate efficient use of available feed resources (crop residues, AIBPs like brewery by-products, horticultural by-products, etc) based on available information		
• Demonstrating the value of improved forage crops through targeted animal response studies.	• Strengthen collaborative research undertaking among specialist on forage crops, animal nutrition and socioeconomics. • Design and conduct pilot animal based trials using promising forage crops for targeted agro-ecologies and production systems.	• Develop forage based feeding systems for various categories of animals in different livestock production systems.	• On farm evaluation, scale up and scale out best bet forage based feeding interventions.
• Widening base of alternative feeds for different species and classes of livestock (ruminants, monogastric animals and fishes).	• Search for locally available alternative supplementary feeds to develop cost effective, biologically efficient and environmentally suitable feeding systems for different categories of animals in various production systems. • Performance (biological and economical) evaluation of selected alternative	• On farm evaluation and demonstration of nutritional interventions based on alternative supplementary feeds. • Scale up and scale out best bet supplementation strategies	• Integrate feedback of on farm evaluation for possible use in commercial feed production. • Continue scaling up and scaling out of best bet supplementation strategies.

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
	supplementary feeds using dose response trials.		
• Availing basic information and technology to improve nutrition of free ranging ruminant	• Investigation of the nutritional status of free ranging ruminant using promising techniques such NIRS assisted fecal profiling technique, nutritional balance and PHYGROW models under pastoral set up and use of marker technique etc. (also consider suitable method of assessing feed intake and nutritional profiling of free ranging poultry). • Study on the use of aforementioned models for prediction of drought	• Continue study on nutritional status of free ranging ruminant and application of models in prediction of drought	• Synthesis of findings and validation for wider use. • Participatory evaluation and demonstration of the technique/ models for improving nutritional status of free ranging ruminant
3.3. Undertaking fundamental animal nutrition research such as development of nutrient requirement with emphasis on local animals as well as studies on protein,	• Collate locally and globally available information pertaining to nutrient requirement and mechanisms of nutrient partitioning of different classes of animals under tropical environment.	• Implementation of collaborative research projects. • Design national research projects in collaboration with	• Synthesis of research findings for setting nutrient requirement of different classes of animals and possible integration into

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
mineral, fatty acids, role of secondary plant metabolites, feed safety and greenhouse emissions	• Design national research projects in collaboration with different institutions for setting key nutrient (CP and energy) requirement for different classes of animals • Build the desired physical and human capacity to engage in determination of mineral, amino acid, fatty acid, secondary plant metabolites, feed safety parameters and greenhouse gas emissions. • Undertake characterization of key feed resources for developing targeted interventions to enhance mineral, amino acid, fatty acid supply and utilization for selected categories of animals. • Design and implement research projects on feed safety issues and role of secondary plant metabolites in livestock production system	different institutions for additional key nutrient beyond CP and energy requirement for different classes of animals • Develop and implement project interventions on appropriate feed/feeding system and animal genetic based interventions to reduce greenhouse gas emissions. • Undertake animal evaluation on the role of secondary plant metabolites in feed utilization and animal production systems. • Undertake animal evaluation on the role of mineral, amino acid, fatty acid nutrition on livestock productivity and product quality.	development of best cost rations. • Continue implementation of project interventions and undertake on farm evaluation of key technological options to reduce greenhouse gas emissions and optimize mineral, amino acid and fatty acid nutrition in livestock production systems.

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
3.4. Investigating interactions of nutrition with health and genetics	• Design appropriate modality for effective research collaboration among different livestock research disciplines. • Joint planning and implementation of research dealing with nutrition-health and nutrition-genetics interactions for livestock productivity and product quality improvement	• Joint implementation and monitoring of designed projects.	• Synthesis of results of joint undertakings and identification of interventions for wider use. • Identification of areas demanding further research interventions.

Expected Outputs of the Strategic Interventions on animal nutrition and feeding systems

- Robust, cost effective and responsive feed evaluation technique to support the need of feed and livestock industry developed
- Appropriate feeds and nutrition technologies suited to different agro-ecologies and production systems identified and recommended for wider use
- Basic information and necessary skills for effective use of alternative feeds in on-farm formulation of best cost ration targeted for various classes of livestock developed.
- Necessary information and intervention to optimize use of horticultural byproducts, crop residues and agro-industrial byproducts availed for wider use
- Appropriate feeding systems based on selected/promising forage crops for different classes of livestock developed
- Availability of alternative supplementary feeds mapped, evaluated and interventions for effective use demonstrated for wider application.
- Information on nutrient requirement of different classes of animals availed to various users (extension system, livestock producers and commercial feed industry).
- Basic information and technologies pertaining to protein nutrition, mineral, fatty acids, role of secondary plant metabolites, feed safety issues and greenhouse gas emissions generated.
- Application of NIRS assisted fecal profiling technique, nutritional balance and PHYGROW models in improving nutrition of free ranging ruminant livestock validated and demonstrated and potential use of the models for prediction of drought under pastoral set up validated
- Information on interactive effects of nutrition with health and genetics generated for improvement of livestock productivity and product quality.

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	Medium-term (6-10 years)	Long-term (11-15 years)
Theme 4. Cross cutting issues			
Gender Mainstreaming gender in animal feeds and nutrition research undertakings	• Assess gender role in feed production, management and utilization. • Integrate feedbacks in research project planning and implementation	• Collect gender disaggregated data in participatory evaluation and demonstration of potential feeds and nutrition interventions	• Evaluate gender role in feeds and nutrition technology adoption and promotion of gender responsive technologies
Climate change Considering climate change in animal feeds and nutrition research (adaptation and resilience to climate change as well as mitigation strategies)	• Study the effect of climate change on feed supply, feed quality and animal productivity. • Identification of mitigation strategies to enhance feed supply and utilization	• Continue study on mitigation strategies to enhance feed supply and utilization	• Continue study on mitigation strategies to enhance feed supply and utilization
Knowledge management and ICT Giving due attention to effective dissemination of research results and knowledge sharing mechanism	• Establishing electronic based information storage and retrieval system for effective sharing of information among researchers and other users. • Preparation of easily understandable guidelines and manuals targeted for various clients (development agents, smallholder farmers, commercial	• Continue updating information storage and retrieval system to promote easy access for various user groups	• Evaluation of knowledge management practices and design alternatives for ease of access and effective utilization towards promotion of feed and nutrition technologies

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
	farmers, feed producers, feed quality regulators, etc)		
Socio-economics Investigations on determinants of feeds and nutrition technology adoption pathway.	• Study on the role of taxation policy on the development of feed and livestock industry. • Study on macro-economic, social and environmental contribution of the feed sub sector	• Continue studies and produce policy briefs as decision support tool for policy makers	
	• Identify and understand bio-physical, socio-economic and cultural factors in adoption of feeds and nutrition technology	• Bring onboard key determinants in the planning phase of research undertaking and technology transfer	• Evaluate breakthroughs in adoption pathway of feeds and nutrition technologies
Conducting studies on enterprise choices (feed production versus production other agricultural commodities) under various production systems	• Design and implement collaborative research projects to generate evidence on opportunity cost of using land for forage or feed crop production versus other agricultural commodities to provide evidence for decision support for farmers to make appropriate/informed enterprise choice • Study opportunity cost of using some crops such maize and sorghum as animal feed (in green forage, silage or	• Continue collaborative research undertaking by bringing onboard new choices encompassing different environments	• Suitability mapping of potential areas where forage production could be the best- bet enterprise choice

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (11-15 years)**
	grain form) versus grain production for direct use as human food		
Human Nutrition Linkages between animal nutrition and human nutrition	• Study causal linkages of animal feeds and nutrition with human nutrition outcomes through the impact of animal feeds and nutrition on availability, safety and quality and affordability of animal source foods for human consumption	• Continue study on the causal linkage and produce fact sheets and policy briefs	
Expected Outputs of the Strategic Interventions on cross cutting issues: • Aspects of gender, climate change, socio-economics, knowledge and ICT and human nutrition are integrated into national feeds and nutrition research agenda • Adoption pathway and key determinants of feeds and nutrition technologies along the value chain identified. • Information for decision support tool to guide informed decision on enterprise choice (forage production versus other agricultural commodities) generated and availed under various production systems. • Establish causal linkages between animal feeds and nutrition and human nutrition			

6. The next steps

Following the approval of the strategy document by the EIAR top management, it is essential to prepare the implementation plan, without which this strategy is not going to reach fruition. The implementation plan document will come out as Volume II of the research strategy, which will serve as the blueprint to guide the National Feeds and Nutrition Research Program for the next fifteen years (2016-2030). The major contents of the implementation plan will revolve, among others, around the following topics:

- Develop implementation plan
- Develop monitoring and evaluation plan
- Develop impact assessment plan
- Develop reassessment plan for the strategy

In order to expedite the development of the implementation plan, it will be important to develop a common Guideline that will serve the EIAR Planning, Monitoring and Evaluation Directorate to provide guidance to the research teams to develop implementation plans. This Guideline is useful to communicate the goals of the strategic plans and establish uniform approaches. The Guideline will contain important considerations in planning a project(s) from the developed strategic plan, including building research teams of various roles and levels. It will generally be of importance that researchers, planners and evaluators will need to become familiar with the Guideline to prepare successful projects from the strategic plans as well as provide realistic estimates of resource requirements for implementing the strategic interventions projected for the short-, medium- and long-term timeframes. The Guideline will, therefore, be prepared with the intention of providing a common structural and conceptual framework that can be followed by the respective teams of research commodities for preparing the implementation plans of their respective strategies.

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8. Annexes

Annex 1. Glossary of important terms used in the strategy

Adaptation: Adjustment in natural or human systems in response to actual or expected climate stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.
Agro-industrial by-products: Secondary products from plant and animal processing and industrial manufacturing that may be used for animal feeding (e.g., distillers' grains, fish meal).
Browse: Parts of the foliage, tender branches or twigs of trees and shrubs, available for animal consumption
Climate change: A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. It refers to any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among other effects.
Crop residues: Portion of plant growth that remains after harvesting grain or seed crop e.g. Straws, stalks, husks, cobs etc.
Feed (feedstuff): Any naturally occurring material suitable for feeding animals.
Feed additives: Non-nutritive products that improve animal performance or preserve feeds.
Feed processing - physical or chemical changes in feedstuffs, which influence their nutritional value. **Formula feeds:** Feeds formulated and mixed by commercial feed manufacturers for specific target animals.
Forage: The part of the vegetation that is available and acceptable for animal consumption, whether considered for grazing or mechanical harvesting; includes herbaceous plants in mostly whole plant form, and browse.
Goal: An observable and measurable end result having one or more objectives to be achieved within a more or less fixed timeframe.
Mission: A written declaration of an organization's core purpose and focus that normally remains unchanged over time. A mission is different from a

vision in that the former is the cause and the latter is the effect; a mission is something to be accomplished whereas a vision is something to be pursued for that accomplishment.

Natural pastures: Natural pastures are naturally occurring grasses, legumes, herbs, shrubs and tree foliage that are used as animal feed.

Nutrient Requirements: Minimum nutrient needs of animals without margins of safety for maintenance, growth, reproduction, lactation and work. Nutrient requirements plus a safety margin is called "nutrient allowance".

Nutrition: The process of digesting, absorbing and converting feed into tissue and energy. It can also refer to the study of this process.

Partner: Individual who joins with other individuals (partners) in an arrangement (partnership) where gains and losses, risks and rewards, are shared among the partners.

PEST analysis: one of the strategic planning tools which covers the remote external environment elements such as political, economic, social and technological. It also includes legal/regulatory and ecological/environmental).

Policy: A statement of course of actions set by the Government in the management of agricultural development affairs which is formulated and implemented at *different levels* of Government. Policy is commonly expressed in the form of laws, rules and regulations, and broad goal oriented guiding declarations.

Premix: A uniform mixture of one or more micro-ingredients (vitamins, trace minerals, amino acids, or medicine) and a diluent or carrier, used to facilitate uniform dispersion of micronutrients into a larger mixture. Essential nutrients may sometimes be added to the water if they are water-soluble. Premixes are usually purchased already combined in set amounts to provide a specified nutritional content e.g broiler premix, layer premix, etc.

Program: A framework that contains similar activities designed to bring developmental changes (result-based); it is designed to enhance growth with a continuous resource allocation from internal and external sources.

Project is a unique and time urgent work effort to provide a result according to a certain specification and within fixed time and budget limit.

Resilience: The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.

Roughage - feed high in fibre (greater than 18% crude fibre); tends to be bulky, coarse and low in energy digestibility and protein.
Stakeholder: a person, group or organization that has interest or concern in an organization. Stakeholders can affect or be affected by the organization's actions, objectives and policies.
Strategy: The route to achieve the desired policy goals via specific elaborations of the resources to be mobilized (means). Strategies link the policy goals to programs that are set in a given plan period.
Supplement - A supplement is feed or feed mixture rich in one or more of protein, energy, vitamins or minerals combined with the basal diet so as to improve the nutritional balance of the diet as a whole.
User: Entity that has authority to use an application, equipment, facility, process, or system, or one who consumes or employs a good or service to obtain a benefit or to solve a problem, and who may or may not be the actual purchaser of the item.
Values: Important and lasting beliefs or ideals shared by the members of a culture about what is good or bad and desirable or undesirable. Values have major influence on a person's behavior and attitude and serve as broad guidelines in all situations. Some common business values are fairness, innovation and community involvement.
Vision: An aspiration description of what an organization would like to achieve or accomplish in the mid-term or long-term future. It is intended to serve as a clear guide for choosing current and future courses of action. See also mission statement.

Annex 2. List and herbage productivity of officially registered / released forage species and varieties in Ethiopia

SN	Species	Variety	Common name	Altitude (m.a.s.l)	DMY (t/ha)	Year registered	Breeder Institute
Grasses (16 varieties)							
1	*Avena sativa*	CI-8237	Oats	1500-3000	10-13	1976	HARC
2	*Avena sativa*	CI-8251	Oats	2000-3000	8-12	2013	HARC
3	*Avena sativa*	Bonsa	Oats	2300-3000	9.7-10.8	2011	SARC
4	*Avena sativa*	Bona-bas	Oats	2300-3000	9.8-10.3	2011	SARC
5	*Avena sativa*	SRCPX80Ab2806	Oats	1500-3000	12.0 -15.0	2015	HARC
6	*Avena sativa*	SRCPX80Ab2291	Oats	1500-3000	11.5-16.0	2015	HARC
7	*Penisetum purpureum*	ILCA-14984	Elephant grass	Up to 2004	10-15	1984	HARC
8	*Phalaris aquatic*	Sirossa	Phalaris	2400-3000	6-8	1982	HARC
9	*Chloris gayana*	Massaba	Rhodes grass	1000-2400	7-12	1984	HARC
10	*Panicum coloratum*	blue grass	Colo Guinea	1000-2400	6-10	1984	HARC
11	*Andropogon gayanus*	Dirki Ayifera	Andropogon	Up to 2000	8-10	2009	PARC
12	*Panicum maximum*	Local panicum	Guinea grass	Up to 2000	9-14	2014	PARC
13	*Penisetum polystachion*	Nech Sar	Netch sar	900-1500	7-12	2014	PARC
14	*Penisetum sphacelatum*	Shebela Sar	Bebeqa Sar	Up to 2000	13.2	2014	DZARC
15	*Cynodon aethiopicus*	DZF-265	Qola Serdo	Up to 2000	12.2	2015	DZARC
16	*Brachiaria mutica*	DZF-483	Para grass	Up to 2000	13.3	2015	DZARC
Herbaceous Legumes (16 varieties)							
17	*Vicia dasycarpa*	Lana	Vetch	1500-3000	5- 7	1976	HARC

18	*Vicia sativa*	ICA-61509	Vetch	2200-2004	5-6	2012	HARC
19	*Vicia sativa*	Gebisa	Vetch	2300-3000	4.3-5.1	2011	SARC
20	*Vicia villosa*	Lalisa	Vetch	2300-3000	6.6-8.4	2011	SARC
21	*Vicia narbonensis*	Abdeta	Narbon vetch	2300-3000	3.1-3.4	2011	SARC
22	*Trifolium quartinianum*	(Native)	Clover	1500-3000	3-6	1976	HARC
23	*Lablab purpureus*	-	Lablab	1000-2004	3-5	1984	HARC
24	*Vigna unguiculata*	Sewinet	Cowpea			2009	PARC
25	*Vigna unguiculata*	Temesgen	Cowpea			2014	Humera
26	*Medicago sativa*	DZF-552	Alfalfa			2014	DZARC
27	*Lupinusangustifolius*	Sanbor	Sweet blue Lupin			2014	Andassa
28	*Lupinusangustifolius*	Vitabor	Sweet blue Lupin			2014	Andassa
29	*Medicago sativa*	Alfalfa-1086	Alfalfa			(2015)	HARC
30	*Medicago sativa*	ML-99	Alfalfa			(2015)	HARC
31	*Lablab purpureus*	ILRI-14417	Dolichos lablab			(2015)	Bako
32	*Lablab purpureus*	ILRI-14455	Dolichos lablab			(2015)	Bako
Browse Trees and Shrubs (5 varieties)							
33	*Chamaecytisus palmensis*	-	Tagasaste	2000-3000	6-10	1992	HARC
34	*Sesbania macrantha*	DZF-092	Sesbania	400-2000	8-10	2012	DZARC
35	*Cajanus cajan*	Dursa	Pigeon pea			2009	MARC
36	*Cajanus cajan*	Kibret	Pigeon pea			2014	Humera
37	*Cajanus cajan*	Tsigab	Pigeon pea			2014	Humera

Rangelands Research Strategy

(2016 - 2030)

List of abbreviations and acronyms

ADLI	Agricultural Development Led Industrialization
APARI	Afar Pastoral and Agro-pastoral Research Institute
CGIAR	Consultative Group for International Agricultural Research
CoE	Center of Excellence
EARI	Ethiopian Agricultural Research Institute
EBI	Ethiopian Biodiversity Institute
EEA	Ethiopian Economic Association
EWCA	Ethiopian Wild life Conservation Authority
FAO	Food and Agriculture Organization
FTC	Farmers Training Center
GDP	Gross Domestic Product
GIS	Geographical Information System
GoE	Growth and Transformation Plan I
GTPII	Growth and Transformation Plan II
ICT	Information and Communication technology
IGAD	Intergovernmental Authority on Development
MoA	Ministry of agriculture
NARI	National Agricultural Research Institute
NGO	Non-Governmental Organization
OARI	Oromiya Agricultural Research Institute
PADS	Pastoral Areas Development Study
PCDP	Pastoral Community Development Project
PEST	Political, Economic, Social and Technology
RPLRP	Regional Pastoral Livelihood Resilience Project
SNNPR	Southern Nations Nationality Peoples Region
SORPARI	Somali Region Pastoral and Agro-pastoral Research Institute
YARC	Yebello Agricultural Research Center

Executive summary

The rangelands are primarily characterized by arid and semi-arid environments, with harsh environmental features. However, these should not be limited to and devoid of development, so long as careful planning and management of available resources is achieved. In Ethiopia, rangelands cover about 61% of the total land area and are located below 1500 masl mainly in the eastern, south, south western and western peripheries. Pastorals and agro-pastorals are the main inhabitants in the area. The rangelands makes up 40% of the nation's cattle, 70% of the goats and sheep and all camels in the country, which makes significant contribution to the national economy and supports 12 to 15 percent of the total population. About 90% of the national livestock export and 26 % of the draught animals comes from the pastoral animals.

Rangelands provide major goods and services of social, economic, cultural, and biological benefits, particularly for pastoral and agro-pastoral communities and associated ecosystems. Yet, benefits have been meager due to increase in human population, mismanagement of rangeland resources, lack of strong institutions and lack of relevant policies. The intensity and magnitude of rangeland degradation has increased over time, where bio-physical conditions such as vegetation cover, soil fertility, feed production and plant bio-diversity are decreasing at an alarming rate. This has resulted in the deterioration of the range-livestock production system with ultimate effect on livelihoods of pastoral communities (poverty, food insecurity) and environmental degradation. The endeavor in research and development of rangelands has made little impacts so far. This has embarked the need for strategic planning in the management and utilization of rangeland ecosystem for their sustainability under current and imminent situations.

The external and internal environments were analyzed and discussed with various stakeholders to clearly identify the weaknesses, strengths, opportunities and challenges of rangelands research. The strategic issues and interventions are formulated considering the major production problems. The major strategic research areas of range ecology and management are identified and planed for the coming fifteen years (2017-2030) includes (1) rangeland biophysical resources condition, (2) assessment and document of rangeland resources (3) rangeland grazing management, range forage production and integration of productive

animals, (4) Rangeland ecological rehabilitation, improvement, management and utilization of rangeland resources (5) climate, livestock and rangelands (6) demonstration of rangeland technologies (7) cross cutting issues like economics, gender and knowledge management. A short, medium and long term strategic plan is required in order to establish guiding framework in the research and development of rangelands which insures the ultimate goals of managing the country's rangeland resources. This is for the betterment of current communities and for future generations and sustained healthy ecosystem function of rangeland.

To achieve those targets, the envisaged strategic direction recognizes integrated application in research and development approaches. The whole implementation working process is also anticipated to address principles of cross cutting issues such as nutrition security, gender and youth sensitivity, environmental protection and climate resilience. The entire implementation process will be guided by an integrated and holistic approach with adequate linkage to other commodities, regional and international organizations engaged in rangeland research. The implementation process also recognizes adequate participation of stakeholders within and beyond agricultural sector using innovation platform and innovation clusters that add value to the process, output and outcomes. Owing to the fact that constraints, potentials and priorities are influenced by various factors arising through time and space, this strategic document is expected to generate technologies of rangeland resources improvement and to be client oriented to accommodate customers' need and government expectation in the process of implementation.

Rangelands Research Strategy

(2016 - 2030)

1. Introduction

1.1. Background

Ethiopia's total livestock population has reached more than 88 million in head count, and is the largest in Africa (MoA, 2010). IGAD estimated in 2010 that pastoralist livestock makes up 30% of the nation's cattle, 70% of the goats and sheep and all camels in the country (PFE, 2010). Rangelands occupy 47%-50% of the terrestrial surface of the Earth, or 68.5 million km^2 (Lean *et al*., 1990; Prentice *et al*., 1992). Africans comprises 25% of the world's total area of rangeland. Rangelands in Ethiopia make about 61% of the national land mass and largely dominate the lowland areas. Of the total land mass of the country, about 12-15% are pastoralists and agro-pastoralists. These areas are characterized by arid and semi-arid environments, diversified vegetation types, livestock and wild animal species as well as untapped mineral resources. The climate is rather harsher with erratic and inadequate rainfall, high temperature and evapo-transpiration, which is unsuitable for crop production without supplementary irrigation. The rangeland vegetation types include: 50% of woody-browse plants located in the Somali and Afar; 35% of open grasslands distributed in the Afar, Somali, Oromiya and SNNPR, and 15% open bush-grassland savanna along the Baro river plains in the Gambela regional state respectively (PADS, 2004). Rangelands are more suitable for pastoralists that rely on extensive livestock production using range feed and water resources, as well as for agro-pastoralists who practice opportunistic crop agriculture along river side. About 20, 24 and 51% of the rangelands are in good, medium and poor condition classes respectively, implying a steady decrease in rangeland production and productivity. Dry matter feed production is between 1.0 and 0.53 tons/ha/annum, with carrying capacity varying from 8 to 15 hectares per Tropical livestock Unit (Amaha, 2008).

The government of Ethiopia has placed due emphasis on rangelands research due to their contribution to food security and generation of income

for pastorals and agro-pastorals. The government has used different policies and strategies to develop the sector. The Agricultural Development Led Industrialization (ADLI) Strategy aims to enhance food security by tackling the challenges of agricultural productivity. Its main features include making appropriate technological interventions in the different agro-ecologies, giving emphasis to rangelands and integrating pastoralists and agro-pastoralists with domestic and external markets. The strategy promotes the use of labor intensive methods to increase outputs. In pastoral areas the focus is to improve livestock production by supplying water, health services, marketing and building roads and other infrastructure. The Rural Development Policy and Strategies are conceived to guide agricultural and rural development. A sustained growth will be promoted by educating pastoralists and agro-pastoralists to upgrade their skills in farming and ensuring their health, availability of drinking water, improving rural finance, rural road and transport, promoting trade and market and giving a guarantee to land ownership. The government's development vision, the existing policies and strategies, achievements of GTP-I and lessons drawn from its implementation is the basis for formulation of the second generation of the Growth and Transformation Plan. The GTP-II is designed to enable the economy to grow at 11% a year to enable the structural transformation of the economy. Investments will be emphasized with high priority to manufacturing industries to provide jobs and increase internal revenue. Agriculture will have a prominent role in increasing crop and animal production to ensure food security, control inflation, and provide agricultural inputs for agro-processing industry.

The Agricultural Growth and Transformation Plan-II focuses on key constraints of agricultural production. The objective is to increase agricultural productivity and contribute to dietary diversity and consumption at a household level. The project operates in 152 'woredas' involving about 1.8 million people from Oromiya, Amhara, SNNPR, Tigray, Benishangul-Gumuz, Gambela, Harari and Dire dewa. The program focuses to strengthen public agricultural support services, agricultural research, small holder irrigation development, agricultural marketing and related activities. The road map focuses to enable the current research capability of the country. It is known that the current research staff in federal, regional and higher learning institutes is about 2047 out of which about 57% have BSc degree, 35% MSc and only 8% PhD. These figures show that the number as well as the quality of the staff is not at the desired level. Looking at the disciplinary professions, it is also

clear that experienced researchers on rangelands are in short supply. The livestock research focuses on commodities such as milk, meat, poultry, camel, fish, honey, wool, feed and pasture.

The major focus of the Ethiopian Agricultural Research Institute (EARI) in the second Growth and Transformation Plan is to enhance productivity as well as capacity of farmers, pastoralists and agro-pastoralists in sustainable manner. The research dimension will be extended to marginal environments such as areas of recurrent drought, salty soils, degraded lands and other areas with irrigation potential. Climate smart agriculture, availability of rangelands technologies and their suitability and accessibility to men, women and young pastoralists and agro-pastoralists will be attended too. In the five year period there will be paramount attention and endeavor to generate or advances rangeland technologies with associated packages for the betterment livelihoods of pastoralists and agro-pastoralists.

1.2. Rationale for the strategy

Rangelands of the country are having various challenges of socio-economic, policy and biophysical resource degradation (Snyman *et al*, 2005; Amaha *et al*, 2008). Increasing declines in quantity and quality of range-feed biomass production in time has now become a potential threat for a sustainable livestock production in the pastoral areas of Ethiopia. Increase in different types of rangeland degradations over time are causing serious decline in vegetation cover in general, and desirable grazing and browsing feed resources in particular (Snyman *et al*, 2005; Amaha *et al*, 2008). Moreover, all sorts of rangeland degradations have resulted in poor animal performance in terms of meat and milk yields and deteriorations in breeding efficiency parameters. In view of the national macro-economic policy of the country, the objectives of improving pastoral livelihoods in one hand and increasing the export of quality and quantity livestock and livestock products is being subject to series of challenges (IGAD, 2004). Degradation of rangeland broadly categorized as bio-physical, socio-economical and institutional entities. Biophysical degradation subdivided in to soil-vegetation cover and climate changes. Biophysical degradation of soil-vegetation cover includes declines in quantity and quality of range-biomass production (less than 1t/ha of dry matter), loss of biodiversity (less vegetation diversity), poor animal performance (less than 1liter per cow per day of milk yield) (Gemedo, 2004), deteriorations in breeding

efficiency parameters, top soil loss. Biophysical degradation in terms of climate change includes recurrent drought, temperature and rainfall variability, carbon stock and GHG emission from rangelands. Socio-economic degradation includes poverty, food insecurity, low export of quality and quantity livestock and livestock products. Institutional degradation includes loose management of rangeland resources and absence of rangeland Policy. Hence, unless research and development efforts are launched to reverse the ever increases degradation in rangelands, then obviously livestock and community development goals in pastoral areas of Ethiopia are likely to fail than succeeding.

The research approach needs to focus on those areas where information is lacking, interventions are limited and technological gaps are visible. This may include detailed investigation on rangeland conditions, range-livestock management practices, trends and current situations of pastoral production systems, available range improvement technologies and its limitations, rangeland interaction with climate change, application of indigenous knowledge, land tenure and policy issues, drought period feed conservation and feeding strategies, management of bush encroachment, ecological rehabilitation of degraded rangelands, application of soil and water conservation techniques. There were some research efforts made by different organization for the last four to five decades to generate available information and possible intervention on the rangelands. Further synthesis of previous studies and documentation, analyzing the gaps, strengthening good practices and strategic planning for further improvement in the future is tremendously important. Therefore, this rangeland research strategy planned for the coming fifteen years of implementation, with three transitional phases, namely, Short term (2017 to 2021), Medium term (2021-2026) and Long term (2026-2030) plans. Particular period of implementation will be five years for each and appropriate technologies that improve rangeland productivity expected to be generated at each phase.

1.3. Vision

- To see improved rangeland ecosystem with optimum productivity and biodiversity maintained.

1.4. Mission

- To generate affordable and adaptable technologies that sustains improvement of livestock productivity

- To generate affordable and adaptable technologies that enhances utilization, management and conservation of rangeland biodiversity

1.5. Goal

- To improve the livelihood (food and nutrition security, and income) of pastoral, agro pastoral and other communities lived in the rangeland by increasing rangeland productivity

1.6. Objectives

The general objective is to improve and sustain the rangeland resources and ultimately create resilience ecosystem for optimizing the benefits of rangelands to community and national economy. The specific objectives are to:

- Generate technologies that enhance rangeland productivity and sustainability thereby improve pastoral and agro-pastoral livelihood.
- Ensure healthy functionality of rangeland resources through creating resilience ecosystem.
- Generate mitigation and adaptation options to combat negative effect of climate change on rangeland resources.
- Demonstrate and document proven technologies and indigenous knowledge to improve rangeland resources, livestock productivity and pastoral wellbeing.
- Develop socio-economic and institutional policy options to be taken by decision makers on intervening in rangeland development.
- Develop a data base on information regarding to rangeland biophysical resources and indigenous knowledge
- Enhance rangeland research capacity and infrastructure in pastoral and agro-pastoral areas.

1.7. Guiding principles

The guiding principle of the rangelands strategy is ensures higher production, productivity and improves the livelihoods of the pastoralists in the rangelands. Rangelands have huge resource potential and significant contributions to the livelihoods, agricultural sector, national economy and

environmental protection. However, there are persistent challenges of rangelands. Some of the major challenges are continuous degradation of the rangelands, shrinkage of land available for grazing, reduced opportunities for mobility, bush encroachment, continuous excision of key grazing areas for irrigation, expansion of farming, climate changes, increasing population, conflict, recurrent drought, flood and poor rangeland management practices. In order to reverse such situation and improve productivity of rangeland, development of this strategy is very crucial. Therefore, to satisfy the vision and objectives of the EIAR, the following major issues of national interest are given due consideration.

- Development of external and internal linkages
- Loyalty and respect to diverse client needs
- Positive attitudes and perception towards researchers and supporting staff
- Must use gender-sensitive approaches to empower women
- Demonstrating transparency and good governance
- Ensure the livelihoods improvement while maintaining the rangelands ecosystem
- Generating, demonstrating and adopting rangeland management practices
- Responsibility and accountability at all levels

2. Importance of rangelands

2.1. Geographic distribution

The pastoral population occupies a large area of Ethiopia. More than half of the country's landmass belongs to pastoralists. Pastoralists are found distributed over 122 districts of the country (Table 1). Pastoralists in Ethiopia are found in seven regions including Afar, Somali, SNNP, Oromiya, Dire dawa, Benshangul-Gumuz and Gambella Regional States. As shown in Fig. 1, Over 97% of the pastoral population lives in Somali, Oromiya, Afar and Southern Region States. Besides the mainly known pastoral regions, others like the Gambella and Benishangul-Gumuz regional states have pastoral communities (Amaha 2010, Davies 2007; EEA 2005).

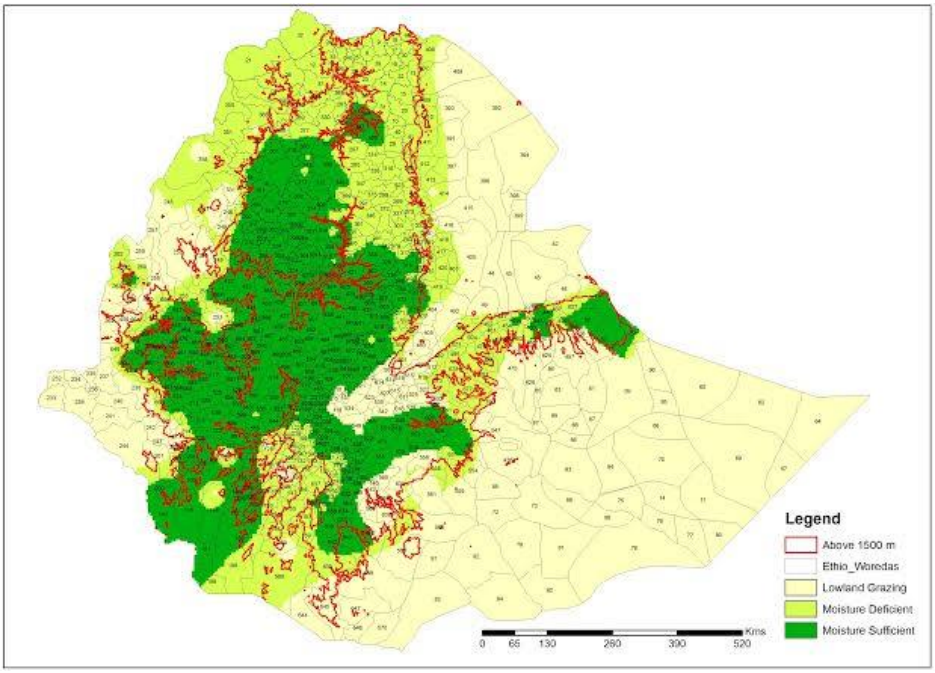

Figure 1. Location of major pastoral communities (Source: Ministry of Agriculture Livestock Sector Analysis (2015)

Rangeland based livestock production is the major livelihood in pastoral areas. Pastoralists use the diverse livestock species to exploit and make use of the different rangeland resources. Of the total cattle population of the country, 40% of the nation's cattle, 70% of the goats and sheep and all camels are owned by pastoralists (Davies 2007; EEA 2005).

Table 1. Land size and population distribution of pastoral in different regions of Ethiopia

Regions	Total surface area ('000km²)	Total pastoral area (km sq.)	Pastoral Districts	Human population ('000)	Livestock density (TLU/km²)
Afar	98.4	90.4	29	1301	7
Benshangul-Gumz	48.3	8.4	3	40.6	1
Dire Dawa	1.2	1.2	1	108.6	32
Gambella	25.8	17.3	5	133.6	17
Oramiya	353.0	152.1	34	4007.9	33
Somali	325.1	325.1	44	4002.2	8
SNNP	112.3	30.4	6	219.7	23
Total	964.1	624.9	122	9813.6	121

(Source: EEA 2005, Davies 2007)

2.2. Economic Contribution of rangelands

2.2.1. National Economy

Rangelands plays significant role in the Ethiopian agriculture particularly of livestock. The livestock sector contribute to the total GDP is about 16%, to the agricultural GDP is around 38% and to the agricultural export is around 40% (CARE-Ethiopia, 2010; EEA, 2005 and Ayele et. al. 2003). Pastoral output underpins almost Ethiopia's entire live animal and meat exports (IGAD LPI Working Paper No 02-11). Out of a total capital value (i.e. 86.455 billion EB) for the national herd, 34.779 billion EB (40%) worth of Ethiopia's livestock were managed by pastoralists. It is estimated in billion EB of 20.258 for cattle, 2.254 for sheep, 5.011 for goats and 7.256 for camels (IGAD LPI Working Paper No 02-11). According to Hatfield and Davies (2006), rangeland contribution is estimated to be 54% and 90% of the national livestock population and export live animals, respectively.

2.2.2. Export market and foreign currency earnings

In Ethiopia, the livestock types and breeds in pastoral areas are highly demanded for meat export markets. Ethiopia's exports consist of live cattle, sheep, goats and camels, as well as chilled goat meat and mutton, which are mainly sourced from pastoral areas. Its ranks second in foreign currency generation in the national foreign economy (IRDA 2012). The sector showed unprecedented growth in formal exports, and this trend has continued to increase (Table 2) (Aklilu Y. and Catley A. 2014).

Table 2. Formal live animal and meat exports in Ethiopia, 2005-2013

Year	Live animals		Meat	
	Number	Value (US$1,000)	Amount (tons)	Value (US$1,000)
2005/06	163,000	27,259	7,717	15,598
2006/07	234,000	36,507	7,917	18,448
2007/08	298,000	40,865	5,875	15,471
2008/09	150,000	77,350	6,400	24,480
2009/10	334,000	91,000	10,000	34,000
2010/11	472,041	148,000	16,877	63,200
2011/12	800,000	207,100	17,800	78,800
2012/13	680,000	150,000	16,500	68,000

Source: Aklilu Y. and Catley A. 2014

2.3. Rangelands contribution to pastoral livelihood (i.e. food, nutrition, income and assets)

In the lowlands of the country, which are predominantly pastoralists, livestock is the major source of food (meat, milk, eggs) and non-food items such as transport services (Davies 2007). At least 50 percent of the gross incomes of households in the rangelands are from the sales of live animals and livestock products like milk, butter, hides, skins and eggs (Ellis and Swift, 1988). It is an established fact that, livestock is a measure of wealth

and social status in pastoral communities. Livestock (particularly cattle), are thus a financial asset (i.e. serve as a source of food, income and storage of wealth), social asset forming for the basis of social relationships through gifts, exchanges and physical asset (i.e. livestock herd, infrastructure) (Edlam, 2003). Rangelands are rich in cultural heritages. In rangelands, the knowledge and skill acquired is passing from generation to generation through local institutions. For instance the deep-well water resources management and grass lands conservation, wet and dry season grazing and settlement rules and the institutions in Borana rangelands are commonly documented (Bassi, 2005).

2.4. Environmental sustainability

Rangelands have various environmental contributions: soil formation, recycling of nutrients, primary production, maintenance of biodiversity, water cycling, maintenance of soil via sediment deposition, weather events, climate change (reduce carbon emission and carbon sequestration), These are collectively creates the biophysical and natural resource capital that are the base for human survival and sustainability of the environment. Pastoralism; extensive livestock production in the rangelands, is one of the most sustainable food systems on the world. Rangeland ecosystems are grazing dependent and sustainable management practices maintains soil fertility and soil carbon, water regulation, pest and disease regulation, biodiversity conservation and fire management. Pastoral rangeland based livestock production protects biodiversity and keeps rangelands open and interconnected, helping to maintain biodiversity and the flow of ecosystem goods and services (Neely et al. 2009; McGahey et al. 2014). Moreover, livestock grazing and management also play important roles in the continued flow of a range of ecosystem goods and services, from soil fertility and the distribution and diversity of plants. The effective management of biomass led to optimum conditions for soil carbon sequestration and the management of fires. The global significance of these services can extend well beyond the boundaries of the rangelands as typified by the huge potential offered by improved grazing management on grasslands for soil carbon sequestration. Some rangeland soils retain carbon for longer periods than forest soils and due to historic carbon losses rangeland soils are said to be far from saturation (Silvestri et al. 2012).

3. Assessment of external and internal environments

Assessing the external and internal environmental factors that influences the program strategic conception, formulation, action and implementation is important to meet the objectives and accomplish the mission of rangeland research program.

3.1. Assessment of external environments

The external factors represent those influences that are outside the EIAR's domain of control. External environments of the program are its clients, users, beneficiaries and partners who have their own mandates, responsibilities and play important roles in rangeland management research and development endeavors in the country. Analysis of the external environments; their positive and negative influences, will help the program to evaluate and determine the chances that the research endeavor will succeed. The positive influences arising from external factors create an opportunities, while negative influences would be considered as challenges. Two categories of external environments were analyzed; the general external environments (PEST+) and operational external environments.

3.1.1. General external environments (PEST+)

The policy dimension:- The 1995 constitution incorporated the issues of pastoralists for the first time in the country. It also formed a department in the ministry of federal affairs which coordinates and facilitates development in pastoral areas and set up pastoralist affairs standing committee in the parliament which oversees pastoral development activities in the country. Regional offices in charge of pastoral development have been established in regions where pastoralism is an important production system. Pastoral Community Development Project (PCDP) and Regional Pastoral Livelihood Resilience Project (RPLRP) by GoE, which provides even greater emphasis to enhance livelihood resilience of pastoral system gave utmost priority for the program. GoE has attempted to incorporate pastoral development in its national development plans (2003-2007 and 2008-2012 plans) that are modeled on the Growth and Transformation Plan (GTP). Therefore, so many opportunities are set forth by the policy environment; with also a number

of challenges that may face in due course, to promote research and development of the rangeland to enhance its productivity (Table 5).

The economic dimension:- Rangelands contributing to 90% of export live animals (EEC, 2005). The stock farming sector ranks second in foreign currency generation. In 2006, Ethiopian exports of livestock and products from stock farming that generated 121 million US dollars. Rangeland based livestock production in pastoral area is the measure of wealth which accounts 40% of national livestock. At least 50 percent of the gross incomes of households in the rangelands are from the sales of live animals and livestock products like milk, butter, hides, skins and eggs (Swift et al., 1988). The GTP's plan for pastoral development also sets ambitious targets; increasing export earnings from live animals and meat exports combined, from US$125 million in 2009/10 to US$1 billion in 2014/15 (GoE, 2010). The research has to; therefore, keep pace with the need of the national economy and pastoralists to increase livestock productivity mainly through increasing rangeland productivity. With all these economic opportunities, there are also pressing challenges that the research needs to address (Table 5).

Socio-cultural dimension:- The pastoral rangelands provide livestock-based direct livelihood support to an estimated 12-15% of the country's human population. Studies indicate that an estimated 93% of the population in pastoral areas is directly dependent on livestock for subsistence. As a key assets, rangeland based livestock production (particularly cattle), are thus a financial asset, serve as a source of food, income and storage of wealth as well as a social asset forming the basis of social relationships through gifts and exchanges. Livestock can be seen as a good measure of the wealth status in a community and of the well-being of households. Livestock also serve the financial role of a bank. Thus, the research can make use of these socio-cultural environments as potential opportunities for reducing poverty and promoting sustainable development in the area.

Environmental dimension: - The natural assets of grazing land, water sources and rangeland products are keys to the pastoralist livelihood system. A major contribution of rangelands comes from ecosystem services. Animal-maintained rangelands appear to support greater species numbers and contribute to well-functioning water cycles, mineral cycles, and energy flows. Rangeland based livestock production system should

also be valued as 'natural resource management systems' that provide a wide range of services and products, such as biodiversity, tourism and raw materials. With regard to the climate change, grasslands have a greater potential ability for carbon sequestration. Rangeland products managed by pastoralist, for example, are increasingly sought after. These include gum arabic, medicinal plants and honey which is a largely untapped potential. It is important to identify what opportunities from these environmental factors the research can make use of the best, at the same time prepared on challenges they may impose.

Operational external environments: - Stakeholder analysis, identification of key stakeholders and the role they play to strengthen the sub-sector and their responsibilities indicated in table 3. In the same table, a list of such stakeholders with their different roles and responsibilities examined as these stakeholders play a crucially important role for successful planning and implementation of the strategy.

3.1.2. Stakeholders analysis

Table 3. List of stakeholders and their roles and responsibilities

No	Name of Stakeholder	Expectation (i.e. roles and responsibilities)
1	Federal and regional research institute	• Joint research engagement • Technical support and experience sharing (training, genetic material, research outputs…) • Financial and human resource sharing and support
2	Higher learning institutes	• Technical support and experience sharing (training, genetic material) • Joint research engagement • Financial and human resource support
3	Ministry of livestock and fishery resources	• Policy and strategy recommendation • Technical support (training, genetic materials) • Human and financial resource support • Research-extension linkage • Joint research development and implementation

No	Name of Stakeholder	Expectation (i.e. roles and responsibilities)
4	Ministry of agriculture and natural resources	• Policy and strategy recommendation • Technical support (training, genetic materials) • Human and financial resource support • Research-extension linkage • Joint research development and implementation
5	CGIAR centers	• Joint research engagement, information and genetic material exchange • Physical infrastructure and facilities • Technical contribution in their research planning and implementation • Financial support
6	IBC (Institute of Biodiversity Conservation)	• Provision and sharing of technical issues and information on genetic material. • Provision of feedback/technical issues/ on performance of indigenous genetic material • Provision of genetic material for long term conservation/maintenance • Joint research development and implementation
7	Pastoralists and agro-pastoralists	• Technical support (genetic material, provision of land for rangeland research, indigenous knowledge and production packages) and participation on policy briefings for government consideration • participation on implementation of research • Beneficiaries
9	NGO	• Research partnership and consultation • Financial support and technical support
10	EWCA (Ethiopian Wild life Conservation Authority)	• Joint establishment of conservation research site including botanic garden • Technical support, information exchange, policy input.

3.1.3. Benchmarking

Pastoral areas in Ethiopia, which cover about 0.7 million square km, are generally known as the range lands. These areas support about 12% of total population of the country. Pastoralism relies on livestock diversity to exploit and make use of the diverse rangeland resources. Rangeland based livestock production plays significant role in the Ethiopian economy, and the sector has huge economic, social and environmental roles and benefits. Despite of this, the benefits obtained from the sector is low compared to other countries. The problem of rangeland are multifaceted (biophysical/environment, economic, institutional and social issues) and need more complex remedies for sustainable rangeland management. Hence, generation of adequate technology in addressing the main problems of this area is crucial. Moreover allocation of sufficient financial resource, establishment of research facilities and support strategies are needed to generate adequate technological packages to significantly improve the rangeland resource, livelihood of pastoral community, enhance livestock off take, support the national economy, and ensure sustainable development.

As part of the external environmental factors, it is also a cogent exercise to examine the potentials of the national rangeland resources which can and should be exploited by drawing lessons from other countries that have advanced levels of research achievements to improve their rangelands productivity and maintain its biodiversity. Accordingly, comparisons in terms of the rangelands contribution to country's national economy (GDP) and export earnings were made between Ethiopia and other exemplary countries and their excellent experiences in rangeland management are considered as benchmarks for the preparation of this strategic document (Table 4). Additionally the status of Ethiopia and benchmarked country were assessed (Annex Table 1). In benchmarked countries, rangeland livestock production has significant contribution to national GDP and export earnings. Therefore, benchmarked countries who advanced in the rangeland research and development works, were identified to adopt and renovate their technological packages to improve the productivity of Ethiopian rangeland resources through research and development. Some of the main reasons for the high contribution of rangelands to GDP and export earnings in the majority of benchmarked countries are based on activities/factors listed below.

- Adequate human, physical and financial capacity improved at all level of the sub-sector.
- Availability of appropriate technologies for ecological rehabilitation/restoration of degraded rangeland.
- Availability of technology for bush control methods, techniques to use bushes for other purposes and presence of information on driving bush encroachment and link between climate change and grazing pressure
- Availability of appropriate soil-water conservation practices for rangeland restoration
- Availability of appropriate range-livestock grazing management techniques developed based on hybrid knowledge (scientific and indigenous knowledge).
- Development of possible alternative uses of rangeland resources for pastoral communities
- Better efficiency to demonstrate and popularize rangeland technologies for rangeland improvement in pastoral areas
- Better documentation of information regarding to rangeland conditions, vegetation types, soil condition and indigenous knowledge
- Continuous monitoring and evaluation of the rangeland resources

Table 4. Rangelands area coverage and its economic contribution in different countries

Country	Area coverage	Pastoral Contribution to		Description
		Agriculture GDP (%)	Country GDP (%)	
Ethiopia	51% of 1.104 million km^2	15	9	250 million in 2011 (Export earnings in USD)
Kenya	81% of 581,309 km²	50	25.4	800 million per year (Export earnings in USD)
Uganda	43% of 199,710 sq km	-	9	About 85% of the total marketed milk and beef

Hatfield, R. and Davies, J. (2006) and REGLAP, (2012)

3.2. Assessment of internal environments

The internal factors represent those influences that exist and operate within the research system of the institute. In this regards, any capacity that exist in EIAR system and is readily available for the research team can be seen as strength of the team while capacities required in delivering the research outputs doesn't exist in EIAR system is weakness of the team. In line with this, the evaluation has focused on institutional capacity (i.e. the available or lacking human, physical and financial resources), technological capacity (i.e. technology generation capabilities) and organizational capacity (i.e. organizational coordination and alignments).

3.2.1 Resources

The human, physical and financial resources have a decisive power on program implementation, coordination and administration. Presence of high staff turnover, lack of skilled technical staff; limited capacity in terms of infrastructure and physical facilities and inadequate budget allocation and release system, and inefficient procurement process are the critical challenges for implantation of different research activities. Therefore, the level of human resources capacity, financial capacity and the physical resources available and lacking were assessed and tabulated as strengths and weaknesses to undertake various researches on rangelands improvement.

3.2.2 Inter and intra disciplinary integrations, complementarities and synergies

Integration of the rangelands with potentially potent disciplines like animal breeding, feed and nutrition, animal health, animal production is very important to improve the livelihoods of the pastoralists. In addition to that of the mainstream disciplines (such as soil science, soil and water conservation, botanist, GIS, meteorologist, range economist, crop protection, etc) there are clear possibilities of realizing complementarities and synergies by working together with experts of other fields.

3.2.3 Organization, implementation and geographic coverage

Unlike most research commodities of EIAR, YPDARC of OARI is the center of excellence (CoE) for Rangeland ecology and management research, coordinating nationwide researches in rangelands. Werer agricultural research center, Assosa agricultural research center, Pawe agricultural research center and Melkasa agricultural research center from EIAR involved in range research. Moreover, SORPARI, APARI, NARI and OARI and their research centers involved at national level. In general, the culture of research collaborations to conduct joint reviews and planning, multi-location trials, etc. among research institutes and universities are good. The research centers are well distributed in major pastoral areas but their numbers are limited as compared to the vast rangeland area coverage of the country.

3.3. Strengths, Weaknesses, Opportunities and Challenges by the Research Themes

Table 5. Summary of the strengths, weaknesses, opportunities and challenges assessed from the perspectives of the external and internal factors

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
Theme 1: General			
• Establishment of rangeland research at program level at national research system • EIAR commitment in expansion and support of range research in unaddressed pastoral areas Ethiopia. • The culture of research collaborations to conduct joint reviews and planning, multi-location trials, etc. among research institutes and Universities	• Lack of national focus on rangeland research • Weak inter and intra disciplinary linkage within EIAR • Insufficient trained man power and high turnover in the area of rangeland research • insufficient of incentives and conducive working environment to maintain rangeland researchers in the harsh pastoral environment • Insufficient financial resources allocation to rangeland research in	• Government commitment and presence of limited policy and strategies for pastoral area research and development • Availability of regional and international research institutes as well as higher learning institutes engaged in range research • Presence of governmental and non-governmental organizations involved in rangeland development • Rich natural resource base (i.e. presence of vast area of rangeland,	• Shrinkage of indigenous rangeland management practice (e.g. mobility) • Climate change (i.e. frequent drought, erratic distribution of rain, flood etc.) • Production system change (land use change) • Insufficient and non-strong pastoral extension system

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
• Availability of some facilities and conducive conditions in conducting range research and development	comparison to the vast coverage of rangelands and its economic significance • Limited of research facilities (vehicles, lab, field equipment's, store, office, etc.) in coordinating and implementing centers • Despite the multidisciplinary nature of the program, professionals in d/t disciplines (i.e. Soil scientist, Botanist, GIS, Range economist, etc.) is lacking in rangeland research • Minimum technology generation status in comparison to rangeland coverage, human and livestock population • Limited incorporation of modern technological tools like GIS and remote sensing in rangeland research.	huge livestock population and different livestock breeds, wildlife, biodiversity, etc.) • Presence of donors which supports research and development in rangelands (IGAD, World Bank) • Attention given by higher learning institutes in producing trained man power in the area of range ecology and pastoral livelihood • Expansion and establishment of new Universities in the country • Conducive government plan to raise foreign exchange earnings from export of live animal and animal products mainly from pastoral areas • Ever increasing domestic demand for range products (meat, milk, gum, resin, etc.	• Unimplemented land use and land tenure policy in pastoral areas • Resource conflict in pastoral area • Population growth and demographic change • Weak institutional linkage in rangeland research and development • Vulnerability of pastoral area for various shocks

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
Theme 2: Assess and document national data base on rangeland resources			
• Past research work on rangeland biophysical resource conditions and trends	• Limited national database on rangeland resources of Ethiopia	• Availability of various research outputs on rangeland resources by Universities, CGIAR centers, regional research institutes	• Weak institutional linkage to share research outputs on rangeland resource
Theme 3: Rangeland biophysical resource conditions			
• Established core research team of climate change and geospatial at directorate level and in some research centers of EIAR • The research team has skilled man power and experience GIS (for range mapping) • There is research team on soil in most of EIAR research center • Availability of multidisciplinary research staffs (socio-	• Lack of strong linkages among different research disciplines • Insufficient efforts to use GIS and remote sensing technology in rangeland research and development • Wide usage of conventional survey methods; costly, time-consuming and limited to accessible areas of the rangelands • Attention given in combining indigenous and scientific knowledge in assessment of rangeland bio-	• Rangeland resources in Ethiopia are an important natural ecosystem that offers basic necessities for millions of pastoralists • High spatial and temporal variability of rangeland resources • Availability of GIS and Remote sensing technology that provides feasible and cost-effective, timely and accurate information • Availability of multispectral and hyper-spectral data to classify vegetation at	• Rangeland degradation • Change in land use • Resource conflict at different level, time and place • Finance and expertise needed in usage of modern GIS tools for rangeland research and development • Harsh nature location of main rangelands of Ethiopia

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
economics, soil and water, range ecology, etc.) • Experience of researchers on rangeland condition assessment • Strong linkages and relation of range researchers with local community	physico-chemical resource condition and trends at national levels • Limited national database on bio-physico-chemical resource conditions in Ethiopia • Limited of rangeland (biotic and a biotic resource) maps for major rangelands of Ethiopia	species level and assess the level of rangeland degradation • Pastoralist indigenous knowledge to rangeland condition and trends analysis	
Theme 4: Rangeland grazing-management, range forage and integration of productive animals			
• Existence of research centers and research facility in major pastoral areas • Availability of un updated information on traditional range management practices • Availability of multidisciplinary research staffs • EIAR efforts in improving the genetic make-up and	• Limited modern technologies and knowledge on grazing management systems • Limited knowledge on feeding and grazing/browsing habit of domestic animals and their feed requirement in pastoral rangelands of Ethiopia • Absence of feed availability maps based on feed resources and feeding habit	• Need of information and data base at national level on the available rangeland management and carrying capacity rangelands spatially and temporally • Stakeholders interest on rangeland development intervention • Dependency of large human population on rangeland resources • Role of rangeland based livestock to the country's export earning	• Predominant communal grazing system prevail in most of the rangelands • Frequent drought • Conflict • Change in rangeland land use tenure system • Limited support and clear policy from the government side to enhance the productivity and

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
productivity of indigenous livestock type • Initiation and efforts of EIAR in development of some adaptive and productive improved and indigenous forage varieties in the pastoral and dry land areas • Availability of some research facilities and man power in generation of technologies	• Limited sufficient adaptive and productive forage varieties or cultivars in the hands of research center • Limited knowledge and information on feeding management practice for rangeland based high value livestock production in pastoral area • Limited knowledge and information on agronomic practice (e.g. mixed pasture) in rangeland based high value livestock production • Limited technologies, knowledge and information on cow-calf responses to dairy or beef cattle production under integrated rangeland management system and that of forage-based systems as well as economic returns to producers in pastoral and agro pastoral areas.	• Ever-increasing usage of modern technological application in rural area of Ethiopia • Availability of large sized and productive rangeland lands and diversified feed resource • Government interest and commitment in improving pastoral livelihood through intensification of small scale livestock farming • Ever increasing demand for livestock and livestock products for pastoral area • Presence of large number of pastoral population as well as their knowledge and experience on livestock production • Availability of productive and diverse forage germplasms at local and international research institutes	intensification of small scale rangeland based livestock production • Frequent amendment of government strategy in pastoral setting in utilization of rangeland resources • Low productivity of domestic animals and lack of sufficient vet and AI services • Number based livestock keeping in pastoral area instead of focusing on productivity

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
	• Limited information and practices of rangeland feed conservation for dry season and feeding for productive animals	• Huge underground water potential of rangelands of Ethiopia	
Theme 5: Rangeland ecological rehabilitation, improvement, management and utilization of degraded rangeland			
• Establishment of research centers in pastoral area and some resource allocation • Availability of range researchers and technical staffs • EIAR initiatives in conserving rangeland botanic resources and their multiplication at EIAR centers • Availability of some lab facilities at national and in some regional research centers • Initiatives of research activities on management of bush and	• Limited restoration technologies and information's (i.e. reseeding, over sowing, enclosure, animal impact, rangeland watershed development, etc.) in comparison to rangeland degradation extent • limited technologies and information on bush encroachment and invasive alien species management/control methods • Lack of both in-situ and ex-situ conservation sites for native and adaptive rangeland plant biotic resources for conservation and rehabilitation	• Rangeland supports greater number of biotic species and contributes to well-functioning of environment and provides ecosystem service • The natural assets of grazing land, water sources and rangeland products are key to the pastoralist livelihood system • Government signatories to international conventions and treaties (e.g. Rio-conventions) • Presence of climate resilience green economy strategy that includes rangeland development	• Encroachment of rangeland by alien and other endemic encroaching plant species • Conflict among tribes • Increased frequency and intensity of climate variability • Limited range and options of mobility • Increased land degradation and continuous loss of adaptive and productive rangeland biotic resources • Threatening of indigenous knowledge and practices on bush management

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
invasive alien species in EIAR centers • Existence of crop protection research team in EIAR centers	• Poor linkage between rangeland and plant protection research disciplines	• Increasing interest from NGOs in implementing range management in pastoral area • Engagement and commitment of international organizations and research institutes to support rangeland rehabilitation effort • Rangelands provides secure livelihoods, provides ecosystem services, promotes wildlife conservation and honors cultural and tradition values • Presence of indigenous knowledge and practice on bush management • Interest of local people in managing their rangelands	• Increased frequency of policy amendments and conflicting policies and strategies in rangeland resource utilization and management • Expansion of cultivated land • Land tenure system
Theme 6: Climate, livestock and rangeland			
• Established core research team of climate change and geospatial at directorate level	• Limited linkages among different research disciplines	• Presence of climate resilience green economy strategy that considers rangeland as an important asset	• Demographic change in pastoral setting • Conflicts

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
and in some research centers of EIAR • The research team has skilled man power and experience climate change research • Commitment of EIAR to support implementation of the national climate resilience green economy strategy	• Climate change and geospatial research team largely engaged on non-pastoral areas • Limited information on C and N storage capacity of Ethiopian rangelands under different range conditions and types. • Emission rate of Ethiopia rangelands and various rangeland management practices not known. • Lack of permanent range sites to monitor carbon storage, climate change impact, etc … • Insufficient databases and models for the interaction of climate, rangeland and livestock production and productivity. • Lack of sufficient protocol in carbon stock, financing and marketing in Ethiopian Rangelands based on	• Engagement and active participation of international organizations and research institutes on modeling of the interaction and relationships of climate, rangeland and livestock • Availability of different climate change models, tools, equipments, etc... to assist the research process • Rangelands capacity in supporting the livelihoods of millions of peoples in the country	• Increased frequency and magnitude of extreme events • Frequent policy amendments and conflicting strategies

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
	carbon sequestration potential (capacity) • Limited technologies, knowledge, information, experiences etc to minimize the effect of climate change on pastoral community		
Theme 7: Demonstration and popularization rangeland management and improvement technologies			
• Initiation and availability of researchers and research centers for the generation f rangeland technologies • There are researchers within EIAR with many experience of range improvement • Availability of the core research team representing the different disciplines that has been established at the coordination center also includes researchers	• Weak and insufficient rangeland technology generation • Less engagement of communities in evaluation and development of rangeland improvement in Ethiopia • Limited effort in demonstration and popularization of rangeland management best practices, to end users • Less attention given to the generation of range rehabilitation	• There exists a strong federal and regional extension system equipped with extension facilities (e.g. Pastoralist Training Centers (FTCs)) and DAs working at grassroots levels with pastoralists and agro-pastoralists • Government strong initiation in conserving and development the natural resources of the country • Global conventions on conservation of biodiversity and Ethiopia among signatory	• Communal ownership nature of rangelands of the pastoral area of the country • Climate change and variability • Technical knowledge of development workers and pastoralists • Loss of biotic resources of the rangelands of Ethiopia

Internal Environments		External Environments	
Strength	**Weakness**	**Opportunity**	**Challenge**
of socio-economics, research extension and gender • Linkage that EIAR have with stakeholders engaged in rangeland development	technologies instead ecosystem assessment • Low rate of adoption of available rangeland technologies • Limited information on the economics of range rehabilitation in relation to rangeland based livestock production • Despite availability of some range rehabilitation techniques applicability in the hand of pastoralists is not properly assessed • Unpopular but model indigenous rangeland management and utilization practices in Ethiopia • Lack of model range-sites in major rangelands of Ethiopia	• Increasing demand of rangeland products • Demographic change (population growth)	• Fluctuation of the price of rangeland product (livestock and livestock product) • Lack of mechanized technologies for range rehabilitation • Communal nature of rangelands • Frequent conflict for rangeland resource in pastoral area

Table 6:- Strategic issues facing the rangeland research program and their relevance in the short-, medium- and long- terms

Strategic Issue	Relevance		
	Short term (1-5 years)	Medium term (6-10 years)	Long term (11-15)
1. General			
1.1. **Lack of national focus on rangeland research** Limited number of experienced and skilled man power and high turnover rate, insufficient incentives and conducive working environment to maintain rangeland researchers in the harsh pastoral setting, limited capacity in utilizing modern experimental tools, despite the multidisciplinary nature of the program, professionals in different disciplines (i.e. Soil scientist, Botanist, GIS, Range economist, etc.) is limited in rangeland research	X	X	X
1.2. Limited research facilities in rangeland research, insufficient financial resource allocation to rangeland research in comparison to the vast coverage of rangelands and its economic significance, lack of permanent rangeland research sites	X	X	X
1.3. Poor linkages among various disciplines and stakeholders, weak inter and intra disciplinary linkage within EIAR, weak linkages and participation of stakeholders in technology generation, week institutional setup	X	X	X
2. Assess and document national data base on rangeland resources			
2.1. Limited national database on biophysical resource conditions in Ethiopia, Limited	X		

Strategic Issue	Relevance		
	Short term (1-5 years)	Medium term (6-10 years)	Long term (11-15)
well developed and reliable information and data's on the rangeland degradation status of major rangelands of Ethiopia,			
3. Rangeland biophysical resource conditions			
3.1. **Updated national database on bio-physical resource conditions in Ethiopia** In sufficient information on the vegetation status rangelands, limited rangeland spatially and temporally (biotic and a biotic resource) maps for rangelands of Ethiopia	X	X	X
3.2. **Limited knowledge and effort to combine modern, conventional, and participatory research tools** • Low participatory research approach (IK) • Less use of GIS, remote sensing and others technologies	X	X	X
4. Rangeland grazing-management, range forage and integration of productive animals			
4.1. **Limited knowledge on grazing management systems** • Grazing and browsing behavior and feed requirement of livestock species • Indicative grazing/browsing capacity of range resources	X	X	X
4.2. **Limited knowledge and information on range forage practices in riverside and irrigable areas in rangelands on** • Research effort and knowledge on range forage of rangelands	X	X	X

Strategic Issue	Relevance		
	Short term (1-5 years)	Medium term (6-10 years)	Long term (11-15)
• Adaptive and productive forage varieties • Conservation practice of range feed resources			
5. Rangeland ecological rehabilitation, improvement, management and utilization of degraded rangeland			
5.1. Encroachment of range sites by endemic encroaching range plants, insufficient data bases and information on factors leads to rangeland endemic species encroachment and their effect on rangeland productivity, lack of sufficient information on traditional management practices of economically important endemic species	X	X	X
5.2. limited of information on effect of range encroachers on livestock health, livestock product qualities produced from animals fed with encroaching species	X	X	X
5.3. Limited knowledge and technologies on management of practices of economically and ecologically important encroachers/weeds	X	X	X
5.4. Limited knowledge and restoration technologies of degraded rangelands, insufficient range watersheds rehabilitation and management technologies	X	X	X
5.5. Limited efforts to establish permanent rangeland technology generation, conservation and multiplication sites	X	X	X
6. Climate, livestock and rangeland			
6.1. Limited information on the interaction of rangeland productivity with climate factors	X	X	X
6.2. Insufficient data's on the role of rangelands in carbon sequestration	X	X	X

Strategic Issue	Relevance		
	Short term (1-5 years)	Medium term (6-10 years)	Long term (11-15)
6.3. Options for adaptation and development early warning system for climate change effect on rangeland based livestock production	X	X	X
7. Demonstration and popularization rangeland management technologies			
7.1. Limited effort in demonstration and popularization of rangeland management best practices, Limited demonstration effort for the available rangeland technologies, Limited participation of end users in popularization	X	X	X
7.2. Limited information on adoption status and impact of rangeland technologies, Level of technology adoption and determinants for adoption of rangeland technologies is limited at national level	X	X	X
7.3. Limited awareness on rangelands, Insufficient training on rangeland technologies for pastoralists, or producers , extension workers, Limited awareness on the cost effectiveness range technologies	X	X	X
8. Cross cutting			
Gender	X	X	X
Knowledge management and ICT	X	X	X
Socio-economics	X	X	X

4. Research themes and strategic interventions

Considering the complex nature of the issues to be addressed by the rangeland research program, most of the research topics are multi-disciplinary, multi-thematic, multi-stakeholder, participatory, and need to be implemented in collaboration with pastoralists and agro-pastoralists and extensionist. Aligned to the goals and priorities of EIAR and guided by the current national agricultural growth and environmental protection policy and strategy. The research strategy is believed to benefit pastoralists, agro-pastoralists, processors, exporters, traders and others involved in the value chains and the nation at large helps in achieving the countries obligation to different protocols and treaties. The research themes are built on eight major research themes as briefly discussed hereunder and the strategic interventions, designed for each of the strategic issues presented under section 6 above and spanning the short, medium and long- terms of fifteen years (2016-2030), are presented in Table 7.

4.1. General

The second five-year Growth and Transformation Plan (GTP II) of Ethiopia projected that the agriculture sector specifically the livestock sector will play a decisive role in supporting the transformation of the country's economy into industrialization. In this regard, rangeland natural resources could play significant role since it's the source of raw materials for leather industry and foreign currency from huge livestock produced and exported as live animal and by slaughtering. Nonetheless, the ever-increasing rangeland degradation and shrinkage of range size due to anthropogenic and human factor is causing the livelihood of pastoral community and the country's economy from the sector not to enhance as expected. As a result, the country has forced to allocate huge amount of money to pastoralists as an emergency intervention and causes the expected foreign exchange earnings from the sector not to be secured. It is, therefore, vital to have a strategy alleviating the problem of rangelands and enhance the productivity of range sites. In order to pursue such an important agenda of national urgency, the research should focus on two important issues that: (i) The national rangeland research should be strengthened in terms human resources (i.e., the researchers engaged in rangeland research should be equipped with modern techniques and

methods of range management and improvements) and research facilities (i.e., greenhouses, modern equipment of GIS, Permanent study sites and soil labs); and (ii) the stakeholders involved in the livestock value chain in general need to have a strong, functional, influential and sustainable forum that will shape up the future of rangeland research, rangeland based livestock production, livestock product processing, livestock export and trade, and consumption.

4.2 Assess and document national data base on rangeland resources

Researches on Ethiopian rangelands have been conducted in the past by federal, regional research institutes and some universities. These research efforts covers mainly the rangelands of Borena, Somali and Afar but the rangelands of Gambela, Benishangul and Southern Ethiopia are getting no attention. The major focus of the rangeland research was on condition assessment, rangeland improvement techniques, control of unwanted range species, climate change and rangeland interactions and on indigenous knowledge. Despite of considerable information and knowledge generated in past research efforts, it is sparsely available. Therefore, there is a need to assess, review and document past research achievements.

4.3 Rangeland biophysical resource conditions

This component addresses research issues related to "Rangeland Condition", usually concerned with the "State of the Rangeland Vegetation Health", that determine what the vegetation should look like under normal climate and optimum management. This includes the direct and indirect changes in vegetation composition, cover, land productivity and stability over time under various regimes of livestock production. In view of livestock improvement schemes under pastoral traditions or otherwise, therefore, rangeland conditions and trends are perhaps the most important concepts in the management of renewable resources in arid and semi-arid lands. Rangeland ecosystems of Ethiopia encompass various and very complicated biotic and a biotic resources which are highly variable from place to place, time to time and region to region. Intervention and management on rangeland resources needs updated information on the

biophysical resources conditions of that particular area and should be intervened based on the actual range conditions. Despite the cover and generalized use of the range resource in Ethiopia rangeland condition assessment is considered a onetime activity and limited updated information. In order to fill the gap temporal and spatial rangeland resource condition assessment and mapping will be conducted for major rangelands of pastoral areas including Benishangul and Gambela.

4.4 Rangeland grazing-management, range forages and integration of productive animals

Rangeland resources of Ethiopia covers more than 60% of the total land masses of the country and it's the base for pastoral livelihood which covers 12-15% of the total human population of the country and takes the lion share of and source of export live animals (up to 90%). But, traditional rangeland management sustained for centuries in Ethiopia facing various challenges and pastoralism are under threat and becomes vulnerable society. There is a need in modification/development of grazing system, based on the carrying capacity of the particular range sites and based on the feed requirement of the grazing animals. In order to make rangeland resources of the countries sustainable enhancement of productivity of rangelands and proper grazing management should be there. And on this theme assessment on traditional grazing management, feed preference of domestic animals based on type and production, development of rangeland agronomy, integration of productive animals etc will be undertaken and proper grazing management for sustainability will be suggested/ recommended.

4.5 Rangeland ecological rehabilitation, improvement, management and utilization of degraded rangeland

In Ethiopia, rangeland conditions are steadily degrading from time to time, as a result of many interacting factors, such as severe over-grazing, land degradation, over cutting of trees and expansion of invasive bushes and weeds. Moreover, bush encroachment has and is transforming potential open grassland savannas into thick bushes and shrubs, indicating the degree in severity of arid and semi-arid rangelands. The rangelands are also subjected to frequent and recurrent droughts resulting in massive

livestock mortalities and impacting famine and poverty by pastoral households. In managing and utilizing rangeland resources sustainably, management of undesirable biological invasion of rangeland botanic resources are becoming the core agenda of rangeland research and national policy and strategy in Ethiopia and other similar countries. In order to support the development of rangeland resources encroached by bushes identification of alien species introduction and their mitigation mechanism, development of management options for encroaching indigenous bushes/shrubs, mitigation of impact of encroachers on livestock, human health and on environmental resources. Despite the significance of rangelands for millions of Ethiopian population and national economy research and development in rangeland improvement schemes is an important investment in order to reverse the negative impacts of different rangeland degradations caused by biotic and/or a biotic factor. Furthermore, improvement impacts enhance livestock performances with higher values for local and export markets and enable the contribution of the sub sector in boosting income generation by pastoralists. In this theme identification and development of effective and adaptable rangeland rehabilitation techniques and popularization of the technology is the main focus area.

4.6 Climate, livestock and rangeland

Climate change is become a threat to global population and pastoral production system which is based on rangeland based production system in Ethiopia is the most susceptible sector to climate variability. In order to support the development of climate resilience pastoral community (rangeland based production system) in Ethiopia, generation of information's and technologies that helps as a mitigation and early warning system will be undertaken based on the data collected and generated and based on the interaction of climate, rangelands and livestock.

4.7 Demonstration and popularization rangeland management technologies

As there was no strong national rangeland research program in Ethiopia, in the past 30 to 40 years, it was not possible to generate many usable rangeland technologies. Despite, there are some works undertaken here and there by different bodies that have valuable out comes on rangeland technologies/management guidelines. For example, many studies in the

past have clearly witnessed that making enclosures in communal grazing lands is superior in terms of vegetation and soil parameters and construction of water conservation structure with the support reseeding adaptable grasses providing better biomass. Therefore, this strategic document will give emphasis on demonstration and popularization of generated information's and technology in order to achieve the expectation from the program.

4.8 Crosscutting themes

4.8.1 Economics

The economics is one of the core members of the rangeland research team and it is as such the vanguard of the group to bring in stakeholders together to formulate economically relevant research agenda as they do also taking out promising research results. Addressing issues related to economic aspects in the strategy is the key to attain the successes that the research team envisages.

4.8.2 Gender

The role of women in the pastoral production system is critical as women contribute to almost all activities except security. But pastoral women have only limited access to resources, services, land and other inputs. Unequal gender relations often make women more vulnerable to the effects of poverty, land degradation, and climate change. If the gender gap were eliminated, FAO asserts that total agricultural output would increase. Cognizant of this, the strategy upholds integration of gender concerns into research objectives, technology development, extension, and evaluation frameworks.

4.8.3 Knowledge management and ICT

Through knowledge management interventions aided by new information technologies, it is possible to help improve pastoralists' access to resources and information's that help them improve their productivity and competitive ability. Knowledge management will also help to create research products in a more collaborative manner that makes them more suitable for diverse audiences. For this purpose, the research team will make results more readily available, spearhead formations of multi-stakeholder platforms that facilitate interaction and promote learning for change, mentoring, and networking.

4.9 Strategic intervention

Table 7. Strategic interventions planned to address critical issues facing the rangeland research commodities in the short-, medium- and long- terms

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	Medium-term (6-10 years)	Long-term (10-15 years)
1. General			
1.1. Lack of national focus on rangeland research	• Hiring additional researchers and technical staff • Upgrading junior researchers • Exposing them to short term training • Arrangement of special treatment for researchers	• Upgrading the educational level of researchers gets short term training on modern research tools	• Upgrading the educational level of researchers gets international short term training and exposure on modern research tools.
1.2. Limited or no research facilities in rangeland research	• Establishment and arrangement of basic research facilities	• Establishment of standard laboratories, seed technology centers, green houses, etc	• Working on modernizing sustainably of technologies and the lab facility

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (10-15 years)**
1.3. Poor linkages among various disciplines and stakeholders	• Strengthening some of the already established linkages within EIAR and with stakes and working on strengthening • Participation and strengthening of rangeland research and development forums,	• Enhancing the linkages and create common rangeland research platforms	• Continue enhancement of the linkages and create common rangeland research platforms
2. Assess and document national data base on rangeland resources			
2.1 Limited and updated national database on biophysical resource conditions status of major rangelands of Ethiopia	• Assess and document biophysical resource conditions of major rangelands		
3. Rangeland biophysical resource conditions			
3.1. Update national database on bio-physical resource conditions in Ethiopia	• Update information on the rangeland condition • Update rangeland (biotic and abiotic resource) maps spatially and temporally	• Develop rangeland management strategy based on updated information	• Modern way of updating information on rangeland developed and strengthen for their wide usage

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (10-15 years)**
3.2. Limited knowledge and effort to combine modern, conventional, and participatory research tools	• Identify the strength and weakness in indigenous knowledge, conventional and modern tools on rangeland resource assessment	• Develop synthetic range resource assessment techniques and tools that Combines indigenous, conventional and modern rangeland resource assessment techniques and tools	• Modern way of using synthetic range resource assessment techniques and tools developed and strength for their wide usage • Develop scientifically accepted rangeland resource assessment protocol of the country
4. Rangeland grazing-management, range forage and integration of productive animals			
4.1. Limited knowledge on grazing management systems	• Assess factors that determine traditional grazing management (climate, conflict, land tenure, productivity, livestock type, etc.) • Testing and verification of different grazing management system in collaboration of pastoralist	• Developing information on trends of rangeland grazing management and their interaction effect on productivity of rangeland temporally • Testing and verifying different grazing management system for different livestock type based on their productivity level • Demonstration of flexible and adaptable grazing management system for major rangelands	• Developing information on trends of rangeland grazing management for temporally and spatially • Developing best grazing management system for different livestock type based on their productivity level in all rangelands of Ethiopia • Wider demonstration of flexible and adaptable grazing management system of Ethiopian rangeland

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (10-15 years)**
4.2. Limited knowledge and information on agronomic practices in riverside and irrigable areas in rangelands	• Collection and identify productive indigenous and adaptive exotic forage species • Maintenance and multiplication of productive indigenous and adaptive exotic forage species • Integrated testing of various rangeland improvement practices • Testing irrigation based rangeland feed development	• Strengthening the collection and identification of productive indigenous and adaptive exotic forage species • Strength of multiplication and maintenance of productive indigenous and adaptive exotic forage species • Identified adaptable and productive indigenous and exotic forage material (herbaceous grasses and legumes) will be tested for their production and their carrying capacity • Development of utilization and conservation practices for rangeland based feed production • Establishment of feed value chain	• Develop modern way of multiplication and maintenance of productive indigenous and adaptive exotic forage species for all range sites of Ethiopia • Modern way of adaptable and productive indigenous and exotic forage material depending on their merits will be developed • Development of synthetic utilization and conservation practices for rangeland based feed production • Developed for sustained and integrated establishment of feed value chain

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (10-15 years)**
5. Rangeland ecological rehabilitation, improvement, management and utilization of rangeland resources			
5.1. Limited of information on the interaction of invasive species encroachment and rangeland condition	• Assess land coverage and ecological distribution, density level and interaction on feed resources of economically important rangeland invasive species for major rangelands	• Develop base line area for each encroached invasive species	
5.2. Limited information on effect of range plant encroachers on livestock health	• Assess herders perception on effect of encroachers plants on accessibility of range and water resources • Identify effect of encroachers plants on public, livestock and livestock product health issue	• Develop ways managing/control these encroachers plants for beneficial use • Effect of encroachers on livestock product quality and economic loss and its effect on rural livelihood	• Develop modern technologies that overcome the problem of these encroachers plants
5.3. Insufficient knowledge and technologies on management of bush/shrub encroachment	• Test and identify best bush management technologies	• Test different modern technologies and indigenous knowledge and identify alternative and effective bush management technologies	• Development of synthetic bush management technologies • Development of strategies for large scale management practices of bush

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	Medium-term (6-10 years)	Long-term (10-15 years)
		• Identify policy issues the management bush encroachment	• Development of policy issues and input in the management of bush encroachment
5.4. Limited information on the cause of rangeland degradation and traditional mitigation	• Assess severity and causes (social, environmental and economic) of rangeland degradation for major rangelands of Ethiopia	• Develop traditional rangeland management system and factors that influences the degradation of rangeland	• Continue assessing traditional rangeland management system and factors that influences their efficiency
5.5. Limited number of restoration technologies for degraded rangelands	• Test the efficiency of technologies so far generated from the perspective of applicability and productivity • Test rangeland rehabilitation with range watershed development • Collect and identify indigenous and exotic forage species applicable for rehabilitation purpose	• Test of best practice in rangeland rehabilitation and integrate them to the context of Ethiopians rangeland • Test integration (indigenous *scientific) on rangeland rehabilitation • Productive rangeland feed botanic resources identified, conserved and multiplied will be used for rangeland rehabilitation	• Development of synthetic knowledge (indigenous *scientific) on rangeland rehabilitation • Develop strategy for scale application of Best performing range land rehabilitation techniques • Develop permanent sources of indigenous and exotic forage species applicable for rehabilitation purpose

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (10-15 years)**
		in wider scale in model range sites	
5.6. Lack of permanent rangeland technology generation, conservation and multiplication sites	• Identification of and establishment of representative sites for permanent site based rangeland ecology	• Standardization of protocols (tools) in conducting permanent plot based rangeland research will be undertaken	• Develop permanent plot based range research will be undertaken
6. Climate, livestock and rangeland			
6.1. Limited information on the interaction of rangeland productivity with climate factors	• Develop information on interactions of climate, livestock and rangelands	• Evaluation and development of databases and models for the interaction of climate, rangeland and livestock production and productivity • Development of models climate factors, rangeland and livestock productivity	• Development of models for climate-rangeland-livestock productivity for national rangeland
6.2. Limited role of rangelands in carbon sequestration	• Development of data bases and information on the role of rangelands on carbon sequestration for major rangelands	• Evaluation protocol on carbon sequestration, financing and marketing in most rangelands of Ethiopia	• Developing information on the role of rangelands on carbon sequestration • Development of protocol on carbon sequestration, financing and marketing and provide policy inputs

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (10-15 years)**
6.3. Limited information for adaptation and development early warning system for climate change effect on rangeland based livestock production	• Conduct technologies that decrease the effects of climate change on pastoralism (sedentarisation, rangeland resources, livestock production, ecosystem, etc) • Evaluate local implementation protocols of rangeland-carbon finance (Institutional options, policy issues) for the effectiveness of sustainable development in rangeland based farming system in the context of climate change in major pastoral area of Ethiopia. • Develop data that used for early warning system based on interaction relationships of climate, livestock and rangelands	• Evaluate development of institutional options and policy issues for the effectiveness of rangeland-carbon finance in sustainable rangeland development in livestock based land use in the pastoral area of Ethiopia • Upgrading development of data bases for early warning system based on interaction relationships of climate, livestock and rangelands for most of rangelands of Ethiopia	• Develop early warning system for national of rangeland • Development modern way of institutional options and policy issues for sustainable rangeland development in livestock based farming system in the context of climate change for all pastoral area of Ethiopia
7. Demonstration and popularization rangeland management technologies			
7.1. Limited effort in demonstration and popularization of	• Identify and organize information on rangeland	• Identify and organize information on rangeland technology popularization effort, their	• Develop strengthening popularization of rangeland technology

Strategic Issue	Strategic intervention		
	Short-term (1-5 years)	Medium-term (6-10 years)	Long-term (10-15 years)
rangeland management best practices	technology popularization effort, their challenge and opportunity • Strengthen popularization of rangeland technology • Enhance the skill of development workers and pastoralists in applying range technologies	challenge and opportunity and develop national range technology popularization protocol • Enhance the skill of research staffs, development workers and pastoralists	• Upgrade skill of research staffs, development workers and pastoralists • Development of model rangeland technology and demonstration guideline for rangeland based livestock production system
7.2. Limited information on adoption status and impact of rangeland technologies	• Conduct adoption study on rangeland technologies and their impact on the livelihoods and environmental conservation	• Conducting impact rangeland technologies and their impact on the livelihoods and environmental conservation and identify intervention area	• Conducting adoption study on rangeland technologies and their impact on the livelihoods and environmental conservation and identify intervention area
8.3. Limited awareness on rangelands	• Create awareness creation campaign and strengthen the capacity building activity	• Awareness creation by different medias and strengthen the capacity building activity	• Awareness creation by modernized ways of different medias and strengthen the capacity building activity
8. Cross cutting			
Gender	X	X	X
Knowledge management and ICT	X	X	X
Economics	X	X	X

5 The next steps

The major contents of the implementation plan will revolve, among others, around the following topics:

- Develop implementation plan
- Develop monitoring and evaluation plan
- Develop impact assessment plan
- Develop reassessment plan for the strategy

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7 Annexes

Annex 1. Glossary

Adaptation: Adjustment in natural or human systems in response to actual or expected climate stimuli or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation.

Climate change: A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods. It refers to any significant change in the measures of climate lasting for an extended period of time. In other words, climate change includes major changes in temperature, precipitation, or wind patterns, among other effects.

Geographic information system (GIS): A computer-based system designed to collect, store, manage, and analyze spatially referenced information and associated attribute data.
Goal: An observable and measurable end result having one or more objectives to be achieved within a more or less fixed timeframe.

Livelihoods: A livelihood comprises the capabilities, assets (stores, resources, claims, and access), and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stress and shocks, maintain or enhance its capabilities and assets, and provide sustainable livelihood opportunities for the next generation; and which contributes net benefits to other livelihoods at the local and global levels in the long- and short-term.

Mission: A written declaration of an organization's core purpose and focus that normally remains unchanged over time. A mission is different from a vision in that the former is the cause and the latter is the effect; a mission is something to be accomplished whereas a vision is something to be pursued for that accomplishment.

Partner: Individual who joins with other individuals (partners) in an arrangement (partnership) where gains and losses, risks and rewards, are shared among the partners.

PEST analysis: one of the strategic planning tools which covers the remote external environment elements such as political, economic, social and technological. It also includes legal/regulatory and ecological/environmental).

Policy: A statement of course of actions set by the Government in the management of agricultural development affairs which is formulated and implemented at *different levels* of Government. Policy is commonly expressed in the form of laws, rules and regulations, and broad goal oriented guiding declarations.

Program: A framework that contains similar activities designed to bring developmental changes (result-based); it is designed to enhance growth with a continuous resource allocation from internal and external sources.
Project is a unique and time urgent work effort to provide a result according to a certain specification and within fixed time and budget limit.

Resilience: The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.
Stakeholder: a person, group or organization that has interest or concern in an organization. Stakeholders can affect or be affected by the organization's actions, objectives and policies.

Strategy: The route to achieve the desired policy goals via specific elaborations of the resources to be mobilized (means). Strategies link the policy goals to programs that are set in a given plan period.
User: Entity that has authority to use an application, equipment, facility, process, or system, or one who consumes or employs a good or service to obtain a benefit or to solve a problem, and who may or may not be the actual purchaser of the item.

Values: Important and lasting beliefs or ideals shared by the members of a culture about what is good or bad and desirable or undesirable. Values have major influence on a person's behavior and attitude and serve as

broad guidelines in all situations. Some common business values are fairness, innovation and community involvement.

Vision: An aspiration description of what an organization would like to achieve or accomplish in the mid-term or long-term future. It is intended to serve as a clear guide for choosing current and future courses of action. See also mission statement.

Vulnerability: The extent to which a natural or social system is susceptible to sustaining damage from hazards caused by climate change, and is a function of the magnitude of climate change, the sensitivity of the system to changes in climate, and the ability to adapt the system to changes in climate. Hence, a highly vulnerable system is one that is highly sensitive to modest changes in climate and one for which the ability to adapt is severely constrained.

Annex 1. Herder scouts and ecologist's assessments of the Kenya rangelands at landscape scale, the cases of Ormia rangelands

Transect name (a)	Landscape classification[a]	Soil indicator[b]	Season of grazing	[c]Grazing suitability (GS)	[d]LGP	Condition[e]	Trends[f] WC	GP[g]	Degradation[h]
Moye Buya guyo	Wayaama	Red soil	Wet	Goats-High	Low-cattle	Moderate	25%–Stable	VH	Threat high But resilient
				Cattle-low					
Qote Jijiga	Omaara sala	Gray	Dry	Cattle-high	High-cattle	Good	50%	VH	Threat high But resilient
				Goats-low		Fair	Declining	Bare ground-80%	
Onmirti	Omaara-adhi	White	Wet/dry	Cattle-high	High-cattle	Poor	Declining, invasive sp. WC 30%	VH	Threat high
								Bare ground 60%	But high resilient
Komora Jiila	Omaara-adhi	White	Wet/dry	Cattle-high	High-cattle	Moderate	Stable	H	Threat moderate
				Goats-moderate			WC no change	Bare ground 30%	
Bura-Komora	Biiy-boora	Dark soil	Wet	Only camels	Low	Poor	Declining, WC 50%	Bare 80%	Threat high

Source: Oba, 2012

Anex 2. Herder scouts and ecologist's assessments of the Ethiopia rangelands at landscape scale, the cases of Afar rangelands

Transect name	Landscape classification[a]	Soil indicator[b]	Season of grazing	[c]Grazing suitability (GS)	[d]LGP	Condition[e]	Trends[f] WC	GP[g]	Degradation[h]
Diktaa Boora	Raasa	Black	Dry	Camels-high	High for all species	Fair	Stable	Heavy	Kaffiin isoole baaro But resilient
				Goats-high			WC < 20%		
				Cattle-High					
Dadaamo	Koma	Rocky	Wet	Goats-moderate	Moderate-goats	Poor	Downward invasive sp. Expanding	Heavy	Aboroiti baaro
				Camels-low			WC > 40%		This land would require heavy investment
Adoptili	Hududo	White	Wet	Low for all species	High	Very poor	Downward	Zero herbaceous cover	Aboroiti baaro
							WC 70% Prosopis		Requires heavy investment
Intiasso	Daale-Raasa	Black with pebbles	Wet	Camels-low	High	Poor	Downward	Very heavy	Aboroiti barro
				Goats-low			Invasive sp.		Requires heavy investment
Hunda halaidi	Dalle-Raasa	Black with pebbles	Wet/dry	High for all sp.	High	Excellent	Stable	Light	Andarhaarra

Source: Oba, 2012

Animal Health Research Strategy

(2016 - 2030)

Executive summary

Animal health is one of the critical aspects of livestock production and plays a crucial role in every step of livestock and livestock products development. Beyond its benefits in improving the efficiency of animal agriculture especially livestock, animal health is vital in ensuring the health and wellbeing of societies. However, animal health, for its routines of disease control and prevention, needs improved technologies, skills and knowledge that could best fit the existing scenarios. Globally, to mitigate the ever-increasing threats arising from a wide range of animal diseases, many technologies have been developed and used. Consequently, the technology type and intensity of usage has made significant differences in the animal health status of countries and this has been extended to wider political and economic implications for developing countries like Ethiopia through livestock and livestock products market limitations and trade bans.

In Ethiopia, animal diseases are rampant and have a wider distribution and extent. Thus, to mitigate the ever-increasing trends of disease threats posed to the animal agriculture and public health, research in animal health is critical. To this end, the animal health research program of EIAR has prepared this strategy to be used as a guiding document for the upcoming 15 years of animal health research and development of the country. The main focus of this strategic document is availing improved animal health technologies and knowledge to the different livestock development partners and stakeholders of the country so as to fast-track the transformation process of the country's livestock sub-sector in particular and the nation's economy in general.

The strategy, after describing its mission, vision, goal and objectives, detailed the guiding principles that were followed during the document development and also explained briefly the importance of animal health research in Ethiopia. To identify the strategic issues facing the animal health research program, the external and internal environments have been thoroughly assessed and the strengths, weakness, opportunities and challenges have also been explained. The identified strategic issues facing the animal health research program includes: Lack of skilled man power in advanced techniques of animal health research engagements; limited research infrastructure (lab facilities, sentinel animals, vehicles; weak

institutional focus, research implementation and results dissemination system; limited availability, quality and coverage of disease prevention technologies and systems (like vaccines, biosecurity); limited information on host-pathogen interaction especially of those emerging and re-emerging diseases; weak epidemiological and surveillance systems; limited technologies for rapid disease detection and traceability of foods of animal origin; inadequate knowledge and information on vector and vector borne diseases dynamics and their control means; limited drug of choice for treatment and underdeveloped drug management and usage systems; limited effort in modernizing and improving the existing ethno veterinary medicine; limited data on the socio-economic and environmental impact of animal diseases and the impact of climate change on animal diseases; inadequate information on research extension and gender.

To mitigate the identified strategic issues, the following research themes have been indicated and the strategic interventions that has to be done with in the short term, medium term and long term has also been identified accordingly. The main research themes include: 1). Primarily, in order to pursue such an important agenda of national urgency, the research should focus on two important issues that: (i) the animal health research program should be strengthened in terms human resources (i.e., the researchers engaged in animal health research should be equipped with modern techniques and methods of diseases control technology improvements); research facilities (i.e., laboratories equipped with modern equipment and facilities for vaccine and diagnostics development, vector control and epidemiological modelling) and enabling research environments (i.e., a focused animal health center and specialized teams have to be in place); and (ii) the stakeholders involved in the disease control technologies value chain in general need to have a strong, functional, influential and sustainable forum that will shape up the future of animal health technologies development, manufacturing, adoption and wider scale utilization. The disease prevention research theme will focus on development or improvement of veterinary vaccines, development and/or improvement of biosecurity and safety protocols and programs and livestock and livestock product identification and traceability systems. Host pathogen interaction has to focus on understanding and exploiting the natural disease resistance/tolerance mechanisms of animals. In the meantime, to prevent or control the incidence of emerging pathogens, the disease mechanisms, and pathogenesis and host dynamics of newly emerging and re-emerging animal disease has to be deciphered. 4). the disease detection/identification theme should focus on development and/ or improvement of disease diagnostic tools (both at field and laboratory level) and disease monitoring systems. 5). the epidemiology and surveillance theme will focus on assessing and mapping the temporal and spatial distribution and extent of important diseases; and developing their surveillance and risk analyses systems.

6). The vector and vector borne diseases control theme has to focus on understanding the vector ecology and biology, developing vector control mechanisms and developing mechanisms for treating or preventing vector borne diseases. 7). The veterinary drugs theme will focus on evaluation of the existing veterinary drugs for their efficacy and safety, development of protocols for the rational use of drugs in farm animals and also development or adoption of improved drugs. 8). The ethno veterinary medicine research theme will focus on understanding and profiling the existing indigenous knowledge of treating diseased animals and also developing improved drugs from the existing traditionally used herbs. 9). the socioeconomics, research extension and climate change will focus in quantifying the socioeconomic impact of animal disease and availing technologies that would help the livestock producers to respond to climate change. 10). the crosscutting themes (gender and knowledge management) uphold integration of gender concerns into research objectives, technology development, extension, and evaluation frameworks. The research team will also make results more readily available, spearhead formations of multi-stakeholder platforms that facilitate interaction and promote learning for change, mentoring, knowledge sharing and networking.

For the proper implementation of the strategy, it is indispensable to develop a clear implementation plan. The strategic plan document should be viewed as a living constantly assessing the external and internal environment for changes regarding emerging opportunities or challenges, internal weaknesses and strengths as well as political, economic, socio-cultural, environmental, technological and legal challenges. The strategies and strategic plan should respond to the new external and internal environments. Therefore, reviewing the strategic plan, monitoring and evaluation, impact assessment and reassessment of the strategies and strategic plan should be done as required. Furthermore, before the implementation of the strategic plan, prioritization of diseases and thematic areas should be done for exploiting the available resources effectively and efficiently.

Animal Helath Research Strategy (2016 - 2030)

1. Introduction

1.1. Background

Animal diseases directly affect livestock production with consequences for food security and food safety, trade, rural development, and the environment, while also affecting the livelihood of farmers (EC, 2012). An increasing number of disease problems or threats faced to the livestock industry and zoonosis are of a global nature. Threats to environmental quality by pharmaceutical and pesticide contamination of food and water, and evolving bacterial drug resistance, jeopardize human and animal health and will continue to present a major research challenge for animal health scientists in the next decade (Boss et al., 2016).

In Ethiopia, animal diseases are rampant in all agro-ecological zones of the country and are exerting both direct and indirect damages to the livestock industry in particular and national economy in general. As many of the animal diseases set to be notifiable by the World Organization for Animal Health (OIE) are endemic in Ethiopia, the country is unable to enter into lucrative international markets of livestock and livestock products. This is because, for the purpose of trade in animals and animal products, Ethiopia must adhere to the standards, guidelines and recommendations established by the OIE mainly the rights and obligations set out by the World Trade Organization (WTO) under the Agreement on Sanitary and Phytosanitary (SPS) Measures (Thiermann, 2005). Fulfilling the international animal health and food safety standards has been a challenge for many countries including Ethiopia. This is due to the fact that infectious and zoonotic diseases intersect with the realities of porous borders and are exacerbated by the unusable agricultural, economic, and political systems prevailed in such environments. Furthermore, due to the widespread animal diseases, the productivity and production efficiency of livestock species is greatly affected and the public is also at risk of contracting by any of the endemic zoonotic diseases.

Thus, to mitigate the ever increasing trends of disease threats posed to the animal agriculture and public health, research in animal health is critical and is needed to assess the role of animals as reservoirs of resistant pathogens; establish interspecies transmission routes (including human to animal); determine risk factors and epidemiology; develop robust and rapid diagnostic and vaccine technologies; standardize laboratory testing of pathogens and drug residues; and develop new and effective treatments. In the broader sense, animal health research includes studies on prevention, control, diagnosis, and treatment of diseases and on the basic biology, welfare and care of animals. It also transcends species boundaries to include the study of spontaneous and experimental models of both human and animal disease and research at important human-animal interfaces, such as food safety, wildlife and ecosystem health, zoonotic diseases, and public policy.

Nevertheless, in Ethiopia, research in the area of animal health was completely missed out until the establishment of Institute of Animal Health Research (IAHR) in 1992 (Tsedeke *et al*., 2004). A decade ago, the then only functioning National Animal Health Research Center based at Sebeta was transferred to the ministry of agriculture for diagnostic services. Following the transfer of the National Animal Health Research Centre, the national animal health research system backpedaled and the animal health research of the country has been remained devoid of any research center for coordination and focused research execution. Subsequently, with in the institute, there has not been any standard animal health research laboratory and the overall animal health research was dismantled. Even the existed efforts of animal health research by different public institutions mainly by higher learning institutions are fragmented, redundant and mostly focused on surveillance activities. Largely, the history of animal health research in Ethiopia hasn't been encouraging and was unable to satisfy the ever increasing demands of animal health technologies in the country. But the country's long and unsuccessful history of animal health research and development can be taken as a lesson to plan future directions.

Thus, to realize the development of its huge livestock potential, Ethiopia will focus in unlocking the bottle necks of livestock production and international trade mainly imposed by animal diseases. To this end, a national animal health research strategy is needed to develop animal health technologies and/or knowledge that could help decipher the bottlenecks of livestock development in the country and hence, this strategic document

has been prepared to be used as a guiding document for the upcoming 15 years and is believed to be instrumental in the process of livestock industry transformation of the country.

1.2. Rationale for developing the strategy

Ethiopia's agricultural lead industrialization strategy is expected to transform the country's production, manufacturing and service sectors especially the agriculture sector. Through this transformation process, Ethiopia plans to join to the middle class economy in 2025. To achieve this goal, the country has already started the implementation of its growth and transformation plan (GTP) since the last five years. In the GTP, clear objectives and goals that lead to the transformation of the agricultural sector has already been set and are being implemented. From the agricultural sector, the livestock sub sector, after transformation, is believed to serve as a new source of income for the national economy and also is expected to lift millions of pastoralists and livestock farmers from poverty, by giving them an opportunity to produce quality products and access to international lucrative livestock markets.

To this end, to complement the agricultural GTP plan and further enrich the focus of livestock development, the subsector has been restructured to a ministerial level, Ministry of Livestock and Fishery Resources, and this ministry in turn, has developed the Ethiopian livestock master plan (ELMP). In the meantime, the Ethiopian Policy Study and Research Center has developed a Ethiopian red meat road map (ERMRM) to further enhance and fulfill the country's envisioned goal of reaching middle class economy. In both the ELMP and ERMRM, animal diseases has been identified as the main bottlenecks of livestock development and also indicated that the animal agriculture of the country could only be transformed only and if only when the prevalent animal diseases are controlled and their risks are mitigated.

Furthermore, these all formulated government objectives, plans and strategies focused in the agricultural sector in general and livestock sub-sector in particular demands the use of improved technologies, knowledge/skills for the proper implementation of the stipulated development plans. In this regard, EIAR is destined to ensuring the national food and nutrition security and sovereignty of the country through sustainable supply of improved technologies, knowledge and skills.

Guided by the objectives and targets of GTP, ELMP and ERMRM therefore, EIAR is impelled to develop a new strategy to fulfill its mission of supporting the national plans through to 2030. Therefore, the National Animal Health Research Program (NAHRP), as an integral part of the EIAR, will have to follow suit, with respect to its mandate commodity, to develop a well-defined research strategy and robust action plan, in order to focus efforts and fast-track desired results. The strategy will specify the contribution of NAHRP to the overall achievement of the objectives of EIAR in terms of the priorities and results to be achieved during the next 15-years period (2016-2030) that the strategy is envisioned for. The strategy will also: serve as a roadmap to guide the research program planning and implementation; be used by the NAHRP, EIAR and stakeholders to track record of results and as a reference that can be monitored and reviewed and for mobilizing in resources from national and/or international sources.

The NAHRP team has a strong conviction that a thriving future for the sub-sector can be achieved only if it involves meaningful collaborations between livestock producers, food/agro-processors, animal health technology manufacturers, traders, technicians, scientists, and other actors engaged in the diseases control value chains. To this end, the research team has formulated a set of principles and values that reflect the vision, mission, goal and objectives of the NAHRP that are commonly shared by the people, institutions and centers for the realization of the outputs articulated in the strategy. These are enunciated and briefly discussed in the following headings.

1.3. Vision

The National Animal Health Research Program envisions to be a leading animal health research and innovation center in Africa providing improved animal health technologies and systems for disease control and prevention.

1.4. Mission

To generate, develop and adapt animal health technologies, knowledge and policy for improving livestock production efficiency, animal welfare, product quality and public health safety.

1.5. Goal

The goal of this strategy is to improve livestock production efficiency, animal welfare and public health safety by developing improved animal health technologies and systems for disease control and prevention.

1.6. Objectives

- Develop a competent human and physical capacity for animal health technology development.
- Develop, improve or adapt improved tools for animal disease prevention and control
- Develop, improve or adapt fast and robust diagnostic and disease detection tools
- Understand the dynamics, host response, risk factors and ecology of animal diseases
- Develop, improve or adapt improved technologies for disease treatment and animal care.
- Quantify the social, economic and public health impact of animal diseases
- Assess the impact of environment and climate change on animal diseases and animal welfare

1.7. Guiding principles

In order to accomplish its mission and fulfill its obligations, the NAHRP has established a set of guiding principles and criteria for selecting research projects and major activities for the implementation of the strategy. The NAHRP will, accordingly, be guided by the following basic and unwavering principles that the NAHRP shall/must:

- be an integral part of the national development efforts of EIAR and thus all its research programs must be based on the policies and priorities of the institute embracing the notions of cost-effectiveness and responsiveness to stakeholders in both the public and private sectors
- ensure that its research outputs will lead to sustainable development and livelihood improvement, and thus the strategy must encompass basic, applied and adaptive research approaches for technology development, demonstration, transfer, dissemination, and adoption
- utilize and promote combinations of the conventional, innovative and advanced science and technology, and ensure high science

quality with due regard to addressing possible ethical, social and environmental impacts during project formulation and implementation
- follow, adhere and implement the basic principles of veterinary ethics and animal welfare during the entire process of technology development, evaluation, verification, demonstration and risk analysis steps
- promote capacity building and institutionalization of integrated, multi-disciplinary, multi-institutional, livelihood-based approaches with various partners and stakeholders on the basis of comparative advantages
- give due attention to inclusiveness in terms of diversity and equal opportunity for all; must use gender-sensitive approaches to empower women
- engrain, in all its deliberations, commitment to excellence, knowledge sharing and access to information
- ensure monitoring mechanisms and evaluation criteria from inception of its projects and activities
- be free from all forms of malpractices and must ensure transparency, accountability and devotion to ethical standards of all concerned actors at all levels

2. Importance of animal health

A growing world population, increasing demand for foods of animal origin, climate change and globalization cause different ecosystems to move closer and to overlap at both local and global level. This promotes the emergence of new and re-emergence of existing pathogens at the intersections among the habitats of humans, domestic animals and wildlife. Moreover, backyard animal husbandry with poor biosecurity is another element that favors the emergence of pathogens. With regard to infectious diseases, the facts that approximately 60% of all known pathogens and 75% of emerging pathogens are zoonotic in nature, with about 70% of all emerging zoonotic pathogens representing vector-transmitted diseases (Taylor et al., 2001) cause increasing concern in animal and human health. Furthermore, global warming may lead to a massive expansion of the endemic areas for many vector-borne diseases as vectors and the pathogens they carry are expected to spread. To address these challenges, an institutional or corporate research and product development should focus in improving or developing animal health products such as vaccines,

diagnostic kits, curative and prophylactic drugs, laboratory equipment, risk analysis software, cutting-edge epidemiology tools, and more (Burgos and Otte, 2009).

In spite of the available unprecedented animal health technologies that could help to meet the challenges of today, more than modern technology is required for tomorrow. Moreover, many of the existing animal health technologies such as vaccines, drugs, diagnostic and epidemiological tools have their own drawbacks and even some of the very important animal diseases don't have a vaccine yet or else its efficacy or safety is questioned. The existing and upcoming challenges of animal agriculture posed by infectious disease should be addressed through animal health research. Animal health research, in addition to its many contributions to human health,—by targeting the prevention and control of agricultural, domestic, wild and aquatic animal diseases—contributes to the quality of human life. Food-animal health, for example, secures a safe and economic food supply for the human population. Animal health research is also essential to the health and increased longevity of service and companion animals and thereby reduces stress in both animals and owners. In general, a dynamic animal health research that best fits to the evolving production system and responds to the ever changing consumer preferences is required to mitigate the existing and other emerging animal production and public health related diseases.

Generally, assessing the significance of research in animal health in Ethiopia may help to get a clear picture on the importance of the program and could also help in identifying and prioritizing research themes of the strategy. Thus, a brief of the importance of animal health research in Ethiopia is considered, assessed and presented as follows.

2.1. Animal agriculture

Animal health directly affects animal agriculture through-animal mortality and morbidity, production losses, lowering product quality and safety. Such losses may also include poor weight gain or productivity, condemnation of product, lower commercial return, and inability to trade nationally and internationally. Moreover, a number of diseases of mammals and birds are of additional global concern due to their zoonotic potential, to evade or subvert host immune defenses, to throw-off more virulent variants, their ability to be carried across geographical boundaries and ability to jump species. Animal agriculture is basically affected through animal health challenges imposed by endemic and emerging

infectious and parasitic diseases including vector borne diseases and non-infectious animal diseases.

2.1.1. Infectious diseases

Infectious diseases of animals are of a major threat to the global animal health and welfare(Ahmed et al., 2006) and their effective control is crucial for agronomic health, for safeguarding and securing national and international food supplies and for alleviating rural poverty in countries like Ethiopia, where majority of their population lives under a poverty level. Many of the devastating infectious diseases are endemic in Ethiopia and threats from old and new pathogens continue to emerge, with changes to global climate, agricultural practices and demography presenting conditions that are especially favorable for the spread of arthropod-borne diseases into new geographical areas. In spite of their impacts on the production and productivity of animals, these disease also hamper local and international trade (Roess et al., 2015).

Among the predominant infectious diseases that are currently affecting animal agriculture in Ethiopia includes: Foot and mouth disease (FMD), brucellosis, Newcastle disease, bovine tuberculosis, peste des petits ruminants (PPR), contagious bovine pleuropneumonia (CCBP), contagious caprine pleuropneumonia (CCPP), African horse sickness are among the most predominant ones. Quantitative data on the real economic burden of these and other infectious diseases prevalent in Ethiopia is missing. But some reports have already indicated the economic impact of few of these diseases. Of which, in feedlot bulls, Alemayehu et al. (2014) reported FMD prevalence of 14.5% and an annual loss of 3.3 million USD due to bulls' rejection from international market. The economic losses of FMD outbreak due to milk loss, draft power loss and mortality were found to be USD 76 per affected herd and USD 9.8 per head of cattle in the affected herds in crop-livestock mixed system; and USD 174 per affected herd and USD 5.3 per head of cattle in the affected herds in the pastoral system (Jemberu et al., 2014). Jibat et al. (2016) also reported a herd level rabies prevalence rate of 11-21% with an annual cost of 228-477USD. A sero prevalence of lumpy skin disease (6% to 64%) (Abera et al., 2015; Gari et al., 2012), Newcastle disease (5.9%-27.4%) (Chaka et al., 2012; Chaka et al., 2013) and infectious bursal disease (76.64% -91.9%) (Degefu et al., 2010; Zeryehun and Fekadu, 2012) were also reported. This all indicates that the prevalent infectious animal diseases, both in ruminant

animals and poultry, remained to be a serious burden for the animal agriculture in particular and overall development of the country in general.

2.1.2. Vector borne and parasitic diseases

The impact of climate change on the transmission and geographical distribution of animal diseases has been associated with changes in the replication rate, dissemination of pathogens, vector and animal host populations, which are sensitive to changing temperature and rainfall. The incidence of vector-borne parasitic and viral diseases, are among those diseases most sensitive to climate. Climate change affect disease transmission by shifting the vector's geographic range and by shortening the pathogen incubation period.

The burden of livestock parasites on communities living in developing countries ultimately contributes to chronic malnutrition, greater human disease burdens, and decreased productivity of both humans and livestock (Rist et al., 2015). Ethiopia is blessed with a larger number and diversity of livestock population than any other comparable African country. A consequence of this is an equally impressive array of micro- and macro parasites as well as arthropod vectors that have co-evolved with their indigenous hosts for millions of years. Consequently, external parasites such as ticks and lice, and endo parasites such as helminthes parasites and hemo-parasites such as trypanosomiasis impacts negatively the country's overall animal agriculture through increased mortality, morbidity and production loss of livestock species, poultry and fish resources. Furthermore, tsetse borne trypanosomosis is excluding some 180,000 to 200,000 km^2 of agriculturally suitable land in the west and south west of the country, putting 14 million heads of cattle, an equivalent number of small ruminants, nearly 7 million equines and 1.8 million camels at risk of contracting trypanosomosis at any one time (MoARD, 2004). In cattle alone, tsetse transmitted animal trypanosomiasis is estimated to cost the sub-Saharan African economy billions of U.S. dollars annually (d'Ieteren et al., 1999).

In Ethiopian cattle, sheep and goats, the overall prevalence of ecto parasite is generally high resulting enormous economic losses through decreased production and productivity, damages to the skin and deaths of the animal (Amare et al., 2014; Hagos et al., 2013; Kemal and Terefe, 2013). Even in backyard chickens, diverse fauna of ectoparasite with a significant prevalence have been reported (Zeryehun and Yohannes, 2015). Internal

parasites like *Fasciola, Eimeria*, cryptosporidium (Ayana et al., 2009; Gebru et al., 2014; Luu et al., 2013); cestodes, trematodes and nematodes (Ameni et al., 2001; Asmare et al., 2016; Regassa et al., 2009) are predominant and responsible for the production loss and death of animals. Though the reports are limited, the burden of parasites on Ethiopian fish resources is also assumed to be massive.

Furthermore, antiparasitic drugs including Trypanocidal drugs, anthelmintic drugs and others are expensive to be used routinely in low input/low output crop-livestock mixed farming systems, may also be rendered ineffective by drug resistance, vector and parasite control can be environmentally damaging and difficult to maintain, and there is no vaccine for many of the parasitic diseases. In consequence, despite previous research and development efforts of the country, parasites still ranks among the country's more serious livestock diseases.

2.1.3. Non infectious diseases

Increasing industrialization and pollution, and intensification of animal production systems impacted negatively on the livestock health and welfare. The resulting diseases are just as erosive and dramatic as many of the infectious diseases. For instance, we are only now beginning to appreciate the erosive effects of long-term exposures to metal and other inorganic pollutants as well as organic pollutants. As livestock has encroached into areas where wildlife occurs, so industry is increasingly encroaching into what were previously traditional farming areas. This is a sobering thought as we begin to become aware of the impact of pollutants on animal and human health. Many pollution-related emerging diseases are only now recognized, described and understood. Moreover, the increased intensification of animal production systems for increased productivity has compromised the natural disease resistance/tolerance of animals and also predisposed these animals to many hormonal and metabolic diseases, which were otherwise unknown before.

Apart from the obvious need to reduce pollution, there is also a need to recognize the interaction between noninfectious and infectious emerging diseases and to understand the effect and role that non infectious diseases play. For example, many of these non-infectious diseases are now known to affect the immune system, thus predisposing animals and people to infectious diseases that may previously not have been a threat (Gummow, 2010).

Animals must consume feed containing essential nutrients to support body functions (maintenance and activity) as well as various productive functions (growth, pregnancy, lactation). Essential nutrients include a wide array of chemical elements and molecules, which cannot be sufficiently synthesized by the body to support daily functions, and are required within some optimum amount on a daily or semiregular basis to support body functions. Nutritional imbalances, deficiencies or erratic management of feeding programs can create large numbers and various types of health problems generally categorized as metabolic diseases. For instances, in dairy cows it comprises a wide array of problem such as energy metabolism associated disease (Fat cow syndrome, ketosis, retained placenta, infertility), diseases associated with low fiber/acidosis (Bloat, laminitis, indigestion, liver abscesses, displaced abomasum, lower milk fat content), Calcium/Phosphorus metabolism diseases/ complications (Hypocalcemia/milk Fever, disease of Calcium - Phosphorus Imbalance) and other feeding management-related disorders (hardware diseases, acidosis, udder oedema). In poultry, the significant metabolic disorders include ascites, round heart disease and aortic rupture, sudden death syndrome, liver and kidney problems and skeletal disorders (Angel, 2007).

Although the etiology and pathogenesis of most of the metabolic disorders are not fully known, herd health programs have to be fine-tuned to avoid metabolic disorders and prevent /control infectious disease because often when metabolic disease increases, opportunistic infectious disease also increases; and stress from metabolic problems may decrease the animal's resistance and compromise immune system function. If intake of any given nutrient is significantly below daily needs for a sufficient period of time, then nutritional deficiency disease and /or in excess of requirements toxicity disease can occur with very costly consequences in productivity and reproduction.

Reproductive disorders are one of the most important problems that affect the production and productivity of livestock at large and dairy and beef cattle in particular. In high-yielding dairy cows high metabolic rates driven by extreme milk production negatively affects reproductive performance whereas in beef cows, in intensive and extensive systems, poor body condition at calving exacerbated by suckling and seasonal factors can lead to various reproduction disorders. The most common reproductive disorders include nutrition (negative energy balance), retained fetal

membrane, uterine infection, anoestrus, cystic ovarian diseases, embryonic mortality, delayed ovulation and persistent Corpus Luteum, repeated breeding and abortion. For instance, in dairy cows an abrupt increase in milk production after calving imposes high metabolic and nutritional requirements on the cow. When dry matter intake does not meet increased energy requirements, a status of negative energy balance (NEB) develops with impaired immune function of endometrium and increased susceptibility to uterine infections, poor oestrus demonstration, less favorable uterine environment for the embryo development and increased early embryonic mortality. Strategic Oestrus management (different management packages and pharmaceutical protocols) is also necessary to achieve predictable breeding and calving seasons.

2.2 Food and leather industry

Food processing industries are critical in improving the availability, transport and storage of foods and more importantly in creating job opportunities. In Ethiopia, as the quality and quantity of production of foods of animal origin is limited, food processing industries (for meat, milk, egg, fish) are not well established and even the existing ones suffer from shortage of supplies. Animal diseases, through animal mortality and morbidity, play a crucial role in decreasing the supply of milk and meat to the local food processing industries.

Skin and hides are among the leading livestock commodities used as raw materials for leather processing industries both for local and export markets. Hides and skins accounted for 12-16% of the total value of exports in the year 1997 (Asfaw, 1997). Skins and hides are perishable resources that can be damaged by parasitic diseases (Kahsay et al., 2015). External parasites such as mange mites, lice, sheep keds and ticks are the major causes of skin diseases that have resulted in downgrading or rejection of skins (Kahsay et al., 2015; Solomon, 2011). Excluding the primarily rejected hide and skins during collection, defects of semi-processed skins caused by external parasites are one of the major limitations in the leather industry. In the Ethiopian tanneries, 35% of sheep and 56% of goat skins have been downgraded and rejected in the year 1997 due to defects by external parasites (Bayou et al., 1998). Thus, due to skin diseases of animals, Ethiopia is unable to exploit the potential of its livestock resources, in the form of skin and hides, and local leather industries are suffering from the shortage of quality skin and hides.

2.3 Public health and food safety

Veterinary public health is another frontier in the fight against human disease and includes the prevention, control and eradication of zoonosis, diseases that are naturally transmitted between vertebrate animals and man. The rate of emergence for emerging infectious diseases has increased dramatically over the last century, and research findings have implicated wildlife as an importance source of novel pathogens. However, the role played by domestic animals as amplifiers of pathogens emerging from the wild could also be significant, influencing the human infectious disease transmission cycle. The impact of domestic hosts on human disease emergence should therefore be ascertained (Morand et al., 2014).

Food safety has been considered a luxury in countries like Ethiopia which have not attained food security. However, the 1996 World Food Summit Plan of Action recognized the importance of food safety, as it defined food security as: "when all people have access to sufficient, safe and nutritious food". In addition, food-borne diseases contribute to decreased worker productivity, disability, and even early death, thus lowering incomes and access to food.

In Ethiopia, due to some cultural and traditional practices, livestock and humans share same housing and people have a tradition of consuming raw milk and meat. Due to this, Ethiopia ranks highest in Africa in the health burden of zoonotic diseases (Grace et al., 2012). On the other hand, suboptimal use of antimicrobials coupled with unhygienic animal husbandry practices is an important risk factor for emerging zoonotic disease and resistant pathogens (Roess et al., 2015).

With a variable prevalence, many of the devastating zoonotic disease such as Bovine tuberculosis (BTB), Rabies, brucellosis and toxoplasmosis are endemic in the country. For instance, Bovine tuberculosis (BTB) is endemic in Ethiopia, with low prevalence in the traditional small scale farming system, varying from 0.2% to 18% at animal level (Gumi et al., 2011; Gumi et al., 2012; Mamo et al., 2013) in pastoral setting; and high prevalence in in intensive dairy farms, 50% at herd-level and 30% at animal level (Firdessa et al., 2012). BTB has also been reported in camels (Beyi et al., 2014; Gumi et al., 2012) , and sheep and goats (Gumi et al., 2012; Kassa et al., 2012). The trend of BTB prevalence appears to increase with intensification of husbandry and proportion of high-yielding exotic

lines in farms (Firdessa et al., 2012). BTB has been isolated in apparently healthy cattle slaughtered in abattoirs resulting in condemnation of some organs and carcasses (Mengistu et al., 2014; Shitaye et al., 2007; Shitaye et al., 2006). Reports (Mengistu et al., 2014; Tigre et al., 2011) indicate that BTB can be easily transmitted between animal and human populations. Usually, BTB has both public health and economic impacts.

The prevalence of foodborne pathogens such as Bovine cysticercosis, *Echinococcus granulosus, Salmonellosis,* Listeriosis, *Campylobacter jejuni and Escherichia coli* is high and these pathogens have already started developing resistance to the existing drugs (Abraham et al., 2013; Dulo et al., 2015; Gebretsadik et al., 2011; Kassa et al., 2007). This imply that the risks associated to consumption of foods of animal origin is of beyond our imagination and poses a significant public health risk, unless measures are taken to identify and mitigate the potential risks.

Thus, generation of evidences that can be used as a decision support tool for development or evaluation of strategies and policies that could help prevent zoonotic and foodborne disease and their associated risks both in humans and animals should be given priority. These evidences and information will have solid ground to design appropriate food borne diseases mitigating/ preventing tools such as: HACCP (Hazard Analysis Critical Control Points) plan, GHP (Good Hygienic Practices) and GAP (Good Agricultural Practices).

2.4 Environment

In the presence of wide spread endemic animal diseases, people are obliged to use prophylactic and curative drugs on their animals. Thus, drugs, besides to their benefits, they may also have unintended effects on animals and microorganisms in the environment. Although the side effects of drugs on human and animal health are usually investigated thorough safety and toxicology studies, the potential environmental impacts of the manufacture and use of medicines are less well understood. Although the environmental occurrence and associated impacts of some compounds such as selected antibacterial compounds have been investigated, the impacts of many other substances found in the environment are not well understood. As a result, questions have already arisen about the effects of veterinary medicines on organisms in the environment and on human health.

Pharmaceuticals are used in large quantities in the livestock sector, mainly antimicrobials and hormones for therapeutic purposes and /or prophylactically to entire groups of healthy animals, typically during stressing events with high risk of infections, such as after weaning or during transport. In addition to diseased animals, they are given to animals routinely in feed or water over longer periods of time to improve growth rates and feed conversion efficiency. However, a substantial portion of the drugs used are not degraded in the animal's body and enter the environment and may affect non-target organisms including plants and various aquatic environments. Recently, scientists have detected low levels of veterinary medicines in soils, surface waters, and ground waters worldwide (Morse and Jackson, 2003). Manure is also the primary vehicle introducing antibiotic drugs, antibiotic resistance bacteria and antibiotic resistance genes from animals into the environment (via soil, water), transfer antibiotic resistance to agricultural (food) then to human clinical settings. Ongoing research on the ecology of naturally occurring and anthropogenically derived antibiotic resistance in agroecosystems is necessary to adequately quantify the benefits and risks associated with use of antibiotics in food animals. Furthermore, the application of non-biodegradable chemicals in an intention of vector and parasite control programs have high risk to human and animal health.

2.5 Wildlife and companion animals

Wildlife diseases have three important implications for society. First, anthropogenic activities continue to bring humans closer to wildlife so transmission of zoonotic diseases from wildlife to humans and domestic animals or vice versa is of increasing concern. Second, wildlife populations are increasingly at risk for diseases that cause severe population declines, which in turn may affect ecosystem health. Third, harvested wildlife (like animals in the zoo) are culturally and economically important in Ethiopia, and captive wild animals in zoological collections are invaluable national assets for education, conservation, and our cultural understanding of wildlife.

In recent years, infectious pathogens from wild animals have become increasingly important throughout the world. This is because; many of the diseases that affect livestock and even humans can also infect pet and wild animals. On the other hand, apart from its influence on the health of many wildlife species, infectious diseases of wildlife have significant impacts on

health of the public and livestock. For instance, foxes and other wild canids have been found responsible for maintaining zoonotic agents, such as, *Echinococcus multilocularis*, as well as pet-relevant pathogens, such as, *Hepatozooncanis*. Together with the canids, and less commonly felids, rodents play a major role as intermediate and paratenic hosts. They carry viruses such as tick-borne encephalitis virus (TBEV), bacteria including *Borrelia* spp., protozoa such as *Toxoplasma gondii*, and helminths such as *Toxocaracanis* (Duscher et al., 2015; Yabsley and Shock, 2013). In dogs, a higher prevalence of helminth parasites such as *Neospora caninum, Ancylostoma spp, Dipylidium caninum, Toxocara canis, Strongyloides stercolaris, Echinococcus granulosus, Trichurisuulpis, Taenia* spp and *Toxoascaris leonine w*ere identified in Ethiopia (Asmare et al., 2014; Merga and Sibhat, 2015; Zewdu et al., 2011). Many of these parasites have more than one host and could infect other animals and humans causing a serious economic and public health impact.

In Ethiopia, flea infected by Rickettsia and Bartonella, emerging zoonotic diseases worldwide, have also been isolated from dogs and cats (Kumsa et al., 2014). Furthermore, high prevalence (24%-75%) of *T. gondi* was reported in cats found in Addis Ababa, Ethiopia (Dubey et al., 2013; Tiao et al., 2013). Likewise, though study in Ethiopia is limited, the role that wild and feral animal populations might play in the incursion and spread of important transboundary animal diseases, such as FMD is higher than expected. Study of wildlife diseases contributes not only to wildlife health and conservation but also to the study of emerging infectious diseases, many of which are zoonotic.

2.6 International Trade and economy

An outbreak of animal disease can have significant economic, social and human health effects, although these effects vary considerably depending on the nature of the disease and the specific outbreak. Some animal diseases can have significant effects on markets. These include direct impacts on loss of production and farm income, unintended costs to adjust from lost output, sector and community losses in welfare, and impacts on markets (prices) and trade.

Historically specific animal diseases have caused substantial economic damage to many countries. For instance, with the confirmed cases of BSE in Canada in May 2003 and the Canadian-U.S. border closed to live cattle

trade and only limited meat trade, U.S. beef prices rose by over 26 percent in 2003. After discovery of a BSE case in the United States in December 2003, U.S. beef prices fell by nearly 11 percent and consequently, the world beef trade declined by an estimated 2.5 percent in 2004 (Beghin et al., 2004). A previous review of studies of the economic impact of transboundary animal diseases also indicates significant losses caused by the perceived threat of transboundary animal disease and control efforts. The studies include losses to Uruguay of added trade revenue estimated up to $90 million per year from the presence of FMD (1996), losses in the United Kingdom in 2000 related to BSE (lost trade, production, and other financial costs) of €5 billion (Otte et al., 2004), losses to the U.K. economy of $3.6–11.6 billion for FMD and $5.8 billion for BSE (USDA, 2001).

Moreover, the direct and indirect social and economic costs associated with infection are hard to assess, but are of dramatic. International disease outbreaks can lead to sudden, major economic shocks for farmers, communities, businesses, organizations and even the global economy. Of even greater concern are the pathogens that jump from animals to human host. In an internal report, the World Bank estimated that a severe influenza pandemic would cost more than US$3 trillion and hit the poor the hardest (FAO, 2013). The 2001 FMD outbreak in the UK took 7 months to eradicate, resulted in the slaughter of more than six million animals and was estimated to cost £8 billion to the public and private sectors, as well as having considerable environmental costs (USDA, 2001). Animal diseases are one of the main causes of restricting livestock export trade from Ethiopia. For instance, live animal export from Ethiopia was banned entry to Saudi Arabia from February 1997 - April 1998 due to the fear of introducing Rift Valley fever (RVF).

Generally, in Ethiopia, there is scarcity of documented evidence on the impact of specific animal diseases on the national economy. But, by inferring reports from other countries, one can easily imagine the extent and breadth of economic loses that Ethiopia has been facing due to its wide spread and prevalent endemic diseases. This is further exacerbated by the existing inefficient animal health services, weak disease control programs, poor biosecurity and biosafety and animal health research and development of the country. Because of these reasons, Ethiopia is unable to export livestock and livestock products to the lucrative markets and even trade with Middle East countries is frequently hampered and embargo is sometimes imposed (AGP-LMD, 2013b).

3. Assessments of external and internal environments

To achieve the stipulated goals of the program and the institute, assessing the internal and external factors that may directly or indirectly influence the implementation of the strategy is important. To this end, the main internal and external environmental factors associated with the success and failure of the strategy are considered, assessed and presented as follows.

The strategic planning tool used by the research team to evaluate and determine the chances that their research endeavor will succeed is the strength, weakness, opportunity and challenges (SWOC)-analysis, which stands for Strengths, Weaknesses, Opportunities and Challenges. The ultimate purpose of performing a SWOC analysis during this strategic design is to reveal positive forces that could be harnessed to work together and potential challenges that need to be recognized and possibly addressed for the strategic planning to meet its objectives.

Since the results from the assessment of the external and internal factors using the SWOC analysis framework are the basis for identifying critical issues that this strategy is formulated to address, brief narrations of the factors are provided hereunder to be followed by a matrix of summarized accounts of the opportunities, challenges, strengths and weaknesses.

3.1 Assessment of external environments

The external factors were analyzed using the SWOC framework in conjunction with additional analytic tools such as PEST (Political/Policy/ Legal, Economic, Socio-cultural and Technological); and critical considerations of current state of affairs, trends of needs and requirements and best solutions that other countries have adopted to get to their present cutting-edge milieu with respect to research and development in animal health. Three sub-topics are, therefore, discussed below to provide deeper perspectives. The current state of affairs is discussed under general external environments; trends and needs under operational external environments; and experiences of countries advanced in the research and development of animal health are discussed under the sub-heading benchmarking. Summaries of the external analysis are then presented in a tabular form at the end of the section (Table 1).

3.1.1. General external environments (PEST+)

Under the general external environment, analysis was made on opportunities and challenges that stem from political, economic, socio-cultural, technological/technical, and environmental (PEST +) dimensions. Methodical analysis of these factors would help to better understand the big picture of external environments influencing either positively or negatively and thus to craft the strategy so that it would make best use of the opportunities created by the positive influences and conversely to be cautious about the negative influences they pose or systematically address the challenges to overcome their impediment.

Political dimension: Since the adoption of the Agricultural Development Led Industrialization (ADLI) by the government of Ethiopia, all the policy and strategy frameworks and development programs recognized agriculture to be the engine of Ethiopia's economic growth and development yet exerting relentless strive to promote steady growth of the industrial sector. From the agricultural sector, considering the number and diversity of livestock resources it has and a rapidly growing economy, the Ethiopian livestock industry is expected to serve as a huge source of income for the national economy. The current GTP II which provides even greater emphasis to industrialization places utmost priority to the livestock and food safety fostering supply of raw materials for the growing agro-industries, import substitution and penetration of new foreign markets. As animal disease is one of the limiting bottlenecks for livestock development, animal health, in this respect, fall among the programs given such precedence. Therefore, so many opportunities are set forth by the policy environment to promote research and development in animal health. As there are conducive policy and legal frameworks put in place, there are also a number of challenges that may surface in due course. Thus, assessments were made whether the strategy is aligned with the national, sectoral and institutional policy, strategy and regulatory/legal frameworks and priorities. Conceivable features of the opportunities to make use of and challenges to be aware of or need to be addressed, from the perspective of the policy dimension, were assessed and sorted out in a matrix of opportunities and challenges presented in Table 1 below.

Economic dimension: The increasingly rising demand for foods of animal origin as a result of increasing population and changing lifestyle create an opportunity for the livestock sub-sector to thrive. Such an increase in the demand side will be the impetus for livestock producers, processing

industries and consumers. The research has to, therefore, keep pace with the need of livestock keepers to increase production mainly through increasing productivity, food safety and minimizing animal mortality and morbidity associated losses; while at the same time meeting the demand of consumers, traders and food processors. In Ethiopia, considering the growing demands for proteins of animal origin both locally and internationally, the livestock products like meat, milk and egg are expected to continue as drivers of economic development especially in rural and pastoral communities where their livelihood depends on livestock. Current trends indicate that, in spite of local demands, meat, hide and skins have been serving and will continue to serve as source of foreign exchange for the national economy. In this regard, the government plans to expand meat trade, beyond sustaining the existing ones, in to more lucrative and sustainable foreign markets. The poultry industry is also one of promising livestock subsectors which is anticipated to serve as source of meat for the ever increasing demands of animal proteins and it will also open job opportunities for youth and women. Furthermore, the current efforts in improving the production and productivity of the dairy industry in Ethiopia are expected gradually to replace imported dairy products. The existing economic opportunities, however, are not without posing some challenges that the animal health research program needs to be cautious about or address during the coming years. These are again detailed out in Table 1.

Socio-cultural dimension: In Ethiopia**,** people have a strong connection with animals and livestock rearing started since antiquity. In almost all ethnic communities, livestock are considered as symbol of wealth and social status. Traditionally and culturally, animals serve as companions, source of food, draught power (trashing, transport and ploughing) and cash incomes. Animals also serve as source of organic fertilizers in mixed crop-livestock production systems. In such scenarios, people are highly exposed to the rampant endemic zoonotic and food borne disease. It is thus essential for the research program together with its key stakeholders to unravel the opportunities that it can make use of and the challenges that it has to face up to in order to address or change the perception of the livestock keepers on zoonotic and foodborne disease should be considered and handled as such to be economically, socially, environmentally profitable, viable, safe and sustainable venture. Therefore, the opportunities accruing and challenges emanating from socio-cultural settings around animal production and the safety and quality of animal products processing and

marketing are examined and presented as elements of the SWOC analysis in the table below.

Technological dimension: Animal health technologies such as drugs, vaccines, diagnostic tools and cutting edge epidemiological software are needed to control and prevent animal diseases. Most of these technologies aren't produced in Ethiopia and even the imported ones are few in number and in quality compared to the number and diversity of diseases in the country. The coverage of these technologies are not enough and communities found in remote areas don't have access for such technologies due to lack of infrastructure issues. Few public institutions are engaged in animal health technology development, manufacturing and service provision. For instance, the National Veterinary Institute (NVI) produces some vaccines and most of these vaccines aren't diverse and don't have a multivalent and marker vaccine properties. In addition to the limited availability of veterinary vaccines, in most cases, the vaccination coverage even for the existing vaccines is too low and the veterinary service of the country is weak. The National Animal Health Diagnostic and Investigation Center (NAHDIC) and NVI have started giving diagnostic services, with some ingredients developed with in, for certain animal diseases but the speed and breadth of diagnosis is not as such promising. In such scenarios, the research program and stakeholders has to investigate, evaluate and develop the different animal health technologies and assess their quality and associated factors so as to be used by livestock keepers for control and prevention of diseases.

Environmental dimension: Ethiopia's wide diversity of agro-ecology is endowed with different animal genetic resources and again the environment, due to its unique properties, is a niche for different parasites, disease vectors and many other endemic diseases. In such environments, the wildlife-livestock-human disease interactions makes disease control and prevention more complicated and challenging. In addition, the country's wide and land locked geographical borders affects disease control and biosecurity programs negatively and animal diseases present in neighboring countries (for example rift valley fever and east coast fever) pose potential risks to the Ethiopian livestock industry. On the other hand, being land locked, the country is relatively in a less position from risks commence from water migratory birds (eg Highly Pathogenic Avian Influenza or Bird Flu). These are among the primary issues that the research program would target to address. It is, therefore, rational to

distinguish what opportunities these environmental factors could offer in order to take advantage of them while at the same time to be prepared to tackle the challenges they may pose. In Table 1 are, thus presented detailed aspects of both the opportunities and challenges surfaced as a result of the analysis of the environmental dimension.

3.1.2. Operational external environments

As operational external environment is by and large about analysis of stakeholders, key stakeholders in the value chain of animal health research were identified and the role they play to strengthen the sub-sector and their demands that they would like the research system delivers are elaborated. A list of such stakeholders with different roles and demands were examined. Different as they are the research program recognizes that the tiny bit of the role each of these stakeholders plays is crucially important for successful designing and implementation of the strategy and the outputs and impacts there. Therefore, assessments were made what opportunities the research program could make use of and, by the same token, what challenges it should face up to coming from these stakeholders by merely being involved in providing services of animal heath, vaccination, disease diagnosis, regulation and research. These stakeholders, for ease of discussion, were grouped as service providers, regulators, clients, partners and competitors and the opportunities and challenges coming from them were analyzed and captured.

3.1.3. Benchmarking

Ethiopia's livestock potential is not only in terms of diverse animal genetic resource and quantity but also a number of other factors discussed in the preceding sections including favorable policy, economic, socio-cultural, technological and environmental circumstances demands solution for the existing animal health challenges. As part of the external environmental factors, it is also a cogent exercise to examine the potentials of addressing animal health issues related to the livestock sub sector which can and should be exploited by drawing lessons from other countries that have advanced levels of research achievements. Accordingly, comparisons, in terms of animal health technologies used for preventing, controlling and/or eradicating economically important animal disease were made between the status that the national research system is found in and that of the benchmarked countries, that have a global access for livestock and livestock products trade. To fulfill the demands of domestic livestock markets and penetrate international lucrative markets, it's noteworthy to

take lessons from other countries and integrating the lessons learnt for exploiting the livestock potential of the country. In this case, the animal health research and development experiences of Namibia, Brazil and Australia has been taken as a bench mark and the experience and technological status of these countries in terms of animal health have been taken in to consideration during the development of this strategy.

3.2 Assessment of internal environments

The assessment of internal environments is an introversive process whereby the research team examines the capacity that exists within the EIAR system and can readily be utilized by the team to deliver outputs. Such a capacity that is readily available for the program denotes the strength of the program while the capacity which is required to deliver the outputs but falls short to exist symbolizes the weakness of the program. Assessment of the internal environment is thus about precise identification and articulation of strengths and weakness of the research program. Capacity in this context encompasses a wide array of topics including institutional capacity which signifies the available or lacking human, physical and financial resources; technical or technological capacity and organizational capacity which deals with the questions of functional integrations within and between disciplines to forge complementarities and synergies. Furthermore, the human, physical and financial resources have a decisive power on program implementation, coordination and administration. Therefore, the level and status of human resources capacity, financial capacity and the physical resources were assessed and tabulated as strengths or weaknesses.

Below are briefly discussed the elements of internal environments examined to synthesize summaries of the Strengths and Weakness provided in Table 1.

3.2.1 Inter- and intra- disciplinary integrations, complementarities and synergies

The success of animal health research depends on integrated and concerted efforts of various research disciplines and sectors. In addition to that of the mainstream disciplines (such as virology, bacteriology, parasitology, immunology, entomology and epidemiology), there are clear possibilities of realizing complementarities and synergies by working together with experts of other fields. Important among these potentially potent areas of

integration include: socio economic and extension, feeds and nutrition, animal breeding and genetics (i.e., dairy, beef, small ruminant, poultry, camel, and fishery research teams), animal-Biotechnology Research, Climate and Geospatial Research and information communication technology (ICT). Assessments were thus made whether or not there could be integrated synergies with these compelling areas of research.

3.2.2 Technologies

There are reports on previous concerted research on the development of animal health technologies, but the pace at which it has been progressing is almost trivial. As it's important to take the lessons learnt during the past decades in animal health research and development of technologies, the achievements made so far has been assessed, considered and documented. For instance, some vaccine and diagnostic tools have been used and epidemiological and surveillance information for some animal diseases were profiled and their management measures were worked out and established. Whether or not the changes brought about by these technologies are in par with the expectations are assessed to point out and build on the strengths and draw lessons from the weaknesses.

3.2.3 Organization, implementation and geographic coverage

Lack of strong systems and procedures (i.e., organizational capacity) at different levels is an area of capacity impediment that affects effectiveness. Poor intra- and inter-institutional linkages are also sources of limitation for rapid progress. Organizational strengths and weaknesses that would correspondingly make the growth of animal health research to take upward or downward trend were analyzed from the center-level, institutional level and national level perspectives.

3.3 Strengths, Weaknesses, Opportunities and Challenges by the Research Themes

Summaries of the strengths, weaknesses, opportunities and challenges assessed from the perspectives of the external and internal environments reflected in terms of strengths, weaknesses, opportunities and challenges pertaining to the different thematic research areas are presented in Table 1 below.

Table 1. Summary of analyses of external and internal environments

Research Theme	Strengths	Weaknesses	Opportunities	Challenges
General	Consideration of animal health as a national research program will help for a better research planning and execution	Lack of skilled human power especially for specific and advanced technologies and absence of core and focused research teams; Shortage of laboratory technicians and research assistants	Animal health is indicated as one of the priority areas identified for intervention in the livestock master plan and GTPII of the Ministry of Livestock and Fisheries; and in the red meat road map	Weak national disease control and prevention, biosecurity and safety schemes, may affect technology adoption
	The culture of research collaborations to conduct joint reviews and planning and multi-location experiments with different research institute and Universities	High attrition rate of experienced researchers and limited staff time for research i.e., most animal health researchers spent most of their time on service other than research.	Higher demands for safe foods of animals which is derived from high demand for quality foods derived from population growth, improved income and changing life style of the people.	Poor animal health service delivery system which is unable to utilize properly even the available animal health technologies
	Presence of different experts, with different level of practical experience,	Poor research linkage with other stakeholders; Weak institutional commitment for the animal health	The recently emerging government initiatives and determination to control animal disease that hamper international lucrative markets;	Many of the low input and low output livestock production systems that have lower technology demand may take

Research Theme	Strengths	Weaknesses	Opportunities	Challenges
	stationed across different research center	research and lack of research center dedicated for animal health	Presence of many local higher learning institutes for producing trained manpower in animal health	longer time to be transformed in to a market oriented intensive production system
	Presence of agricultural biotechnology laboratory in Holeta which is equipped with different advanced instruments that can be used for animal health research.	Limited budget and Poor research input procurement procedures	Enabling government incentives for import substitution of high quality foods of animal origin like dairy products and expansion of local food industries demands improved animal health technologies	Weak regulatory and legal frameworks on food safety, biosecurity and drug use.
				Emerging and remerging diseases due to climate and ecological changes
		Lack of field vehicles, self-contained laboratories equipped with pathogen containment facilities and standard store for temperature sensitive consumables	Availability of advanced veterinary technologies in the global market that could easily be adapted here in Ethiopia	Slow pace of privatization in veterinary service and limited number of private companies involved in animal health technology manufacturing and trading.
			Presence of huge and diverse animal genetic resources in the country can be taken as driving factor for the demand of animal health technologies	
		Poor scientific equipment maintenance and repairing system	Presence of many higher learning institutions offering veterinary education, research and services.	

Research Theme	Strengths	Weaknesses	Opportunities	Challenges
Disease prevention	Presence of biotechnology laboratory that can be used for vaccine research and other related researches	Lack experienced researchers on vaccine development, evaluation and other key disciplines	Higher demand for vaccines and other disease prevention technologies nationally	Weak support from none governmental organizations and limited external (international) fund for research on animal health
	Experimental animals (chicken, cattle, sheep and goats) present in different centers can be used for animal health research like vaccine trials	Absence of dedicated and specialized laboratories for research on disease prevention like vaccine technologies development.	The newly emerging and re-emerging diseases needs new research dimension that could be taken as an opportunity for developing new disease prevention technologies	Absence of private companies for manufacturing and trading of vaccines and other disease prevention technologies in Ethiopia
	Some information have been collected on the specific animal diseases and recommendations are also available for prevention of some animal diseases	Absence of controlled animal farms (sentinel herd for controlled vaccine trials)	Nationally, presence of vaccine production institute (NVI) that can be used for manufacturing of newly developed vaccines and Presence of a third party for vaccine quality approval (PAN VAC); globally presence of different companies engaged in vaccine manufacturing and trading.	The existing poor veterinary services delivery systems have negative impact on the overall vaccine demands of the country
	Presence of veterinary clinics in some centers that can support animal health research	absence of critical team dedicated towards research on specific animal health technologies like vaccines		Lack of vaccines in number, type and quality
			Presence of high demand for exporting veterinary vaccines	Poor national vaccination programs and weak veterinary service delivery systems

Research Theme	Strengths	Weaknesses	Opportunities	Challenges
Host-Pathogen interaction	Some information available on the natural resistance of local animals to different diseases	Lack of detailed data and understanding on the disease resistance/tolerance mechanisms of local animals	Emerging technologies in genomics and proteomics combined with advances in computational methods could help to understand host pathogen interactions	Lack of data on diseases resistance/tolerance characteristics of different species of livestock and Poor understanding on the pathogenesis of newly emerging pathogens
Disease Identification/ detection	Presence of molecular disease diagnostic laboratory at biotechnology center (Holeta)	Lack experienced and skilled researchers and laboratory technicians in the area of diagnostic tool development and /or improvement	Disease diagnosis is a criteria for livestock and livestock products export market	Absence of Animal identification and traceability system of the country
	Presence of veterinary clinics in few research centers	Absence of dedicated and specialized laboratories and storage facilities for diagnostic tools development, evaluation and improvement	Presence of referral and regional laboratories dedicated for animal disease diagnosis	Lack of improved diagnostic kits; Difficulty of differentiating Vaccinated and unvaccinated animals
		Absence of critical team that executes focused research on diagnostic tool development and improvement	The presence of different transboundary and zoonotic animal diseases affecting national and international trade demands improved diagnostic tools, this in	Emerging and re-emerging animal diseases needs an improved or new diagnostic tools, which is difficult to develop with in short period of

Research Theme	Strengths	Weaknesses	Opportunities	Challenges
			turn demands research on diagnostic tools.	time, for their earlier and better detection.
			The global availability of improved animal disease diagnostic tools and the advances in genomics, proteomics, nanotechnology and bioinformatics creates an opportunity for the development of rapid and reliable diagnostic tools	Absence of local private companies that could take over and commercialize diagnostic kits
Epidemiology and surveillance	Information on certain diseases for their epidemiology and surveillance is available	Limited epidemiological information on many of the economically important diseases	Presence of national referral and regional laboratories that can directly be used for epidemiological and disease surveillance tasks	Limited knowledge on the spatial and temporal distribution, extent and breadth of many of the economically important disease
	Presence of experienced researchers on epidemiological surveillance of animal diseases	lack of epidemiological modeling and disease risk analysis tools and facilities	Presence of international disease specific referral laboratories	Absence of national disease information network and epidemiological data base
	Clinics and mini labs present in certain centers can be used for preliminary	Lack of skilled man power on disease modeling and risk analysis; Absence of	availability of different array of rapid, and reliable diagnostic, communication and traceability technologies in the global market	National borders are porous enough to allow disease dissemination from neighboring countries creating

Research Theme	Strengths	Weaknesses	Opportunities	Challenges
	diagnosis (screening) of samples	epidemiological research units/teams		national biosecurity risks to Ethiopia
			Epidemiological and surveillance information is a criteria for livestock and livestock products export market	Uncontrolled free ranging wildlife and livestock movement in the country complicates disease epidemiology
			Awareness and collaboration of neighboring and other trading countries on transboundary animal diseases	Customary trend of sharing residence with livestock and consumption of raw livestock products predisposes humans to zoonosis and vice versa
				Rapid mutability and unpredictable variability of pathogens
Vector and vector borne diseases control	Some research experience on Trypanosomiasis and tsetse fly	Absence of a focused research team or program for vector and vector borne disease	Scientific advancements in the area of genomics, proteomics and phenomics could lead to effective vector and vector borne disease control technology development	Absence of an effective vaccine against vector borne diseases like trypanosomiasis
	Availability of research farms and facilities that can be used for tsetse fly and other vectors research	Limited effort on development of control and prevention technologies for vector and vector borne diseases	Greater push from local communities and government to control vectors and vector borne diseases	Absence of an effective vector control technologies and programs

Research Theme	Strengths	Weaknesses	Opportunities	Challenges
	Some recommendations are available on the control and prevention of vector and vector borne diseases like trypanosomiasis and tsetse fly	Lack of researchers in some disciplines like veterinary entomology	Presence of National TseTse and Trypanosomiasis Control Institute dedicated for Tse tse and trypanosomiasis control hastens technology uptake and adoption.	Increasing vector niche due to climate change and change in vegetation cover
		Lack of vector specific laboratory facilities		Emergence of drug resistance in vector borne diseases like trypanosomiasis
Curative and prophylactic drugs	Presence of information and knowledge in the area of anti-helminthic and antibiotic resistance	Lack of expertise and research team in certain disciplines like pharmacology, pharmacognosy and toxicology	Policy support and Investment opportunity for pharmaceutical industry	Weak & unregulated retail marketing and field use of veterinary medicaments; absence of regulatory and legal frameworks on field application of veterinary drugs
			Wider range of veterinary pharmaceuticals are available on the global market, and presence of some private veterinary suppliers in Ethiopia	
			Establishment of Veterinary Drugs and Feeds Administration and Control Authority for the control and administration of veterinary drugs in the country	Lack of alternative drug choice (narrow range) on domestic market
				Uncontrolled and illegal drug venders, increasing bogus drugs on market & weak regulatory action

Research Theme	Strengths	Weaknesses	Opportunities	Challenges
Ethno veterinary medicine	Existence of high Interest & motivation of researchers in documentation of herbs	Lack of inventory and registration of herbs and indigenous knowledge	Presence of herbalists and traditional healers in the country	Ecological deterioration and deforestation affecting natural resources /herbs
	Presence of some information generated on some herbal medicines and traditional knowledge	Weak research undertaking on ethno-veterinary medicine	Existence of rich indigenous knowledge and substantial number of herbs	The existing cultural and traditional practices have impacted negatively on the transparency and access of traditional knowledge and herbs.
	Presence of plot of land across research centers that can be used for herbarium research; Presence of research on medicinal plants at Wondogenet Research Center		Increasing public awareness on the effect drug residue and importance of using natural herbs; emergence of pathogens resistant to the existing conventional drugs	Undermining of traditional healers & deliberate ignorance by some scholars; Frustration from plagiarism or violation of patent right
			Presence of medicinal plant research under the institute of public health	Limited information on the chemical and physical property of herbs
Socio-economics, research extension and gender	Presence of socioeconomic experts in most of the agricultural research centers	Poor culture of collaborative project development and implementation between socio economic and animal health researchers	The urge of government and livestock producers to access international lucrative livestock markets demands for the use of improved animal health technologies	Limited information on the impact of diseases on gender, economy and public health of the country

Research Theme	Strengths	Weaknesses	Opportunities	Challenges
	Existing collaboration among scientists between extension and animal health experts	Limited effort to quantify the economic and social impact of animal diseases	Presence of internet and other modern communication tools that can be used for technology promotion	Poor information on the extension status, constraints and prospects of the country
Climate change, knowledge management	Presence of expertise on both climate change and knowledge management	Skilled expertise on climate change simulations and modelling	The country's climate resilient green economy policy	The continuing and unpredicted climate variability predisposes animals to unexpected diseases and calamities
	Absence of infrastructure and skilled man power for accessing and managing critical research data	Limited access to international journals for publication and use	Presence of open source journals and the global advances in ICT and communications	Difficulty of getting access to international journals and scientific article publishers
		Poor ICT infrastructure in most of the agricultural research centers		

4. Strategic issues facing the animal health research program

Table 2. Strategic issues facing the animal health research program and their relevance in the short-(1-5 years)**, medium**(6-10 years)**- and long**(10-15 years)**- terms**

Strategic Issue	Relevance in the		
	Short term	Medium term	Long term
4.1. General (across all themes)			
4.1.1 Lack of skilled man power in advanced techniques of animal health research engagements • Limited skill in advanced techniques of animal health biotechnology • Shortage of skilled laboratory technicians, research assistants and researchers • High attrition rate of experienced researchers • Limited staff time for disciplines	X	X	X
4.1.2. Limited research infrastructure (lab facilities, sentinel animals, vehicles) • Lack of self-contained, specialized labs equipped with pathogen containment facilities and standard stores • Lack of adequate facilities for experimentation on animals (including sentinel animals and associated facilities) • Shortage of vehicle for field work	X	X	X
4.1.3 weak institutional focus, research implementation and results dissemination system • Poor research input procurement procedures • Poor scientific equipment maintenance and repairing system • Absence of animal health research center • absence of effective animal health research output communication and dissemination system	X	X	X

Strategic Issue	Relevance in the		
	Short term	Medium term	Long term
4.1.4. Linkage and collaboration • limited linkage and collaboration with other institutions that conduct animal health researches	X	X	X
4.1.5. Animal welfare and ethics • Lack of animal welfare and ethics practice in the national research and development agenda	X		
4.2. Disease prevention (vaccine, biosafety, biosecurity)			
4.2.1. Availability of vaccines for many animal diseases • limited vaccines for many of cattle, sheep, goats, poultry, camel and equines diseases • limited vaccines for pet animal diseases • Absence of vaccines for diseases of pig, wildlife and fish	X	X	X
4.2.2.Quality of some existing vaccines • Absence of marker vaccines (enabling the differentiation of infected from vaccinated animals); • Many of the existing vaccines have difference in vaccine strain and field strain which results in vaccine failure (immunizing failures) • limited polyvalent vaccines against many pathogens or strains • Many vaccines lacks efficacy and/or safety i.e., failed protection or shows adverse side effects like converting vaccine (live) to disease	X	X	X
4.2.3. coverage, type and supply of veterinary vaccines • Lack of thermostable vaccines that can be used in remote areas • Under developed infrastructure required for vaccine transport and storage like cold chain • Shortage of supply of efficacious and safe vaccines (in the market) • Low vaccination coverage of existing vaccines • Poor or no national vaccination campaign programs and lack of legal support for enforcing national vaccination programs	X	X	X

Strategic Issue	Relevance in the		
	Short term	Medium term	Long term
4.2.4. National bio-security and bio-safety schemes • Lack of clear risk analysis procedure/protocols on the bio-security of importation of animal germplasms and biologicals • Lack of specific biosecurity protocols that could be recommended for application at national, regional and farm levels • Lack of national and/or regional biosecurity programs, • Inefficient legal and regulatory frameworks for enforcing biosecurity at national, regional and farm level (including animal movement control and quarantine). • Lack of proper pathogen containment and biosafety facilities (SPS) and legal enforcement procedures	X	X	X
4.3. Host pathogen interaction			
4.3.1. Information on diseases resistance/tolerance characteristics of different indigenous species of livestock • Lack of data on diseases resistance/tolerance characteristics of different animal species and breeds (cattle, small ruminants, poultry, equine and camel) in the country • Inadequate application of immunogenetics in identifying disease resistance/ tolerance of different animal breeds	X	X	
4.3.2. Information and preparedness on understanding the disease and disease mechanisms and host response of emerging and re-emerging pathogens • Limited capacity in deciphering the type and pathogenesis of newly emerging livestock diseases on disease mechanisms and host dynamics of the newly emerging or re-emerging livestock diseases • Lack of understanding and information on host pathogen interaction on many of the endemic diseases • Limited knowledge on dynamics of host spectrum	X	X	X

Strategic Issue	Relevance in the		
	Short term	Medium term	Long term
4.4. Epidemiology and surveillance (infectious and non-infectious diseases, parasite infestations)			
4.4.1. Information on the type, distribution and extent of animal diseases • Limited data on the prevalence and incidence of some animal diseases • Limited information on the spatial and temporal distribution of animal diseases across the country (Disease mapping) • Inadequate knowledge on risk factors of many animal diseases • Lack of data on strain types/genotypes of many of the circulating pathogens • Weak disease notification and reporting system • Lack of animal and product identification and traceability systems	X	X	X
4.4.2. Risk analysis and disease modeling • limited knowledge on the application of risk analysis in importing biological materials (including live animals and germplasm) • limited application of disease modeling techniques for early warning, disease prediction and transmission pattern	X	X	X
4.4.3 Biobank (national reference serum, pathogen and data repositories) • Limited national pathogen isolates that can be used as a reference (for virus, bacteria, fungus and parasites) • Limited serum or antibody bank for pathogens with economic and public health importance • Lack of national epidemiological data base (repository)	X		

Strategic Issue	Relevance in the		
	Short term	Medium term	Long term
4.5. Disease identification/Detection			
4.5.1. Laboratory based disease diagnostic tools • Limited tools for rapid and reliable disease detection and surveillance of pathogens • Limited information on the detection and characterization of new and emerging zoonotic infectious agents.	X	X	X
4.5.2. Field based diagnostic tools for detecting animal diseases • Lack of rapid and accurate field based disease detection tools like pen side diagnostic kits that could be used by animal owners. • Lack of improved tools for detection of diseases in free-ranging wildlife populations.	X	X	X
4.5.3. Animal and animal product identification and traceability tools and systems • Limited diagnostic and detection tools and systems for food adulteration • Inadequate food safety diagnostic tools both at laboratory and field level • Inadequate food safety and quality traceability systems			
4.6. Vector and vector borne disease control			
4.6.1. Information on vector biology and ecology • Lack of knowledge on the vector dynamics associated with ecological and climate changes • Limited information on vector host preference and host-vector interaction • Limited biological vector control technologies • Limited integrated vector control technologies • Limited information on the environmental impact of existing vector control technologies	X	X	X
4.6.2. Knowledge of vector borne diseases, their distribution and impact	X	X	X

Strategic Issue	Relevance in the		
	Short term	Medium term	Long term
• Limited knowledge on type and distribution of vector borne diseases • Absence of information on the impact of vector borne diseases on animal product quality and safety • limited prevention and control options for many of the vector borne diseases			
4.7. Veterinary drugs			
4.7.1. Drug use and management: • Absence of regular monitoring and surveillance of drug resistance development on commonly used veterinary drugs • Weak legal enforcement procedures for prohibiting nonprofessional veterinary drug handling and prescription • limited public awareness on drug use and drug resistance development • limited veterinary drug quality, efficacy and safety control systems	X	X	X
4.7.2. Availability and supply of veterinary drugs • Limited local veterinary drug manufacturing industries • Limited research and development on veterinary drugs • Inadequate drug supply and narrow drug of choice on domestic market for veterinary use	X	X	X
4.7.3. National risk analysis and mitigation schemes on veterinary drugs and biologicals • Inadequate risk analysis and mitigation procedure/protocols on the importation and use of pharmaceuticals and biologicals • Lack of specific biosecurity protocols that could be recommended for drugs and biologicals use on farm animals • Lack of risk analysis mechanism on feed related toxin and diseases like BSE, aujeskis disease, Jacobs diseases in animals	X	X	X

Strategic Issue	Relevance in the		
	Short term	Medium term	Long term
4.8. Ethno veterinary medicine			
4.8.1. Development and use of herbal medicine for veterinary medication • Lack of wider scale registration and documentation of herbs of medicinal importance • Lack of transparency and fear of plagiarisms on the identification and registration of herbs of medicinal importance • limited enforcement and legal support on patent right of herbal medicines • Limited capacity for the extraction and identification of active ingredients in herbs of medicinal importance • Limited information on the geographical and seasonal distribution of medicinal plants	X	X	X
4.8.2. Information on type and distribution of toxic plants affecting livestock • Limited data and documentation on types of toxic plants affecting farm animals • In adequate information on level of toxicity and pathogenicity of toxic plants • Lack of information on ecology, biology and distribution of toxic plants in the country	X	X	X
4.8.3 Inventory and documentation of indigenous knowledge on animal diseases management • Negligence and/ or lack of focus on use of indigenous knowledge in treating animal diseases and health management • Lack of information on the presence of indigenous knowledge for preservation, preparation and use of medicinal herbs and practices • Lack of information on the application and use of traditional knowledge (traditional healers)	X	X	X

Strategic Issue	Relevance in the		
	Short term	Medium term	Long term
4.9. Socio-economics, research extension and climate change and environment			
4.9.1. Information on the socio economic impact of diseases • Limited information on the economic and public health impact of animal diseases • lack of data on the effect of animal diseases on Social welfare and livelihoods	X	X	X
4.9.2. Information on the impact of climate and environment on animal health • Lack of information on vector ecology related to climate change • Absence of data on disease emergence and distribution patterns associated to climate • Absence of information on the impact of animal diseases on the environment and vice versa (lack of information on the impact of environment on animal diseases and animal welfare)	X	X	X
4.10. **Cross cutting themes: gender, knowledge management**			
4.10.1. Information on the role of gender: • Limited knowledge on women and children vulnerability and risk conditions posed by zoonotic diseases • In adequate information on the role of women in animal disease identification and care	X	X	X
4.10.2. Knowledge management: • Limited access to reputable international journals • Limited research results communication and dissemination system.	X	X	X

5. Research themes and strategic interventions

Considering the complex nature of the issues to be addressed by the research team, most of the research topics are multi-institutional, multi-thematic, multidisciplinary, participatory, and need to be implemented in collaboration with different stakeholders like livestock producers, livestock product processors, consumers, therapeutic and diagnostic animal health product manufacturers and others involved in the livestock industry. Aligned to the goals and priorities of EIAR and guided by the current national agricultural growth and transformation framework, the research strategy is believed to benefit livestock producers, food-processors, animal health technology manufacturers, traders and others involved in the value chains and the nation at large. The research themes are built on six major research programs as briefly discussed hereunder and the strategic interventions, designed for each of the strategic issues elucidated under section IV above and spanning the short-, medium- and long- terms of fifteen years (2016-2030), are presented in Table 2.

5.1 Research themes

5.1.1. General

During the second five-year GTP II period, the agriculture sector will still play a decisive role to transform the country into industrialization. In this regard, the livestock sub sector could contribute much since it serves as source of raw materials for agro and food processing industries. Nonetheless, the increased morbidity and mortality of livestock, the declining trend of quality and safety of foods of animal origin are the present bottlenecks for attaining food self-sufficiency and penetrating international livestock markets. As a result, the country has to heavily depend on the import of large amount of livestock products (mainly dairy products), incurring a large amount of foreign currency. It is, therefore, vital to have a strategy of import substitution and international livestock market penetration, where product quality and food safety are critical. In order to pursue such an important agenda of national urgency, the research should focus on two important issues that: (i) the animal health research program should be strengthened in terms human resources (i.e., the researchers engaged in animal health research should be equipped with

modern techniques and methods of diseases control technology improvements); research facilities (i.e., laboratories equipped with modern equipment and facilities for vaccine and diagnostics development, vector control and epidemiological modelling) and enabling research environments (i.e., a focused animal health center and specialized teams have to be in place); and (ii) the stakeholders involved in the disease control technologies value chain in general need to have a strong, functional, influential and sustainable forum that will shape up the future of animal health technologies development, manufacturing, adoption and wider scale utilization.

5.1.2. Disease prevention

The presence of endemic livestock diseases combined with emerging and re-emerging new diseases affects livestock production efficiency and again compromises food safety, posing a serious risk to the public as well. To prevent such diseases from emerging or re-emerging and control the existed ones, improved vaccines supported by biosecurity and biosafety programs and reliable livestock and livestock product traceability systems are used. To this end, the research will focus on development or improvement of veterinary vaccines, development and/or improvement of biosecurity and safety protocols and programs and livestock and livestock product identification and traceability systems.

5.1.3. Host pathogen interaction

Understanding host pathogen interaction helps to better develop disease prevention technologies and protocols, and robust disease detection mechanisms. Host resistance is one of the critical aspects that determines the onset of disease. Animals differ naturally in responding and fighting against diseases inflicted by different pathogens. As some species and breeds of animals are more susceptible to specific or general infection than others, some animals are also more resistant or tolerant, especially the local ones, than others and there is an inherent genetic variability even with in breeds of specific animal species that could be exploited during breeding of animals for producing disease resistant animals. Thus, research has to focus on understanding and exploiting the natural disease resistance/tolerance mechanisms of animals. In the meantime, to prevent or control the incidence of emerging pathogens, the disease mechanisms, pathogenesis and host dynamics of newly emerging and re-emerging animal disease has to be deciphered.

5.1.4. Disease detection

Many of the pathogens affecting livestock species could only be diagnosed after the development of infection/infestation. This often leads to failure to treatment, production loss and even death of affected animals. Contaminated foods of animal origin could also pass routine inspection procedures ultimately causing causalities to consumers. To address these complications, disease diagnostic kits supported by disease surveillance and monitoring systems both at the animal and food level has been used in many other countries. Thus, the research will focus on development and/ or improvement of disease diagnostic tools (both at field and laboratory level) and disease monitoring systems.

5.1.5. Epidemiology and surveillance

For the effective control and prevention of livestock diseases, the distribution, extent and seasonal variability of each of the diseases has to be mapped. Then only after this, effective vaccines, diagnostic tools or other disease surveillance and monitoring systems are developed and used; and biosecurity programs are designed and implemented. Epidemiological and surveillance data could also help to access global livestock and livestock products market by building confidence of consumers. It's therefore, critical to focus on assessing and mapping the temporal and spatial distribution and extent of important diseases; and developing their surveillance and risk analyses systems.

5.1.6. Vector and vector borne diseases control

Due to climate change and ecological changes, the rising distribution and intensity of vectors is deteriorating a wide range of fertile land which was suitable for livestock production otherwise. People living in such environments are affected directly and will remain in poverty unless mitigation options are in place. Even other areas that are currently dependent on livestock for their livelihood and have potential risks of exposure to vector borne diseases may gradually be condemned to poverty. Some of the vector borne disease are of zoonotic in nature and poses a significant public health risk to the communities living with in the vector infested areas. To mitigate such urgent problems, the research will focus on understanding the vector ecology and biology, developing vector control mechanisms and developing mechanisms for treating or preventing vector borne diseases.

5.1.7. Veterinary drugs

As drugs have been used in farm animals to cure or prevent many diseases, the production and productivity of livestock has shown tremendous improvement in the last decades. Whereas, many microbes and parasites have already become resistant to the existing antibiotics and anti-parasitic drugs respectively. In the meantime, some drugs, when applied to food animals, have undesirable side effects that can potentially harm the health of the public. To mitigate such problems, research will focus on evaluation of the existing veterinary drugs for their efficacy and safety, development of protocols for the rational use of drugs in farm animals and also development or adoption of improved drugs.

5.1.8. Ethno veterinary medicine

In Ethiopia, most of the rural communities have a tradition of using indigenous knowledge and herbs to treat or prevent their animals from different diseases. In spite of its potential benefits; through the advent of climate change, globalization and urbanization; the trend of treating animals using indigenous knowledge and herbs has been declining. Whereas, due to shifting in consumers preference, undesirable side effects of some conventional drugs and the emergence of antibiotic resistant pathogens, the search for alternative natural ways of animal treatment and prophylactic options is becoming more important than ever. Thus, research will focus on understanding and profiling the existing indigenous knowledge of treating diseased animals and also developing improved drugs from the existing traditionally used herbs.

5.1.9. Socioeconomics, research extension and climate change

The socio-economics and extension group will be included in the animal diseases control research team and will play a decisive role to bring in stakeholders together to formulate relevant research agenda as they do also take out promising research results to demonstration and adoption processes. Addressing issues related to socio-economics and research extension in the strategy is the key to attain the successes that the research team envisages.

In Ethiopia, climate change is already having an impact on the livelihoods of different communities in different corners of the country. The impact of animal diseases due to climate change is also expected to rise. Therefore,

animal health research strategy will place due considerations to availing technologies that would help the livestock producers to respond to climate change through use of improved animal health technologies to control disease vectors and associated risk factors.

5.1.10. Crosscutting themes (gender, knowledge management)

Women and children play a crucial role in small scale (low input and low output) livestock production systems starting from general husbandry to livestock products processing and marketing. In this process, women and children are exclusively at risk of contracting from zoonotic and food borne diseases causing further harm beyond the negative economic impacts of livestock morbidity and mortality caused by diseases. Cognizant of this, the strategy upholds integration of gender concerns into research objectives, technology development, extension, and evaluation frameworks.

Through knowledge management interventions aided by new information technologies, it is possible to help improve smallholders' access to technologies and information that help them improve their farm productivity and competitive ability. It will also help to create research products in a more collaborative manner that makes them more suitable for diverse audiences. For this purpose, the research team will make results more readily available, spearhead formations of multi-stakeholder platforms that facilitate interaction and promote learning for change, mentoring, knowledge sharing and networking.

5.2 Strategic Interventions

Strategic interventions of the animal health research program was carried based on the previously identified issues for 9 major research thematic areas and other areas which needs capacity building. The strategic themes identified for intervention are disease prevention, disease detection/ identification, Host-pathogen interaction, disease epidemiology and surveillance, vector and vector borne disease control, veterinary drugs, ethno veterinary medicine, Socioeconomics, other cross cutting themes and capacity building (table 3).

Table 3. Strategic interventions planned to address critical issues facing the animal health research program in the short- medium- and long- terms

Strategic Issues	Strategic Interventions		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (10-15 years)**
5.2.1. General (Relevant across themes)			
1.1. Avail skilled man power in advanced techniques of animal health research engagements	• Short and long term training on: - Vaccine design, development, and evaluation -Disease diagnostic and disease surveillance tool and systems design and development - disease modelling and risk analysis and mitigation option development	• long term training and continues on job Short term training of researchers and laboratory technicians • Establish best talent acquisition and retaining mechanisms and systems	• Long term training and continues on job Short term training of researchers and laboratory technicians • Establish talent acquisition and retaining mechanisms and systems
1.2. Improve the existing research infrastructures and develop new ones	• Establish sentinel herds and associated facilities for controlled trials • Establish dedicated laboratories equipped with facilities	• Update laboratory facilities	Update laboratory facilities
1.3. Establish a strong institutional commitment and	• Set a focused core research teams for animal health research program based on core disciplines	• Establish a dedicated national animal health research center	Continual improvement of animal health research center in terms of infrastructure and facilities

Strategic Issues	Strategic Interventions		
	Short-term (1-5 years)	Medium-term (6-10 years)	Long-term (10-15 years)
research implementation system.	• Establish a transparent, accountable and responsible research system • Improve the existing research input procurement and scientific equipment maintenance systems • Establish strong Linkage and collaboration with other institutions that conduct animal health researches	• Establish strong Linkage and collaboration with other institutions that conduct animal health researches • Strengthening linkage and collaboration with other institutions that conduct animal health researches	
1.4. Establish institutional animal welfare and ethics assessment systems	• Develop comprehensive animal welfare and ethics practices and systems in the national research and development agenda	• Improve animal welfare and ethics practices and systems in the national research and development agenda	

Expected Outputs from strategic interventions on general issues:

- Experts (researchers and technical assistants) trained and retained.
- Physical infrastructure and facilities required for full-fledged research on animal health developed
- Reliable and dependable system for scientific equipment maintenance and research input supply system established.
- Strong institutional support attained and National Animal Health Research Center equipped with enabling facilities established

Strategic Issues	Strategic Interventions		
	Short-term (1-5 years)	Medium-term (6-10 years)	Long-term (10-15 years)
5.2.2. Disease prevention (vaccines, biosecurity and biosafety)			
2.1. evelop/improve vaccines against animal disease.	• Adopt vaccines developed elsewhere against food animals and equines diseases	• Develop/improve vaccines against selected food animal diseases • Adopt vaccines developed elsewhere against selected equines, pet and companion animals • Adopt vaccines developed elsewhere against selected wildlife and fish diseases	• Develop/ improve vaccines against selected food animal diseases • Develop /improve vaccines against selected diseases of equines, pet and companion animals and fish
2.2. Improve the quality of existing vaccines	• Evaluate the safety and efficacy vaccines	• Evaluate the safety and efficacy vaccines • Develop marker vaccines and mechanisms for identifying vaccinated animals from infected animals	• Evaluate the safety and efficacy of available vaccines • Develop marker vaccines and mechanisms for identifying vaccinated animals from infected animals
2.3. Improve supply of veterinary vaccines.	• Design and develop effective vaccination programs for livestock	• Evaluate and improve livestock vaccination programs	• Evaluate and improve vaccine management systems across the value chain

Strategic Issues	Strategic Interventions		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (10-15 years)**
	• Develop and evaluate vaccine management systems across the value chain.	• Develop and evaluate vaccine management systems across the value chain.	• Evaluate and improve livestock vaccination programs
2.4. Establish national biosecurity and biosafety schemes	• Develop biosecurity protocols (national, regional and farm level) • Develop animal disease emergency management plans (guidelines)	• Develop and improve biosecurity programs based on the previously developed protocols • Develop national biosafety and pathogen containment systems • Evaluate and improve animal disease emergency management plans.	• Evaluate and improve biosecurity programs • Evaluate and improve animal disease emergency management plans • Evaluate and improve the existing biosafety systems
Expected Outputs of the Strategic Interventions on disease prevention : • Safe and efficacious veterinary vaccines adopted, developed and/or improved. • The quality and supply of veterinary vaccines evaluated and improved. • Recommendation given on vaccine management across the value chain. • National biosecurity protocols and programs developed and evaluated. • Biosafety protocols and programs developed and evaluated			
5.2.3 Host pathogen interaction (Disease resistance/tolerance, pathogenesis, host Dynamics)			
3.1. Identify the mechanisms of disease	• Assess and identify diseases resistance/tolerance characteristics of different livestock species.	• Assess and identify diseases resistance/tolerance characteristics of different livestock species.	• Develop protocols for future use of disease tolerant/resistant animal species/breeds.

Strategic Issues	Strategic Interventions		
	Short-term (1-5 years)	Medium-term (6-10 years)	Long-term (10-15 years)
resistance/tolerance in livestock species	• Identify gene(s) responsible for disease resistance/tolerance characteristic and preparing protocols for future use in other species/breeds. • Understand expression and regulatory mechanisms of genes responsible for disease resistance/tolerance in different livestock species.	• Identify gene(s) responsible for disease resistance/tolerance characteristic and preparing protocols for future use in other species/breeds. • Understand expression and regulatory mechanisms of genes responsible for disease resistance/tolerance in different livestock species.	
3.2. Understand the Pathogenesis, disease mechanisms and host dynamics of emerging diseases	• Assess and identify diseases which lacks information and understanding for their pathogenesis and host dynamics • Understand host-pathogen interaction (for selected and prioritized livestock diseases)	• Decipher disease mechanisms, pathogenesis and host dynamics of selected emerging diseases. • Understand host-pathogen interaction (for selected and prioritized livestock diseases).	• Identify markers that can be used for control and or prevention of the emerging diseases

Expected Outputs of the Strategic Interventions on Host pathogen interaction :

- Disease resistance/tolerance characteristics of different livestock species and breeds identified
- Mechanisms designed to utilize tolerance/resistance characteristic of a given species/breed identified.
- Pathogenesis, disease mechanisms and host dynamics of emerging diseases known
- Information and markers that could be used development of Prevention and control options for emerging diseases identified.

Strategic Issues	Strategic Interventions		
	Short-term (1-5 years)	Medium-term (6-10 years)	Long-term (10-15 years)
5.2.4. Epidemiology and surveillance (disease epidemiology, risk analysis and pathogen characterization)			
4.1. Assess the type, distribution and extent of animal diseases and associated risks	• Determine the epidemiology of diseases of economic and public health importance affecting (food animals, wildlife and companion animals) • Mapp epidemiological units • Evaluate and improve disease notification and reporting systems • Analyze potential risks for important animal diseases (related to livestock and livestock products market)	• Develop risk analysis protocols and systems (including but not limited to diseases modelling) • Evaluate and improve disease notification and reporting systems • Update the epidemiology of diseases of economic and public health importance affecting (food animals, wildlife and companion animals)	• Develop and improve disease risk analysis protocols and systems • Update the epidemiology of diseases with economic and public health importance affecting (food animals, wildlife and companion animals) • Disease risk analysis for important animal diseases (related to livestock and livestock products market) • Evaluate and improve disease notification and reporting systems
4.2. map/genotype circulating strains of pathogens	• Strain typing/genotyping of selected circulating pathogenic viruses, Strain typing/genotyping of selected circulating pathogens	• Assess Strain/genotype variability in selected pathogenic viral/bacterial species.	• Assess Strain/genotype variability in selected pathogenic viruses/bacteria
4.3. Establish biobank (national reference serum, pathogen	• Establish national serum bank • Establish national repository for reference pathogens.	• Establish national epidemiological data base (repository)	

Strategic Issues	Strategic Interventions		
	Short-term (1-5 years)	Medium-term (6-10 years)	Long-term (10-15 years)
and data repositories)			
Expected Outputs of the Strategic Interventions on epidemiology and surveillance : • The type, distribution and extent of animal diseases and associated risks factors assessed and quantified • Strain/genotype of circulating strains of pathogens mapped/genotyped • National serum bank established • National repository for reference pathogens established • National epidemiological database (repository) established.			
5.2.5. Disease identification (disease diagnostic tools and tracking systems)			
5.1. Develop, adapt and/or improve rapid and reliable laboratory based disease diagnostic tools	• Design livestock disease detection and surveillance systems • Develop/improve rapid and robust diagnostic tools	• Develop/improve rapid and robust diagnostic tools • Evaluate and improve livestock disease detection and surveillance systems	• Develop/improve rapid and robust diagnostic tools • Understand the interactions between pathogens and hosts.
5.2. Improve, adapt/develop field based, rapid, reliable and easy to use diagnostic tools	Develop and/or improve animal disease and food safety surveillance systems	• Develop and/or improve rapid and reliable pen side diagnostic kits that could be used by farmers. • Design/develop or improve disease detection and	• Develop and/or improve rapid and reliable pen side diagnostic kits that could be used by farmers.

Strategic Issues	Strategic Interventions		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (10-15 years)**
		surveillance systems for free ranging wildlife • Develop and/or improve animal disease and food safety surveillance systems	• Evaluate/improve free ranging wildlife disease detection and surveillance systems • Develop and/or improve animal disease and food safety surveillance systems
5.3. Improve livestock and food identification, traceability and surveillance systems	• Evaluate and improve animal identification, traceability and surveillance systems • Design, develop or improve traceability systems for foods of animal origin	• Evaluate and improve animal identification and traceability systems • Evaluate and improve traceability systems for foods of animal origin	
Expected Outputs of the Strategic Interventions on disease identification: • Rapid and reliable laboratory based disease diagnostic tools developed and/or improved • Field based rapid, reliable and easy disease diagnostic tools improved/developed • Livestock disease detection and surveillance systems and tools improved/developed • A reliable and dependable animal and food identification, traceability and surveillance system developed/improved.			
5.2.6 Vector and vector borne diseases control			
6.1. Understand vector biology and ecology; and	• Avail base line data on type and distribution of vectors and vector borne diseases	• Understand the vector dynamics associated with ecological and climate changes	• Avail information on vector host preference and host-vector interaction

Strategic Issues	Strategic Interventions		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (10-15 years)**
assess and understand vector borne diseases, their distribution and impact	• Study the economic and public health impact of vectors and vector borne diseases	• Assess the type and distribution of vector and vector borne diseases • Avail information on the impact of vector borne diseases on animal product quality and safety	• Understand vector and vector borne diseases dynamics associated with ecological and climate changes
6.2. Improve or develop technologies for controlling vector and vector borne disease	• Explore and adapt control technologies against certain vector and vector borne diseases	• Develop/improve vector control technologies • Develop/improve disease control tools against vector borne diseases	• Develop/improve vector control technologies • Develop/improve disease control tools against vector borne diseases
Expected Outputs of the Strategic Interventions on vector and vector borne disease control: • Type, distribution and dynamics of vectors and vector borne diseases known. • The economic and public health impact of vector and vector borne diseases studied • Technologies for controlling vector and vector borne diseases Explored, adapted/improved. • The impact of vector borne diseases on animal product quality and safety known			
5.2.7 Veterinary drugs			
7.1. Develop evidences based protocols that can be used for establishing a	• Evaluate and improve the legal frame work used for regulating the professional use and handling of veterinary medicaments, prescription	• Evaluate and improve controlling scheme or protocol for veterinary drugs use and medication.	• Evaluate and improve the legal frame work used for regulating the professional use and handling of veterinary medicaments, prescription

Strategic Issues	Strategic Interventions		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (10-15 years)**
robust regulatory system for veterinary pharmaceuticals handling and use	and use through generating evidences based protocols.	• Develop a regulatory system or protocol to control drug residue in marketable products of food of animal origin.	and use through generating evidences based protocols.
7.2. Avail and supply quality veterinary drugs	Update scheme for the evaluation of imported veterinary drugs Assess the efficacy, safety and efficiency of veterinary drugs	• Design and develop effective drugs for veterinary use • Assess the efficacy, safety and efficiency of veterinary drugs	• Design and develop effective drugs for veterinary use • Assess the efficacy, safety and efficiency of veterinary drugs
7.3. Develop national risk analysis and mitigation schemes on veterinary drugs use and trade	• Identify the risks and hazards associated to specific veterinary drug use and trade. • Develop drug risk analysis and hazard identification protocols and schemes.	• Develop/improve drug handling and safety protocols (national, regional and farm level) to avoid problems associated with drug handling and use	• Evaluate and improve veterinary drug risk analysis, hazard identification and mitigation protocols

Expected Outputs of the Strategic Interventions on disease prevention :

- Reliable and effective veterinary drugs handling and use (prescription) protocols and legal frame works developed and/or improved.
- Quality veterinary drugs availed, improved and/or developed.
- Veterinary drug risk analysis, hazard identification and mitigation protocols developed.

Strategic Issues	Strategic Interventions		
	Short-term (1-5 years)	Medium-term (6-10 years)	Long-term (10-15 years)
5.2.8 Ethno veterinary medicine (herbs - active ingredient identification, mechanism of action; toxins, indigenous knowledge,)			
8.1. Develop/improve herbal medicines for veterinary medication	• Establish wider scale inventory and documentation system of medicinal plants • Develop protocols for collection and extraction of active ingredients of collected herbs • Determine pharmaceutical properties of registered herbs and developing commercial preparation of herbs to drugs • Determine toxicological characteristics of identified and registered herbs of medicinal importance	• Establish wider scale inventory and documentation system of medicinal plants • Determine pharmaceutical properties of registered herbs and developing commercial preparation of herbs to drugs • Determine toxicological characteristics of identified and registered herbs of medicinal importance	• Determine pharmaceutical properties of registered herbs and developing commercial preparation of herbs to drugs • Determine toxicological characteristics of identified and registered herbs of medicinal importance • Commercialize identified and tested herbs of medicinal value.
8.2. Assessment of type and distribution of toxic plants affecting livestock	• Assessment of type, ecological distribution and seasonal patterns of toxic plants • Assessing toxic effects and active ingredients of toxic plants	• Assessment of type, ecological distribution and seasonal patterns of toxic plants • Assessing toxic effects and active ingredients of toxic plants	

Strategic Issues	Strategic Interventions		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (10-15 years)**
8.3. Assessment and documentation of beneficiary indigenous knowledge of animal diseases management	• Establishment national scheme for assessing and registering cherished indigenous knowledge in the area of animal disease control and treatment • Investigation of mechanism of action of indigenous knowledge in controlling and treatment of animal diseases	• Investigation of mechanism of action of indigenous knowledge in controlling and treatment of animal diseases • Popularizing the use of confirmed indigenous knowledge in controlling and treating animal diseases	• Investigation of mechanism of action of indigenous knowledge in controlling and treatment of animal diseases • Popularizing the use of confirmed indigenous knowledge in controlling and treating animal diseases
Expected Outputs of the Strategic Interventions on epidemiology and surveillance : • An effective and improved drugs developed from traditionally used herbal plants. • The type and distribution of toxic plants affecting different livestock species known. • The indigenous knowledge used for animal diseases management in different communities assessed and documented.			
5.2.9 Socio-economics, research extension, climate change and environment			
9.1. Socio-economics: avail information on the social and economic impact of diseases	• Quantify the economic impact of animal diseases • Assessing the public health and social impact of animal diseases	• Quantify the economic impact of animal diseases • assess the effect of animal diseases on Social welfare and livelihoods	• assess the effect of animal diseases on Social welfare and livelihoods

Strategic Issues	Strategic Interventions		
	Short-term (1-5 years)	**Medium-term (6-10 years)**	**Long-term (10-15 years)**
9.2. Climate change and environment: generate information on the impact of climate and environment on animal diseases	• Quantify the impact of climate change on animal disease • explore vector ecology, disease emergence and distribution patterns associated to climate • Assessment of effect of climate changes on type, distribution and active ingredients of plants of medicinal importance • Explore the impact of animal diseases on the environment and vice	• Quantify the impact of climate change on animal disease • Assess vector ecology, disease emergence and distribution patterns associated to climate • Assess effect of climate changes on type, distribution and active ingredients of plants with medicinal importance. • Assess the impact of animal diseases on the environment and vice versa	• assess vector ecology, disease emergence and distribution patterns associated to climate • Assess the impact of animal diseases on the environment and vice versa (and the impact of environment on animal diseases and animal welfare)
9.3. Extension: avail information on the adoption, dissemination and promotion status and impact of technologies used for disease control	• Conduct adoption study on improved technologies and their impact on the livelihoods of the adopters	• Conduct adoption study on improved technologies and their impact on the livelihoods of the adopters	• Conduct adoption study on improved technologies and their impact on the livelihoods of the adopters
	• Conduct extension activities to demonstrate and popularize disease control technologies • Promote and campaign the importance of disease control	• Conduct extension activities to demonstrate and popularize disease control technologies • Promote and campaign the importance of disease control	• Conduct extension activities to demonstrate and popularize disease control technologies • Promote and campaign the importance of disease control

<table>
<tr><th rowspan="2">Strategic Issues</th><th colspan="3">Strategic Interventions</th></tr>
<tr><th>Short-term (1-5 years)</th><th>Medium-term (6-10 years)</th><th>Long-term (10-15 years)</th></tr>
<tr><td></td><td>through mass media and internet and evaluating its impacts</td><td>through mass media and internet and evaluating its impacts</td><td>through mass media and internet and evaluating its impacts</td></tr>
<tr><td colspan="4">Expected Outputs of the Strategic Interventions on Cross cutting themes:
The economic, public health and social impact of animal diseases quantified.
The impact of climate change and environment on animal diseases studied.
The ecology, emergence and distribution patterns of diseases associated to climate change known.
Disease control technologies demonstrated and popularized
The adoption of improved animal health technologies and their impact on the livelihoods of the adopters known</td></tr>
<tr><td colspan="4">5.2.10. Cross cutting themes: gender and knowledge management</td></tr>
<tr><td rowspan="2">10.1 Gender - Asses the risk level and vulnerability of women and children by zoonotic diseases and food safety related risks</td><td>Asses the risk level and vulnerability of women and children by zoonotic diseases and food safety related risks
Study the role of women in animal disease identification and care</td><td>Asses the risk level and vulnerability of women and children by zoonotic diseases and food safety related risks
Study the role of women in animal disease identification and care</td><td>Asses the risk level and vulnerability of women and children by zoonotic diseases and food safety related risks</td></tr>
<tr><td colspan="3">Consider gender equality and ensure that woman get their fair share of the benefits of research results</td></tr>
<tr><td colspan="4">10.2 Knowledge management: Consider modern facilities of ICT are instrumental in knowledge and information transfer processes.</td></tr>
</table>

6. The next steps

For the proper implementation of the strategy, it is indispensable to develop a clear implementation plan. The strategic plan document should be viewed as a living constantly assessing the external and internal environment for changes regarding emerging opportunities or challenges, internal weaknesses and strengths as well as political, economic, socio-cultural, environmental, technological and legal challenges. The strategies and strategic plan should respond to the new external and internal environments. Therefore reviewing the strategic plan, monitoring and evaluation, impact assessment and reassessment of the strategies and strategic plan should be done as required. Furthermore, before the implementation of the strategic plan, prioritization of diseases and thematic areas should be done for exploiting the available resources effectively and efficiently.

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