IGAD Centre for Pastoral Areas and Livestock Development (ICPALD)

Total Economic Valuation of Pastoralism in Ethiopia

STUDY REPORT

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Disclaimer

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Building Resilience

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FOREWORD

Total Economic Valuation (TEV) is one of the most widely used and commonly accepted frameworks for assessing value of an ecosystem to provide evidences for decision making. As a land-based system, pastoralism remains invisible to market-based appraisals, yet it has multiple dimensions and benefits. Applying the total economic valuation framework can help us to show the economic logic of pastoralism to policy makers, development practitioners, planners, and investors or businesses. These are the people who often make decisions based on financial rationale.

In the Arid and Semi-Arid Lands (ASALs) of the IGAD region, pastoralism and agro-pastoralism represent the major livelihoods and production systems which employ the largest percentage of the population. In Ethiopia, both pastoralism and agro-pastoralism remain central to the provision of means of livelihoods in the lowlands, and contribute immensely to the local and national economies.

In recognition of the multiple functions and benefits of pastoralism in Ethiopia, and issues of its under-valuation due to lack of empirical evidence, the IGAD Centre for Pastoral Areas and Livestock Development (ICPALD) commissioned a study on total economic valuation of pastoralism. The study results were presented at a national workshop and further enriched with inputs from relevant stakeholders, including government and non-state actors. It was planned that the evidence from this study would provide useful information for decision makers and various stakeholders concerned with pastoral development and advocacy.

More specifically, the economic valuation approach, data and information can be used in the design, formulation and implementation of policies, strategies and investment interventions at different levels.

Dr. S. J. Muchina Munyua
Director, ICPALD

ABBREVIATIONS AND ACRONYMS

APVGM	Annualized Present Value of Gross Margin
CELEP	Coalition for European Lobbies on Eastern African Pastoralism
CIFOR	Center for International Forestry Research
GDP	Gross Domestic Product
GIS	Geographic Information System
GM	Gross Margin
ICPALD	IGAD Centre for Pastoral Areas and Livestock Development
IGAD	Intergovernmental Authority on Development
IUCN	International Union for Conservation of Nature
MODIS	Moderate Resolution Imaging Spectroradiometer
PV	Present Value
PVGM	Present Value of Gross Margin
RPLRP	Regional Pastoral Livelihoods Resilience Project
TEV	Total Economic Valuation
WISP	World Initiative for Sustainable Pastoralism
WTP	Willingness to Pay

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EXECUTIVE SUMMARY

Inadequate empirical evidence on the economic value of pastoralism is one of the reasons why there is limited supportive public policies and investment. And also why there is weak lead organizational structure for sustainable development of pastoralism in Ethiopia and elsewhere. This lack and little support to pastoralism indicates neglect to this mode of livestock production and subsequently contributes to inefficient utilization and degradation of rangeland resources.

And so, the main objective of this study is to determine the baseline economic value of pastoralism in Ethiopia using a mix of valuation methodologies in order to support evidence-based policy and investment decision making for pastoralism and pastoral area development.

Methodologically, the main contribution of this work is in terms of the implementation of an integrated bio-economic simulation model to better capture the direct economic value of livestock production. First, the livestock herd/flock growth simulation model is used to project pastoral livestock populations and the various livestock products and services produced are estimated by applying technical herd/flock growth parameters to the livestock population generated.

Secondly, the goods and services generated are valued using market prices and are simulated over a 20 year period. They are discounted to the present value using a discount rate of 10%.

Thirdly, in the absence of data, the benefit transfer method (BTM) is used in the economic valuation of climate regulation services associated with pastoralism. The major goods and services valued in this study include: livestock products and services, climate regulation services, honey, tourism, gum and resin.

The results of the economic valuation indicate that pastoralism, as a maintained livelihood practice in the lowland rangelands of Ethiopia represents huge wealth which generate significant economic values for the pastoral households and the nation. These results have wider implications for the re-evaluation, formulation and implementation of policies and investment strategies for food and nutrition security, sustainable rangeland use and conservation. The baseline economic values allow at least the recognition of the minimum opportunity costs of changes in pastoral land use from the baseline situations. Some of the major findings are highlighted below:

The economic value of pastoral livestock assets (cattle, camels, goats and sheep) is estimated at ETB 256.0 Billion ($US 8.5 Billion) in 2019 market prices: the rangelands in lowland Ethiopia support huge livestock populations. In 2019 for instance, cattle, camels, goats and sheep populations are estimated at 14.1, 4.5, 20.4, and 15.7 million heads, respectively. This stock represents substantial sources of wealth both to pastoral households and to the national economy, and support sustainable income generation from the livestock sector. In terms of livestock species, cattle alone account for almost half of the pastoral livestock assets followed by camels which account for 19% of the value of livestock assets. Goats and sheep account for 31% of the total value of livestock assets.

The pastoral livestock production provides significant livestock off-take for subsistence consumption and commercial sales: The estimated annual live-animal equivalent cattle off-take from the pastoral livestock production is estimated at 977,465 heads of cattle. The corresponding figures for camels, goats and sheep is 238,917; 2,780,132 and 2,174,137 heads respectively. In terms of meat equivalents, the annual volume of beef, camel meat, goat meat and sheep meat is 93.3, 54.7, 32.5 and 28.5 million kilograms, respectively.

The pastoral livestock production provides significant milk off-take for subsistence consumption and commercial sales: The annual cow milk production from the agro-pastoral and pastoral livestock production system is approximately701.2 million liters. The corresponding figures for camels and goats is 967.8 and 130.5 million liters, respectively.

The total annual economic value of pastoral livestock production is estimated at ETB 83.3 Billion ($US 2.8 Billion) in 2019 market prices: This points to the significant annual value addition by pastoral livestock production to the national economy. The pastoral livestock production system accounted for about 63% of the total value addition, whereas the agro-pastoral production system accounts for the remaining 37%. In terms of livestock species considered, cattle and camel constitute almost equal percentages of the value addition. Goats account for about 23% of the total value addition.

The pastoral livestock production provides significant manure and draft power in support of agriculture in agro-pastoral production system: The projected annual pastoral manure production is close to 61.92 billion tons. The quantity of draft power supply is about 17.8 million oxen days. The annual cumulative value addition for manure and draft power is in the range of ETB 12.59 (US$ 0.42) and ETB 0.68 (US$ 0.02) billion, respectively.

There is also significant value added by supplementary products and activities associated with pastoralism such as: climate regulation services, tourism, gum and resins and honey production: The annual economic value from the climate regulating services is estimated at ETB 173.8 Billion (US$ 5.8 Billion). The tourism sector in Ethiopia is a rapidly growing sector, generating an estimated ETB 38.40 Billion ($US 1.27 Billion) in the pastoral area alone. The tourism potential of the lowlands is highly underutilized due to the low level of development in services catering for tourism such as hotels, transportation and lodges. The annual value-added from the gum and resin is estimated at ETB 7.01 Billion (US$ 0.23 Billion). The total economic value of honey for the entire pastoral area of Ethiopia is roughly estimated at ETB 31.25 Billion (US$ 1.03 Billion).

In general, the overall contribution of supplementary products and activities associated with pastoralism is about ETB 249.66 (US$ 8.33) billion. This indicates the amount, by how much, the value of pastoralism would be underestimated if we do not consider the benefits of other goods and services associated with pastoralism. It is also important to note that this value is only a conservative estimate. It is not exhaustive of the values of all goods and services that can be associated with pastoralism. More work is required in the future to improve the coverage of goods and services to be included in the valuation work. Furthermore, it is important to note that the dry forest biomass generates substantial value from subsistence and commercial uses of fuelwood, charcoal and construction material. However, as these products involves significant trade-off and contribute to rangelands degradation their value is not computed.

The risk of rangelands biodiversity loss to unwise lowland rangeland utilization and degradation, making all the values to be lost forever, is very high. In this regard, the results of this economic valuation can be used for advocacy and in the formulation of various policy instruments to design various incentive mechanisms and protect the rangeland environment. Some of the important recommendations are highlighted below.

Integration of the economic valuation work with interventions in the lowland rangeland uses: It has been observed that the interventions in the lowland rangelands uses have been not informed by economic valuation work. There is therefore a need for stakeholders (pastoralist, government, non-governmental organization, donors and private sectors) engagement and awareness creation for integration of the economic valuation work with the design, development and implementation of interventions in the lowland rangeland uses. This could, for example, involve the implementation of a mandatory requirement of economic valuation work in the lowland rangeland use decisions. This will improve the efficiency of resource allocation and protect the livelihood of the pastoralists and the environment.

Generate spatially explicit data on rangeland goods and services and TEV results: This study is conducted for the entire pastoral area of Ethiopia. However, in practice, the interventions are site-specific. Meaning, they do not necessarily encompass the whole pastoral area. Thus, the computed TEV does not apply if the intervention is for smaller site-specific areas. In this regard, there is a need to produce spatially explicit or geo-referenced goods and services and TEV results in order to inform site-specific investments in the lowland rangelands. The integration of the TEV results with the geographic information system (GIS) facilitates the quick presentation and aggregation of economic values at different levels. It also allows one to assess the policy and investment interventions at the project (site-specific), sectoral and ecosystem levels.

Building analytical capacity for economic valuation: Analytical capacity building for economic valuation study is desirable. The lowland areas are where many still think that there are relatively better opportunities to acquire large areas of land as compared to the highlands which are already highly populated. This creates more demand for the lowland rangeland use, especially from the large scale commercial farms. Thus, it is necessary for IGAD to spearhead and strengthen the analytical capabilities in economic valuation for the countries in the region, in order to guide policy and investment decisions towards efficient utilization of the lowland rangeland resources. Training of national staff in the simulation model used in this study would be a good starting point.

Support sustainable commercialization of rangeland products: The lowland rangelands in Ethiopia represent areas where livestock is produced with minimal use of modern inputs. This provides the opportunity to trade organic products for local and global markets, such as eco-labeled meat, milk, and honey, as well as several dry forest products like gum and resins. The international market can be exploited by careful branding of the rangeland products.

Exploit the global carbon market opportunities: The lowland rangelands afford various kinds of environmental goods and services. Currently, climate change is one of the biggest challenge facing the world. The rangeland environment can play a critical role in climate change mitigation by providing natural mechanism to capture carbon from the atmosphere and store it. For this reason, the climate regulation services through carbon trade represents an emerging market opportunity for the pastoralists to earn additional money while also allowing the sustainable flow of goods and services from the rangeland. In order to explore and exploit the global carbon trade opportunities, it will be essential to develop national capacities for quantification of and regular monitoring of carbon dioxide sequestration potential of pastoral production system.
It is important to note that this economic valuation is limited by scope in terms of livestock species considered, supplementary goods and services covered, ecological services reflected and the scale of valuation. For example, in this study the economic valuation of pastoralism is limited to the pastoral (farm) gate price due to the limited time available for this study. Despite that, the pastoral sector has significant economic linkages with other sectors of the economy. The study also focused on the direct values of livestock production and key supplementary goods and services. In the future more detailed valuation work is required to provide comprehensive economic valuation of pastoralism.

1. INTRODUCTION

1.1 Background

In general, there are several forms of capital (human, social, financial, natural and physical) required for the social and economic advancement of the society (Bourdieu, 1986). Capital can be defined as an asset that would generate value over a certain period of time. With this in mind, it is argued that the main challenge facing humanity presently is finding ways to harness all available forms of capital. Also, how they can do it in a manner that promotes human welfare and maintains the integrity of the natural environment for current and future uses (Slaus and Jacobs, 2011). The main development challenge in the pastoral areas of Ethiopia is how to best combine the rangelands natural capitals[1] with other forms of capitals for optimal values and sustainability.

It is worth noting that development issues in the pastoral areas of Ethiopia are related to the size of the natural capital stock or resource basis of pastoralism in the country. Consequently, the size of the capital stock is one of the key determinants of the gains from pastoralism. This capital stock is measured by the size of the land and water bodies that contain the different biomes or ecosystems, rendering different goods and services that support livestock production, among other things. Table 1 shows the size of different land cover or land use types for lowlands areas by agro-pastoral and pastoral production systems in Ethiopia and a corresponding map in Figure 1. The total land area covering the lowlands[2] is about 57 million hectares of land. It accounts for the 50% of the total land area of the country.

At the broader level, in order to facilitate detailed livestock sector analysis, two major livestock production systems are identified in the lowland areas of Ethiopia: the agro-pastoral and pastoral production systems (Shapiro et al., 2013). The area under the pastoral production system is about 43 million hectares which accounts for about 75% of the total lowland area while the agro-pastoral area accounts for 25%. When it comes to land use/cover, the open shrub lands and grasslands, the

1 Natural capital is defined as the natural world (e.g., animals, soils, air, plants, water and minerals) –the stock of natural resources that produce a flow of ecosystem services benefits to human beings and that does not require human agency to be produced or maintained (Costanza and Daly, 1992).

2 Lowland areas in Ethiopia are defined as the areas with an altitude below 1500 meters above sea level. These areas are also commonly referred to as arid and semi-arid land (ASAL).

biomes directly relevant for livestock productions, account for about 70% of the total lowland areas. Table 2 shows the regional distribution of the lowland land use/cover. The highest land area is observed for the Somalia region, accounting for more than half of the lowland areas in the country followed by Oromia, Afar, SNNP and Gambella, with corresponding area shares of 19%, 17%, 5% and 1%, respectively.

Table 1: Land use/cover patterns of pastoral and agro-pastoral areas (Lowland) of Ethiopia in 2010

Land Use/ Cover	Agro-pastoral		Pastoral		Total	
	Area (Ha)	%	Area (Ha)	%	Area (Ha)	%
Barren or sparse vegetation	390,358	2.73	5,294,463	12.32	5,684,821	9.93
Closed shrub lands	1,179,716	8.26	3,323,267	7.73	4,502,983	7.86
Cropland / natural vegetation	1,334,968	9.35	722,121	1.68	2,057,089	3.59
Croplands	179,199	1.25	286,694	0.67	465,893	0.81
Deciduous broadleaf forest	145,072	1.02	402,206	0.94	547,278	0.96
Evergreen broadleaf forest	297,945	2.09	30,453	0.07	328,398	0.57
Grasslands	4,351,904	30.47	5,385,840	12.53	9,737,744	17.01
Mixed forest	980	0.01		0.00	980	0.00
Open shrub lands	3,689,395	25.83	26,643,182	62.00	30,332,577	52.98
Permanent wetlands	1,481	0.01	5,412	0.01	6,893	0.01
Savannas	1,283,575	8.99	207,811	0.48	1,491,386	2.60
Water body	1,043	0.01		0.00	1,043	0.00
Woody savannas	1,424,999	9.98	674,533	1.57	2,099,532	3.67
Total area	14,280,635	100	42,975,982	100	57,256,617	100

Source: NASA moderate resolution imaging spectroradiometer (MODIS), 2010. Note: The cropland/ natural vegetation has crop lands with natural vegetation while the croplands are clear fields with no natural vegetation in the fields

Thus, the lowland areas cover a very large geographic area. As a result, it provides huge grazing and/or browsing lands that supports livestock production. The main livestock species kept in lowland areas of Ethiopia are cattle, camels, goats, sheep and equines. They are reared for meat, milk, draft power and manure depending on the production system in which they are present. For example, all the livestock mentioned are kept for meat production while cattle, camels and goats are kept also for milk production. Cattle is also used for draft power in the agro-pastoral production system while camels are used for transportation purposes wherever they are reared. Camels are the dominant means of transporting salt bars from the traditional salt extracting sites in Afar to the nearby towns. They are also used as means of transport for for the pastoral households.

Table 3 shows the baseline[3] herd/flock sizes and number of livestock herds or flocks and livestock population by agro-pastoral and pastoral production systems. As of 2019, the total cattle, camels, goats and sheep population of the lowland areas of Ethiopia was 14.1, 4.5, 20.4 and 7.2 million, respectively[4]. The agro-pastoral and pastoral production systems jointly accounted for 28%, 100%, 70%, and 50% of the national cattle, camels, goats and sheep population, respectively. This indicates the significant role of lowland areas in the national livestock population. At the moment, there are limited commercial livestock production activities in the pastoral areas of Ethiopia.

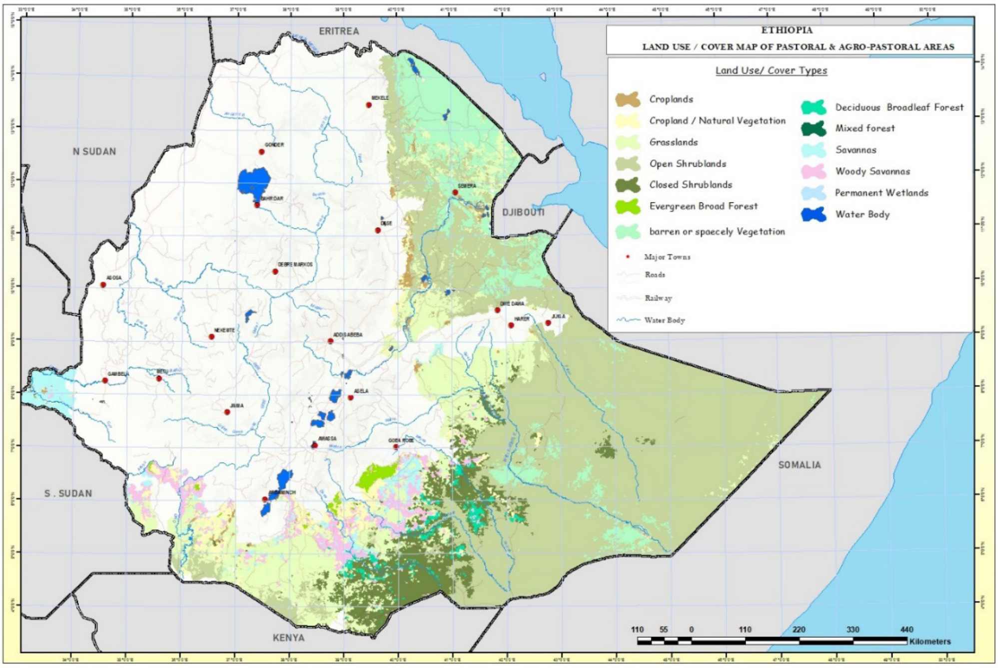

Figure 1:Map of Agro-Pastoral and Pastoral Areas of Ethiopia

Source: NASA moderate resolution imaging spectroradiometer (MODIS), 2010.

The lowland areas are home to more than 10 million people with diverse and rich historical and cultural heritage. Forest, wetlands and savannas support different wild plants and animals –endemic plants and animals included. The dry forests in the low lands provide diverse forest products and services. There are several conservation areas and big rivers flowing through the lowlands like Awash, Omo, Genale and Wabishebele.

3 The baseline livestock population data for 2019 is based on the projection of livestock population in 2013 by Shapiro et al. (2013).

4

The lowland areas of Ethiopia are also home to ecological and historical sites that are a great tourist attraction. For instance the UNESCO registered archaeological site in Afar and several aesthetic and wonder landscapes that exist in the lowlands. The culture and lifestyle of the pastoral people in itself is also a major sources of tourist attractions.

Table 2: Land use/cover patterns of agro-pastoral and pastoral areas by regions of Ethiopia

Land Use/ Cover	Agro-Pastoral and Pastoral Areas (Ha)					
	Afar	Gambella	Oromiya	SNNP	Somalia	Total
Barren or sparse vegetation	3,798,740		25,631	3,349	1,857,197	5,684,917
Closed shrub lands	5,307		1,017,352	8,866	3,471,465	4,502,990
Cropland / natural vegetation	298,521	16,618	993,767		126,398	1,435,304
Croplands	310,684	20,872	59,316	673,197	23,604	1,087,673
Deciduous broadleaf forest			142,141		405,130	547,271
Evergreen broad forest			301,317	27,081		328,398
Grasslands	1,693,314	7,441	5,679,773	981,059	1,376,148	9,737,735
Mixed forest			980			980
Open shrub lands	3,560,562		919,765	340,091	25,512,075	30,332,493
Permanent wetlands	5,455	1,438				6,893
Savannas	999	728,909	602,280	122,622	36,576	1,491,386
Water body	1,043					1,043
Woody savannas	673	16,103	1,170,947	615,775	296,036	2,099,534
Total area	9,675,298	791,381	10,913,269	2,772,040	33,104,629	57,256,617
Regional share (%)	17	1	19	5	58	100

Source: NASA moderate resolution imaging spectroradiometer (MODIS), 2010.

Table 3: Baseline assumptions of agro-pastoral and pastoral livestock populations in Ethiopia, 2019

Livestock Species	Sub-system	Herd/flock Size	Number of herds/flocks	Livestock Population	Relative importance of pastoral livestock population	
					Within sub-system (%)	National (%)
Cattle	Agro-pastoral	8.29	700,500	5,807,145	41.24	11.11
	Pastoral: Small	6.31	400,500	2,527,155	17.95	5
	Pastoral: Medium	17.00	338,000	5,746,000	40.81	11.54
	Total			**14,080,300**	**100**	**27.65**
Camels	Agro-pastoral	10.96	113,650	1,245,604	27.62	27.78
	Pastoral: Small	1.08	50,000	54,000	1.2	1.11
	Pastoral: Medium	16.05	200,000	3,210,000	71.18	71.11
	Total			**4,509,604**	**100**	**100**
Goats	Agro-pastoral	14.09	500,444	7,051,256	34.67	25.97
	Pastoral: Small	7.89	42,909	338,552	1.66	1.34
	Pastoral: Medium	25.97	498,650	12,949,941	63.67	43.13
	Total			20,339,748	100	70.44
Sheep	Agro-pastoral	10.73	308,088	3,305,784	21.07	11.26
	Pastoral: Small	7.38	148,020	1,092,388	6.96	3.72
	Pastoral: Medium	27.91	404,473	11,288,841	71.96	38.45
	Total			**15,687,013**	**100**	**53.43**

Source: Projection based on Shapiro et al. (2013).

1.2 Justification

In the lowlands of Ethiopia, traditional pastoral livestock production system is the main means of livelihood. It has been associated with multiple and most often synergetic uses of the rangeland's ecosystem goods, services and functions. But due to increase in human population, urbanization and income growth, there is a rising demand for other uses of the rangeland's ecosystem goods and services such as rain-fed and irrigated commercial crop farming. The rain-fed and irrigated farming could involve significant trade-offs with traditional pastoral livestock production systems that have been practiced for ages without significant negative impact on the rangeland environment. With climate change and increased human activities, the problem of rangeland degradation is also becoming a big issue that needs public policy and investment attentions.

Given these general trends, one of the important challenges in promoting coherent pastoral area development in Ethiopia is lack of evidence about relative economic importance of pastoralism in the country. Some vital aspects that need to be addressed in this regard are the size of the pastoral economy in Ethiopia, and how much value the pastoral system adds to the national economy annually? Ideally, the different economic sectors in the national economy could receive differential policy and investment priorities based on their perceived and/or assessed relative contributions to the national economy measured by the gross domestic product (GDP). In the case of Ethiopia, the contribution of pastoralism is not well-represented in the national accounts (Shapiro et al., 2013).

Furthermore, it is well documented that GDP measure also has some limitations. This is because it focuses or measures marketable output of the economy only. So in the case of economic valuation of pastoralism, it is important to look into other measures that consider both market and non-market values. This would give a better understanding and reflection on the welfare of pastoralists as well as the multiple benefits of the ecosystem where they co-exist. As a result, the total economic valuation was born to capture all the economic values of man-made capital assets and natural resources while also incorporating non-marketed goods and services such as values of ecosystems goods and services.

The gap in empirical evidence regarding the economic importance of pastoralism and pastoral system has made pastoralism to be devalued and viewed as less important and marginal. In turn, it has not been given the priority it deserves at the regional and national policy and investment decisions table, hence neglected. The practice has been considered as wasteful, unproductive and results in poor land management. As if that was not enough, there have been discussions and national policies aiming at ending pastoralism as a whole. Attempts to change the pastoral and agro-pastoral systems to less resilient systems, such as rain-fed or irrigated crop farming is a clear indication of the perceived lower economic value attached to pastoralism.

In general, the lack of clear and deep understanding of the economic values of pastoralism can result in misguided policies and mismanagement of dryland resources, be it utilization, conservation, or restoration, which will negatively affect the livelihoods of pastoralists and the environment. It is against this background that the assessment of the economic benefits of pastoralism with the TEV framework is expected to fill the gap in the current empirical evidence on the economic contribution of pastoralism. This will in turn, inform public policy and investment decisions in lowland rangelands to protect the livelihoods of pastoralists and the environment. This TEV establishes the baseline of comprehensive economic value of pastoralism and thus provides an indication of what can be obtained from the lowland rangeland in its current state. The ultimate objective of the economic valuation exercise is to build up a strong case for economic argument on policy, investment and advocacy for pastoralism.

The current method of computation of TEV is generally challenged by the availability and quality of empirical data. The quantities and values of goods and services used in the valuation are obtained from the patchy government official point estimate statistics which are less reliable and less representative. It is also observed that previous valuation effort do not take into account the growth dynamics of livestock population, the natural capital nature of livestock asset and its long-term production stability. All these factors, if not properly accounted for, undermine or overestimate the true economic contribution of pastoralism, specifically livestock production. There is need for a systematic modeling approach to identify, quantify and value goods and services produced from pastoral livestock production system.

To fill this gap, simulation is the best way available. In this study, herd/flock growth simulation model is applied in order to derive/quantify goods and services from the pastoral livestock production systems. This simulation model takes into account the livestock biological growth processes and the management practices in the different production systems. The model helps to adequately and effectively capture the quantities of livestock goods produced and services provided. Thus, the result constitutes core data for the computation of total economic values of pastoralism.

The economic model used is based on the natural capital budgeting approach which is discussed in detail in the methodology section. There are three key features in our economic modeling approach. First, this model, within the general TEV valuation framework, is very well integrated with biological livestock growth model which not only allows the computation of the economic values of pastoralism but also allows ex-ante evaluations of the financial and economic feasibility of various policies, management and investment interventions in the rangelands. Second, it considers both current and future streams of benefits. Third, it also captures the costs of intermediate inputs used in the production of goods and services in pastoral production system.

In general, this study aims to provide two critical aspects about Ethiopian pastoralism: the size of the Ethiopian pastoral economy and its annual value addition to the national economy. It also allows for the assessment of the relative economic importance of different livestock species and products at the animal, herd, individual, household, production systems and national levels.

1.3 Objectives of the Study

The inadequate empirical data on the economic value of pastoralism is considered to be one of the reasons for the lack of adequate public policy, investment and overall weak institutional support for pastoralism in Ethiopia. Therefore, the main objective of this study is to determine the baseline economic value of pastoralism use in order to enhance evidence-based policy and investment decision making and advocacy for pastoralism. The specific objectives are:

1 To identify, quantify and value pastoral livestock and livestock products,
2 To identify, quantity and value other goods and services associated with pastoralism, and;
3 To aggregate the annual economic values obtained at different levels at the individual, household, sub-systems, regional or national levels

1.4 Scope and Limitations of the Study

This study is conducted for the pastoral and agro-pastoral livestock production systems in Ethiopia as a whole. The results might not apply for the mixed crop-livestock production systems. There is lack of clear geographic delineation of pastoral areas of Ethiopia and as a result the areas used are roughly based on estimates from secondary sources. It is also important to note that the animals considered in this study are limited; the major livestock species considered include cattle, camels, goats and sheep. There are also other livestock species kept by the pastoralist like poultry and pack animals, but they are excluded from valuation due to data unavailability. It is also important to note that agro-pastoralists cultivate land and generate income from crop and crop related activities. In this case however, effort is not made to capture this as it involves trade-off with livestock production. Furthermore, it is believed that the value of subsistence use and commercial sale of wild plants and animal foods, woods for charcoal, firewood and construction could be very significant and requires time for data collection and careful trade-off analyses and hence it is not included in the study.

The TEV computation in this assignment focused mainly on the use values (direct and indirect values) and excluded non-use values. Computation of non-use values requires household survey to collect data on the willingness to pay. This needs significant time and resources in implementing a household survey for non-use values. The economic contribution of pastoral livestock production is also computed at the pastoral household's gate level while it is clear that goods and services generated in the lowland areas create substantial value addition along the value chains within and outside the pastoral production areas. For example, the value added due to live animals and meat exports, skins and hides are not included.

There are also significant economic benefits generated by selling and subsistence use of fire woods, charcoal, construction materials, wild animal and plant as foods and medicines, etc. But the values of all these products and services are not documented. This indicates the need for continued research for comprehensive computation of TEV of pastoral and agro-pastoral systems. Non-use value determination requires the solicitation of value for non-use of some parts of the pastoral areas as use and non-use values are not mutually exclusive; a given resource cannot be used and unused at the same time. At the moment, non-utilization of rangeland resources (total conservation) is not practical. This makes it very important to carefully consider the economic benefits of rangeland resources, as undervaluation undermines the importance and hence sustainability of rangeland resource utilization.

2. CONCEPTUAL FRAMEWORK AND EMPIRICAL APPROACH

2.1 The Concept of Total Economic Valuation

The proposed analytical framework for the computation of the economic valuation of the pastoral and agro-pastoral (PAP) production system is based on the TEV framework. The framework is widely implemented by a number of regional and international organizations advocating for supportive polices to pastoral livelihoods such as the International Union for Conservation of Nature (IUCN), Coalition for European Lobbies on Eastern African Pastoralism (CELEP), World Initiative for Sustainable Pastoralism (WISP) and Intergovernmental Authority on Development (IGAD) among others. The TEV framework is used to identify, classify, quantify and value goods and services produced from a given ecosystem. The detailed discussion of the TEV framework is found in Davis (2007), Hatfield and Jonathan (2006) and Rodiriguez (2008). The application of TEV framework in pastoralism is also common (SOS-Sahel Ethiopia, 2008; ICPALD, 2016 and Caroline, 2019). The main theoretical framework of economic valuation is about putting economic values on certain goods and services. The economic value of a good and service is defined as price the consumer is willing to pay (WTP) for a good and service (Defra, 2007). This study aims at identifying, measuring, quantifying and valuing of pastoralism. The information generated helps as critical input in scarce resource allocation decision for sustainable social economic development of the society.

In the total economic valuation, two approaches are explicitly considered. First, the economic value of livestock as store of wealth obtained by multiplying the livestock population with corresponding appropriate current market prices. Livestock as the store of wealth has significant implications for investment, insurance, credit and risk management in the pastoral sector. Second, the annual value addition from livestock production captured by quantifying subsistence consumption and commercial sale. This approach allows us to capture both the size of pastoral economy and its potential to generate additional economic values over time. Therefore both the stock and flow nature of the livestock production system are taken into account in the valuation process.

The description of the various components of TEV is given in Figure 2 following Hatfield and Jonathan (2006). In general, TEV is given as a sum of use and non-use values of goods and services. The use values are further classified as direct and indirect use values and option values. As the name implies, the direct use values takes into consideration goods and services that are used directly by human beings. They include the value of consumptive uses such as meat and milk; and the value of non-consumptive uses which do not require harvesting of the products and are considered as indirect use values. The direct use values involve observable quantities of products whose prices are usually observed in the market-places or recorded and available as secondary sources of data.

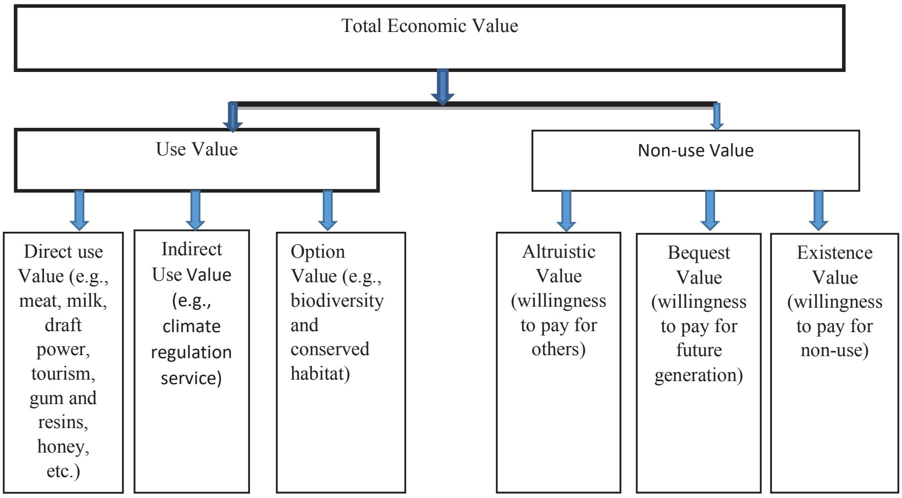

Figure 2: Schematic presentation of total economic valuation framework

There are several valuation techniques used to determine the use and non-use value: market prices, travel costs methods, benefit transfer methods, contingence valuation (see: Hatfield and Jonathan, 2006). In the case of use values of livestock and livestock products, the market price are used to measure values. For example, the value is obtained by multiplying the quantity of goods and services by its observed market prices and subtracting the costs of intermediate inputs used to produce the goods and services.

In the case of tourism or recreation use, the travel cost method could be used whereby the benefits received from the tourism (in the pastoral area) is computed by multiplying the number of visitors by tourist's actual travel costs or their stated willingness to pay to visit particular sites. It can be collected through contingent valuation surveys. But in Ethiopia, such disaggregated data is not available by agro-pastoral and pastoral production systems. Alternative methods of estimation should be used. Thus, in our case, the proportion of area was used in apportioning the total tourism revenue of the country.

Non-use values refer to the utility people may experience simply by knowing that a resource exists even if they never expect to use that resource directly. There are three categories of non-use values in the TEV framework: altruistic values, bequest values and existence values (see: Figure 2). The altruistic value is given by the willingness to pay for others to use resources while the existence value is the willingness to pay for the assurance that something will exist. The bequest value is the willingness to pay to preserve some resources for the future generation.

In the case of environmental values like the value of the ecosystem services in carbon sequestration, the benefit transfer method appliesto estimate the economic value of carbon sequestered (de Groot et al., 2012). Data on the areas of pastoral land by land use type is obtained for the pastoral areas. Then, the total quantity of carbon sequestered per unit area determined by land-use types because capacity of carbon sequestration varies by land use types. Lastly, the total volume of carbon sequestered is multiplied by the unit price of carbon sequestration from elsewhere. This is based on the assumption that the global community will compensate (or there will be market for it) the pastoralists for their management practices which results in carbon sequestration, by maintaining the health of dryland ecosystem.

In the case of non-use values, contingent valuation (CV) surveys are used to estimate the non-use or existence values based on consumers' willingness to pay (WTP). However, due to resource and time limitations, existence (non-use) value is not quantified. In this valuation process, attempts are made to measure or estimate the annual total net benefits from pastoralism. Livestock products like meat, milk, hides and skins are examples of consumptive direct use values, recreation is a non-consumptive direct use, biodiversity conservation is often considered to provide existence value, although aspects of it can also be considered as indirect use of option value (Hatfield and Jonathan, 2006).

2.2 Empirical Approach in Measuring the Economic Values

One of the main challenges in the development of pastoralism is the lack of strong economic case for effective public and investment interventions. This is because the economic contribution of pastoralism is not properly captured and documented. TEV is an effort to measure the value of flow of benefits from the goods and services from pastoral systems, which includes its environment. Some of the goods and services generated from pastoral production system and associated activities include meat, milk, skins, hides, manure, transport, draft power, honey, gum, incense, tourism and carbon sequestration, among others. To undertake computation of TEV, the first step will be identifying the economic benefits, considering both current and future flows of multiple goods and services from the pastoral production systems. The second step is the quantification of volume of goods and services from the pastoral production system. And, the third step is valuation of goods and services produced from the pastoral production system using different valuation techniques: market prices and benefit transfer method.

The empirical approach proposed here for livestock and livestock products is based on an integrated bio-economic simulation model: first, the herd/flock growth model projects the livestock population and associated goods produced and services provided over a 20-year period. For this purpose, well-established herd/flock demographic parameters are used to project livestock population. The technical parameters required for the herd/flock projections are derived based on data from secondary sources and are given in Annexes 1 to 17.

Thereafter, the economic model based on capital budgeting approach is applied. This approach considers the present value of all the current and future benefits that the livestock production system generates (Gittinger, 1982). The financial data used in the capital budgeting is given in Annex 18 and 19.

The capital budgeting modeling approach takes into account the long-term production potential of pastoral system. The initial simulation analysis is conducted at the herd/flock level for representative herd/flock size classes but the results of the simulation analysis can be aggregated at different levels: herd/flock, production system, regional and national levels. It could also be disaggregated at the individual animal level. This work introduces a modeling approach to improve the TEV framework of pastoralism in Ethiopia and could be replicated elsewhere. The next sections present in more details the two major components of the bio-economic simulation model used: the herd/flock growth simulation model and the economic simulation model.

2.2.1 Herd/Flock Growth Simulation Model

The sage-structured population projection matrix model is used to simulate herd/flock growth over a 20-year period while applying appropriate demographic parameters. The population projection matrices are based on Leslie (1945); Caswell (2001); and Caswell (2007). Recent applications of population projection matrices to the study of livestock population growth dynamics include: Lesnoff (1999); Lesnoff et al. (2000); Lesnoff et al. (2010); Lesnoff et al. (2012). In general, there are two types of population projection matrices which are widely used in analyzing livestock population growth dynamics over time. The first matrix model is called the Leslie population projection matrix model which classifies the livestock population by age, hence an age-structured matrix model (Leslie, 1945).

The second matrix model is called the Lefkovitch population projection matrix model, which classifies livestock population by their stage of growth or life cycle, and hence is called the stage-structured population projection matrix model (Lefkovitch, 1965). Each approach has its advantages and disadvantages. The Leslie matrix is considered to be data intensive. It requires age specific demographic data and mathematically more demanding due to higher dimensions of matrices as compared to the stage-structured Lefkovitch matrix model. In terms of application also, the stage-structured matrix is more practical, as the utilization of livestock for different purposes are mainly based on stages of growth (age ranges) rather than age-specific per se. Both matrix models project the population in *t+1* time period using the initial population at *t* time period and annual transition parameters. For both population projection matrices, the availabilities of reliable demographic data (e.g., fecundity rates and mortality rates) is critical for the accuracy of prediction. For this study, the Lefkovitch sex and stage-structured population projection matrix model is adopted due to its advantages as discussed above.

In a Lefkovitch stage-structured livestock population projection matrix model, the structure of the herd/flock is defined in terms of animal numbers in different age and sex cohorts. Thus, the female and male cattle are divided into three discrete growth stages: juvenile, sub-adult and adult. In general, the stage durations for sub-adults and adult animals are assumed to be different by sex of animal and by production system analyzed. The projection interval, or time step used for the projection is one year and the overall projection time horizon is 20 years. The herd/flock growth model is run by different herd/flock size classes and for representative pastoral livestock production systems since demographic parameters are assumed to vary by stages of growth and production system.

Mathematically, the stage-structured deterministic population projection matrix model for the analysis of herd/flock[5] growth dynamics considered here is given as a discrete time first-order difference equation:

$$n_{t+1} = An_t n_{t+1} = An_t \tag{1}$$

Where $\boldsymbol{n}_{t+1}$ denotes the 6x1 state vector of herd/flock sizes by sex and by stage of animal growth (life-cycle) at a time *t+1*; $\boldsymbol{n}_t$ is a 6x1 state vector of herd/flock size by sex and stage of animal growth at time *t,* also known as the initial set of abundance and **A** is a square 6x6 Lefkovitch annual stage-structured population projection matrix used to analyze livestock population dynamics in discrete time (Lefkovitch, 1965). The **A** matrix is used to generate a new state variable or vector $\boldsymbol{n}_{t+1}$ and contains the annual transition probabilities derived from annual demographic rates (annual fecundity rates, annual mortality rates and annual offtake rates for subsistence and commercial use). In general, the Lefkovitch population projection matrix **A** is a generalization of the Leslie age-structured matrix and is given as:

$$\boldsymbol{A} = \left[\begin{array}{cccccc} 0 & 0 & 0.5F_a & 0 & 0 & 0 \\ G_{j,s} & P_{s,s} & 0 & 0 & 0 & 0 \\ 0 & G_{s,a} & P_{a,a} & 0 & 0 & 0 \\ \hline 0 & 0 & 0.5F_a & 0 & 0 & 0 \\ 0 & 0 & 0 & G_{j,s} & P_{s,s} & 0 \\ 0 & 0 & 0 & 0 & G_{s,a} & P_{a,a} \end{array}\right] \tag{2}$$

where F_a is the fecundity of adult female animal which is the product of annual parturition rate and net prolificacy rate, the subscripts *j*, *s* and *a* denote juvenile, sub-adult and adult animal, respectively irrespective of the sex of the animal and $G_{i,j}$ is the probability that an animal of a given sex in stage *i* will enter the next stage *j (j=i+1)* in the next time period; and $P_{i,i}$ denotes the probability of an individual animal of a given sex surviving and remaining (or persisting) in the same stage *i*. The structure and formulation of Leslie and Lefkovitch matrices are similar but the difference is in terms of the columns and matrix entries. In the case of Leslie matrix, the columns of matrix **A** represent the age of animal while in the case of Lefkovitch matrix the column represents the different stages of growth. The other difference between the two is that the matrix entries in the case of Leslie

5 It is important to note that the structure of bio-economic simulation model is similar for all ruminants except the difference in the value of demographic parameters used.

matrix is given in terms of fecundities in the first raw which indicate reproductive contribution for different animal growth stages and survival probabilities (p_i) across the diagonals of the matrix. On the other hand, in the case of Lefkovitch matrix, the fecundities are given in the first raw but the survival probabilities are broken down in to two: the probability of an individual surviving and moving from class i to the stage j ($G_{i,j}$) and the probability of an individual surviving and remaining (or persisting) in the same stage i ($P_{i,i}$).

Given the duration of animal in each stage (d_i) and the stage-specific survival probabilities, the matrix **A** entries for G_i and P_i are computed using the following formulas (Crouse et al. 1987):

$$P_i = \left(\frac{1-p_i^{d_i-1}}{1-p_i^{d_i}}\right) p_i P_i = \left(\frac{1-p_i^{d_i-1}}{1-p_i^{d_i}}\right) p_i \tag{3}$$

$$G_i = p_i^{d_i}\left(\frac{1-p_i}{1-p_i^{d_i}}\right) G_i = p_i^{d_i}\left(\frac{1-p_i}{1-p_i^{d_i}}\right) \tag{4}$$

where p_i is the annual survival rate computed using equation (5) below following Lesnoff et al. (2012.) based on sex and stage specific demographic rates: annual mortality rate (m_i) and sex-stage specific annual offtake rate (o_i). The survival probability is given as follows:

$$p_i = 1 - m_i - o_i p_i = 1 - m_i - o_i \tag{5}$$

Equation (5) indicates a self-recruiting herd/flock growth model or endogenous population dynamics model where animals are not imported from outside the population for accelerating growth (Lesnoff et al., 2012). Thus, the animal demographic behavior is assumed to be influenced mainly by mortality and subsistence and commercial offtake rates only[6]. Finally, the first order difference equation (1) for the projection of animals by their stages of growth can be given in vectors and matrix representations as follows:

6 Note: The offtake is computed as a summation of the offtake for subsistence consumption and commercial purpose.

$$
\begin{bmatrix} F_{j,t+1} \\ F_{s,t+1} \\ F_{a,t+1} \\ M_{j,t+1} \\ M_{s,t+1} \\ M_{a,t+1} \end{bmatrix} = \left[\begin{array}{cccccc} 0 & 0 & 0.5F_a & 0 & 0 & 0 \\ G_{j,s} & P_{s,s} & 0 & 0 & 0 & 0 \\ 0 & G_{s,a} & P_{a,a} & 0 & 0 & 0 \\ \hline 0 & 0 & 0.5F_a & 0 & 0 & 0 \\ 0 & 0 & 0 & G_{j,s} & P_{s,s} & 0 \\ 0 & 0 & 0 & 0 & G_{s,a} & P_{a,a} \end{array}\right] * \begin{bmatrix} F_{j,t} \\ F_{s,t} \\ F_{a,t} \\ M_{j,t} \\ M_{s,t} \\ M_{a,t} \end{bmatrix} \begin{bmatrix} F_{j,t} \\ F_{s,t} \\ F_{a,t} \\ M_{j,t} \\ M_{s,t} \\ M_{a,t} \end{bmatrix} \tag{6}
$$

where the subscripts in the **A** matrix denote the stages of animal growth in *i* and *i+1* and the multiplication of the fecundity rate by 0.5 is to indicate the 1:1 female to male ratio at birth assumed in the model. Note that the matrix **A** is divided into sex-stage specific blocks as indicated by the horizontal line, the entries in the upper block are for the female animal while the entries in the lower blocks are for the male animal. The basic assumption of the above transition matrix is that only adult females can produce newborn animals, hence female dominant matrix model (Lesnoff, 1999).

Once the transition matrix **A** is set-up, the next step in the analysis of herd/ flock dynamics is to find out the eigenvalues and eigenvectors of the population projection matrix **A**. This is because several important parameters which characterize the herd/flock dynamics emerge from the analysis of the eigenvalue and eigenvector of the transition matrix **A**. First, the dominant eigenvalue (**λ**) of matrix **A** represents the finite (asymptotic) cattle population multiplication rate while log (**λ)** gives intrinsic[7] annual growth rate (***r***) which is the continuous /;;growth rate per individual animal in the population. Thus, in the long-run the animal population follows exponential growth rate given by ln (**λ):**

$$\lambda = e^r \; \lambda = e^r \tag{7}$$

$$\lambda^t = e^{rt} \lambda^t = e^{rt} \tag{8}$$

Since **A** is 6X6 square matrix there are 6 possible eigenvalues and six associated eigenvectors with matrix **A**. However, the annual rate of increase of population is given by the dominant eigenvalue. The eigenvalues are defined as the solutions to the characteristic equation:

7 The finite rate of population growth and the intrinsic rate of population growth are related via the simple relationship: log (**λ**) =r.

$$det(A - \lambda I) = 0det(A - \lambda I) = 0 \quad (9)$$

where *det* denotes determinant and **I** is an identity matrix. The λ could indicate the herd/flock size (or population) is declining (λ <1), the herd/flock size is staying constant (λ=1**),** or the herd/flock size is increasing (λ >1) in the long-run and shows that potential exists for increased commercial offtake above the current level. For example, λ equal to 1.2 means population increases by 20% per year and λ equal to 0.93 means the population will decrease by 7% per year in the long-run. Second, the normalized eigenvector (***w***) associated with the dominant eigenvalue gives the stable stage-structured proportion for a given animal herd/flock size. Third, the standardized eigenvectors (***v***) associated with the dominant eigenvalue of the transpose of matrix **A** provide the reproductive values of different stages of animal production as compared to the juvenile, this measures the relative contributions of different stage of animal growth to long-term growth in herd/flock size.

It is also important to note that several important simplifications of the presentation of the projection matrix model can be made once the dominant eigenvalue and the associated eigenvector are determined. These simplifications are useful for projection purposes. For the reason that, there is equivalence between the transition matrix and the dominant eigenvalue and as a result the following relationship holds:

$$Aw = \lambda * wAw = \lambda * w$$
(10)

From equation (10) it follows that **A** is equal to λ and the population projection equation (1) can be alternatively given as:

$$n_{t+1} = \lambda * n_t n_{t+1} = \lambda * n_t \quad (11)$$

For *T* large, **λ** is also approximated by annual empirical multiplication rate given as the ratio of N_{t+1} to N_t. Equation (1) can be also generalized to give the livestock projection model at any time *t* given the initial herd/flock size and stable herd/flock proportion as:

$$n_t = n(0) * \lambda^t * wn_t = n(0) * \lambda^t * w \quad (12)$$

Where $\mathbf{n}_t$ is a vector of livestock population at time *t*; *n* (0) is scalar and denotes the initial herd/flock size; *λ* is the dominant eigenvalue and ***w*** is the normalized eigenvector associated with the dominant eigenvalue and denotes stable stage proportions. Similarly, given the stable sex and stage distribution, and asymptotic cattle growth rate, the total commercial live animal offtake for an animal with i^{th} sex in j^{th} growth stage at any time t can be obtained using the following commercial offtake function:

$$O_{ij,t} = O_{ij} * n(0) * \lambda^t * wO_{ij,t} = O_{ij} * n(0) * \lambda^t * w \quad (13)$$

Where $O_{ij,t}$ is a vector of commercial offtake of the i^{th} sex in j^{th} growth stage at t time. The total carcass equivalent commercial live animal offtake at a given time period is given by aggregating the carcass offtake rates across sex and stage classes. This shows the quantity of commercial offtake with constant animal growth rate and stable stage-structure ***w***.

The herd/flock projection model used here allows one to estimate various outputs from the animal production over time: commercial off-take of live animals (and its meat equivalents), milk, manure and draft power production by different classes of livestock species (cattle, camels, sheep and goats) and herd/flock size classes and production systems.

2.2.2 Economic Model

The lowland rangeland ecosystem provides grazing land which supports livestock production. The rangeland can be considered as a form of capital. With this observation in mind, rather than looking at the current flow of benefits from the livestock production system in a single year, it is important to consider the present value of all the current and future benefits that the livestock production system generates. Therefore, the economic model proposed to compute the TEV of livestock is based on a capital budgeting approach. This approach requires stream of current and future costs and benefits to be reduced to a comparable present worth using the process of discounting as outlined in Gittinger (1982).

The TEV of a given livestock species is assessed by herd/flock size classes and production systems using the present value (*PV*) of annual gross margins (*GM*) generated from livestock production over a period of 20 years. The *GM* is given as the difference between the total revenue (TR_t) of multiple outputs (meat, milk, manure, or draft power depending on the livestock production system) generated from livestock production and variable costs (VC_t) associated with livestock production for stable herd/flock size and structure. The major variable costs include: costs of veterinary drugs, medicine and mineral supplements. Due to the difficulty of getting this data, percent intermediate costs is assumed instead. The livestock management affects the reproduction and mortality rates. This in turn affects the performance of livestock in different production systems by affecting the rate of herd/flock growth and potential off-take rates.

Generally, the herd/flock growth model is linked to the economic model whereby the off-takes from the herd growth model are monetized.
Mathematically, the present value of the gross margin (*PVGM*) for a given herd/flock size class is given as:

$$PVGM = \sum_{t=0}^{T} \frac{(TR_t - VC_t)}{(1+\delta)^t} = \sum_{t=0}^{T} \frac{GM_t}{(1+\delta)^t} \; ; t = 0,1,3,\dots,T; T = 20 \qquad (14)$$

where *T* is the assumed relevant projection time horizon in years, assumed to be 20 years in our case; *δ* is the discount rate (10% assumed); GM_t is the annual gross margin accrued in period *t*. The *GM* represents return to pastoral households' labor, land and capital in livestock production and is a farm gate measure of the gross domestic product (*GDP*) for the specified livestock species. In general, the higher the *PVGM* is the better. Furthermore, if availability of data allows, the net profit for a given livestock species production can be obtained as the difference between the *GM* and the fixed costs. The net profit indicates the extent to which the livestock producers are earning normal or excess profit and thus reflects the level of competition and risk that exists. But due to lack of data on the fixed costs for individual pastoral households, it was not possible to compute the net pastoral income or net profits for the pastoral livestock production systems.

The life cycle of livestock production is different by livestock species and production systems due to the difference in the biology and objectives of the livestock production in different production systems which affect the length of project or time horizon of the project. In a situation like this where the project time horizons are different, for comparing the *GM* for different livestock enterprises or crop enterprises, it is important to analyze the *GM* in terms of annual equivalent cash flows. Thus, the annualized present value of gross margin (*APVGM*) is given as:

$$APVGM = PVGM * \frac{\delta * (1+\delta)^t}{(1+\delta)^t - 1} APVGM = PVGM * \frac{\delta * (1+\delta)^t}{(1+\delta)^t - 1} \qquad (15)$$

It is important to note that the proposed modeling allows application of big spatial data analysis in the pastoral production system. Once the *APVGM* is derived can be combined with the Geographic Information System (GIS) data and livestock population data to generate specific animal's *GM* at the household level, for aggregation at different levels. The computed *GM* could be mapped by assigning it to the mapped livestock population in a given production system or for the country as a whole. This approach allows one to assess the geographic magnitude and distribution of benefits of intervention, and to match their level of interventions and expenditures to potential benefits (Thornton and Herrero, 2014).

3. METHOD OF DATA COLLECTION

Both primary and secondary sources of data were utilized in the computation of the TEV of pastoralism in Ethiopia. The TEV work involved desk work in Addis Ababa and field mission travels to four major pastoral regional States of Ethiopia: Afar, Oromiya, Southern Nations and Nationalities People Regional State (SNNPR), and Somali[8]. The data collection period was spread from June 10, 2019 to August 30, 2019 (see: Annex 1). Primary data on livestock and livestock products prices was collected during the field missions through market observations and from the expert and key informant interviews (See Annex2: for people contacted). The prices of livestock and livestock products used in the study are summarized and given in Annexes 20 and 21[9]. The demographic parameters and initial herd/ flock size and structure required for pastoral livestock population projection and eventually to derive the livestock and livestock products for the economic valuation are prepared based on Shapiro et al. (2017) and presented in Annexes 3 to 19. Compilation of the technical parameters by Shapiro et al. (2017) involved nation-wide consultation with livestock experts and the use of data from different sources including the Central Statistical Authority (CSA). The herd and economic simulation models are run using Microsoft excel spreadsheets. The economic values of honey, gum and resins and climate regulation services are done based on the data obtained from the published work. They therefore provide only rough estimates which need to be refined in future.

8 It is believed that some level of pastoralism is also practiced in Gambella and Benishangul regions but not included in the field mission due to time constraint.

9 One of the major problems for the pastoral areas of Ethiopia is there is no systematic time series price data collection for different markets. Therefore, the livestock price data used in this analysis is based on snapshot survey of selected markets which rises the issue of temporal and spatial representativeness.

4. RESULTS AND DISCUSSIONS

4.1 The Value of Livestock Asset

As a natural capital, livestock represent significant sources of wealth both to the pastoral households and to the national economy by commanding sustainable income from the pastoral area. The size of the livestock holding measured in terms of economic values is an important determinant of the capacity of the pastoral sector to generate additional economic values, by supporting investments and saving functions, and cushioning pastoralists' risks and financial emergency needs. Livestock also play several cultural roles and building social capital among pastoralists.

Table 4 provides summaries of values of pastoral livestock assets in 2019 market prices by livestock species and agro-pastoral and pastoral livestock production systems in Ethiopia. The value of livestock asset for pastoralism in Ethiopia is found to be ETB 256 billion (US$ 8.48 billion). When it came to livestock species, cattle alone account for almost half of the pastoral livestock asset followed by camels which account for 19% of the value of livestock asset. In terms of sub-production system, 65% of the livestock wealth in dry lands is located in the pastoral production system while the agro-pastoral production system accounted for 35% of the livestock wealth. In general, this analysis indicates that pastoral livestock in Ethiopia is a billions of dollars' worth economy that should receive adequate public policy and investment interventions accordingly.

Table 4: Summary of economic values of pastoral livestock assets by livestock species and agro-pastoral and pastoral livestock production systems in Ethiopia, based on 2019 market prices

Livestock species	Annual economic value (10^9 ETB)			Total Value (10^9 ETB)	Total Value (10^9 USD)	Proportion of Value (%)
	Agro-pastoral	Pastoral: Small	Pastoral: Medium			
Cattle	51.49	22.30	51.50	125.29	4.15	49
Camels	13.71	0.59	35.49	49.79	1.65	19
Goats	15.55	0.74	27.96	44.24	1.46	17
Sheep	7.98	2.56	26.16	36.69	1.21	14
TOTAL	88.72	26.18	141.11	256.02	8.48	100
Proportion of value (%)	35	10	55	100		

Source: Derived based on bio-economic simulation model. Note: [2]The official exchange rate of 1 USD to 30.18 ETB on the date of November 20, 2019 is used.

4.2 The Total Economic Valuation of Pastoralism

4.2.1 Volume of Livestock and Livestock Products

Volume of live animals off-taken

The pastoral livestock production provides significant live animal off-takes for subsistence consumptions and for commercial sales (Table 5). The average herd/ flock level off-takes are provided by livestock species and production systems in order to highlight productivity differences of livestock species and production systems. The aggregate annual live-animal equivalent cattle off-take from the pastoral livestock production as a whole is estimated at 977,465 heads while the corresponding figures for camels, goats and sheep is 238,917; 2,780,132 and 2,174,137 heads, respectively. In terms of meat equivalents, the aggregate annual volume of beef, camel meat, goat meat and sheep meat produced is 93.3, 54.7, 32.5 and 28.5 thousand tons, respectively.

Volume of milk off-taken

The pastoral livestock production also provides significant milk off-take for subsistence consumption and commercial sales (Table 6). The annual cow milk production from the agro-pastoral and pastoral livestock production system is estimated at 701.2 million liters while the corresponding figures for camels and goats is 967.8 and 130.5 million liters, respectively. These large volumes of live animal and milk off-takes from the pastoral areas indicate the existence of large market size for the pastoral areas of Ethiopia. This has policy and investment implications for the national economy.

Volume of manure and draft power

The pastoral livestock production also provides significant manure and draft power in support of agriculture in the agro-pastoral production system (Table 7). The annual manure production is estimated at 62 billion tons while the quantity of draft power supply is estimated at 17.8 million oxen days. It is important to note that camels play a very critical role in transporting salt from the traditional salt mining sites in Afar region but this information is not documented. 4.2.2 Values of livestock and livestock products

Economic value of live animals

The economic valuation is conducted at the herd level. To enhance the utilization of the results, the economic values are aggregated by production systems, livestock species and nationally. These figures allow one to see the economic significance of pastoralism at different levels for whom and for which livestock species. This information could be put into the design and formulation of food security and poverty reduction strategies.

The total annual economic value addition due to live animal off-take for subsistence consumptions and commercial sales from pastoral area is estimated at ETB 23.13 billion ($US 0.77 billion) in 2019 market prices (Table 5). This indicates the significant annual value addition that pastoral livestock production contributes to the national economy. In terms of the livestock species considered, cattle, camels, goats and sheep accounts for 38%, 14%, 23%, and 25%, respectively.

Table 5: Estimated annual quantities of live animal off-takes and corresponding annual economic values by livestock species and agro-pastoral and pastoral livestock production systems in Ethiopia, based on 2019 market prices

Livestock Species/ Production System	Average live off-take per herd/ flock (Head)	Total live off-take from the sub-system (Head)	Average annual meat production from the herd/ flock (Kg)[1]	Total annual meat production from the sub-system (10^6 KG)	Annualized present value of live off-take per herd/flock (ETB)	Total annualized present value of live off-take from the sub-system (10^6 ETB)	Annualized present value of live off-take per animal head (ETB)	Annualized present value of live off-take per capita (ETB)
Cattle								
Agro-pastoral	0.6	420,300	54.3	37.38	5,391.63	3,776.84	650.38	1,147.16
Pastoral small herd size	0.37	148,185	36.25	14.27	3,622.14	1,450.67	574.03	770.67
Pastoral medium herd size	1.21	408,980	125.51	41.69	10,895.98	3,682.84	640.94	2,318.29
Sub-total		**977,465**		**93.34 (44.66)**		**8,910.34(38.27)**		
Camels								
Agro-pastoral	0.58	65,917	132.43	15.05	8,035.87	913.28	733.20	1,709.76
Pastoral small herd size	0.06	3,000	13.03	0.65	787.00	39.35	728.70	167.45
Pastoral medium herd size	0.85	170,000	195.11	39.00	11,827.14	2,365.43	736.89	2,516.41
Sub-total		**238,917**		**54.72 (26.18)**		**3,318.05(14.25)**		
Goats								
Agro-pastoral	1.71	855,759	19.99	10.00	4,069.00	2,036.31	288.79	865.74
Pastoral small herd size	0.92	39,476	10.82	0.46	2,204.59	94.60	279.42	469.06
Pastoral medium herd size	3.78	1,884,897	44.13	22.00	6,443.78	3,213.19	248.12	1,371.02
Sub-total		**2,780,132**		**32.46(15.53)**		**5,344.09(22.95)**		
Sheep								
Agro-pastoral	0.74	227,985	9.72	3.00	2,559.46	788.54	238.53	544.57
Pastoral small herd size	1.07	158,381	13.97	2.07	2,775.55	410.84	376.09	590.54
Pastoral medium herd size	4.42	1,787,771	57.87	23.40	11,153.24	4,511.18	399.61	2,373.03
Sub-total		**2,174,137**		**28.47(13.62)**		**5,710.56(24.53)**		
TOTAL				**208.99**		**23,283.04**		

Source: Based on bio-economic simulation model, the time horizon for the projection is 20 years with discount rate of 10%. Note: [1]The live animal offtake is for subsistence consumption and/or commercial sale. The annual beef production is in carcass weight equivalent assuming 45-50% dressing percentage. The per capita value is computed assuming pastoral household size of 4.8.

Table 6: Estimation of annual quantities of milk off-take and corresponding economic value of milk production by livestock species and agro-pastoral and pastoral livestock production systems in Ethiopia, based on 2019 market prices

Livestock Species/ Production System	Average annual milk production from the herd/flock (Liter)[1]	Total annual milk production from the sub-system (10^6 Liter)	Annualized present value of milk production per herd/ flock (ETB)	Total annualized present value of milk production from the sub-system (10^6 ETB)	Annualized present value of milk production per animal head (ETB)	Annualized present value of milk production per capita (ETB)
Cattle						
Agro-pastoral	335.11	234.74	4,956.89	3,472.30	579.08	1,054.66
Pastoral small herd size	272.71	109.22	3,982.01	1,594.79	631.31	847.24
Pastoral medium herd size	1,056.91	357.23	14,766.41	4,991.05	869.43	3,141.79
Sub-total		**701.20(38.96)**		**10,058.14(21.45)**		
Camels						
Agro-pastoral	2,337.04	265.60	56,437.94	6,413.95	5,147.12	12,008.07
Pastoral small herd size	232.95	11.65	5,624.35	281.22	5,227.24	1,196.67
Pastoral medium herd size	3,452.84	690.57	83,380.77	16,675.57	5,146.96	17,740.59
Sub-total		**967.82(53.77)**		**23,371.54(49.84)**		
Goats						
Agro-pastoral	77.70	38.99	1,150.70	575.86	81.69	244.83
Pastoral small herd size	40.65	1.75	6,188.13	265.53	791.09	1,316.62
Pastoral medium herd size	180.26	90.13	25,304.41	12,618.04	974.23	5,383.92
Sub-total		**130.51(7.27)**		**13,459.43(28.70)**		
GRAND TOTAL		**1,799.54 (100)**		**46,889.11(100)**		

Source: Based on bio-economic simulation model. Note: [2]The time horizon for the projection is 20 years. The milk offtake is for subsistence consumption and commercial sale. The per capita value is computed assuming pastoral household size of 4.8.

Table 7 Volume and value of manure and draft power generated by agro-pastoral and pastoral livestock production systems in Ethiopia

Livestock Species	Sub-system	Volume of manure production (10^6 tons)	Total drafts power production (oxen-days, 10^6)	Value of manure production (10^6 ETB)	Value of drafts power production (10^6 ETB)
Cattle	Agro-pastoral	32,655.37	17.84	10,786.7	681.63
	Pastoral: Small	--	--	--	--
	Pastoral: Medium	--	--	--	--
	Sub-total	--	--	--	--
Camels	Agro-pastoral	27,418.43	--	1406.15	--
	Pastoral: Small	--	--	--	--
	Pastoral: Medium	--	--	--	--
	Sub-total	--	--	--	--
Goats	Agro-pastoral	1,259.82	--	295.77	--
	Pastoral: Small	--	--	--	--
	Pastoral: Medium	--	--	--	--
	Sub-total	--	--	--	--
Sheep	Agro-pastoral	589.94	--	99.68	--
	Pastoral: Small	--	--	--	--
	Pastoral: Medium	--	--	--	--
	Sub-total	--	--	--	--
	GRAND TOTAL	**61,923.56**	**17.84**	**12,588.30**	**681.63**

Source: Based on bio-economic simulation model. Note: [2]The time horizon for the projection is 20 years. The milk offtake is for subsistence consumption and commercial sale.

Economic value of milk

The total annual economic value addition from milk off-take for subsistence consumptions and commercial sales from pastoral area is estimated at ETB 46.89 billion ($US 1.55 billion) in 2019 market prices (Table 6). This indicates the significant annual value addition by pastoral milk production to the national economy. Livestock species; cattle, camels and goats accounts for 21%, 50% and 29%, respectively. Note the emerging domestic and export markets for camel milk due to its cultural, healthy and therapeutic nature. Currently, camel milk is exported from Jigjiga town to Middle East, Major US and EU towns and locally to Dire Dawa, Adama, and Addis Ababa.

Economic value of manure and draft power

Volume and value of manure and draft power generated by agro-pastoral and pastoral production systems are given in Table 7. The annual value addition for manure is estimated at ETB 12.59 billion (US$ 0.42 billion) while for draft power the annual value addition is found to be ETB 0.68 billion (US$ 0.02 billion). The combined annual value addition for manure and draft power is ETB 13.27 (US$ 0.44) billion. This makes contribution of pastoralism to agriculture to be very significant yet such values are what is usually overlooked in the discussion regarding the contribution of livestock to the national economy.

Economic value of transport

The pastoral households are highly dependent on camel transport. So far there are several millions of adult camels which can be potentially deployed for transport purpose. Sadly, apart from the transportation of salt in Afar region, transport service by camel is rarely monetized. Because of this, it was not possible to capture the economic value of transport for the pastoral sector as a whole.

Economic value of all livestock and livestock products

The combined economic values of livestock and livestock products is assessed at the herd level to see the importance of individual livestock species, taking into account all the goods and services the individual livestock species provide (meat, milk, manure and draft power). Table 8 presents the herd level performance of different livestock species by production system. The annual economic value addition of cattle herd varied from ETB 7,604.20 for small pastoral herd to 27,008.48 for agro-pastoral herd. This means there are large variations in herd/flock level performances across the production systems. This is attributed to environmental and management practices. Therefore, the difference in performance of different livestock species need to be considered in designing development interventions.
The results also show the variability of value addition by different livestock species across pastoral production systems.

Table 8 Summary of annual total economic values of pastoral livestock productions by livestock species and agro-pastoral and pastoral livestock production systems in Ethiopia, (ETB/ Animal Herd/Year, based on 2019 market prices)

Livestock Species	Agro-pastroal	Pastoral: Small	Pastroal: Medium
Cattle	27,008.48	7,604.20	25,662.39
Camels	76,846.88	6,411.36	95,207.91
Goats	5,810.71	8,392.72	31,748.19
Sheep	2,883.00	2,775.50	11,153.24

Source: Derived based on bio-economic simulation model.

4.2.2 Economic Value of Rangelands Environmental Products

The economic value of gum and resins

Ethiopia is endowed with an estimated 2.8 million hectares of dry forest. This forest support the production of economically and commercially important gum and resins (Alemu and Worku, 2017). The potential total annual production from this area is estimated at 292,542 tons. The agro-pastoral and pastoral regions account for about 1.2 million hectares of the dry forest land with the corresponding annual gum and resins production of 31,850 tons. Assuming an average farm gate price of 275 Birr/Kg (Alemu and Worku, 2017) and percentage intermediate inputs costs of about 20%, due to labour costs involved in the harvesting, storing and transporting, the annual farm value added from the gum and resin is potentially estimated at ETB 7.01 Billion (US$ 0.23 Billion)[10]. Despite this, the current utilization rate of the potential that exists is very low. For example, the average volume of gum and resins exported over the last five years is 6257 tons accounting for only about 20% of the potential production (Figure 3).

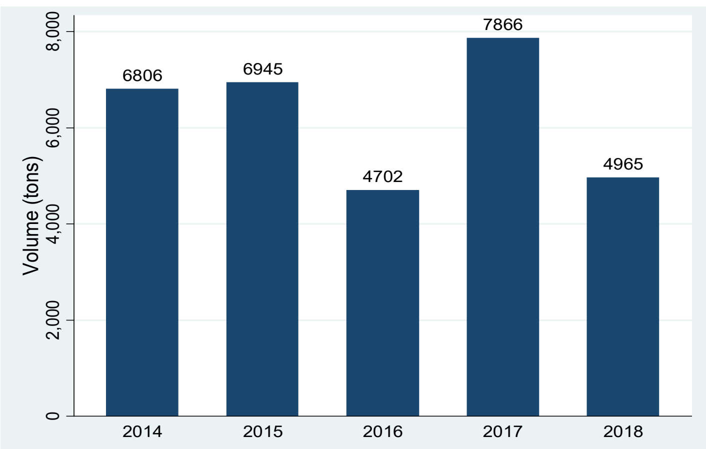

Figure 3: Trends in the volume of gum resins from Ethiopia, 2014-2018

Note: Source National Bank of Ethiopia.

10 Table 1 in Alemu and Worku (2017) is used in the computation of the annual economic value of gum and resin production.

The economic value of tourism

In 2018, nationally, based on the Bureau of Statistics of Ethiopian Tourism Commission, there were 849,122 tourist arrivals in the country. This generated a revenue of ETB 95.87 Billion (US$ 3.18 Billion). As there is no information on the disaggregated revenue at the regional level or pastoral areas, we assume that half of the revenue is attributed to the pastoral areas based on the proportion of pastoral land at the national level. (See: Table 1). With this background in mind, it would be safe to say that the annual economic value of tourism in the pastoral area is estimated at ETB 38.40 Billion (US$ 1.27 Billion).

The economic value of carbon sequestration services

With the development of carbon trade and green economy, there is great economic opportunity in pastoral areas. The potential economic value that can be captured from climate regulation services can be identified through the benefit transfer method. For this purpose, the information on the land use/cover given in Table 1 and the global climate regulation service values estimated for climate regulation services by different biomes in de Groot et al. (2012) are used. The results of the computation of the value of climate regulations service are presented in Annex 22. The annual economic value from the climate regulating services is estimated at ETB 173.8 Billion (US$ 5.8 Billion).

The realization of this potential benefit depends on the country's strategic efforts to tap into in the global carbon market.

The economic value of honey production

The Ethiopian lowland rangelands are characterized by different ecosystems. The different fauna and flora which are very conducive for beekeeping. Honey production could be considered as one of the very synergetic enterprises that can go hand in hand with pastoralism. There is growing domestic and international demand for honey. It can have substantial impact on the pastoral households' income and national economy. As things stand, the potential of honey production is less exploited in the pastoral areas of Ethiopia.

The economic value of honey is evaluated with the assumption of traditional honey production in order to demonstrate outcome at the minimum effort. The case study of beekeeping practice and honey production in Afar regional State (Reda et al., 2018) is used[11]. Based on this study, the average volume of

11 Given data shortage, this study is considered to be roughly representative of the pastoral areas in Ethiopia.

honey produced per household per annum using traditional method of honey production is about 88.75 kg and the average local price is 182.94 ETB/kg. This indicates that, at the household level, the pastoralists are earning a gross revenue of ETB 16,235.93 per annum. The total economic value of honey production is computed by multiplying the average annual per household revenue by the total number of pastoral households in Ethiopia. With an average pastoral household size of 4.7 and pastoral human population of 10,658,961 in 2017 and growing at 3% per annum the number of pastoral households are estimated at 2,405,977 in 2019. Therefore, the total economic value of honey for the entire pastoral area of Ethiopia is roughly estimated at ETB 31.25 Billion (US$ 1.03 Billion)[12].

4.2.3 Total Economic Value of Pastoralism in Ethiopia

The results of various components of TEV on pastoralism in Ethiopia are given in Tables 9 and 10. Table 9 summarizes the livestock and livestock products components by production systems and livestock species. The aggregate total economic valuation is presented in Table 10. You will notice that the total economic valuation of livestock and livestock products is estimated at ETB 83.3 (US$ 2.7) billion and cattle account for 36%. By production system the pastoral system accounts for more than 60% of the values of livestock and livestock products.

The total economic value of pastoralism in Ethiopia is estimated at ETB 332.94 Billion ($US 11.09 Billion) in 2019 market prices (Table 10). This shows the significant annual value addition by pastoral livestock production and associated activities to the national economy. The pastoral livestock and livestock products account for about 25% of the total value addition for pastoralism. This shows that even with our very conservative projections of the benefits of supplementary products which is still not exhaustive, the factors associated with pastoralism like tourism, honey and gum production and climate regulation service can have significant positive economic gains on the pastoral and national economy.

12 Assuming 100% adoption rate, the annual benefit from honey is estimated at ETB 39.06 Billion. However, honey production might not be possible everywhere and the adoption rate should be adjusted downwards based on the suitability of a given area for honey production.

Table 9 Summary of annual total economic values of pastoral livestock productions by livestock species and agro-pastoral and pastoral livestock production systems in Ethiopia, based on 2019 market prices

Livestock Species	Annual economic value (10^9 ETB)			Total Value (10^9 ETB)	Total Value (10^9 USD)2	Proportion of Value (%)
	Agro-pastroal	Pastoral: Small	Pastroal: Medium			
Economic value of livestock production						
Cattle	18.65	3.02	8.61	30.28	1.00	36
Camels	8.73	0.32	19.04	28.09	0.93	34
Goats	2.91	0.36	15.83	19.10	0.63	23
Sheep	0.89	0.41	4.51	5.82	0.19	7
TOTAL	**31.18**	**4.11**	**47.99**	**83.29**	**2.74**	**100**
Proportion of value (%)	37.00	5.00	58.00			

Source: Derived based on bio-economic simulation model. Note: [2]The official exchange rate of 1 USD to 30.18 ETB for the date of November 20, 2019 is used.

Table 10 Various components of TEV of pastoralism in Ethiopia

Categories of TEV	Value (ETB Billion/Year)	Value (USD[2] Billion/Year)	Proportion of value (%)
Pastoral livestock and livestock products			
Live animal	23.12	0.77	6.94
Milk	46.89	1.55	13.98
Manure	12.59	0.42	3.79
Draft power	0.68	0.02	0.18
Sub-total	**83.29**	**2.76**	**24.89**
Supplementary products			
Honey	31.25	1.03	9.29
Tourism	38.40	1.27	11.45
Gum and resin	7.01	0.23	2.07
Climate regulation service	173.00	5.80	52.30
Sub-total	249.66	8.33	75.11
Total	**332.94**	**11.09**	**100.00**

Note: [1]The live animal includes subsistence consumption and commercial sales in live animal equivalent. [2]The official exchange rate of 1 USD to 30.18 ETB for the date of November 20, 2019 is used.

5. CONCLUSIONS AND RECOMMENDATIONS

Inadequate empirical evidence on the economic value of pastoralism has been considered as one of the reasons why there is limited supportive public policies, investments and overall institutional support for sustainable development of pastoralism in Ethiopia and elsewhere. This is attributed to neglect, inefficient utilization and degradation of rangeland resources. The main objective of this study is to determine the baseline economic value of pastoralism in Ethiopia. The study used a mix of valuation methodologies in order to support evidence-based public policy and investment decision, making for pastoral area development. The major contribution of this work is in terms of the implementation of an integrated bio-economic simulation model to better capture direct economic value of livestock production.

This study investigated the economic value of pastoralism in Ethiopia within the total economic valuation framework. Pastoralism is a multi-billion dollar economy that represents significant source of wealth to the national economy which can promote sustainable income from the livestock sector. The results of economic valuation indicate that pastoralism, as a maintained livelihood practice in the rangelands of Ethiopia, generates substantial economic values at both the pastoral household, regional states and national levels.

The results of the study provide potentially useful information for decision makers and various stakeholders concerned with pastoral development and advocacy. Livestock specific economic valuation data derived from individual households, herd or flock levels, production systems and nationally can be adopted in the design, formulation and implementation of rangeland policy and investment interventions. The baseline economic values allow one to at least recognize the minimum opportunity costs of changes in pastoral land use from the baseline situations.

The risk of rangelands biodiversity loss to unwise lowland rangeland utilization and degradation, making all the values to be lost forever, is very high. In this regard, the results of this economic valuation can be utilized for advocacy and in the formulation of various policy instruments to design various incentive mechanisms to protect the rangeland environment. Some of the important recommendations are highlighted below.

Integrate the economic valuation work with interventions in the lowland rangeland uses. Interventions in the lowland rangeland uses have rarely been informed by economic valuation work. There is a need for stakeholders (government, non-governmental organization, donors and private sectors) to engage and create awareness for integration of the economic valuation work with the design, development and implementation of interventions in lowland rangeland uses. This may involve the implementation of a mandatory requirement of economic valuation work in the lowland rangeland use decisions. This will improve the efficiency of resource allocation, and protect the livelihood of the pastoralists and the environment.

Generate spatially explicit data on rangeland goods and services and TEV results. This study was conducted for the entire pastoral area of Ethiopia. However, in practice, interventions are site-specific, meaning interventions do not necessarily encompass the whole pastoral area. Thus, the computed TEV does not apply if the intervention is for smaller site-specific areas. In this regard, there is a need to produce spatially explicit or geo-referenced goods and services and TEV results in order to inform site-specific investments in the lowland rangelands. The integration of TEV results with the geographic information system (GIS) will facilitate quick presentation and aggregation of economic values at different levels. It will also allow one to assess the policy and investment interventions at the project (site-specific), sectorial and ecosystem levels.

Build analytical capacity for economic valuation.
Many still think that the lowland areas hold relatively better opportunities to acquire large areas of land as compared to the already densely populated highlands. In view of this, more demand is expected for the lowland rangeland use, especially from the large scale commercial farms. There is need for IGAD to spearhead and strengthen the analytical capabilities in economic valuation for the countries in the region, in order to guide policy and investment decisions towards efficient utilization of the lowland rangeland resources. Training of national staff in the simulation model used in this study serves as a strong starting point.

Support sustainable commercialization of rangeland products. The lowland rangelands in Ethiopia represent areas where livestock is produced with minimal use of modern inputs, providing the opportunity to produce organic products for local and global markets, such as eco labeled meat, milk, and honey, as well as several dry forest products like gum and resins. The international market can be exploited by careful branding of the lowland rangeland products.

Exploit the global carbon market opportunities.

The lowland rangelands provide various kinds of environmental goods and services. Currently, climate change is one of the greatest challenges facing the world. The rangeland environment can play a critical role in climate change mitigation by providing natural mechanisms to capture carbon from the atmosphere and store it. In this regard, the climate regulation services through carbon trade represents an emerging market opportunity for the pastoralists to earn additional money while also allowing the sustainable flow of goods and services from the rangeland. To explore and exploit the global carbon trade opportunities, there is need for the development of national capacities for the quantification and regular monitoring of carbon dioxide sequestration potential of pastoral production system.

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ANNEXES

Annex 1 Baseline assumptions of cattle herd age and sex structures for projecting agro-pastoral and pastoral cattle populations

	Agro-pastoral			Pastoral: small herd size			Pastoral: medium herd size		
Stage class		Structure			Structure			Structure	
	Herd size	Global	Intra-sex	Herd size	Global	Intra-sex	Herd size	Global	Intra-sex
Young female (F_j)	0.70	0.08	0.14	0.98	0.14	0.21	1.59	0.09	0.14
Sub-adult female (F_s)	1.47	0.17	0.28	0.42	0.06	0.09	2.79	0.16	0.25
Adult female (F_a)	3.02	0.35	0.58	3.36	0.48	0.71	6.73	0.40	0.61
Young male (M_j)	0.70	0.08	0.23	0.42	0.06	0.20	1.59	0.09	0.27
Sub-adult male (M_s)	1.31	0.15	0.42	0.28	0.04	0.13	2.06	0.12	0.35
Adult male (M_a)	1.10	0.13	0.35	1.40	0.20	0.67	2.22	0.13	0.38
Total	**8.29**			**6.31**			**17.00**		

Source: Computed based on Shapiro et al. (2013).

Annex 2 Baseline assumptions of camel herd ages and sex structures for projecting agro-pastoral and pastoral camel populations

	Agro-pastoral			Pastoral: small herd size			Pastoral: medium herd size		
Stage class		Structure			Structure			Structure	
	Herd size	Global	Intra-sex	Herd size	Global	Intra-sex	Herd size	Global	Intra-sex
Young female (F_j)	0.85	0.08	0.13	0.08	0.08	0.13	1.25	0.08	0.13
Sub-adult female (F_s)	1.67	0.15	0.25	0.17	0.16	0.25	2.47	0.15	0.25
Adult female (F_a)	4.19	0.38	0.62	0.42	0.39	0.62	6.19	0.38	0.62
Young male (M_j)	0.85	0.08	0.20	0.08	0.08	0.21	1.25	0.08	0.20
Sub-adult male (M_s)	1.40	0.13	0.33	0.14	0.13	0.33	2.06	0.13	0.33
Adult male (M_a)	2.01	0.18	0.47	0.19	0.17	0.46	2.92	0.18	0.47
Total	**10.96**			**1.08**			**16.15**		

Source: Computed based on Shapiro et al. (2013).

Annex 3 Baseline assumptions of goats flock age and sex structures for projection of agro-pastoral and pastoral goat populations

	Agro-pastoral			Pastoral: small flock size			Pastoral: medium flock size		
Stage class		**Structure**			**Structure**			**Structure**	
	Flock size	**Global**	**Intra-sex**	**Flock size**	**Global**	**Intra-sex**	**Flock size**	**Global**	**Intra-sex**
Young female (F_j)	1.33	0.09	0.15	0.76	0.10	0.15	2.51	0.10	0.15
Sub-adult female (F_s)	1.99	0.14	0.23	1.07	0.14	0.22	3.94	0.15	0.24
Adult female (F_a)	5.49	0.39	0.62	3.08	0.39	0.63	9.78	0.38	0.60
Young male (M_j)	1.34	0.10	0.25	0.76	0.10	0.26	2.51	0.10	0.26
Sub-adult male (M_s)	2.25	0.16	0.43	1.27	0.16	0.44	4.44	0.17	0.46
Adult male (M_a)	1.68	0.12	0.32	0.88	0.11	0.30	2.79	0.11	0.29
Total	**14.09**			**7.82**			**25.97**		

Source: Computed based on Shapiro et al. (2013).

Annex 4 Baseline assumptions of sheep flock age and sex structures for projection of agro-pastoral and pastoral sheep populations

	Agro-pastoral			Pastoral: small herd size			Pastoral: medium herd size		
Stage class		**Structure**			**Structure**			**Structure**	
	Herd size	**Global**	**Intra-sex**	**Herd size**	**Global**	**Intra-sex**	**Herd size**	**Global**	**Intra-sex**
Young female (F_j)	0.81	0.08	0.12	0.68	0.09	0.15	2.69	0.10	0.15
Sub-adult female (F_s)	1.61	0.15	0.24	1.07	0.15	0.23	4.06	0.15	0.23
Adult female (F_a)	4.39	0.41	0.64	2.92	0.40	0.62	10.85	0.39	0.62
Young male (M_j)	0.80	0.07	0.20	0.68	0.09	0.25	2.70	0.10	0.26
Sub-adult male (M_s)	1.81	0.17	0.46	1.21	0.16	0.45	4.55	0.16	0.44
Adult male (M_a)	1.31	0.12	0.33	0.81	0.11	0.30	3.07	0.11	0.30
Total	**10.73**			**7.38**			**27.91**		

Source: Computed based on Shapiro et al. (2013).

Annex 5 Baseline assumption of stage specific demographic rates used in creating cattle population projection matrices for agro-pastoral and pastoral cattle production systems in Ethiopia

Stage class	Class age range in year	Stage duration in year (d_i)	Annual mortality rate (m_i)	Annual offtake rate (o_i)	Annual survivorship rate (s_i)	Annual fecundity rate (F)
Agro-pastoral						
Young female (F_j)	0-1	1	0.14	0.00	0.86	0.00
Sub-adult female (F_s)	1-3.5	2.5	0.06	0.05	0.89	0.00
Adult female (F_a)	3.5-11	7.5	0.04	0.05	0.91	0.56
Young male (M_j)	0-1	1	0.15	0.10	0.75	0.00
Sub-adult male (M_s)	1-3.5	2.5	0.09	0.20	0.71	0.00
Adult male (M_a)	3.5-9.5	6	0.07	0.21	0.72	0.00
Pastoral - small herd size						
Young female (F_j)	0-1	1	0.12	0.00	0.88	0.00
Sub-adult female (F_s)	1-3.5	2.5	0.07	0.02	0.91	0.00
Adult female (F_a)	3.5-11	7.5	0.05	0.05	0.90	0.56
Young male (M_j)	0-1	1	0.16	0.06	0.78	0.00
Sub-adult male (M_s)	1-3.5	2.5	0.12	0.10	0.78	0.00
Adult male (M_a)	3.5-9.5	6	0.09	0.20	0.71	0.00
Pastoral - medium herd size						
Young female (F_j)	0-1	1	0.10	0.00	0.90	0.00
Sub-adult female (F_s)	1-3	2	0.06	0.02	0.92	0.00
Adult female (F_a)	3-10.5	7.5	0.05	0.06	0.89	0.56
Young male (M_j)	0-1	1	0.16	0.12	0.72	0.00
Sub-adult male (M_s)	1-3	2	0.12	0.10	0.78	0.00
Adult male (M_a)	3-8	5	0.09	0.15	0.76	0.00

Source: Based on Shapiro et al. (2013).

Annex 6 Baseline assumption of stage specific demographic rates used in creating camel population projection matrices for agro-pastoral and pastoral camel production systems in Ethiopia

Stage class	Class age range in year	Stage duration in year (d_i)	Annual mortality rate (m_i)	Annual offtake rate (o_i)	Annual survivorship rate (s_i)	Annual fecundity rate (F)
Agro-pastoral						
Young female (F_j)	0-1	1	0.35	0.00	0.65	0.00
Sub-adult female (F_s)	1-4.3	3.3	0.06	0.02	0.92	0.00
Adult female (F_a)	4.3-19.3	15	0.03	0.04	0.93	0.45
Young male (M_j)	0-1	1	0.35	0.05	0.60	0.00
Sub-adult male (M_s)	1-4.3	3.3	0.06	0.10	0.84	0.00
Adult male (M_a)	4.3-20.2	15.9	0.03	0.10	0.87	0.00
Pastoral - small herd size						
Young female (F_j)	0-1	1	0.35	0.00	0.65	0.00
Sub-adult female (F_s)	1-4.3	3.3	0.06	0.02	0.92	0.00
Adult female (F_a)	4.3-19.3	15	0.03	0.04	0.93	0.45
Young male (M_j)	0-1	1	0.35	0.05	0.60	0.00
Sub-adult male (M_s)	1-4.3	3.3	0.06	0.10	0.84	0.00
Adult male (M_a)	4.3-20.2	15.9	0.03	0.10	0.87	0.00
Pastoral - medium herd size						
Young female (F_j)	0-1	1	0.35	0.00	0.65	0.00
Sub-adult female (F_s)	1-4.3	3.3	0.06	0.02	0.92	0.00
Adult female (F_a)	4.3-19.3	15	0.03	0.04	0.93	0.45
Young male (M_j)	0-1	1	0.35	0.05	0.60	0.00
Sub-adult male (M_s)	1-4.3	3.3	0.06	0.10	0.84	0.00
Adult male (M_a)	4.3-20.2	15.9	0.03	0.10	0.87	0.00

Source: Based on Shapiro et al. (2013).

Annex 7 Baseline assumption of stage specific demographic rates used in creating goats population projection matrices for agro-pastoral and pastoral goat's production systems in Ethiopia

Stage class	Class age range in year	Stage duration in year (d_i)	Annual mortality rate (m_i)	Annual offtake rate (o_i)	Annual survivorship rate (s_i)	Annual fecundity rate (F)
Agro-pastoral: small						
Young female (F_j)	0-0.5	0.5	0.26	0.00	0.76	0.00
Sub-adult female (F_s)	0.5-1.5	1	0.12	0.09	0.79	0.00
Adult female (F_a)	1.5-6.5	5	0.10	0.10	0.80	1.32
Young male (M_j)	0-0.5	0.5	0.26	0.07	0.67	0.00
Sub-adult male (M_s)	0.5-1.5	1	0.12	0.50	0.38	0.00
Adult male (M_a)	1.5-4.0	2.5	0.10	0.17	0.73	0.00
Pastoral - small flock size						
Young female (F_j)	0-0.5	0.5	0.29	0.00	0.71	0.00
Sub-adult female (F_s)	0.5-1.5	1	0.12	0.09	0.79	0.00
Adult female (F_a)	1.5-6.5	5	0.10	0.10	0.80	1.32
Young male (M_j)	0-0.5	0.5	0.24	0.05	0.71	0.00
Sub-adult male (M_s)	0.5-1.5	1	0.12	0.55	0.33	0.00
Adult male (M_a)	1.5-4.0	2.5	0.10	0.17	0.73	0.00
Pastoral - medium flock size						
Young female (F_j)	0-0.5	0.5	0.24	0.00	0.76	0.00
Sub-adult female (F_s)	0.5-1.5	1	0.14	0.09	0.77	0.00
Adult female (F_a)	1.5-6.5	5	0.10	0.10	0.80	1.32
Young male (M_j)	0-0.5	0.5	0.24	0.05	0.71	0.00
Sub-adult male (M_s)	0.5-1.5	1	0.12	0.55	0.33	0.00
Adult male (M_a)	1.5-4.0	2.5	0.10	0.15	0.75	0.00

Source: Based on Shapiro et al. (2013).

Annex 8 Baseline assumption of stage specific demographic rates used in creating sheep population projection matrices for agro-pastoral and pastoral sheep production systems in Ethiopia

Stage class	Class age range in year	Stage duration in year (d_i)	Annual mortality rate (m_i)	Annual offtake rate (o_i)	Annual survivorship rate (s_i)	Annual fecundity rate (F)
Agro-pastoral						
Young female (F_j)	0-0.5	0.5	0.20	0.00	0.80	0.00
Sub-adult female (F_s)	0.5-1.5	1	0.10	0.05	0.85	0.00
Adult female (F_a)	1.5-4.5	3	0.05	0.03	0.92	1.20
Young male (M_j)	0-0.5	1.5	0.22	0.00	0.78	0.00
Sub-adult male (M_s)	0.5-1.5	1	0.15	0.20	0.65	0.00
Adult male (M_a)	1.5-3.5	2	0.10	0.80	0.10	0.00
Pastoral - small flock size						
Young female (F_j)	0-0.5	0.5	0.21	0.00	0.79	0.00
Sub-adult female (F_s)	0.5-1.5	1	0.11	0.02	0.80	0.00
Adult female (F_a)	1.5-6.5	5	0.10	0.03	0.87	1.20
Young male (M_j)	0-0.5	0.5	0.22	0.00	0.78	0.00
Sub-adult male (M_s)	0.5-1.5	1	0.15	0.20	0.65	0.00
Adult male (M_a)	1.5-3.5	2	0.10	0.80	0.10	0.00
Pastoral - medium flock size						
Young female (F_j)	0-0.5	0.5	0.21	0.00	0.79	0.00
Sub-adult female (F_s)	0.5-1.5	1	0.15	0.05	0.80	0.00
Adult female (F_a)	1.5-6.5	5	0.10	0.03	0.87	1.20
Young male (M_j)	0-0.5	0.5	0.22	0.00	0.78	0.00
Sub-adult male (M_s)	0.5-1.5	1	0.15	0.20	0.65	0.00
Adult male (M_a)	1.5-3.5	2	0.10	0.80	0.10	0.00

Source: Based on Shapiro et al. (2013).

Annex 9 Annual Lefkovitch stage-structured cattle population projection matrices for agro-pastoral and pastoral cattle production systems

	Stage at year t					
Stage at year t+1	F_j	F_s	F_a	M_j	M_s	M_a
Agro-pastoral						
F_j	0.00	0.00	0.23	0.00	0.00	0.00
F_s	0.86	0.56	0.00	0.00	0.00	0.00
F_a	0.00	0.32	0.82	0.00	0.00	0.00
M_j	0.00	0.00	0.23	0.00	0.00	0.00
M_s	0.00	0.00	0.00	0.75	0.49	0.00
M_a	0.00	0.00	0.00	0.00	0.25	0.72
Pastoral -small herd size						
F_j	0.00	0.00	0.23	0.00	0.00	0.00
F_s	0.88	0.57	0.00	0.00	0.00	0.00
F_a	0.00	0.34	0.82	0.00	0.00	0.00
M_j	0.00	0.00	0.23	0.00	0.00	0.00
M_s	0.00	0.00	0.00	0.78	0.52	0.00
M_a	0.00	0.00	0.00	0.00	0.26	0.71
Pastoral - medium herd size						
F_j	0.00	0.00	0.23	0.00	0.00	0.00
F_s	0.90	0.48	0.00	0.00	0.00	0.00
F_a	0.00	0.44	0.81	0.00	0.00	0.00
M_j	0.00	0.00	0.26	0.00	0.00	0.00
M_s	0.00	0.00	0.00	0.72	0.44	0.00
M_a	0.00	0.00	0.00	0.00	0.34	0.76

Source: Based on Shapiro et al. (2013).

Annex 10 Annual Lefkovitch stage-structured camel population projection matrices for agro-pastoral and pastoral camel production systems

	Stage at year t					
Stage at year t+1	F_j	F_s	F_a	M_j	M_s	M_a
Agro-pastoral						
F_j	0.00	0.00	0.20	0.00	0.00	0.00
F_s	0.65	0.68	0.00	0.00	0.00	0.00
F_a	0.00	0.25	0.89	0.00	0.00	0.00
M_j	0.00	0.00	0.20	0.00	0.00	0.00
M_s	0.00	0.00	0.00	0.60	0.63	0.00
M_a	0.00	0.00	0.00	0.00	0.20	0.87
Pastoral -small herd size						
F_j	0.00	0.00	0.20	0.00	0.00	0.00
F_s	0.65	0.68	0.00	0.00	0.00	0.00
F_a	0.00	0.25	0.89	0.00	0.00	0.00
M_j	0.00	0.00	0.20	0.00	0.00	0.00
M_s	0.00	0.00	0.00	0.60	0.63	0.00
M_a	0.00	0.00	0.00	0.00	0.20	0.87
Pastoral - medium herd size						
F_j	0.00	0.00	0.20	0.00	0.00	0.00
F_s	0.65	0.68	0.00	0.00	0.00	0.00
F_a	0.00	0.25	0.89	0.00	0.00	0.00
M_j	0.00	0.00	0.20	0.00	0.00	0.00
M_s	0.00	0.00	0.00	0.60	0.63	0.00
M_a	0.00	0.00	0.00	0.00	0.20	0.87

Source: Based on Shapiro et al. (2013).

Annex 11 Annual Lefkovitch stage-structured goat population projection matrices for agro-pastoral and pastoral goat production systems

	Stage at year t					
Stage at year t+1	F_j	F_s	F_a	M_j	M_s	M_a
Agro-pastoral						
F_j	0.00	0.00	0.46	0.00	0.00	0.00
F_s	0.74	0.00	0.00	0.00	0.00	0.00
F_a	0.00	0.79	0.70	0.00	0.00	0.00
M_j	0.00	0.00	0.46	0.00	0.00	0.00
M_s	0.00	0.00	0.00	0.67	0.00	0.00
M_a	0.00	0.00	0.00	0.00	0.38	0.73
Pastoral -small herd size						
F_j	0.00	0.00	0.46	0.00	0.00	0.00
F_s	0.71	0.79	0.00	0.00	0.00	0.00
F_a	0.00	0.00	0.70	0.00	0.00	0.00
M_j	0.00	0.00	0.46	0.00	0.00	0.00
M_s	0.00	0.00	0.00	0.71	0.00	0.00
M_a	0.00	0.00	0.00	0.00	0.33	0.73
Pastoral - medium herd size						
F_j	0.00	0.00	0.51	0.00	0.00	0.00
F_s	0.76	0.00	0.00	0.00	0.00	0.00
F_a	0.00	0.77	0.70	0.00	0.00	0.00
M_j	0.00	0.00	0.51	0.00	0.00	0.00
M_s	0.00	0.00	0.00	0.71	0.00	0.00
M_a	0.00	0.00	0.00	0.00	0.33	0.75

Source: Based on Shapiro et al. (2013).

Annex 12 Annual Lefkovitch stage-structured sheep population projection matrices for agro-pastoral and pastoral sheep production systems

	Stage at year t					
Stage at year t+1	F_j	F_s	F_a	M_j	M_s	M_a
Agro-pastoral						
F_j	0.00	0.00	0.38	0.00	0.00	0.00
F_s	0.80	0.00	0.00	0.00	0.00	0.00
F_a	0.00	0.85	0.64	0.00	0.00	0.00
M_j	0.00	0.00	0.38	0.00	0.00	0.00
M_s	0.00	0.00	0.00	0.78	0.00	0.00
M_a	0.00	0.00	0.00	0.00	0.65	0.10
Pastoral -small herd size						
F_j	0.00	0.00	0.47	0.00	0.00	0.00
F_s	0.79	0.00	0.00	0.00	0.00	0.00
F_a	0.00	0.85	0.74	0.00	0.00	0.00
M_j	0.00	0.00	0.47	0.00	0.00	0.00
M_s	0.00	0.00	0.00	0.78	0.00	0.00
M_a	0.00	0.00	0.00	0.00	0.65	0.09
Pastoral - medium herd size						
F_j	0.00	0.00	0.49	0.00	0.00	0.00
F_s	0.79	0.00	0.00	0.00	0.00	0.00
F_a	0.00	0.80	0.74	0.00	0.00	0.00
M_j	0.00	0.00	0.49	0.00	0.00	0.00
M_s	0.00	0.00	0.00	0.78	0.00	0.00
M_a	0.00	0.00	0.00	0.00	0.65	0.09

Source: Based on Shapiro et al. (2013).

Annex 3 Baseline assumption of stage specific technical parameters used in generating livestock products from agro-pastoral and pastoral cattle production systems in Ethiopia

Stage class	Live weight (Kg/ Animal)	Manure production (Kg/Animal/Day)	Meat carcass yield (%)	Skins/hides (Kg/ Animal)
Agro-pastoral				
Young female (F_j)	95	6.8	50	10
Sub-adult female (F_s)	180	12	50	15
Adult female (F_a)	230	17	50	18
Young male (M_j)	105	6.8	50	10
Sub-adult male (M_s)	180	12	50	15
Adult male (M_a)	250	17	50	25
Pastoral - small herd size	**85**	**6.8**	**50**	**10**
Young female (F_j)	180	12	50	15
Sub-adult female (F_s)	230	17	50	18
Adult female (F_a)	105	6.8	50	10
Young male (M_j)	180	12	50	15
Sub-adult male (M_s)	250	17	50	25
Adult male (M_a)				
Pastoral - medium herd size				
Young female (F_j)	95	6.8	50	10
Sub-adult female (F_s)	180	12	50	15
Adult female (F_a)	230	17	50	18
Young male (M_j)	105	6.8	50	10
Sub-adult male (M_s)	180	12	50	15
Adult male (M_a)	250	17	50	25

Source: Based on Shapiro et al. (2013).

Annex 14 Baseline assumption of stage specific technical parameters used in generating livestock products from agro-pastoral and pastoral camel production systems in Ethiopia

Stage class	Live weight (Kg/ Animal)	Manure production (Kg/Animal/Day)	Meat carcass yield (%)	Skins/hides (Kg/ Animal)
Agro-pastoral				
Young female (F_j)	128	3.4	45	--
Sub-adult female (F_s)	294	6	45	--
Adult female (F_a)	500	8.5	45	--
Young male (M_j)	140	3.4	45	--
Sub-adult male (M_s)	324	6	45	--
Adult male (M_a)	600	8.5	45	--
Pastoral - small herd size				
Young female (F_j)	128	3.4	50	--
Sub-adult female (F_s)	294	6	50	--
Adult female (F_a)	500	8.5	50	--
Young male (M_j)	140	3.4	50	--
Sub-adult male (M_s)	324	6	50	--
Adult male (M_a)	600	8.5	50	--
Pastoral - medium herd size				
Young female (F_j)	128	3.4	50	--
Sub-adult female (F_s)	294	6	50	--
Adult female (F_a)	500	8.5	50	--
Young male (M_j)	140	3.4	50	--
Sub-adult male (M_s)	324	6	50	--
Adult male (M_a)	600	8.5	50	--

Source: Based on Shapiro et al. (2013).

Annex 15 Baseline assumption of stage specific technical parameters used in generating livestock products from agro-pastoral and pastoral goat production systems in Ethiopia

Stage class	Live weight (Kg/Animal)	Manure production (Kg/Animal/Day)	Meat carcass yield (%)	Skins/hides (Kg/Animal)
Agro-pastoral				
Young female (F_j)	10	0.1	50	1
Sub-adult female (F_s)	22	0.2	50	1.5
Adult female (F_a)	31	0.4	50	2.5
Young male (M_j)	10	0.1	50	1
Sub-adult male (M_s)	26	0.2	50	1.5
Adult male (M_a)	37	0.4	50	3.5
Pastoral - small herd size				
Young female (F_j)	10	0.1	50	1
Sub-adult female (F_s)	22	0.2	50	1.5
Adult female (F_a)	31	0.4	50	2.5
Young male (M_j)	10	0.1	50	1
Sub-adult male (M_s)	26	0.2	50	1.5
Adult male (M_a)	37	0.4	50	3.5
Pastoral - medium herd size				
Young female (F_j)	10	0.1	50	1
Sub-adult female (F_s)	22	0.2	50	1.5
Adult female (F_a)	31	0.4	50	2.5
Young male (M_j)	10	0.1	50	1
Sub-adult male (M_s)	26	0.2	50	1.5
Adult male (M_a)	37	0.4	50	3.5

Source: Based on Shapiro et al. (2013).

Annex 16 Baseline assumption of stage specific technical parameters used in generating livestock products from agro-pastoral and pastoral sheep production systems in Ethiopia

Stage class	Live weight (Kg/ Animal)	Manure production (Kg/Animal/Day)	Meat carcass yield (%)	Skins/hides (Kg/ Animal)
Agro-pastoral				
Young female (F_j)	9	0.1	50	0
Sub-adult female (F_s)	22	0.2	50	0
Adult female (F_a)	28	0.4	50	3
Young male (M_j)	10	0.1	50	0
Sub-adult male (M_s)	27	0.2	50	0
Adult male (M_a)	34	0.4	50	3
Pastoral - small herd size				
Young female (F_j)	9	0.1	50	0
Sub-adult female (F_s)	22	0.2	50	0
Adult female (F_a)	28	0.4	50	3
Young male (M_j)	10	0.1	50	0
Sub-adult male (M_s)	27	0.2	50	0
Adult male (M_a)	34	0.4	50	3
Pastoral - medium herd size				
Young female (F_j)	9	0.1	50	0
Sub-adult female (F_s)	22	0.2	50	0
Adult female (F_a)	28	0.4	50	3
Young male (M_j)	10	0.1	50	0
Sub-adult male (M_s)	27	0.2	50	0
Adult male (M_a)	34	0.4	50	3

Source: Based on Shapiro et al. (2013).

Annex 17 Summary of technical parameters for milk production by agro-pastroal and pastroal livestock production systems in Ethiopia

		Reproduction			Milk production		
Livestock Species	Sub-system	Parturition rate (%)	Net prolificacy (#)	Fecundity	Lactation length (days)	Yield (Liter/ day)	Production (Liter/year/ herd)
Cattle	Agro-pastoral	0.56	1	0.56	160.00	1.50	240.00
	Pastoral: Small	0.56	1	0.56	160.00	1.50	240.00
	Pastoral: Medium	0.56	1	0.56	180.00	1.60	288.00
Camels	Agro-pastoral	0.45	1	0.45	360.00	3.6.	1296.00
	Pastoral: Small	0.45	1	0.45	360.00	3.6.	1296.00
	Pastoral: Medium	0.45	1	0.45	360.00	3.6.	1296.00
Goats	Agro-pastoral	1.08	1.22	1.32	84.00	0.20	16.80
	Pastoral: Small	1.09	1.20	1.31	84.00	0.20	16.80
	Pastoral: Medium	1.20	1.20	1.44	84.00	0.20	16.80
Sheep	Agro-pastoral	1.00	1.20	1.20	--	--	--
	Pastoral: Small	1.00	1.20	1.20	--	--	--
	Pastoral: Medium	1.00	1.20	1.20	--	--	--

Source: Based on Shapiro et al. (2013).

Annex 18 Summary of livestock prices used in the computation of economic values of livestock assets and livestock production by livestock species and sexes for selected agro-pastoral and pastoral regions in Ethiopia, 2019

Livestock species	Sex	Stage-class	Price (ETB/Head)				Mean Price (ETB/ Head)	Percent intermediate costs		
			Afar	Oromiya	SNNP	Somali		Live animal	Milk	Manure
Cattle	Male	Juvenile	5000	2500	3000	2000	3125	0.20	0.30	0.24
	Male	Sub-adult	7000	8000	5500	4000	6125	0.20	0.30	0.24
	Male	Adult	9600	17000	15500	8000	12525	0.20	0.30	0.24
	Female	Juvenile	6000	3000	3500	2000	3625	0.20	0.30	0.24
	Female	Sub-adult	8000	9000	7000	5000	7250	0.20	0.30	0.24
	Female	Adult	10000	12500	10000	18000	12625	0.20	0.30	0.24
Camels	Male	Juvenile	6500	5000	--	5000	4125	0.00	0.29	0.00
	Male	Sub-adult	9000	11000	--	7000	6750	0.00	0.29	0.00
	Male	Adult	14000	26000	--	15000	13750	0.00	0.29	0.00
	Female	Juvenile	6500	5000	--	5000	4125	0.00	0.29	0.00
	Female	Sub-adult	9000	12000	--	18000	9750	0.00	0.29	0.00
	Female	Adult	14000	23000	--	25000	15500	0.00	0.29	0.00
Goats	Male	Juvenile	500	500	1200	1000	800	0.03	0.29	0.00
	Male	Sub-adult	1200	1500	1700	1500	1475	0.03	0.29	0.00
	Male	Adult	2600	3700	3000	4000	3325	0.03	0.29	0.00
	Female	Juvenile	500	500	800	1000	700	0.03	0.29	0.00
	Female	Sub-adult	1500	1300	1100	1300	1300	0.03	0.29	0.00
	Female	Adult	3000	3500	1750	3500	2937.5	0.03	0.29	0.00
Sheep	Male	Juvenile	500	400		1600	625	0.03	0.29	0.00
	Male	Sub-adult	2000	800	1750	1900	1612.5	0.03	0.29	0.00
	Male	Adult	5000	1700	2500	5000	3550	0.03	0.29	0.00
	Female	Juvenile	500	400		1600	625	0.03	0.29	0.00
	Female	Sub-adult	3000	650	1350	1700	1675	0.03	0.29	0.00
	Female	Adult	4000	1500	1750	4000	2812.5	0.03	0.29	0.00

Source: Percent intermediate costs is computed based on Shapiro et al. (2013) while the summary of livestock prices is based on price collected through field interviews of key informants and pastoral market observations by consultant during the period May to June, 2019.

Annex 19 Livestock product prices by livestock species and agro-pastroal and pastroal livestock production systems in Ethiopia, 2019

Livestock Species	Sub-system	Meat		Milk		Organic Manure		Draft power	
		Price	Percent of intermediate costs	Price	Percent of intermediate costs	Price	Percent of intermediate costs	Price	Percent of intermediate costs
Cattle	Agro-pastoral	155.00	0.20	17.75	0.24	0.40	0.00	40.00	0.00
	Pastoral: Small	155.00	0.20	17.50	0.24	0.40	0.00	40.00	0.00
	Pastoral: Medium	155.00	0.20	17.50	0.24	0.40	0.00	40.00	0.00
Camels	Agro-pastoral	175.00	0.00	30.00	0.29	0.40	0.00	--	--
	Pastoral: Small	175.00	0.00	30.00	0.29	0.40	0.00	--	--
	Pastoral: Medium	175.00	0.00	30.00	0.29	0.40	0.00	--	--
Goats	Agro-pastoral	200.00	0.03	17.50	0.29	0.40	0.00	--	--
	Pastoral: Small	200.00	0.03	17.50	0.29	0.40	0.00	--	--
	Pastoral: Medium	200.00	0.03	17.50	0.29	0.40	0.00	--	--
Sheep	Agro-pastoral	150.00	0.03	--	--	0.40	0.00	--	--
	Pastoral: Small	150.00	0.03	--	--	0.40	0.00	--	--
	Pastoral: Medium	150.00	0.03	--	--	0.40	0.00	--	--

Source: Percent intermediate costs is computed based on Shapiro et al. (2013) while the summary of livestock prices is based on price collected through field interviews of key informants and pastoral market observations by consultant during the period May to June, 2019.

Annex 20 Computation of the monetary value for climate regulation services (carbon sequestration)

Land Use/Cover	Area (Ha)	Service value (US$/Ha/Year, 2007 price levels)	Service value (US$/Ha/Year, adjusted for 2019 price levels)	Total service value (US$/Ha/ Year, 2007 price levels)
Barren or sparse vegetation	5,684,821	0	0	0
Closed shrub lands	4,502,983	51	63	285,044,227.48
Cropland / natural vegetation	2,057,089	159	197	405,968,159.82
Croplands	465,893	159	197	91,944,356.26
Deciduous broadleaf forest	547,278	491	609	333,527,193.72
Evergreen broad forest	328,398	491	609	200,135,330.42
Grasslands	9,737,744	159	197	1,921,751,568.60
Mixed forest	980	491	609	597,240.62
Open shrub lands	30,332,577	51	63	1,920,088,523.19
Permanent wetlands	6,893	17364	21552	148,559,292.54
Savannas	1,491,386	159	197	294,326,220.21
Water body	1,043	17364	21552	22,478,941.26
Woody savannas	2,099,532	51	63	132,902,895.04
Total	**57,256,617**			**5,757,323,949.16**

Note: The 2019 price service fee was adjusted for inflation. According to the Bureau of labour Statistics consumer price index, today's prices are 24.12% more than the average prices throughout 2007. Google search result. Using the 2019 1 US Dollar to 30.18 ETB Exchange rate the total climate regulating service fee is about ETB 173.8 Billion (US$ 5.8 Billion).

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