Alliance

SmaRT Program

Assessing the environmental impacts of SmaRT intervention packages in Small Ruminant Production Systems in Ethiopia

CLEANED baseline and scenario assessment report

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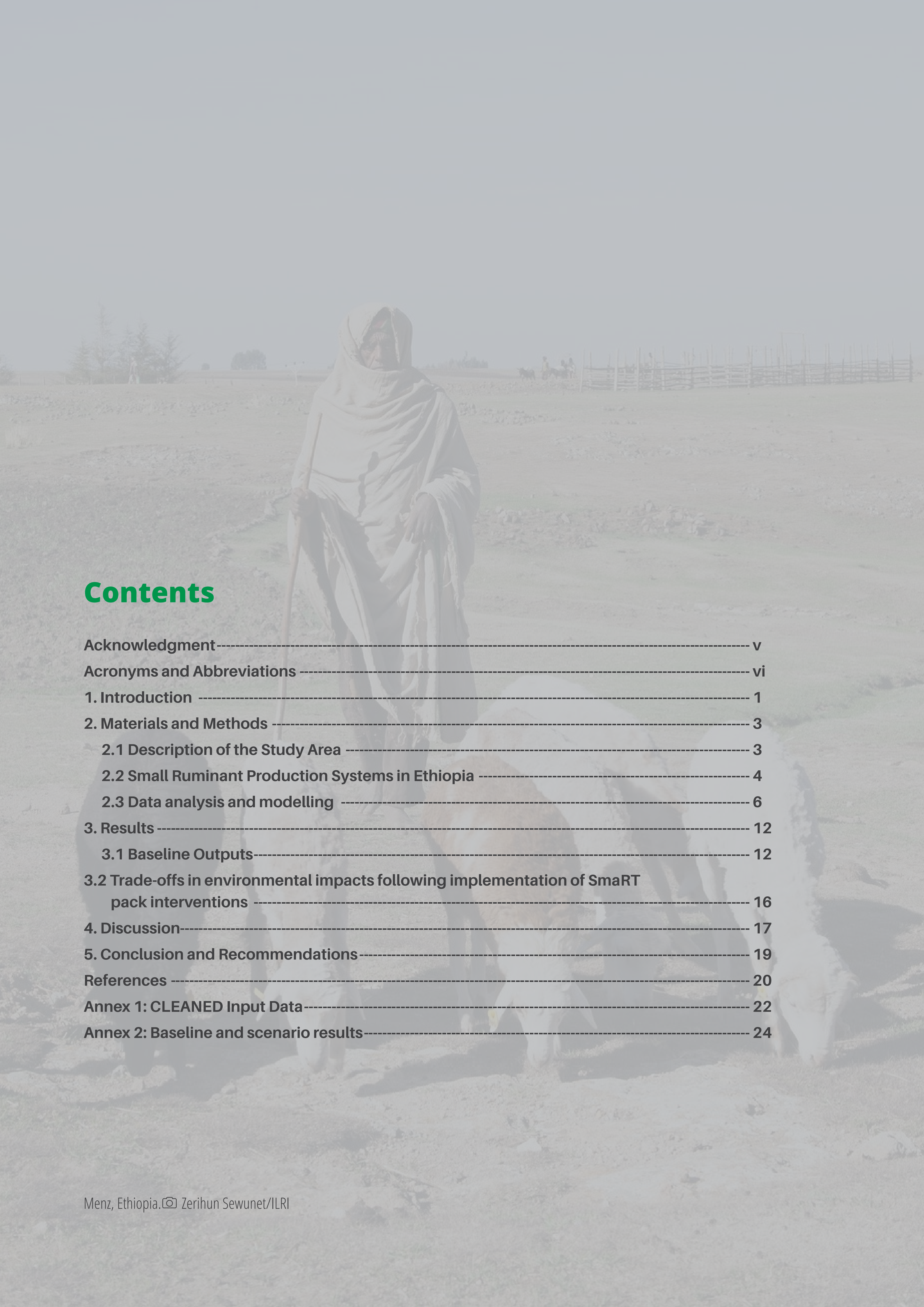
Acronyms and Abbreviations

C02eq.	Carbon dioxide equivalents
CIAT	International Center for Tropical Agriculture
CLEANED	Comprehensive Livestock Environmental Assessment for improved Nutrition, a secured Environment and sustainable Development along livestock value chains
CRP	CGIAR Research Program
CSA	Central Statistical Agency
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GHGe	Greenhouse Gas emission
ICARDA	International Center for Agriculture Research in the Dry Areas
ILRI	International Livestock Research Institute
ISRIC	International Soil Reference and Information Centre
N	Nitrogen
SmaRT	Small Ruminant Transformation
SNNPR	Southern Nations, Nationalities, and People's Region
USDA	United States Department of Agriculture
MRS	Mixed Rainfall Sufficient



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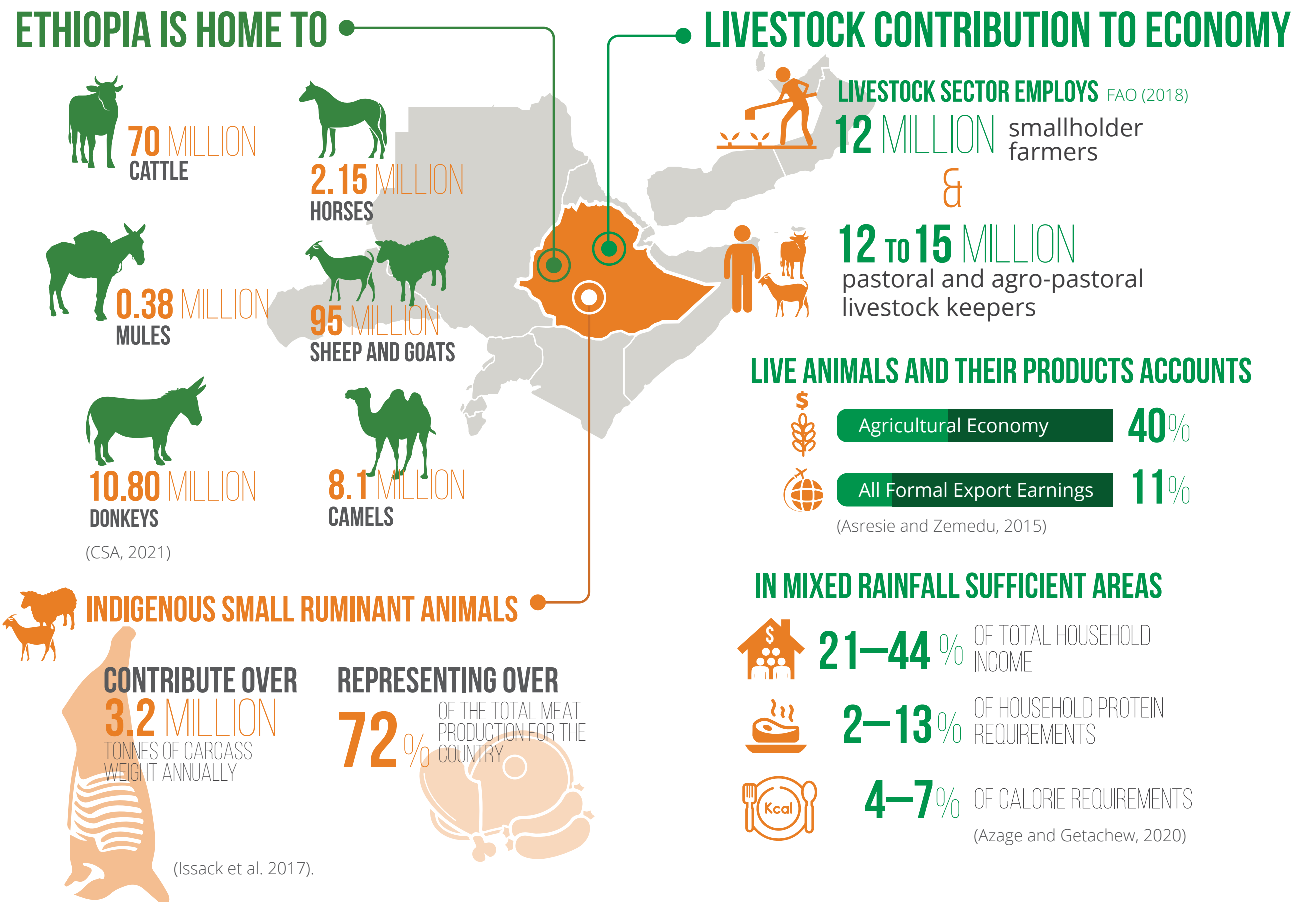

1. Introduction

Ethiopia is endowed with significant livestock resources and is believed to have the largest livestock population in Africa (Azage and Getachew, 2020). It is a home to 70 million cattle, 95 million sheep and goats, 2.15 million horses, 10.80 million donkeys, 0.38 million mules, and about 8.1 million camels (CSA, 2021). According to FAO (2018), the livestock sector employs about 12 million smallholder farmers and 12 to 15 million pastoral and agro-pastoral livestock keepers. The contribution of live animals and their products to the agricultural economy accounts for 40%, excluding the values of draught power, manure and transport of people and products (Asresie and Zemedu, 2015). Livestock also contributes to about 11% of all formal export earnings. In mixed rainfall sufficient areas (MRS), livestock contributes 21–44% of total household income, 2–13% of household protein requirements and 4–7% of calorie requirements (Azage and Getachew, 2020). Indigenous small ruminant animals are crucial sources of both tangible and intangible economic, social, nutritional, and environmental benefits (Kassie et al. 2021). They contribute over 3.2 million tonnes of carcass weight annually, representing over 72% of the total meat production for the country (Issack et al. 2017).

Small ruminant livestock production systems can be broadly categorized as: a) pastoral and agropastoral; b) mixed crop-livestock; c) small-scale urban and peri-urban; and d) large-scale commercial systems. Mixed crop-livestock farming is dominant in the highlands and midlands, while pastoral and agro-pastoral systems dominate the lowlands (Azage and Getachew, 2020). Small ruminant animals are mainly kept by subsistence farmers and pastoralists since they are perceived to be at lower risk to lose than large ruminant animals (Awgichew et al. 1991). Since they require lower initial capital investment and other production resources such as land and feed, small ruminant animals are the best options to improve food security and diversify household livelihood strategies (Kassie et al. 2021).

Whilst small ruminant production is more carbon efficient compared to cattle (FAO, 2021), the expected increase in demand for small ruminant related products - due to shifting dietary patterns and population growth - pose a threat to the sustainability of these systems and associated value chains. According to FAO 2016, small ruminant farming has been linked to deforestation, land degradation, biodiversity loss, and water scarcity, in addition to being a growing source of greenhouse gas emissions (GHGe).

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Although there have been several studies conducted regarding the challenges and impacts of small ruminant production systems in Ethiopia, most of them solely focus on the breeding programs and fattening practices. Environmental assessments cannot be ignored amidst rising concerns of environmental degradation as a result of changing livestock production systems. These assessments are imperative to guide decision making during the planning phase of farm scale interventions.

As a response to the increased sustainability concerns, The Alliance of Bioversity International and CIAT, ICARDA, and partners used the Comprehensive Livestock Environmental Assessment for improved Nutrition, a secured Environment and sustainable Development along livestock value chains (CLEANED) tool to assess the environmental impact of the small ruminant production value chains in four Woredas in Ethiopia. (CLEANED) is an ex-ante tool that assesses environmental impacts of livestock systems and value chains in terms of land requirements, productivity, economics, soil impacts (e.g., erosion, N balance), greenhouse gas emissions (GHGe) and water impacts (Mukiri, J. et al. 2019). The model was used to quantify the baseline environmental situation and the likely changes to environmental footprints as a result of the proposed interventions.

As part of the CGIAR Research Program on Livestock (CRP) and in the framework of the Small Ruminant value chain Transformation (SmaRT) pack project, the Alliance of Biodiversity International and the International Center for Tropical Agriculture (CIAT) and the International Center for Agriculture Research in the Dry Areas (ICARDA), and a range of local partners, came together to implement integrated approaches of small ruminant production. The integrated approach included different productivity improvement technologies, such as genetic improvement through community-based breeding improvement, feed & nutrition, animal health, in combination with collective marketing and environmental sustainability.

The vision was to benefit Ethiopian people from sustainable and efficient small ruminant value chains in which their animals would become more productive and livestock markets would work for producers, consumers, and business. The people would have more affordable and healthier small ruminant products while improving the livelihoods and capacities of people involved in the whole value chain (Rischkowsky, B.A., 2019). The CLEANED environmental assessments were carried out in all SmaRT study sites (Abergele, Bonga, Doyogena and Menz) and aimed to answer the following research questions:

1. What are the current land, soil, water, and GHGe environmental footprints of the small ruminant systems in Abergele, Bonga, Doyogena, and Menz?
2. What are the environmental trade-offs and synergies following the uptake of SmaRT pack intervention packages in Abergele, Bonga, Doyogena, and Menz?

2. Materials and Methods

2.1 Description of the Study Area

The study was undertaken within the SmaRT pack project led by Alliance of Bioversity International and International Center for Tropical Agriculture and International Livestock Research Institute (ILRI), together with their partners in intervention sites (Figure 1). The assessment was conducted between the periods of March and September in 2021.

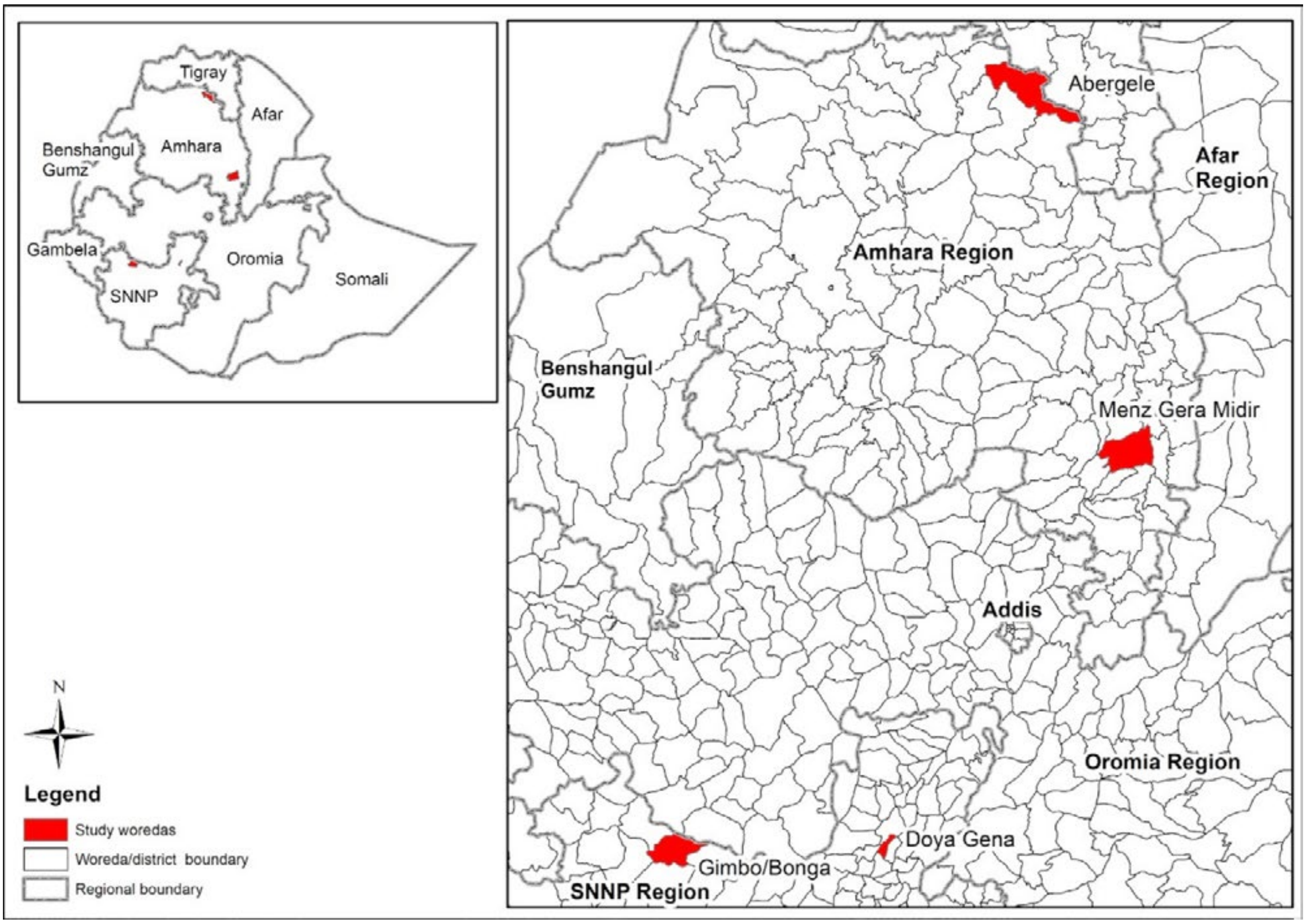

Figure 1: Map of the project sites

Physical, and socio-economic attributes of the study area

Abergele is a woreda (district) in the Amhara region of Ethiopia. It is part of the Waghemira Zone and is bordered on the south by the Zikuala woreda, on the southwest by the Sehala woreda, on the northwest by the Semien Gondar Zone, on the north and east by the Tigray Region, and on the southeast by the Soqota woreda. The annual average rainfall for Abergele ranges from 681 mm, and the area has an altitude of 1150-2100 meters above sea level (m.a.s.l) (Eba et al., 2020). The woreda has a total land area of 1,766.65 km^2, and an estimated total population of 51,482 people (CSA, 2021). The main livelihood activity in Abergele is mixed livestock-crop production. According to a study conducted by the CSA in 2020/21, 84.36% of farmers in the Amhara region held both crops and livestock, while 11.54% only grew crops and the remaining 4.09% only raised livestock.

Bonga is a town and separate woreda in southwestern Ethiopia. It is the administrative center of the Keffa Zone of the Southern Nations, Nationalities, and Peoples Region (SNNPR). Bonga is located southwest of the city Jimma upon a hill in the upper Barta valley and surrounded by the Gimbo woreda. The area has an elevation of 1,714 m.a.s.l, an annual rainfall of 1359 mm, and an estimated total population as of 53,535 people (CSA, 2021). The Bonga Forest Reserve is among the last remaining subtropical moist forests of any significant size found in Ethiopia, and it covers about 500 km2 of land area. Although the area is known mainly for its coffee production, only about 11.81% of farmers in the SNNPR grow crops (CSA, 2021). The vast majority of Bonga residents hold both crops and livestock (85.76%), 11.81% grew crops and the remaining rely on livestock only for their livelihoods.

Doyogena is another woreda located in the SNNPR of Ethiopia. It is part of the Kembata Tembaro Zone and is bordered on the south by Kacha Bira, on the west and north by the Hadiya Zone, and on the east by Angacha. The altitude of the area ranges from 2420 to 2740 m.a.s.l, and it experiences an annual average rainfall of 1238 mm (Tadesse et al., 2021). The primary farming system in the district is a mixed livestock-crop production where cereals are the main crops grown, and livestock production includes cattle, sheep, and poultry. Doyegena has an estimated population of 109,251 people (CSA, 2021).

Menz Gera Midir is a woreda in the Amhara region of Ethiopia. It is located at the eastern edge of the Ethiopian highlands in the Semien Shewa Zone and the district is bordered on the south by the Menz Lalo Midir woreda, on the southwest by Menz Keya Gebreal woreda, on the west by the Qechene River which separates it from the Debub Wollo Zone, on the north by the Geshe Rabel woreda, on the northeast by the Antsokiyana Gemza woreda, and on the east by the Efratana Gidim woreda. The average annual rainfall for Menz is 1071 mm, and the area sits at an elevation of 2,809 meters. Although agriculture in Menz Gera Midir is predominantly characterized by mixed crop-livestock production systems, intensive crop production is constrained by frost, poor soil fertility, and unreliable rainfall in the areas with higher altitude (Gebre, 2009). Cereals are the main crops grown in the woreda, and sheep is the major component of the livestock herd compositions. Menz Gera Midir has an estimated population of 154,127 people (CSA, 2021).


Tesfaye Getachew 2021/ICARDA

2.2 Small Ruminant Production Systems in Ethiopia

Most sheep and goats are produced in mixed crop-livestock and pastoral and agro-pastoral production systems characterized by low levels of input and technologies, feed scarcity and disease challenge (Alemayehu, 2006). The mixed crop-livestock production system is often found in the highland agro-ecological zones where livestock production is secondary to crop production. The system comprises of very small flock sizes due to shrinkage of grazing areas per household, limited feed availability and land degradation (Solomon et al. 2014). On the other hand, the pastoral and agro-pastoral production systems are found in the arid and semi-arid agro-ecological zones where the majority of small ruminants are concentrated. These areas are the major sources of livestock products for the Ethiopian export market (Legese and Fadiga, 2014). The pastoral system is based on wide-ranging communal grazing lands primarily using natural vegetation where thorny enclosures are common while the agro-pastoral system is characterized by a combination of pastoral and mixed crop-livestock production systems with periodic use of crop residues (Grum, 2010).

The sheep and goats are exposed to any combination of both extensive and intensive husbandry methods, either simultaneously or varied according to changes in climatic condition or physiological state of the animal (OIE, 2012). The intensive management system of small ruminants involves housing of animals and feeding them in the stables with concentrated feedstuffs. It is mainly practiced in areas with shortage of land such as highland areas where most of the available land is used for crop cultivation (OIE, 2012). It is a labor-intensive system and generally fewer numbers of livestock are kept than in extensive or semi-intensive. According to traditional Ethiopian classifications of livestock production systems, highland areas are more than 1500 m.a.s.l and cover 40% of the country, primarily the regions of Tigray, Amhara and parts of Oromia and SNNPR (Legese et al., 2014). The major pastoral lowland areas are located in the Somali region, part of Oromia region, the Afar region, and part of SNNPR.

Majority of the sheep and goat breeds are indigenous. Sheep breeds include the Horro, Menz, Bonga, Arsi and Black-Head Ogaden, Bagait and Afar breeds. Some of the major goat breeds include Afar, long and short-eared Somali, Abergelle, Begait and Hararghe Highland goats (Tegegne et al., 2006).

The extensive small ruminant production systems in this assessment were representative of an extensive livestock production system in each location. They were characterized by the management, breed type, herd composition, and animal diet (Table 1).

Table 1: Small ruminant production systems in Abergele, Bonga, Doyogena, and Menz

Site	Livestock Systems	Season	Season Months	Management System	Breed Type	Type and No. of Animals	Type of Feed (%)
Abergele, Lowland	Extensive Sheep	Wet	July to Sep	Grazing	Indigenous breed	Goats Does: 18 Goats Bucks: 2 Goats - Fattening Bucks: 2 Kids: 15	Grazing – 100%
		Dry	Dec to June				Grazing – 70% Sorghum residues – 13% Cow pea – 8% Natural pasture Hay – 5% Concentrate 4%
Bonga	Extensive	Wet	Feb to May	Grazing with supplementation	Indigenous breed	Sheep Ewes : 4 Sheep Breeding Rams: 1 Sheep Fattening Rams: 2 Sheep Lambs: 4	Natural pasture grazing – 90% Aftermath grazing – 5% False banana waste – 4% Banana waste – 1%
		Dry	June to Jan				Natural pasture grazing – 90% Aftermath grazing – 4% False Banana waste – 4% Banana waste – 2%
Doyogena Highland	Extensive	Wet	May to Oct	Grazing	Indigenous breed	Sheep Ewes: 1.83 Sheep Fattening Rams: 0.12 Sheep Lambs: 0.80 Breeding ram: 0.90	Grazing – 50% False banana supply – 17% Avena sativa– 5% Concentrate - 11% Wheat straw - 4%
		Dry	Nov to April				Grazing – 50% False banana supply – 17% Avena sativa– 6% Concentrate – 15% Wheat straw – 11% Natural grass hay – 11%
Menz	Extensive	Wet	Nov to May	Grazing with supplementation	Indigenous breed	Sheep Ewes: 19 Sheep Breeding Rams: 3 Sheep Fattening Rams: 3 Sheep Lambs: 6	Natural pasture grazing – 70% Aftermath grazing – 20% Barley straw – 3% Lentil residue – 2% Wheat straw – 2% Faba bean residue – 3%
		Dry	Jun to Oct				Natural pasture grazing – 85% Aftermath grazing – 10% Barley straw – 5%

2.3 Data analysis and modelling

CLEANED process

The CLEANED tool was used to assess the environmental impacts of small ruminant production systems in Abergele, Bonga, Doyogena, and Menz, in Ethiopia. CLEANED empowers end users to better design sustainable livestock systems by identifying potential environmental footprints and synergies of proposed practices or development interventions. The ex-ante, minimum data entry tool consists of inputs, parameters, and results computed from the back-end calculations (Mukiri et al., 2019). Table 2 gives a summary of indicators quantified in this study.

Table 2: CLEANED indicators used for this study

Indicator	Explanation
Land requirements	Estimates the total land required to grow the feed items prerequisite for the animals present on the livestock enterprise.
Soil impacts	Calculated by N flows, entering and leaving the livestock enterprise.
Water impacts	Estimates the amount of water used for feed production. It is presented by the actual crop evapotranspiration.
GHG impacts	It is calculated from different sources of emission using the Intercontinental Panel on Climate Change tier two methodologies.

The key input and parameter data needed in CLEANED include:

- Agro-Ecological Data – rainfall, season days, soil N, Soil C, Evapo-transpiration
- Livestock Data – herd numbers, species, breed types, weights
- Livestock Diet – feed type consumed; portion of feed consumed
- Feed- Crop Management – yields, inputs, harvest management

This data was collected from primary and secondary sources. Primary sources included key experts working within the SmaRT pack project sites i.e., field extension officers, farmers and researchers. Secondary sources included literature sources such as Feedipidea, SmaRT project repository, USDA nutritional database, FAO repositories, ISRIC, Tropical Forages facts sheet, and CGIAR publications. Annex 1 gives a breakdown of the data used and their sources. Figure 2 shows the result of using both literature and primary data to construct a typical annual feed basket for small ruminant systems.

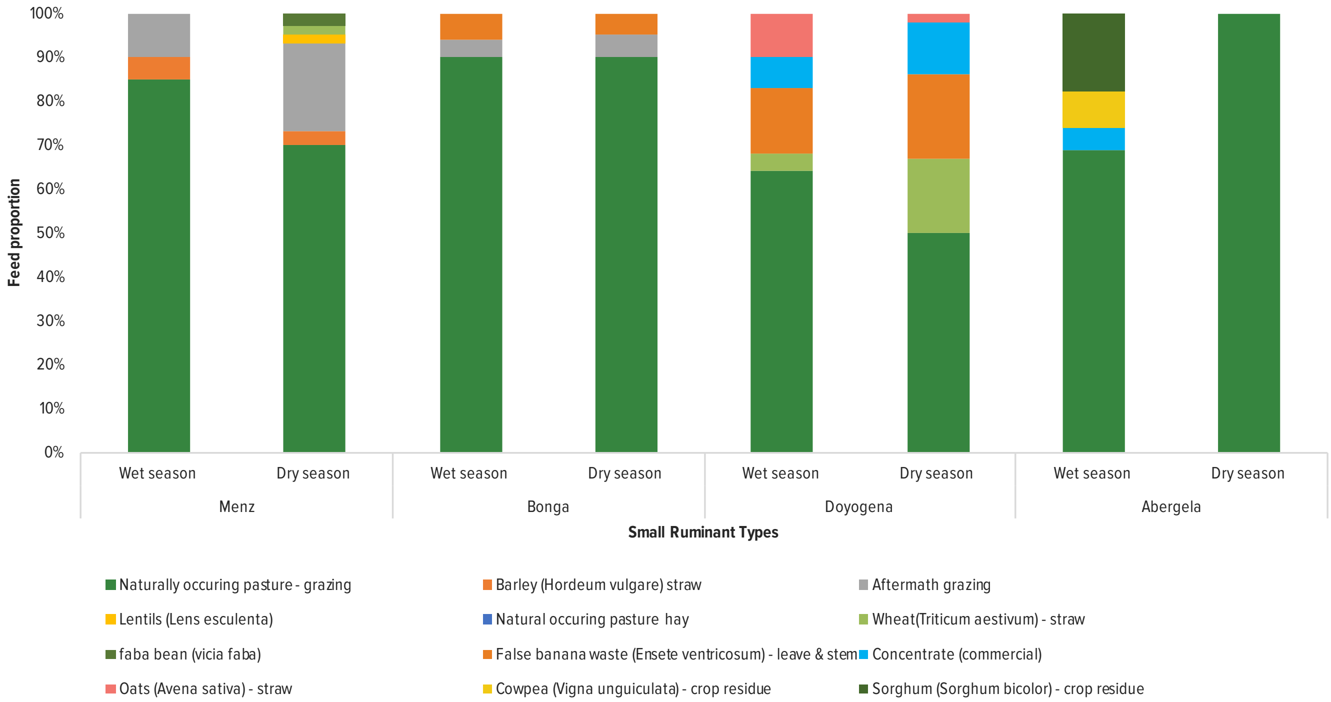

Figure 2: Typical feed baskets of small ruminants in the study sites

Baseline calculation and validation

The baseline environmental footprints for the extensive small ruminant production systems in Abergele, Bonga, Doyogena, and Menz were calculated. Due to the political unrest and COVID-19 situation in Ethiopia, the expert validation workshop was held virtually to verify the baseline data (Ashagrie et al, 2021). The workshop involved eight experts from Alliance of Bioversity International and CIAT, the International Livestock Research Institute (ILRI), and ICARDA. Preliminary models result on CLEANED were shared and discussed by participants. The participants felt as though the total land area for feed production was overestimated, especially for Menz. They felt there was an over-reliance of grazing despite cut and carry also being practiced within the systems. As a result, the feed baskets were recalibrated to reflect the assessments on the ground using a more accurate feed basket data from ICARDA feed experts.

SmaRT pack intervention scenarios

During the internal expert validation workshop, participants were able to examine the SmaRT Pack interventions that have already been operational for an extended period in Ethiopia (Table 3). Participants were able to help develop future scenarios for model implementation that reflected best-bet integrated intervention packages per system. The discussion was centered on the evaluation of combination of interventions that made sense for the different types.

Table 3: SmaRT Pack interventions

Legend: Heard Health | Feeds and Forages | Genetics

Menz	Bonga	Sekota/Abergele	Doyogena
Deworming SR for GI Parasites and lungworms	Deworming SR for GI Parasites and lungworms	Deworming SR for GI Parasites and lungworms	Deworming SR for GI Parasites and lungworms
Deworming dogs for coenuruses	Deworming dogs for coenuruses	Vaccination for ovine pasteurellosis	Vaccination for ovine pasteurellosis
Vaccination for ovine pasteurellosis	Vaccination for ovine pasteurellosis	Vaccination for PPR	Vaccination for PPR
Vaccination for PPR	Vaccination for PPR	Vaccination for sheep pox	Vaccination for sheep pox
Vaccination for sheep pox	Vaccination for sheep pox	Vaccination for Anthrax	Vaccination for Anthrax
Vaccination for Anthrax	Vaccination for Anthrax	Vaccination for CCPP	Targeted feeding for pregnant ewes/ does
Targeted feeding for pregnant ewes/ does	Targeted feeding for pregnant ewes/ does	Targeted feeding for pregnant ewes/does	Smart nutritional strategies development and flushing of breeding ewes and rams
Smart nutritional strategies development and flushing of breeding ewes and rams	Smart nutritional strategies development and flushing of breeding ewes and rams	Establish breeder cooperatives in new sites	Integration of identified cultivated forages into the feeding systems
Integration of identified cultivated forages into the feeding systems	Integration of identified cultivated forages into the feeding systems	Breeding bucks selection and ranking	Breeding ram selection and ranking
Establish breeder cooperatives in new sites	Breeding ram selection and ranking	Pregnancy testing, mass synchronization and artificial insemination	Pregnancy testing, mass synchronization and artificial insemination
Breeding ram selection and ranking	Pregnancy testing, mass synchronization and artificial insemination		Breeding sire procurement and avail best rams for breeder cooperative, distribute to the new intervention site and other beneficiary
Pregnancy testing, mass synchronization and artificial insemination	Breeding sire procurement and avail best rams for breeder cooperative, distribute to the new intervention site and other beneficiary		
Breeding sire procurement and avail best rams for breeder cooperative, distribute to the new intervention site and other beneficiary			

The workshop participants agreed to test on two packages:

1. Herd health interventions in combination with the genetics interventions (dis-integrated package 1)
2. Herd health, genetics interventions together with a fattening intervention from the feeds and forages package (integrated package 2).

The interventions were implemented in CLEANED with the assumption that the main productivity gains including reduced mortality and increased productivity will be achieved because of better health, genetics, and fattening exercise from feeds and forage. Table 4-11 give a breakdown of those assumptions.

Table 4: Abergele dis-integrated package 1

Input/ Parameter	Baseline value		Scenario value		% Change	
Goats Does	18		20		11%	
Goats - Bucks	2		2.1		5%	
Goats - Fattening Bucks	2		4		100%	
Goats -Kids	15		16		7%	
Does -Average annual growth per animal (kg)	0.67		0.45		-33%	
Bucks -Average annual growth per animal (kg)	9		9.5		6%	
Fattening Bucks-Average annual growth per animal (kg)	12		12		0%	
Kids -Average annual growth per animal (kg)	10		13		30%	
Does -Average Body weight (kg)	25		26		4%	
Bucks -Average Body weight (kg)	11		13.7		25%	
Fattening Bucks -Average Body weight (kg)	13		17		31%	
Kids -Average Body weight (kg)	11.7		13.95		19%	
Parturition interval (years)	1		1		0%	
Feed items	**Wet season**	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**
Naturally occurring pasture - grazing	69%	100%	69%	100%	0%	0%
Concentrate (commercial)	5%		5%		0%	0%
Cowpea (*Vigna unguiculata*) - crop residue	8%		8%		0%	0%
Sorghum (Sorghum bicolor) - crop residue	18%		18%		0%	0%

Table 5: Abergele integrated package 2

Input/ Parameter	Baseline value		Scenario value		% Change	
Goats Does	18		20		11%	
Goats - Bucks	2		2.1		5%	
Goats - Fattening Bucks	2		4		100%	
Goats -Kids	15		16		7%	
Does -Average annual growth per animal (kg)	0.67		0.45		-33%	
Bucks -Average annual growth per animal (kg)	9		9.5		6%	
Fattening Bucks-Average annual growth per animal (kg)	12		12		0%	
Kids -Average annual growth per animal (kg)	10		13		30%	
Does -Average Body weight (kg)	25		26		4%	
Bucks -Average Body weight (kg)	11		13.7		25%	
Fattening Bucks -Average Body weight (kg)	13		17		31%	
Kids -Average Body weight (kg)	11.7		13.95		19%	
Parturition interval (years)	1		1		0%	
Feed items	**Wet season**	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**
Decrease of Naturally occurring pasture - grazing	69%	100%	55%	100%	-20%	0%
Increase of Concentrate (commercial)	5%		14%		180%	
Increase of Cowpea (*Vigna unguiculata*) - crop residue	8%		12%		50%	
Sorghum (Sorghum bicolor) - crop residue	18%		18%		0%	

Table 6: Bonga dis-integrated package 1

Input/ Parameter	Baseline value		Scenario value		% Change	
Sheep Ewes - Bonga	4		4		0%	
Sheep - Breeding Rams - Bonga	1		0.26		-74%	
Sheep - Fattening Rams - Bonga	2		4		100%	
Sheep - Lambs - Bonga	4		5.17		29%	
Ewe -Average annual growth per animal (kg)	1.03		1.07		4%	
Breeding Rams -Average annual growth per animal (kg)	7.3		8		10%	
Fattening Rams -Average annual growth per animal (kg)	12.6		13		3%	
Lambs - Average annual growth per animal (kg)	26		31		19%	
Ewes -Average Body weight (kg)	30		34.1		14%	
Breeding Rams -Average Body weight (kg)	31		34		10%	
Fattening Rams -Average Body weight (kg)	32		35		9%	
Lambs -Average Body weight (kg)	15		17		13%	
Parturition interval (years)	0.5		0.7		40%	
Feed items	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
Naturally occurring pasture - grazing	90%	90%	90%	90%	0%	0%
Aftermath grazing	4%	5%	4%	5%	0%	0%
False banana waste (*Ensete ventricosum*) - leave & stem	6%	5%	6%	5%	0%	0%

Table 7: Bonga integrated package 2

Input/ Parameter	Baseline value		Scenario value		% Change	
Sheep Ewes - Bonga	4		4		0%	
Sheep - Breeding Rams - Bonga	1		0.26		-74%	
Sheep - Fattening Rams - Bonga	2		4		100%	
Sheep - Lambs - Bonga	4		5.17		29%	
Ewe -Average annual growth per animal (kg)	1.03		1.07		4%	
Breeding Rams -Average annual growth per animal (kg)	7.3		8		10%	
Fattening Rams -Average annual growth per animal (kg)	12.6		13		3%	
Lambs - Average annual growth per animal (kg)	26		31		19%	
Ewes -Average Body weight (kg)	30		34.1		14%	
Breeding Rams -Average Body weight (kg)	31		34		10%	
Fattening Rams -Average Body weight (kg)	32		35		9%	
Lambs -Average Body weight (kg)	15		17		13%	
Parturition interval (years)	0.5		0.7		40%	
Feed items	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
Decrease of Naturally occurring pasture - grazing	90%	90%	70%	60%	-22%	-33%
Aftermath grazing	4%	5%	4%	5%	0%	0%
False banana waste (*Ensete ventricosum*) - leave & stem	6%	5%	6%	5%	0%	0%
Introduction of Mogne Abeba (foolish-Flower) - leaves	0%	0%	20%	30%	---	---

Table 8: Doyogena dis-integrated package 1

Input/ Parameter	Baseline value	Scenario value	% Change
Sheep Ewes - Doyogena	1.83	2	9%
Sheep - Breeding Rams - Doyogena	0.9	0.16	-82%
Sheep - Fattening Rams - Doyogena	0.12	2.5	1983%
Sheep - Lambs - Doyogena	0.8	1.8	125%
Ewes -Average annual growth per animal (kg)	0.97	0.7	-28%
Breeding Rams -Average annual growth per animal (kg)	6	7	17%
Fattening Rams - Average annual growth per animal (kg)	12	14	17%
Lambs - Average annual growth per animal (kg)	28.1	29.7	6%
Ewes -Average Body weight (kg)	28.75	30.6	6%
Breeding Rams -Average Body weight (kg)	29	32	10%
Fattening Rams -Average Body weight (kg)	30	33	10%
Lambs -Average Body weight (kg)	14	15	7%

Input/ Parameter	Baseline value		Scenario value		% Change	
Parturition interval (years)	0.77		0.77		0%	
Feed items	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
Naturally occurring pasture - grazing	64%	50%	64%	50%	0%	0%
Wheat (*Triticum aestivum*) - straw	4%	17%	4%	17%	0%	0%
False banana waste (*Ensete ventricosum*) - leave & stem	15%	19%	15%	19%	0%	0%
Concentrate (commercial)	7%	12%	7%	12%	0%	0%
Oats (*Avena sativa*) – grain	10%	2%	10%	2%	0%	0%

Table 9: Doyogena integrated package 2

Input/ Parameter	Baseline value		Scenario value		% Change	
Sheep Ewes - Doyogena	1.83		2		9%	
Sheep - Breeding Rams - Doyogena	0.9		0.16		-82%	
Sheep - Fattening Rams - Doyogena	0.12		2.5		1983%	
Sheep - Lambs - Doyogena	0.8		1.8		125%	
Ewes -Average annual growth per animal (kg)	0.97		0.7		-28%	
Breeding Rams -Average annual growth per animal (kg)	6		7		17%	
Fattening Rams - Average annual growth per animal (kg)	12		14		17%	
Lambs - Average annual growth per animal (kg)	28.1		29.7		6%	
Ewes -Average Body weight (kg)	28.75		30.6		6%	
Breeding Rams -Average Body weight (kg)	29		32		10%	
Fattening Rams -Average Body weight (kg)	30		33		10%	
Lambs -Average Body weight (kg)	14		15		7%	
Parturition interval (years)	0.77		0.77		0%	
Feed items	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
Naturally occurring pasture - grazing	64%	50%	64%	50%	0%	0%
Decrease of Wheat (*Triticum aestivum*) - straw	4%	17%	4%	12%	0%	-29%
False banana waste (*Ensete ventricosum*) - leave & stem	15%	19%	15%	19%	0%	0%
Increase of Concentrate (commercial)	7%	12%	7%	15%	0%	25%
Increase of Oats (*Avena sativa*) – grain	10%	2%	10%	4%	0%	100%

Table 10: Menz dis-integrated package 1

Input/ Parameter	Baseline value		Scenario value		% Change	
Sheep Ewes - Menz	19		18		-5%	
Sheep - Breeding Rams - Menz	3		0.5		-83%	
Sheep - Fattening Rams - Menz	3		5		67%	
Sheep - Lambs - Menz	6		8		33%	
Ewe -Average annual growth per animal (kg)	0.39		0.69		77%	
Breeding Rams -Average annual growth per animal (kg)	5.4		6		11%	
Fattening Rams -Average annual growth per animal (kg)	7.2		8		11%	
Lambs -Average annual growth per animal (kg)	12.7		17.7		39%	
Ewes -Average Body weight (kg)	22		25		14%	
Breeding Rams -Average Body weight (kg)	24		26		8%	
Fattening Rams -Average Body weight (kg)	25		27		8%	
Lambs -Average Body weight (kg)	10		12		20%	
Parturition interval (years)	0.66		0.66		0%	
Feed items	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
Naturally occurring pasture - grazing	85%	70%	85%	70%	0%	0%
Barley (*Hordeum vulgare*) straw	5%	3%	5%	3%	0%	0%
Aftermath grazing	10%	20%	10%	20%	0%	0%
Lentils (*Lens esculenta*)	0%	2%	0%	2%	0%	0%
Wheat (*Triticum aestivum*) - straw	0%	2%	0%	2%	0%	0%
Faba bean (*vicia faba*)	0%	3%	0%	3%	0%	0%

Table 11: Menz integrated package 2

Input/ Parameter	Baseline value		Scenario value		% Change	
Sheep Ewes - Menz	19		18		-6%	
Sheep - Breeding Rams - Menz	3		0.5		-83%	
Sheep - Fattening Rams - Menz	3		5		67%	
Sheep - Lambs - Menz	6		8		33%	
Ewe -Average annual growth per animal (kg)	0.39		0.69		77%	
Breeding Rams -Average annual growth per animal (kg)	5.4		6		11%	
Fattening Rams -Average annual growth per animal (kg)	7.2		8		11%	
Lambs -Average annual growth per animal (kg)	12.7		17.7		39%	
Ewes -Average Body weight (kg)	22		25		14%	
Breeding Rams -Average Body weight (kg)	24		26		8%	
Fattening Rams -Average Body weight (kg)	25		27		8%	
Lambs -Average Body weight (kg)	10		12		20%	
Parturition interval (years)	0.66		0.66		0%	
Feed items	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
Decrease of Naturally occurring pasture - grazing	85%	70%	52%	20%	-39%	-71%
Increase of Barley (*Hordeum vulgare*) straw	5%	3%	10%	24%	100%	700%
Removal of Aftermath grazing	10%	20%	0%	0%	-100%	-100%
Increase of Lentils (*Lens esculenta*)	0%	2%	5%	14%	---	600%
Removal of Wheat (*Triticum aestivum*) - straw	0%	2%	0%	0%	0%	-100%
Removal of faba bean (*vicia faba*)	0%	3%	0%	0%	0%	-100%
Introduction of Naturally occurring pasture - green fodder	0%	0%	27%	25%	---	---
Introduction of Naturally occurring pasture hay	0%	0%	7%	17%	---	---

Figure 3 shows a legend used to visualize results of the intervention packages. Scenarios that resulted in a positive environmental change were represented using "+" signs. These represent efficiency gains due to improved herd health and genetics or improved herd health and genetics together with feeds and forage inputs. Scenarios worsening the current environmental situation were represented using " – " signs.

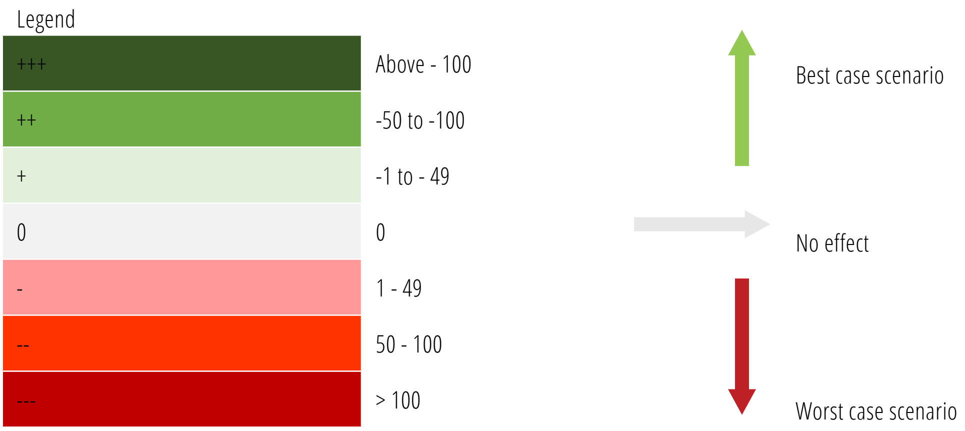

Figure 3: Different color shades and intervals used to visualize package scenarios

3. Results

3.1 Baseline Outputs

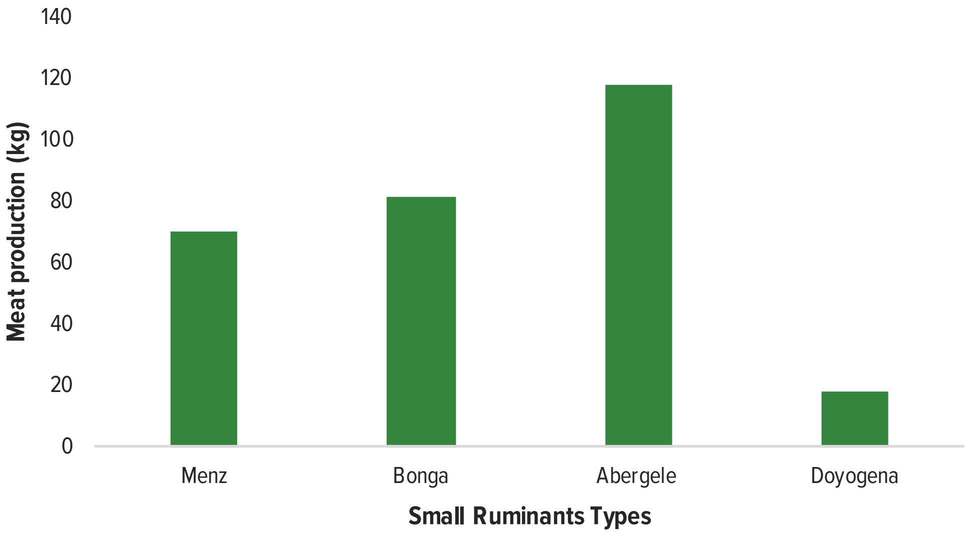

Figure 4: Annual meat production from the small ruminant enterprises

- Out of the four extensive systems, the typical Abergele system produces the most meat while the one in Doyogena registers the least amount of meat produced in a year.
- Both Bonga and Menz also produce a substantial amount of meat per year.

Above picture changes drastically when you express the meat production in terms of productivity per area used for feed production (Figure 5).

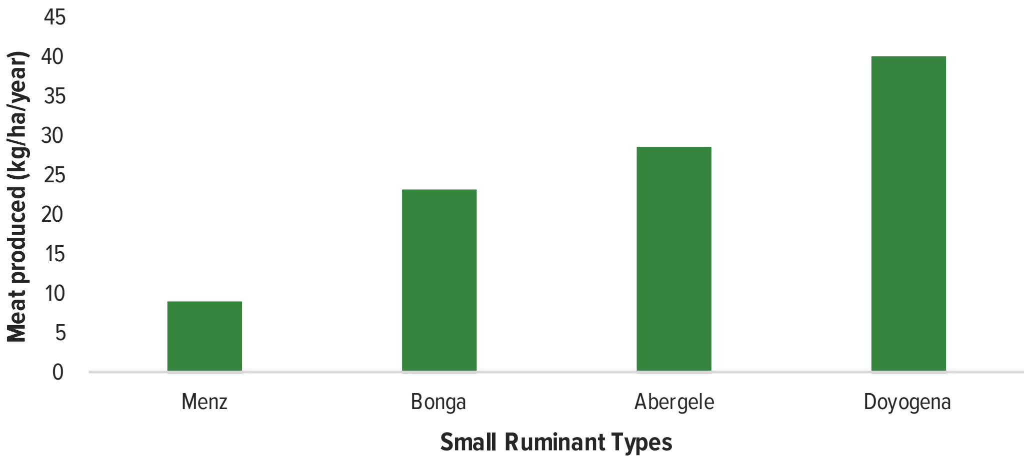

Figure 5: Productivity per area used for feed production in the systems

- Menz is less productive compared to other systems.
- Highest productivity per unit hectare in Doyogena, making it to be the most efficient system amongst the other three.

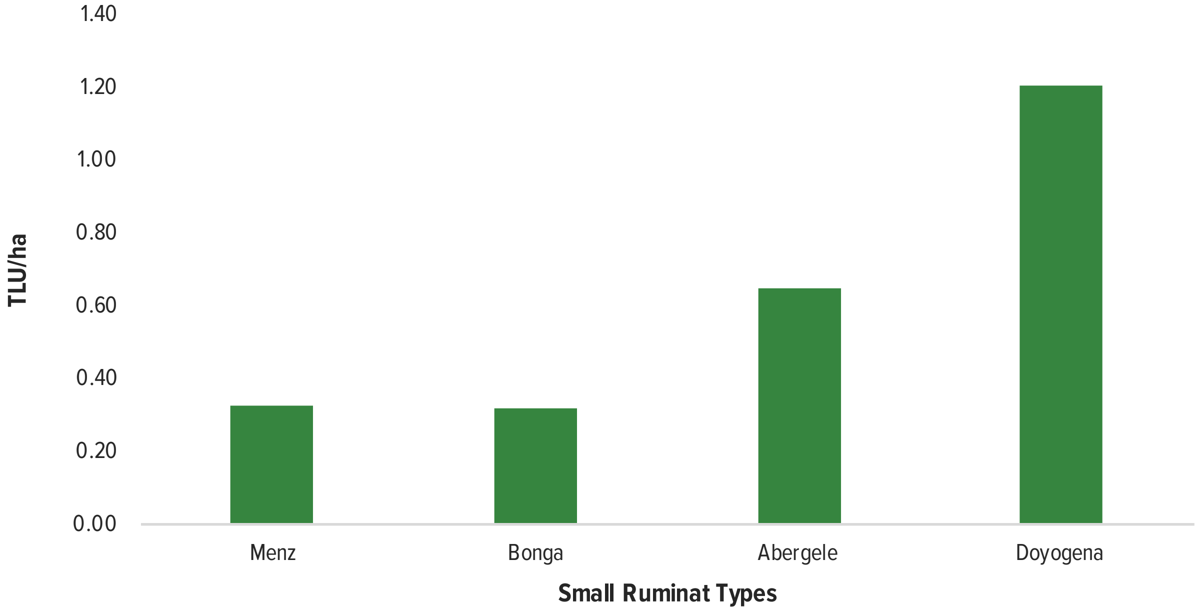

Figure 6: Total Livestock Unit (TLU) per hectare for Small Ruminant Systems

- Highest TLU/ha in Doyogena followed by Abergele.
- Menz and Bonga have the lowest and similar TLU/ha.

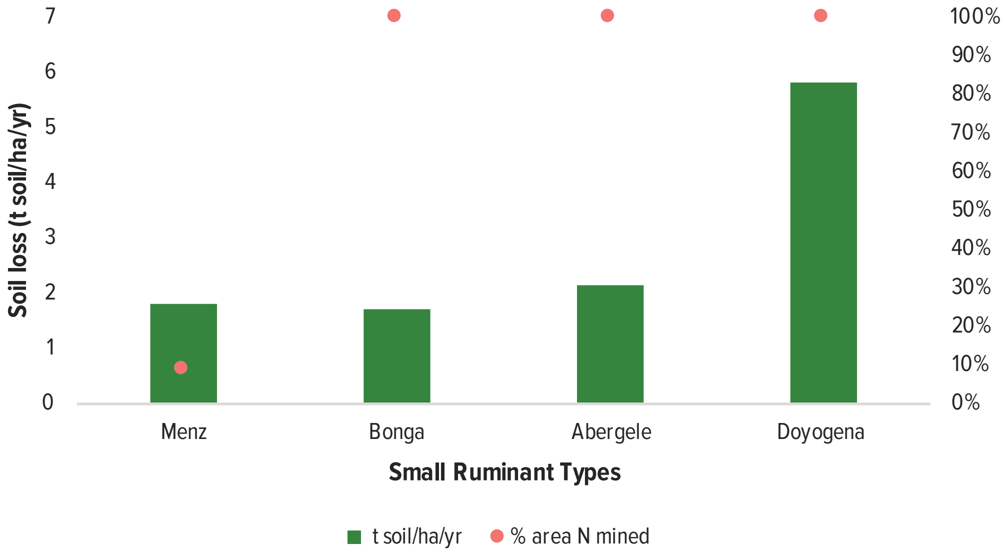

Figure 7: Soil loss and Nitrogen balance (percentage area N mined) across the small ruminant systems

- There is high loss of nitrogen albeit low fertilizer inputs in all systems except in Menz where nitrogen is replenished back to the soil through organic and inorganic inputs and additional fixation from leguminous plants.
- Doyogena is losing up to 6 tonnes of soil per hectare every year due to topographical nature of the area and high crop cultivation activities with less soil conservation practices.

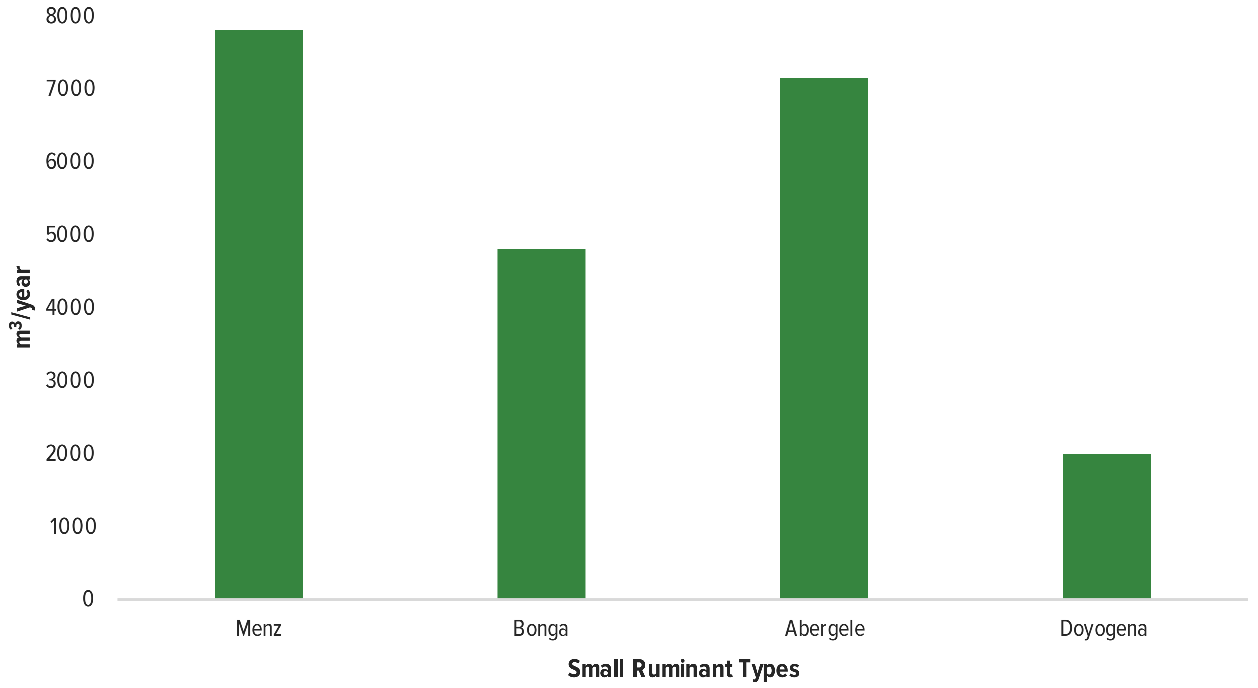

Figure 8: Total annual water use in the small ruminant enterprises

» High water requirements in Menz and Abergele consumerate with livestock numbers and high usage of natural pasture and crop residues that require much water for growth.

» A change to livestock feeding (adoption of fast maturing feed crops or supplement with concentrates) is necessary to reduce water stress in the systems.

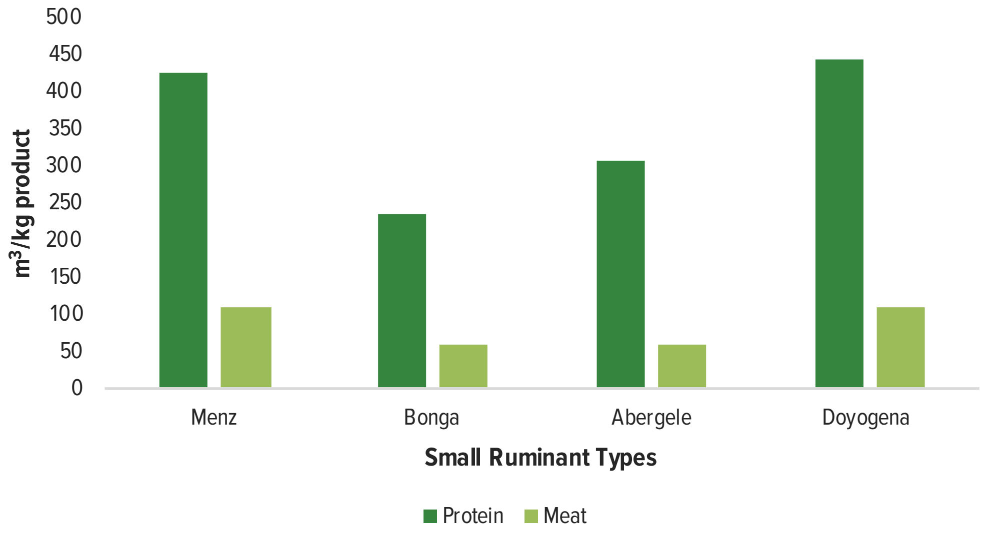

Figure 9: Total water use per kg of livestock product

» Out of the four systems, Bonga is the most water efficient.

» More water is required to produce a kg of protein and meat in both Menz and Doyogena.

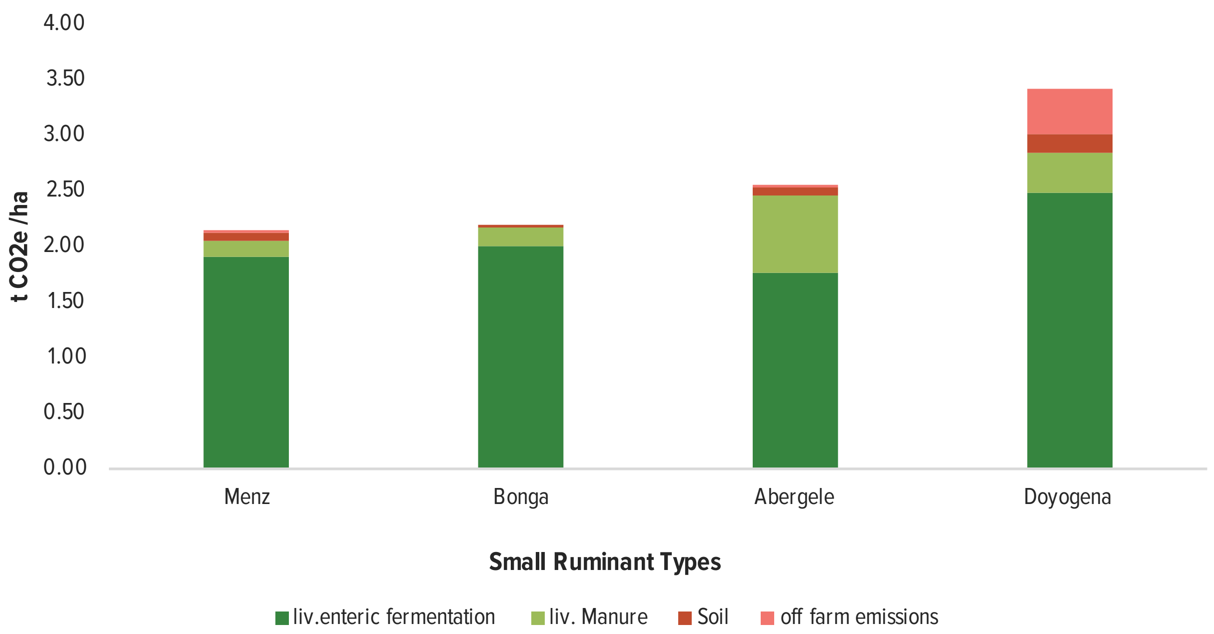

Figure 10: Sources of CO_2 in the Small Ruminant Systems

- » Relatively high GHG emissions (GHGe) across the systems but most in Doyogena.
- » Enteric fermentation is the major source of GHGe mainly due to high intake of low-quality feeds in all systems.
- » Relatively high manure emissions and off-farm emissions from Abergele and Doyogena respectively.

Figure 11: GHG emission intensity per livestock products

- » Menz system emits most of GHGe for producing a kilogram of meat and protein compared to the other systems.
- » Doyogena exhibits the lowest carbon footprint when producing a kilogram of meat and protein.

3.2 Trade-offs in environmental impacts following implementation of SmaRT pack interventions

Table 12: Environmental trade-offs and synergies of SmaRT pack interventions

Small Ruminant Systems	Land Requirements		Production	Soil Impacts		Water impacts			GHG Emissions		
	ha/yr	Ha/kg meat	Meat produced (kg/ year)	% Area N mining	Erosion (t soil/ha/yr)	m^3/year	m^3/kg meat	m^3/kg protein	t CO2eq./year	kg CO2 eq. /kg meat	kg CO2eq./kg protein
Abergele Package 1	-	+	+		+	-	+	+	-	+	+
Abergele Package 2	-	+	+		-	-	+	+	-	+	+
Bonga Package 1	-	+	++		-	-	+	+	-	+	+
Bonga Package 2	+	+	++		-	+	++	++	+	+	+
Doyogena Package 1	++	++	+++		+	++	++	++	++	++	++
Doyogena Package 2	++	++	+++		+	++	++	++	++	++	++
Menz Package 1	-	+	++			-	+	+	-	+	+
Menz Package 2	-	+	++	---	-	-	+	+	+	+	+

- Extra land in total is required to produce more meat in Abergele and Menz. However, area feed required to produce a kilogram of meat is reducing across the systems.
- There is a significant increase in meat production for all intervention packages.
- Both integrated and dis-integrated intervention packages promoted by SmaRT Ethiopia show synergies as there are overall environmental efficiency gains per unit of output.
- Doyogena systems have the highest environmental gains.
- The percentage area with N mining is increasing in Menz; however, it was the only system where it was not yet at 100%

Mieso, Mirab Hararghe Zone of the Oromia Region, Ethiopia. ©ILRI

4. Discussion

The baseline results from the CLEANED assessment provided useful information regarding the current environmental impacts of small ruminant livestock systems in Abergele, Bonga, Doyogena, and Menz. Across all four woredas, there is a higher dependance on natural pastures than crop residues. About 93% of the total land requirement for the combined livestock systems relied on natural grass, and the remaining 7% used crop residues. This is attributed to the fact that natural pasture is more readily available during the wet and dry season in the extensive systems than crop residues that are only available during the harvesting period. For example, Abergele feeds crop residue to the ruminants in wet season only and completely rely on naturally occurring pasture during the dry season. Despite Menz having a low Tropical Livestock Unit (TLU), it requires the most land area. This is driven by the dependence on natural pasture and aftermath grazing and their low yields per hectare in the area. The small ruminant system in Doyogena requires the least amount of land for feed production per TLU or kg of meat (Figure 5 and Figure 6). This can be ascribed to the diverse basket consisting of crops with higher residue yielding per hectare (Wheat and Enset ventricosum). However, the system had off-farm land requirements associated with the production of concentrates (Table 1).

The small ruminant production system in Menz has a very low extend of Nitrogen (N) mining of 9% compared to the 100% N mining for other production systems (Figure 7). In Menz, N was replenished through recycling organic manure, additional inorganic inputs and symbiotic fixation from leguminous plants such as faba beans and lentils. A complete depletion of nitrogen in other systems can be attributed to the lack of sufficient fertilizer and/or manure being added back to the soil despite continuous cultivation practices. In terms of soil erosion, the small ruminant system in Doyogena has the highest total soil loss per hectare per year (Figure 7). Along with the intense cultivation practices, the region's high precipitation levels, poor land management, and topographical nature contribute to its significant soil erosion.

Accounting for total water use in a year, Doyogena is the most water efficient system (Figure 8) . High water requirements in Menz and Abergele consumerate with livestock numbers and high usage of natural pasture and crop residues that require much water for growth. However, on relative terms i.e., m^3/kg product, Bonga is the most water efficient. More water is required to produce a kg of protein and meat in both Menz and Doyogena (Figure 9).

Enteric fermentation is the major source of GHGe and high in all systems (Figure 10). This correlates with the composition of the feed baskets, that mainly depend on low quality feeds. Low quality feeds take more time to be digested by animals and this creates more room for methane emissions. Poor manure management also increases emissions as result of increased volatilization activity in the soil. Doyogena has notable emissions from off-farm emissions, and this is due to its high usage of Nitrogen, Phosphorus and Potassium (NPK) fertilizer that has a higher GHGe factor. Menz system emits more GHGe when producing a kilogram of meat and protein than other systems. Doyogena exhibits the lowest carbon footprint when producing a kilogram of meat and protein due to better feed basket (Figure 11 and Table 1).

In regard to environmental trade-offs of the SmaRT pack interventions, both dis-integrated (improved animal health and genetics) and integrated (improved animal health, genetics and fattening exercise) packages are likely to result in increased meat production and reduced environmental footprints per unit of outputs in the small ruminant production systems (Table 12). The implementation of the dis-integrated package, is expected to result in reduced water use, area feed and GHGe per kilogram of meat by an average of 40% in all the systems. Production is also increasing across due to better animal health and improved genetics. However, total land requirement, water use and GHG emissions are expected to increase slightly in Menz and Bonga, while in Abergele they go up by an average of 23%. It is only in Doyogena the dis-integrated package is expected to come with environmental gains across all indicators.

Comparatively, an integrated package is projected to reduce water use and GHGe intensity per kilogram of meat by an average of 50% and 46% respectively in all the systems. It reduces total land requirements by up to 63% in Doyogena while Abergele and Menz register a slight increase of 2%, which is much lower than the dis-integrated package. A reduction of up to 50% in area feed per kg of meat is expected across the systems. In matters soil health, only Doyogena would experience a reduction in total soil loss per hectare. In the other systems this is expected to increase by a small fraction. Usage of nitrogen did not change in most systems because only the percentage intake of the baseline feed basket changed and not the feed items with an exception of Menz where a change in feed basket is expected to increase nitrogen mining by eight-fold but reduce total GHGe by 5% . Even though total reductions in water use and GHGe in Abergele and Menz are foreseen to slightly increase, a relative reduction shows a greater pathway for an eventual future decrease.


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Tesfaye Getachew 2021/ICARDA

Doyogena District, Ethiopia. Georgina Smith/ILRI

5. Conclusion and Recommendations

Land area requirements will always be a point at issue with extensive production systems that heavily rely on natural pasture for grazing. The low energy and crop yields of naturally occurring pastures require a large land mass to sustainably provide enough feed for the small ruminants. However, eliminating natural pastures is neither ideal nor environmentally reasonable. The only solution to prevent further expansion of land is to introduce better forage that have a higher biomass and nutrient yield or increase supplementation and reduce intake of natural pasture. This will result in a reduced feed area per system and a lowered competition between food and feed crops.

Improved feeding may also lead to a decrease in enteric fermentation, which is a major source of GHGe across the small ruminant production systems. GHGe from manure can also be reduced by proper management and encouraging nutrient recycling in all systems. It is also recommended that the small ruminant system in Doyogena either reduce the usage of NPK fertilizer or switch to alternative fertilizers. This will reduce their GHGe from off-farm emissions. Continuously replenishing the soil with the right kind of nutrients and improving soil coverage is key to achieving a positive impact on soil health in all systems.

Overall, the SmaRT pack integrated and dis-integrated intervention packages show synergies as there is an overall environmental efficiency gains per unit of most outputs. However, to boost overall environmental efficiencies and/or achieve absolute reductions, this study recommends a fully integrated package in all systems with a further refinement of the feed basket to include supplementation on the current small ruminant diet.

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Annex 1: CLEANED Input Data

1. Menz

Input/ Parameter	Value	Reference
Herd composition (nr)	31	ILRI, 2009
Sheep Ewes - Menz	19	ILRI, 2009
Sheep - Breeding Rams - Menz	3	ILRI, 2009
Sheep - Fattening Rams - Menz	3	ILRI, 2009
Sheep - Lambs - Menz	6	ILRI, 2009
Ewe -Average annual growth per animal (kg)	0.39	Expert (Tesfaye and Aemiro)
Breeding Rams -Average annual growth per animal (kg)	5.4	Expert (Aemiro and Tesfaye)
Fattening Rams -Average annual growth per animal (kg)	7.2	Expert (Aemiro and Tesfaye)
Lambs - Average annual growth per animal (kg)	12.7	ILRI data (2009)
Ewes -Average Body weight (kg)	22	EIAR, 2017,ILRI, 2009, Expert opinion (Aemiro, Tesfaye)
Breeding Rams -Average Body weight (kg)	24	EIAR, 2017,ILRI, 2009, Expert opinion (Aemiro, Tesfaye)
Fattening Rams -Average Body weight (kg)	25	EIAR, 2017,ILRI, 2009, Expert opinion (Aemiro, Tesfaye)
Lambs -Average Body weight (kg)	10	EIAR, 2017,ILRI, 2009, Expert opinion (Aemiro, Tesfaye)
Parturition interval (years)	0.6	EIAR, 2017
Barley	2.55	Seyoum et al., 2007, Holeta nutrition lab data
Natural pasture grazing/DM Yield tonne/ha	2.10	Seyoum et al., 2007, Holeta nutrition lab data
Natural pasture hay/DM Yield tonne/ha	1.98	Seyoum et al., 2007, Holeta nutrition lab data
Wheat /DM Yield tonne/ha	2.87	Seyoum et al., 2007, Holeta nutrition lab data
faba bean (vicia faba)/DM Yield tonne/ha	2.34	Seyoum et al., 2007, Holeta nutrition lab data
Lentils (Lens esculenta)/DM Yield tonne/ha	1.50	Seyoum et al., 2007, Holeta nutrition lab data
Aftermath /DM Yield tonne/ha	0.00	FAO (1987)
UREA N kg total per/ha	100	Farmer's practice
DAP N total per/ ha	18	Farmer's practice

2. Bonga

Input/ Parameter	Value	Reference
Herd composition (nr)	11	ILRI, 2009
Sheep Ewes - Bonga	4	ILRI, 2009
Sheep - Breeding Rams - Bonga	1	ILRI, 2009
Sheep - Fattening Rams - Bonga	2	ILRI, 2009
Sheep - Lambs - Bonga	4	ILRI, 2009
Ewe - Average annual growth per animal (kg)	1.03	Expert (Tesfaye and Aemiro)
Breeding Rams -Average annual growth per animal (kg)	7.3	Expert (Aemiro and Tesfaye)
Fattening Rams -Average annual growth per animal (kg)	12.6	Expert (Aemiro and Tesfaye)
Lambs - Average annual growth per animal (kg)	26	ILRI data (2009)
Ewes -Average Body weight (kg)	30	EIAR, 2017,ILRI, 2009, expert opinion (Aemiro, Tesfaye)
Breeding Rams -Average Body weight (kg)	31	EIAR, 2017,ILRI, 2009, expert opinion (Aemiro, Tesfaye)
Fattening Rams -Average Body weight (kg)	32	EIAR, 2017,ILRI, 2009, expert opinion (Aemiro, Tesfaye)
Lambs -Average Body weight (kg)	15	EIAR, 2017,ILRI, 2009, expert opinion (Aemiro, Tesfaye)
Parturition interval (years)	0.5	EIAR, 2017
Natural pasture /DM Yield tonne/ha	2.1-3	Seyoum et al., 2007
Banana/DM Yield tonne/ha	5.7-12	Zinabu et al., 2019
Aftermath/DM Yield tonne/ha	0.5	FAO (1987)
Kocho/DM Yield tonne/ha	6-12	Pijls et al., 1995, Chiche (1995), CSA (2008-2011)

3. Doyogena

Input/ Parameter	Value	Reference
Herd composition (nr)	3.65	Taye et.al, 2016
Sheep Ewes - Doyogena	1.83	Taye et.al, 2016
Sheep - Breeding Rams - Doyogena	0.9	Taye et.al, 2016
Sheep - Fattening Rams - Doyogena	0.12	Taye et.al, 2016
Sheep - Lambs - Doyogena	0.8	Taye et.al, 2016
Ewes -Average annual growth per animal (kg)	0.97	Dr. Tesfaye ICARDA Staff
Breeding Rams -Average annual growth per animal (kg)	6	Dr. Tesfaye ICARDA Staff
Fattening Rams - Average annual growth per animal (kg)	12	Dr. Tesfaye ICARDA Staff
Lambs - Average annual growth per animal (kg)	28.1	Dr. Tesfaye ICARDA Staff
Ewes -Average Body weight (kg)	28.75	Dr. Tesfaye ICARDA Staff
Breeding Rams -Average Body weight (kg)	29	Dr. Tesfaye ICARDA Staff
Fattening Rams -Average Body weight (kg)	30	Dr. Tesfaye ICARDA Staff
Lambs -Average Body weight (kg)	14	Dr. Tesfaye ICARDA Staff
Parturition interval (years)	0.7	Taye et.al, 2016
Natural pasture/DM Yield tonne/ha	2.5	Taye et.al, 2016
Wheat /DM Yield tonne/ha	3.96	Taye et.al, 2016
Oats /DM Yield tonne/ha	2.88	Taye et.al, 2016
Enset/DM Yield tonne/ha	8.8	Taye et.al, 2016
NPK N kg per/ha	150	Farmer Practice

4. Abergele

Input/ Parameter	Value	Reference
Herd composition (nr)	37	ICARDA technical reoprt by Bekahign Breeder at Abergele
Goats Does	12	Bekahgn Wondim, Mulatu Gobeze, Baye Biresaw (2019)
Goats - Bucks	2	Bekahgn Wondim, Mulatu Gobeze, Baye Biresaw (2019)
Goats - Fattening Bucks	2	Bekahgn Wondim, Mulatu Gobeze, Baye Biresaw (2019)
Goats -Kids	15	Bekahgn Wondim, Mulatu Gobeze, Baye Biresaw (2019)
Does -Average annual growth per animal (kg)	0.67	Dr. Tesfaye, ICARDA staff
Bucks -Average annual growth per animal (kg)	9	Dr. Tesfaye, ICARDA staff
Fattening Bucks -Average annual growth per animal (kg)	12	Dr. Tesfaye, ICARDA staff
Kids -Average annual growth per animal (kg)	10	Dr. Tesfaye, ICARDA staff
Does – Average Body Weight (kg)	25	Dr. Tesfaye, ICARDA staff
Bucks – Average Body Weight (kg)	11	Dr. Tesfaye, ICARDA staff
Fattening Bucks – Average Body Weight (kg)	13	Dr. Tesfaye, ICARDA staff
Kids– Average Body Weight (kg)	11.7	Dr. Tesfaye, ICARDA staff
Parturition interval (years)	1	Dr. Tesfaye, ICARDA staff
Natural pasture grazing/DM Yield tonne/ha	2.5	Bekahgn Wondim, Mulatu Gobeze, Baye Biresaw (2019)
Cowpea/DM Yield tonne/ha	6	Bekahgn Wondim, Mulatu Gobeze, Baye Biresaw (2019)
Sorghum/DM Yield tonne/ha	4	Bekahgn Wondim, Mulatu Gobeze, Baye Biresaw (2019)
UREA N kg total per/ha		Bekahgn Wondim, Mulatu Gobeze, Baye Biresaw (2019)

Annex 2: Baseline and scenario results

	Land Requirements						Production			Soil Impacts								
	Baseline		Package 1		Package 2		Baseline	Package 1	Package 2	Baseline			Package 1			Package 2		
	ha/yr	Ha/kg meat	ha/yr	Ha/kg meat	ha/yr	Ha/kg meat	Meat produced (kg/yr)	Meat produced (kg/yr)	Meat produced (kg/yr)	% Area N Mining	Erosion (t soil/ha/ yr)	Erosion (t soil/yr)	% Area N Mining	Erosion (t soil/ha/ yr)	Erosion (t soil/yr)	% Area N Mining	Erosion (t soil/ha/yr)	Erosion (t soil/yr)
Abergele	4.155	0.035	5.098	0.031	4.163	0.025	118.355	165.271	165.271	100%	2.129	8.847	100%	2.129	10.854	100%	2.393	9.962
Bonga	3.499	0.043	3.943	0.031	2.736	0.022	81.560	126.805	126.805	100%	1.708	5.978	100%	1.719	6.778	100%	1.731	4.737
Doyogena	0.449	0.025	0.171	0.003	0.168	0.003	18.035	52.768	52.768	100%	5.809	2.609	100%	5.799	0.989	100%	5.790	0.973
Menz	7.721	0.110	8.237	0.072	8.084	0.071	70.418	114.272	114.272	9%	1.806	13.944	9%	1.806	14.875	73%	2.248	18.176

Water Impacts									GHG Emissions								
Baseline			Package 1			Package 2			Baseline			Package 1			Package 2		
m3/year	m3/kg meat	m3/kg protein	m3/year	m3/kg meat	m3/kg protein	m3/year	m3/kg meat	m3/kg protein	t CO2eq/ year	kg CO2 eq. /kg meat	kg CO2eq/ kg protein)	t CO2eq/ year	kg CO2 eq. /kg meat	kg CO2eq/ kg protein	t CO2eq/ year	kg CO2 eq. /kg meat	kg CO2eq/ kg protein
7167.005	60.555	304.996	8793.138	53.204	279.458	7184.026	43.468	228.318	10.454	88.332	444.897	12.991	78.604	412.873	12.261	74.189	389.678
4815.919	59.048	233.756	5425.750	42.788	169.344	3764.708	29.689	117.501	7.547	92.538	366.335	8.348	65.830	260.537	7.308	57.635	228.104
1988.885	110.278	441.113	754.724	14.303	57.210	743.014	14.081	56.323	1.345	74.567	298.270	0.451	8.540	34.160	0.444	8.414	33.655
7794.031	110.683	425.703	8314.856	72.764	279.861	8518.916	74.550	286.730	16.390	232.754	895.207	17.245	150.916	580.447	15.623	136.719	525.844

SmaRT Program

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