


Assessing the environmental impacts of intervention packages in Cattle and Pig Production Systems in Mai Son district, Vietnam

CLEANED baseline and scenario assessment report

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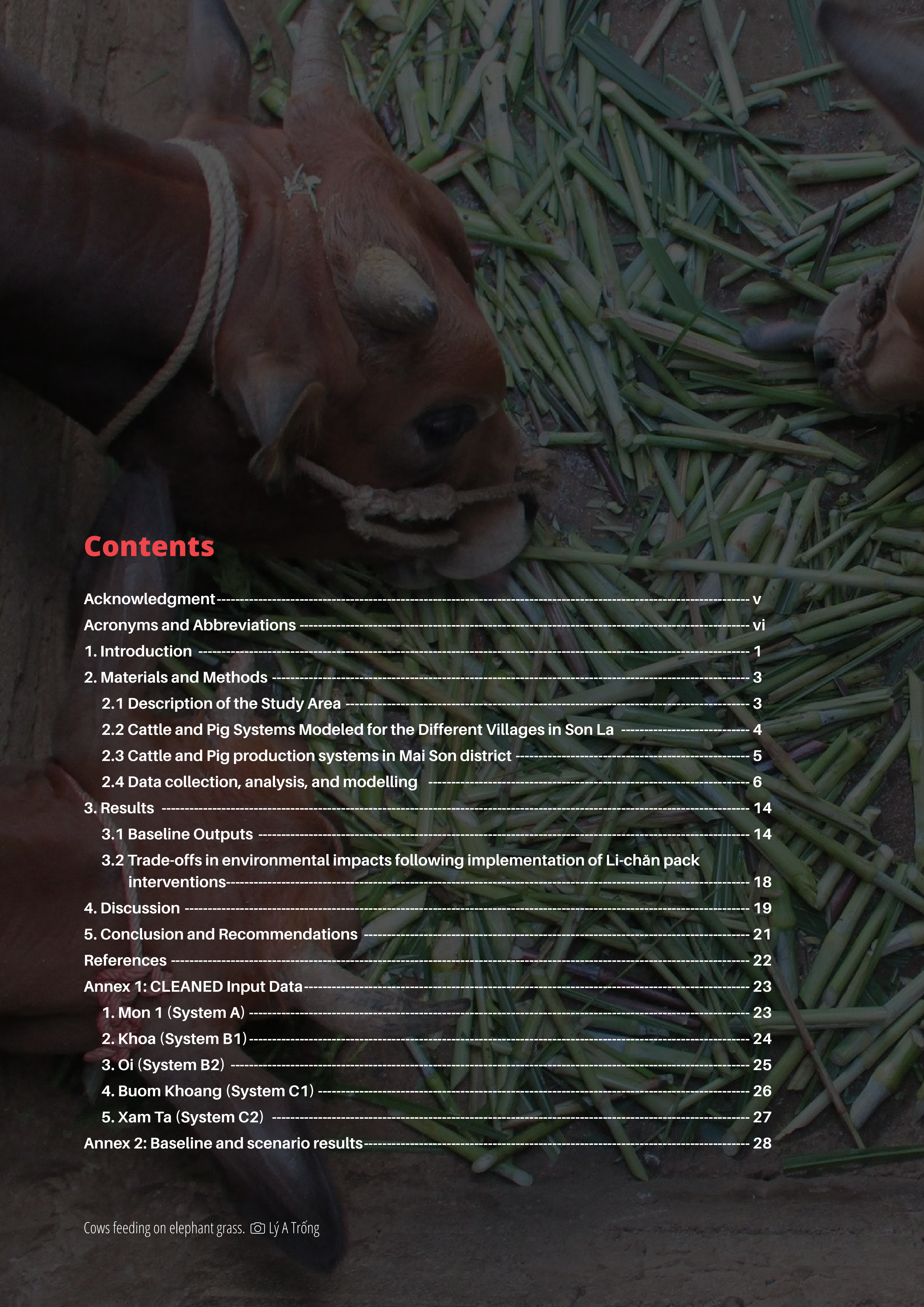
Acronyms and Abbreviations

AI	Artificial Insemination
ABC	Alliance of Bioversity International and CIAT
ACIAR	Australian Centre for International Agricultural Research
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
FAO	Food and Agriculture Organization
G-FEAST	Gendered Feed Assessment Tool
GHGe	Greenhouse Gas emission
ILRI	International Livestock Research Institute
ISRIC	International Soil Reference and Information Centre
N	Nitrogen
N_20	Nitrous oxide
NIAS	National Institute of Animal Science
NOMAFSI	Northern Mountainous Agriculture and Forestry Science Institute
NWH	Northwest Highlands
TLU	Tropical Livestock Units
USDA	United States Department of Agriculture



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Dụ is weeding the green elephant grass field of the Li-chăn project. 📷 Lý A Trống

1. Introduction

Son La is the largest mountainous province located in the northern highlands of Vietnam with a total area of 1.4 million ha and a total population of 1,252,700 (88 people/ km2) (Douxchamps et al., 2021). The northern highlands refer to the northern provinces with a high elevation characterized by mountains, uplands and midlands (Duteurtre et al., 2020). About 88% of Son La population lives in the rural areas (Son La Statistical Yearbook, 2020). Poverty rates reach 70%, 2.7 times higher than the rest of the country, and stunting in children below 5 years old is 35% (Nguyen 2016; WB 2015).

The Northwest Highlands (NWH) in particular is one of the poorest regions in the country, with 80% of households relying on agriculture and forestry for their income (MALICA, 2020). Despite the development constrains due to steep slopes, uneven grounds, low soil fertility, and high rates of soil erosion, the northern highlands are still considered as favorable areas for forestry, cash crops, and livestock production (Minot et al., 2006; Vien, 2003). Animal husbandry is an important component of households' livelihoods (Minot et al., 2006) and accounts for more than 22% of their incomes (Epprecht, 2005).

Due to increasing consumer demand for meat and dairy products, livestock has quickly become one of the fastest growing agricultural sectors in Vietnam (Dung et al., 2020). Although demand for livestock products is rising, smallholder farmers in the NWH are not capitalizing on this market opportunity. Increased production in the region is constrained by feed and forage availability, low agricultural inputs, poor access to information and services, and animal exposure to long cold winters (ACIAR, 2021; Hammond et al., 2021; Douxchamps et al., 2021). In addition, current grazing-based livestock systems compete for land due to expanding crop production on the hill slopes (ACIAR, 2021). Over the last few decades, deforestation and expansion of agriculture onto steep slopes using majority monocropping practices has resulted in forest loss, degradation of agro-ecosystems and landscape fragmentation that threatens environmental sustainability and food security (Hoang et al. 2017).

To address some of these challenges, the Alliance of Bioversity International and CIAT (ABC), International Livestock Research Institute (ILRI) and a range of local partners in Vietnam are implementing Li-chăn project initiatives. Li-chăn is a project under the CGIAR Research Program on Livestock (Livestock CRP) that is envisioned to provide research-based solutions to transition smallholder farmers to sustainable and resilient livelihoods and to more productive small-scale enterprises that will help feed future generations. The project area is Mai Son district, Son La province in the NWH. Six villages were selected for project implementation in 2021: Khoa and Xam Ta in Chieng Chung commune; Mon 1, Oi, Buom Khoang in Chieng Luong commune. Increased livestock production in these areas is seen as a priority in order to alleviate poverty and address environmental issues of intensified cropping (ACIAR 2021). The implementation of animal health and genetic interventions aims to boost productivity of the animals. Feeds and forage interventions seek to solve the perennial feed shortages particularly during the winter season and improve animal nutrition and livestock productivity (Atieno et al., 2021).

Although intensifying livestock production in the six selected villages has been identified as a way of increasing livestock productivity and income of smallholder livestock farmers, the expected increase in demand for cattle and pig related products due to shifting dietary patterns and population growth pose a threat to the sustainability of these systems and associated value chains. Livestock 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) (FAO, 2013). Assessing the proposed interventions and their upshot in ecosystem services is imperative to understand the trade-offs and synergies associated with the new technologies. This will enable the smallholder farmers to identify pathways with highest productivity gains and lowest environmental footprints.

ABC applied 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 cattle and pig systems in Son La province in Vietnam. 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 due to the proposed interventions. The vision was to benefit Vietnamese people from sustainable and efficient livestock value chains in which their animals would become healthier and more productive while improving the livelihoods and capacities of people involved in the whole value chain. The CLEANED environmental assessments were carried out in two communes – Chiềng Chung and Chiềng Luong, and aimed to answer the following research questions:

1. What are the current land, soil, water, and GHGe environmental footprints of the multi-species (Cattle and Pig) production systems in Mon 1 (A), Khoa (B1), Oi (B2), Buom Khoang (C1), and Xam Ta (C2)?

2. What are the likely environmental trade-offs and synergies following the uptake of Li-chăn interventions in Mon 1 (A), Khoa (B1), Oi (B2), Buom Khoang (C1) and Xam Ta (C2)?


Lường Thị Dung

2. Materials and Methods

2.1 Description of the Study Area

The study was undertaken within the Li-chăn project led by Alliance of Bioversity International and International Center for Tropical Agriculture (ABC) and International Livestock Research Institute (ILRI) in close collaboration with Northern Mountainous Agriculture and Forest Science Institute (NOMAFSI) and a range of local stakeholders from Vietnam. The assessment was conducted from April to November 2021.

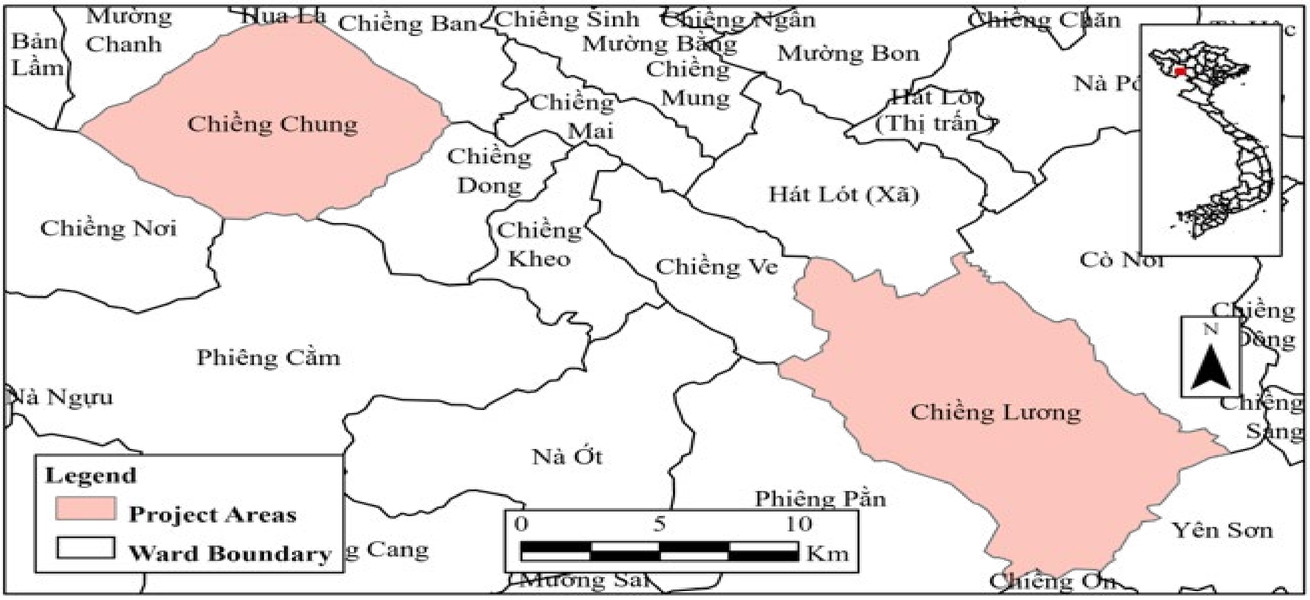

Figure 1: Map of Project Sites

Geographical and demographic characteristics of the study area

The northern highlands account for about 30% of the total surface area in Vietnam and comprise more than 2000 administrative communes (Duteurtre et al. 2020). Encompassed by the various mountain ranges, with some peaks exceeding 3000 m, around 39% of the communes are located at a medium altitude of 200–600 m, and another 39% pf the communes are at an altitude higher than 600 m. Due to its topography, the northern highlands is characterized by three main ecosystems: the warm irrigated valleys in the low mountain zone (200–300 m elevation), to rain–fed hilly landscapes in the mid–elevation mountain zone (300–800 m), and a high mountain zone (> 800 m) (Vien, 2003).

Son La is the largest mountainous province in northern Vietnam with a total area of 1.4 million ha and a total population of 1,252,700 people, with about 88% of the population living in rural areas (Douxchamps et al. 2021). The main ethnic groups comprise of Thai, Kinh, H'Mong and Muong. Ethnic minorities account for 83.7% of the total population (Douxchamps et al., 2021). Mai Son, where our study sites are located, is a rural district of the Son La province located in the Northwest region of Vietnam. It has a total area of 1,410 km2, and as of 2019, the district has a total population of 163,881 people (General Statistics Office of Vietnam, 2019). The climate of Mai Son is continental tropical monsoon and is influenced by topography (Douxchamps et al. 2021). Cold and dry winters last from October to March, while the remaining months are hot, humid, and rainy. The average temperature is 21.5°C and the average annual rainfall is 1,400 mm with an average of 118 rainy days per year. About 80% of rain falls between June and September (Le and Marshall, 2021).

Farm Typology

One-hundred and nine households were interviewed using the Gendered Feed Assessment (G-FEAST) tool in Son La, North-West Vietnam between April and November 2021. The G-FEAST tool was designed to identify opportunities and constraints in animal feeding practices for different household types by assessing the availability and use of local feed resources, identify challenges and constraints affecting livestock production through the gender lens, opportunities for improved animal nutrition and propose context-specific interventions on livestock feed for improved animal nutrition (Lukuyu et al., 2019a; Lukuyu et al., 2019b). As mixed systems with cows and pigs formed the majority in the region, households that did not have cattle or pigs were removed, resulting in a total of one-hundred and four households in our dataset.

The interview responses were grouped into a farm typology with households close to roads and markets, in the valley bottoms with the best soil and most commercialized and intensified farming systems classified as farm Type A; those on the valley edges and slopes, who practice more mixed agriculture and are less specialized classified as farm Type B; and those high on the slopes who have poor road access, poorer quality land, and are generally more extensive and subsistence-oriented than the others classified as farm Type C (Hammond et al., 2020).

Six villages were selected for Li-chăn project implementation in 2020-2021: Khoa and Xam Ta in Chiềng Chung commune; Mon 1, Mon 2, Oi, and Buom Khoang in Chiềng Luong commune. Five case study model farms were selected (One from each village except Mon 2) from the household list for the CLEANED environmental assessments, representing different farm types, i.e. A, B1, B2, C1 and C2 (Table 1) according to the aforementioned criteria. The differentiation into B1 and B2 in type B arose from the feeding diets being different in the two villages (Khoa and Oi), while the sub-division of type C arose from differences in management system and herd composition.

2.2 Cattle and Pig Systems Modeled for the Different Villages in Son La

The cattle and pig production systems as seen in Table 1 were verified by the team before the assessment began (Mwema et al., 2021). This was based on G-FEAST[1] reports, farmer follow up together with expert opinion.

Some villages especially those in high altitudes graze their cattle in the forest. Lý A Nủ

1 Otieno, M.; Mai, T.; Douxchamps, S.; Peters, M; Duncan, A. (2021) Rapid survey of livestock feed resource availability and use in Mai Son district, Son La province, Vietnam, using the Gendered Feed Assessment Tool (G-FEAST). Hanoi (Vietnam): CGIAR Research Program on Livestock. 22 p. https://hdl.handle.net/10568/111524

Table 1: Cattle & Pig Systems in Mon 1, Khoa, Oi, Buom Khoang, and Xam Ta

Livestock system	Site	Management system	Type and No. of animals	Type of feed	
				Cattle	Pigs
A	Mon 1 - Chieng Luong - Mai Son - Son La	Confined and tethering	Adult cattle - male: 2	Rice straw: 36%	Banana trunk: 60%
			Pigs - growers: 7	Grazing: 10%	Maize (Zea mays) - cracked grains: 5%
				Maize stover: 3%	Taro leaves: 20%
				Elephant grass: 30%	Collected forage: 15%
				Sugarcane tops: 17%	
				Maize (Zea mays) - cracked grains: 4%	
B1	Khoa - Chieng Chung - Mai Son - Son La	Confined and tethering	Steers/heifers: 3	Rice straw: 11%	Banana trunk: 40%
			Pigs - growers: 1	Grazing: 53%	Natural forage: 5%
				Cut and carry: 6%	Cultivated vegetable: 5%
				Maize stover: 2%	Rice bran: 30%
				Elephant grass:10%	Maize (Zea mays) - cracked grains: 20%
				Banana trunk: 17%	
				Rice bran: 1%	
B2	Oi - Chieng Luong - Mai Son - Son La	Confined and tethering	Cows (local): 2	Rice (Oryza sativa) - straw: 7%	Naturally occurring pasture - green fodder: 30%
			Pigs-grower: 4	Elephant grass (cultivated): 40%	Banana trunk: 50%
			Pigs-sow: 1	Sugarcane tops: 40%	Maize cracked grains: 10%
				Banana trunk: 10%	Rice bran: 10%
				Rice bran: 3%	
C1	Buom Khoang - Chieng Luong - Mai Son - Son La	Confined and tethering	Cows (local): 2	Grazing: 45%	Banana trunk: 20%
			Calves: 2	Cut and carry: 15%	Collected forage: 40%
			Pigs - growers: 2	Elephant grass: 10%	Maize (Zea mays) - cracked grains: 40%
				Sugarcane tops: 25%	
				Rice straw: 5%	
C2	Xam Ta - Chieng Chung - Mai Son - Son La	Grazing/ semi grazing - (young confined)	Cows (local): 5	Grazing: 100%	Banana trunk: 50%
			Steers/heifers: 3		Maize (Zea mays) - cracked grains: 20%
			Calves: 2		Cassava tuber root: 20%
			Adult cattle - male: 2		Natural occurring pasture - green fodder: 10%
			Pigs - growers: 6		
			Pigs - lactating/ pregnant sows: 1		

2.3 Cattle and Pig production systems in Mai Son district

In Chiềng Chung and Chiềng Luong communes, the different farming systems range from grazing and extensive systems at the top of the mountains to intensive farms with strong crop and livestock at the bottom of the valleys, with varying socio-economic and ecological conditions (Hammond et al., 2021). The most predominant production system in the region is the mixed crop - livestock farming.

According to participants in a focus group from a study conducted by Livestock CRP, most farmers in the NWH villages keep less than five pigs at a time, and one to three cattle at a time (Nga et al., 2021). Low cattle production is often a result of low feed and forage quality (Huyen et al., 2010). The feeding systems for cattle are mainly through tended native pasture (74%), stall feeding using crop residues, and free grazing on communal land and forests (Atieno et al., 2021). However, current cattle productions in the region have begun transitioning from extensive to semi-intensive and intensive systems (Ba et al., 2015). In regard to pig systems, most farmers in the NWH villages follow the traditional practice of allowing their pigs to roam freely to forage for feed, which allows for natural breeding but without any control of mating (Nga et al., 2021). Despite the low productivity, indigenous pig breeds in the region are well-adapted to local harsh conditions and showing better resistance to diseases than improved pig breeds (Le et al., 2016). Although Mai Son district has a long history of pig production, local farmers generally have limited knowledge in pig feed practices and this greatly affects the productivity and health of the pig herd (Atieno et al., 2021).

2.4 Data collection, analysis, and modelling

CLEANED process

The CLEANED tool was used to assess the environmental impacts of representative cattle and pig production systems in five selected villages in Mai Son district, Son La province, Vietnam. 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. The indicators are expressed as absolute values as well as relative per unit area or per Tropical Livestock Unit (TLU). The conversion of animal numbers to TLU was carried out using revised methodology (methods 3) described by Ostrow et al. 2020.

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 the GFEAST interviews and key experts working within the Li-chăn pack project sites i.e., field extension officers, farmers, and researchers. Secondary sources included literature sources such as Feedipidea, Li-chăn project repository, USDA nutritional database, FAO repositories, ISRIC, Tropical Forages facts sheet, and CGIAR publications. Figure 2 and Figure 3 show the result of using both literature and primary data to construct a typical annual feed basket for multi-species systems.

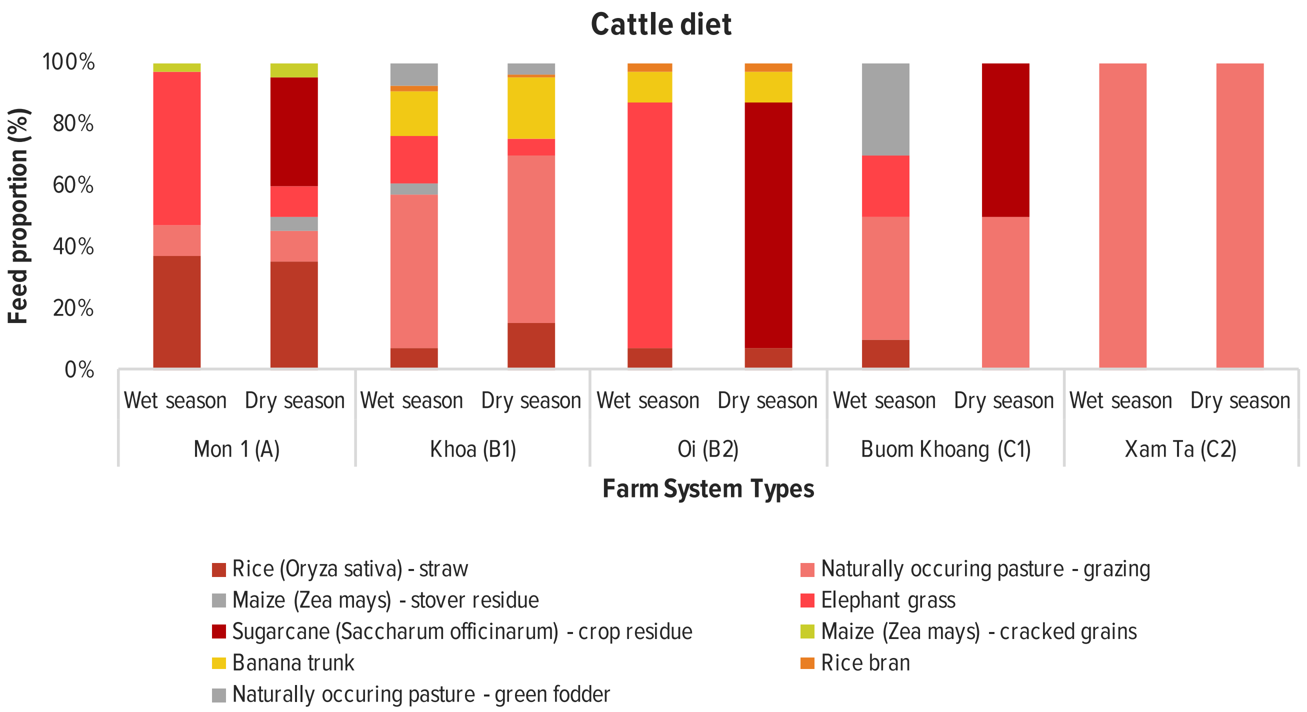

Figure 2: Annual cattle diet across the different systems

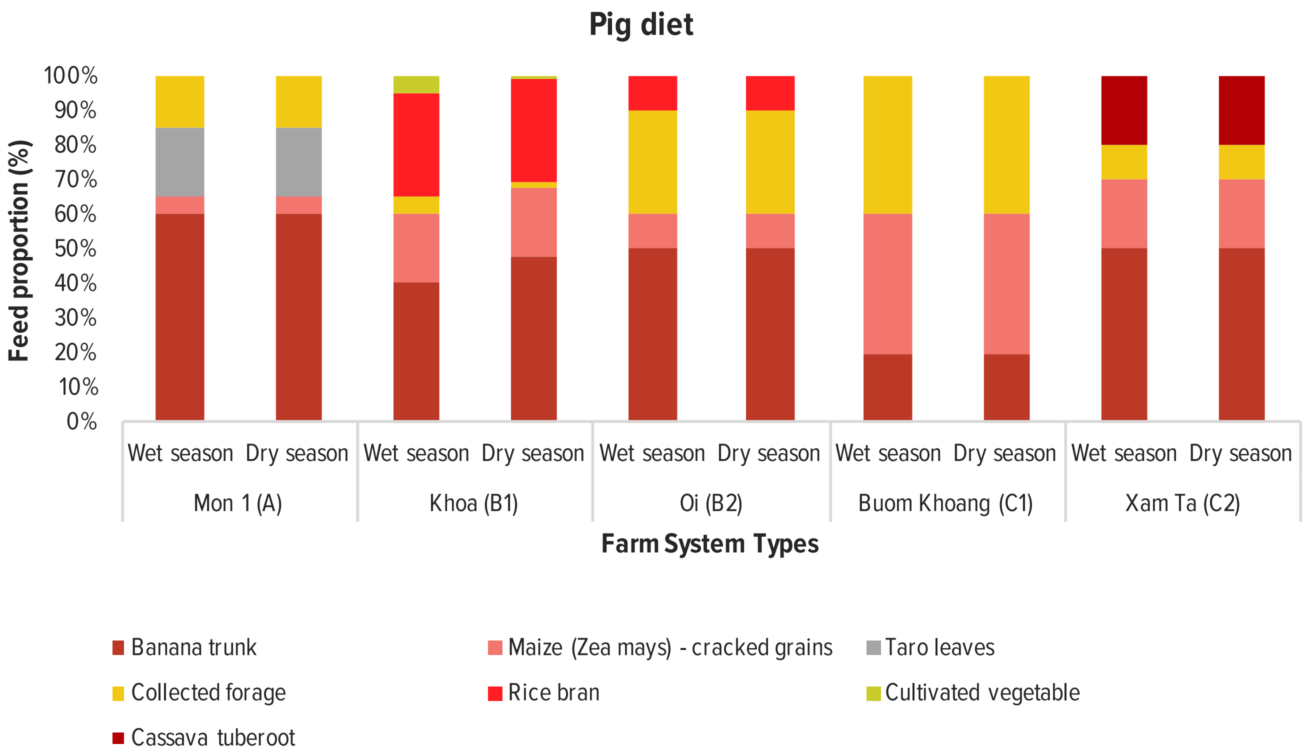

Figure 3: Annual pig diet across the different systems

Baseline calculation and validation

The baseline environmental footprints for the confined and extensive cattle and pig production systems in Mon 1 (A), Khoa (B1), Oi (B2), Buom Khoang (C1), and Xam Ta (C2) were calculated. Due to the COVID-19 pandemic, a virtual internal expert validation workshop was held to verify the baseline data (Mwema et al., 2021). The workshop involved experts from ABC, ILRI, and other local partners. Preliminary models result on CLEANED were shared and discussed by participants. Discussion was centered on the evaluation of combination of interventions that made sense for the different types.

Li-chăn intervention scenarios

During the internal expert validation workshop, participants were able to examine the Li-chăn interventions that have already been promoted in the study sites for the last one year, these include (Animal Health and Genetics, Livestock and Environment, and Feeds and Forages).

Table 3: Intervention Packages in the different regions

Legend
Animal Health
Feeds and Forages
Genetics
Livestock and Environment

Animal Health	Fenced stable
	Quarantine place
	Roofed stable
	Drainage system for stable
	Cleaning and Disinfecting farmhouse
	Visitors' control
	Vaccine, antibiotics, and other drugs
	Recording for husbandry situation, use of vaccines, drugs, and illness/death
Feeds and Forages	Cover crop/ Grass contour
	Feed processing and preservation
	Improved forage varieties
Genetics	Artificial insemination (AI) on pigs
	AI on cattle
Livestock and Environment	Composting

Mon 1 A	Khoa B1	Oi B2	Buom Khoang C1	Xam Ta C2
Cleaning and Disinfecting farmhouse	Cleaning and Disinfecting farmhouse	Cleaning and Disinfecting farmhouse	Cleaning and Disinfecting farmhouse	Cleaning and Disinfecting farmhouse
Visitor's control	Visitor's control	Visitor's control	Visitor's control	Visitor's control
Vaccine, antibiotic, and other drugs	Vaccine, antibiotic, and other drugs	Vaccine, antibiotic, and other drugs	Vaccine, antibiotic, and other drugs	Vaccine, antibiotic, and other drugs
Improved forage seed	Improved forage seed	Improved forage seed	Improved forage seed	Improved forage seed
AI on pigs	AI on pigs	AI on pigs	AI on pigs	AI on pigs
AI on cattle	AI on cattle			

The interventions were implemented in CLEANED with the assumption that important productivity gains of reduced mortality and increased productivity will be achieved because of better health, genetics, and improved feeding. During the expert validation workshop, the team agreed to test a fully integrated package (Animal health and Genetics, Livestock and Environment intervention together with a Feeds and Forages intervention).

Tables 4-8 give a breakdown of feed and livestock data assumptions.

Table 4: Mon 1(A) Integrated Intervention Package

Input/Parameter	Baseline Value		Scenario Value		% Change	
Herd composition (nr):						
Adult cattle - male	2		4		100%	
Pigs - growers	7		7		0%	
Average Body Weight (kg):						
Adult cattle - male	225		295		31%	
Pigs - growers	17		35		106%	
Average annual growth per animal (kg):						
Pigs - growers	40		65		63%	
Feed Items:	***Wet Season***	***Dry Season***	***Wet Season***	***Dry Season***	***Wet Season***	***Dry Season***
Cattle diet						
Removal of Rice (Oryza sativa) - straw	37%	40%	0%	0%	-100%	-100%
Removal of Natural pasture	10%	10%	0%	0%	-100%	-100%
Slight increase in Elephant grass	50%	10%	50%	15%	0%	50%
Removal of Sugarcane (Saccharum officinarum) - crop residue	0%	35%	0%	0%	---	-100%
Change in Maize (Zea mays) - cracked grains	3%	5%	10%	0%	233%	-100%
Introduction of Green elephant[2] (forage)	0%	0%	12%	30%	---	---
Introduction of Brachiaria hybrid (forage)	0%	0%	10%	20%	---	---
Introduction of Mombasa Guinea (forage)	0%	0%	18%	35%	---	---
Pig diet						
Removal of Natural pasture	15%	15%	0%	0%	-100%	-100%
Slight increase in Taro leaves	20%	20%	35%	20%	75%	0%
Introducing Elephant grass as a Pig diet	0%	0%	0%	15%	---	---
Banana trunk	60%	60%	60%	60%	0%	0%
Maize (Zea mays) - cracked grains	5%	5%	5%	5%	0%	0%

2 Green elephant is an improved version of Elephant grass that was created to withstand winter conditions

Table 5: Khoa (B1) Integrated Intervention Package

Input/Parameter	Baseline Value		Scenario Value		% Change	
Herd composition (nr):						
Steers/heifers	3		0		-100%	
Pigs - growers	1		3		200%	
Cows local-female	0		2		---	
Calves	0		3		---	
Pigs - dry sows/boars	0		1		---	
Average Body Weight (kg)						
Steers/heifers	190		0		-100%	
Pigs - growers	20		40		100%	
Cows local -female	0		320		---	
Calves	0		25		---	
Pigs - dry sows/boars	0		75		---	
Average annual growth per animal (kg)						
Steers/heifers	50		0		-100%	
Pigs - growers	40		65		63%	
Calves	0		95		---	
Pigs - dry sows/boars	0		65		---	
Feed Items:	***Wet Season***	***Dry Season***	***Wet Season***	***Dry Season***	***Wet Season***	***Dry Season***
Cattle diet						
Removal of Rice (Oryza sativa) - straw	11%	15%	0%	0%	-100%	-100%
Reducing intake of Natural pasture	58%	59%	54%	35%	-7%	-41%
Rice bran	1%	1%	1%	0%	0%	-100%
Removal of Elephant grass	15%	5%	0%	0%	-100%	-100%
Reducing intake of Banana trunk	15%	20%	10%	10%	-33%	-50%
Introduction of Maize (Zea mays) - cracked grains	0%	0%	8%	17%	---	---
Introduction of Green Elephant (Forage)	0%	0%	15%	20%	---	---
Introduction of Mombasa Guinea	0%	0%	12%	18%	---	---
Pig diet						
Natural pasture	5%	1%	5%	1%	0%	0%
reducing intake of Rice bran	30%	30%	29.5%	29.5%	-2%	-2%
Reducing intake of banana trunk	45%	49%	40%	48%	-11%	-2%
Increasing intake of maize (Zea mays) - cracked grains	20%	20%	25%	21%	25%	5%
Introduction of Probiotics to supplement the diet	0%	0%	1%	1%	---	---

Table 6: Oi (B2) Integrated Intervention Package

Input/Parameter	Baseline Value		Scenario Value		% Change	
Herd composition (nr):						
Pigs-dry sows	1		1		0%	
Pigs-growers	4		6		50%	
Adult cattle-male	1		1		0%	
Cows local - female	1		1		0%	
Average Body Weight (kg)						
Pigs-dry sows	70		75		7%	
Pigs-growers	20		40		100%	
Adult cattle-male	360		380		6%	
Cows local - female	300		320		7%	
Average annual growth per animal (kg)						
Pigs-dry sows	0		65		---	
Pigs-growers	40		65		63%	
Parturition interval (years)						
Cows local - female	1.25		1.25		0%	
Feed Items:	***Wet Season***	***Dry Season***	***Wet Season***	***Dry Season***	***Wet Season***	***Dry Season***
Cattle diet						
Removal of Rice (Oryza sativa) - straw	7%	7%	0%	0%	-100%	-100%
Rice (Oryza sativa) - bran	3%	3%	3%	0%	0%	-100%
Reducing intake of Elephant grass	80%	0%	30%	12%	-63%	---
Removal of sugarcane (Saccharum officinarum) - crop residue	0%	80%	0%	0%	---	-100%
Banana trunk	10%	10%	10%	10%	0%	0%
Introduction of Brachiaria hybrid (forage)	0%	0%	20%	25%	---	---
Introduction of Ubon Paspalum	0%	0%	12%	18%	---	---
Introduction of Mombasa Guinea	0%	0%	25%	35%	---	---
Pig diet						
Increasing intake of Rice (Oryza sativa) - bran	10%	10%	15%	15%	50%	50%
Removal of Naturally occurring pasture - green fodder	30%	30%	0%	0%	-100%	-100%
Reducing the intake of banana trunk	50%	50%	40%	40%	-20%	-20%
Removal of maize (Zea mays) - cracked grains	10%	10%	0	0	-100%	-100%
Introducing Mombasa Guinea as a pig diet	0%	0%	30%	30%	---	---
Supplementing the diet with Concentrate	0	0	15%	15%	---	---

Table 7: Buom Khoang (C10) Integrated Intervention Package

Input/Parameter	Baseline Value		Scenario Value		% Change	
Herd composition (nr):						
Cows local - female	2		1		-50%	
Adult cattle - male	0		1		---	
Calves	2		2		0%	
Pigs - growers	2		2		0%	
Average Body Weight (kg)						
Cows local - female	300		320		7%	
Adult cattle - male	0		390		---	
Calves	25		27		8%	
Pigs - growers	10		35		250%	
Average annual growth per animal (kg)						
Calves	80		95		19%	
Pigs - growers	40		65		63%	
Parturition interval (years)						
Cows local - female	1.25		1		-20%	
Feed Items:	***Wet Season***	***Dry Season***	***Wet Season***	***Dry Season***	***Wet Season***	***Dry Season***
Cattle diet						
Removal of Rice (Oryza sativa) - straw	10%	0%	0%	0%	-100%	---
Reducing intake of Naturally occurring pasture - grazing	40%	50%	39%	50%	-3%	0%
Increasing the intake of Naturally occurring pasture - green fodder	30%	0%	35%	0%	17%	---
Increasing intake of Elephant grass	20%	0%	25%	0%	25%	---
Sugarcane (Saccharum officinarum) - crop residue	0%	50%	0%	50%	---	0%
Introduction of Stylo (Stylosanthes guianensis) - in wet season only	0	0	1%	0%	---	---
Pig diet						
Naturally occurring pasture - green fodder	40%	40%	40%	40%	0%	0%
Banana trunk	20%	20%	20%	20%	0%	0%
Maize (Zea mays) - cracked grains	40%	40%	40%	40%	0%	0%

Table 8: Xam Ta (C2) Integrated Intervention Package

Input/Parameter	Baseline Value		Scenario Value		% Change	
Herd composition (nr):						
Cows local - female	5		7		40%	
Steers/heifers	3		0		-100%	
Calves	2		5		150%	
Adult cattle - male	2		2		0%	
Pigs- lactating/pregnant sows	1		1		0%	
Pigs - growers	6		6		0%	
Average Body Weight (kg)						
Cows local - female	360		390		8%	
Steers/heifers	70		0		-100%	
Calves	20		25		25%	
Adult cattle - male	360		390		8%	
Pigs- lactating/pregnant sows	70		80		14%	
Pigs - growers	10		30		200%	
Average annual growth per animal (kg)						
Steers/heifers	130		0		-100%	
Calves	80		95		19%	
Pigs- lactating/pregnant sows	60		60		0%	
Pigs - growers	40		65		63%	
Parturition interval (years):						
Cows local - female	1.25		1		-20%	
Pigs- lactating/pregnant sows	0.5		0.5		0%	
Feed Items:	***Wet Season***	***Dry Season***	***Wet Season***	***Dry Season***	***Wet Season***	***Dry Season***
Cattle diet						
Reduction of Naturally occurring pasture - grazing	100%	100%	100%	80%	0%	-20%
Introduction of Green elephant - forage	0%	0%	0%	10%	---	---
Introduction of Mombasa Guinea	0%	0%	0%	10%	---	---
Pig diet						
Banana trunk	50%	50%	50%	50%	0%	0%
Cassava (Manihot esculenta) - tubers	20%	20%	20%	20%	0%	0%
Maize (Zea mays) - cracked grains	20%	20%	20%	20%	0%	0%
Naturally occurring pasture - green fodder	10%	10%	10%	10%	0%	0%

Figure 4 below shows a legend used to visualize results of the integrated package. Scenarios that resulted in a positive environmental change were represented using "+" signs, and scenarios worsening the current environmental situation were represented using "–" signs. The more "+" or "–" signs a scenario has, the greater the intensity of the environmental change with respect to improved animal health and genetics, composting, and adoption of improved forages.

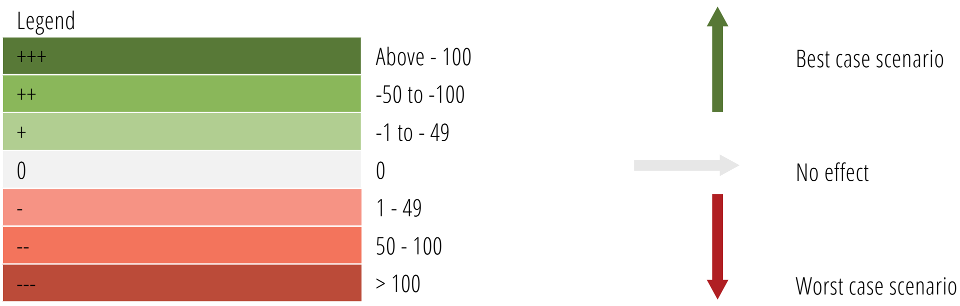

Figure 4: Different color shades and intervals used to visualize Li-chăn scenarios

3. Results

3.1 Baseline Outputs

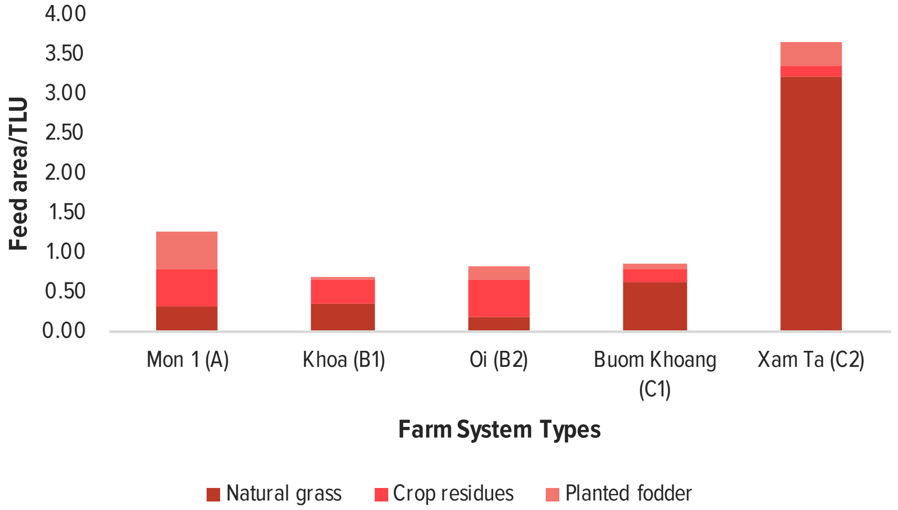

Figure 5: Feed area per Tropical Livestock Unit across the Systems

» Type C systems rely heavily on natural pasture while systems A and B depend mainly on planted forage crops and crop residues for livestock feeding

» Feed area/TLU varies greatly across the systems[3]

» More area per TLU is required to produce feeds in System C2

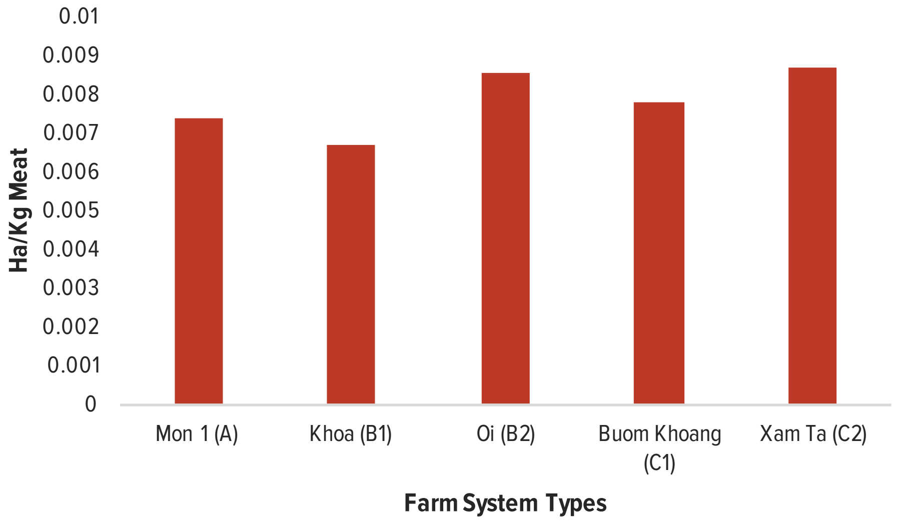

Figure 6: Total feed area required to produce a kilogram of beef or pork across the Systems

» Relatively large land requirements per Kg of meat produced across the systems but mostly in systems C2 and B2.

» Out of the five systems modelled, B1 is the most land use efficient system.

3 Application of method 3 in conversion of Tropical Livestock Unit (TLU) in the context of measuring biomass. Ostrow et al. (2020). Tropical Livestock Units: Re-evaluating a Methodology. Frontiers in Veterinary Science. 7. http://dx.doi.org/10.3389/fvets.2020.556788

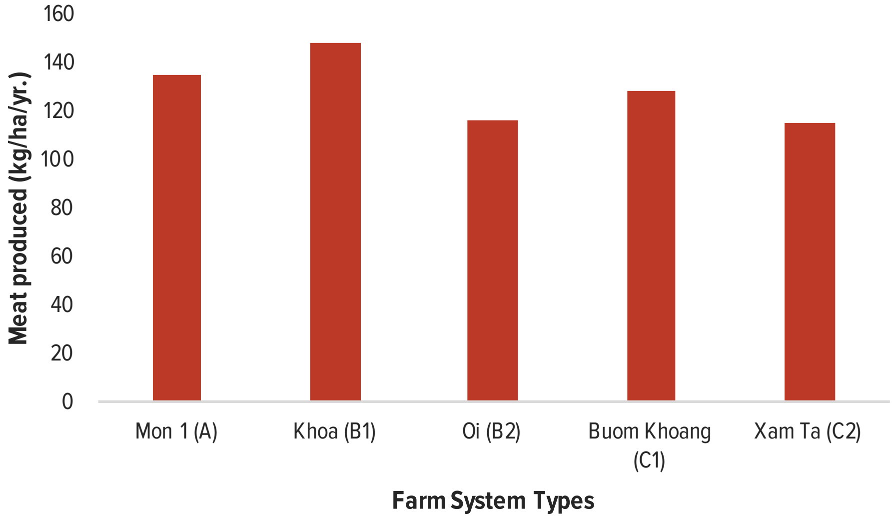

Figure 7: Productivity across the systems

- Out of the five systems assessed, B1 is the most productive system
- Land productivity is lowest in systems C2 despite producing more meat in total.

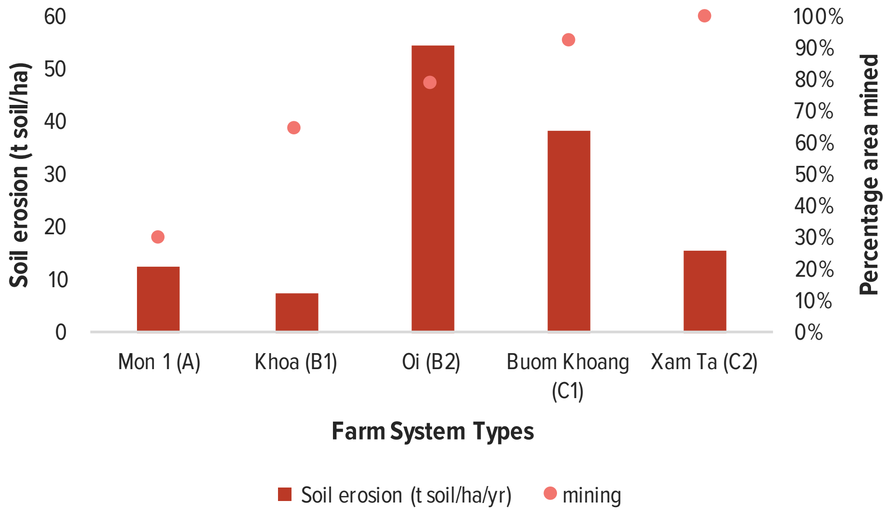

Figure 8: Soil nutrient balance and erosion across the systems

- Most soil is lost through erosion in systems B2 and C1 due to topography and continuous cultivation practices.
- The extent of nitrogen mining is highest in systems C1 and C2 that reported low crop inputs.
- Minimal nutrient mining in systems A and B1 due to high inputs of inorganic fertilizer in addition to recycling of livestock manure and practicing mulching.

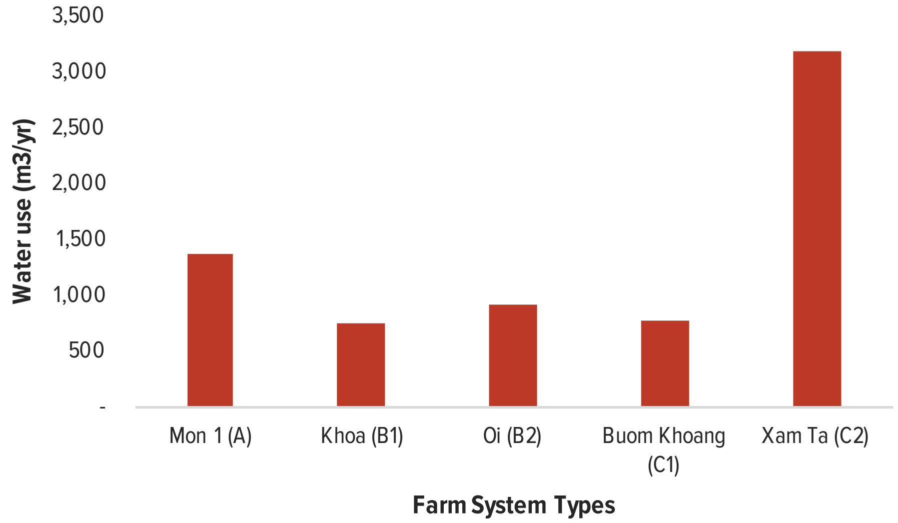

Figure 9: Total water use in the systems

» Most water is required in C2 due to the bigger herd size.

» Total water use correlates with rainfall within the region.

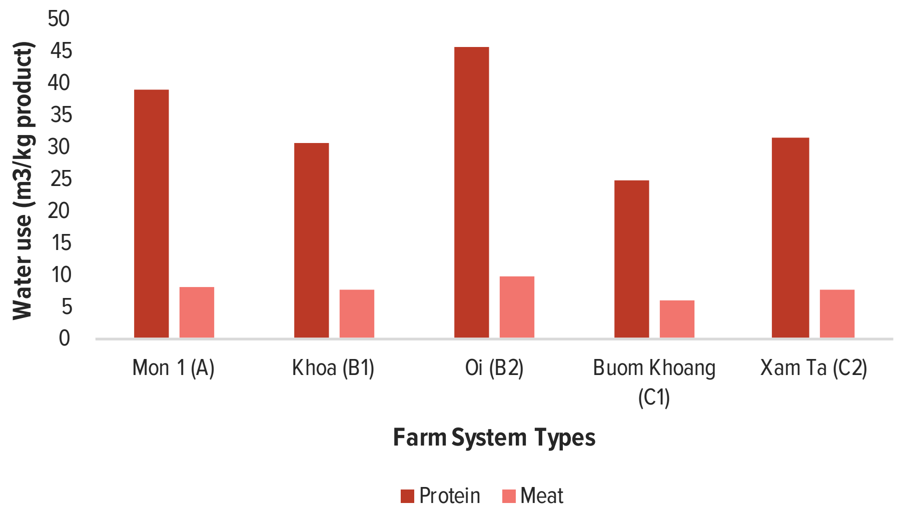

Figure 10: Water required to produce one kilogram of meat and protein in the systems

» C1 is the most water efficient system; most water is used per kg of meat or kg of protein in B2.

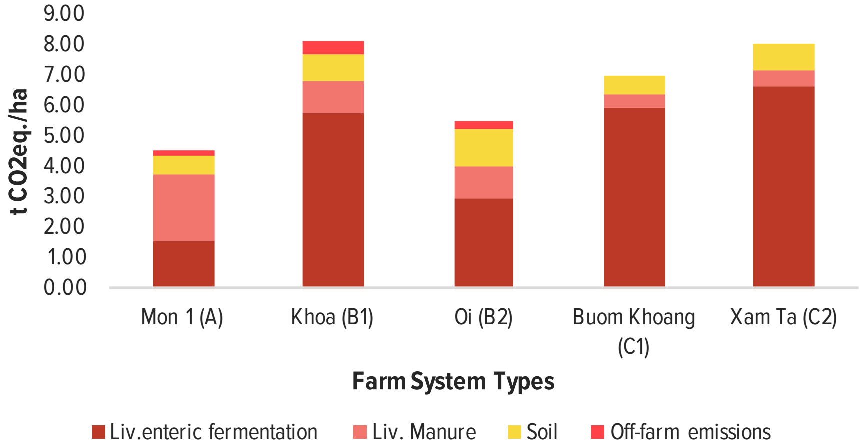

Figure 11: Sources of Greenhouse gas emissions

- In all the systems, enteric fermentation was the main source of GHGe followed by manure use.
- Off-farm emissions are common in Systems type A and B due to high use of mineral fertilizer.

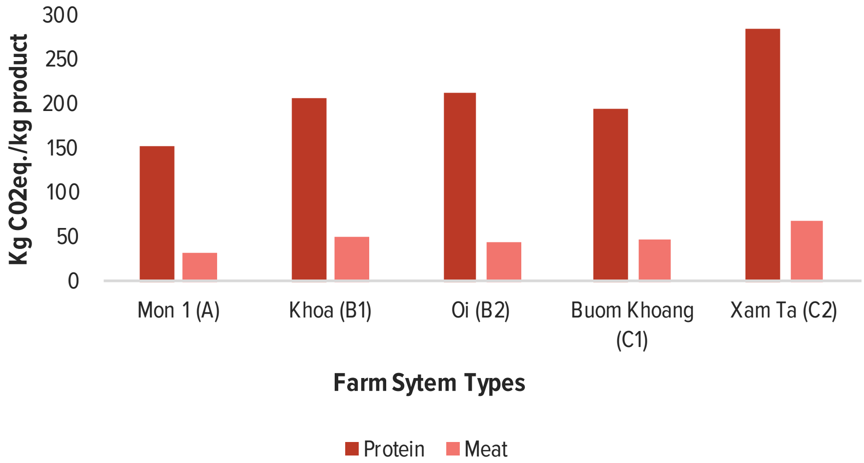

Figure 12: Greenhouse gas emission intensity per kg of livestock product

- The emission intensity of producing a kilogram of meat and protein is higher in Xam Ta (C2) than other systems.
- Mon 1 (A) exhibits the lowest carbon footprint when producing a kilogram of meat and protein.

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

Table 9: Environmental trade-offs and synergies of the integrated Li-chăn interventions

	Land requirements		Production	Soil impacts			Water impacts			GHG emissions		
Farm System Types	ha/yr	Ha/kg meat	Meat produced (kg/year)	% Area N mining	Erosion (t soil/yr)	Erosion (t soil/ha/yr)	m3/year	m3/kg meat	m3/kg protein	t CO2eq./year	kg CO2 eq. /kg meat	kg CO2eq./kg protein
System A (Mon 1)	-	+	++	+	-	-	-	+	+	--	+	+
System B1 (Khoa)	--	+	+++	+	-	+	--	+	+	-	++	++
System B2 (Oi)	++	++	+++	-	++	++	+	++	++	+	++	++
System C1 (Buom Khoang)	-	+	+	+	-	+	-	+	+	-	+	+
System C2 (Xam Ta)	-	+	+	+	+	+	-	+	-	-	-	-

- Extra land is required to produce more meat in all systems except B2 where area required for feed production is expected to reduce by 53%.
- There is a significant increase in meat production expected across the systems due to increases in animal live weight gains.
- The integrated intervention packages promoted by Li-chăn show synergies as there are overall environmental efficiency gains per unit of output in most systems.
- System B2 is likely to experience the highest environmental gains with the ongoing implementation of Li-chăn initiatives.

Villagers burn straw to make land available for growing new crop. This causes air pollution and farmers are advised to bring the straw home to feed their cattle, to make compost as an organic fertiliser, and grow delicious mushrooms. 📷 Lèo Thị Xiền

“Learning from the training by the Li-chăn project, I know that mixing rice bran helps fermentation, and sealing the bags protects the air-free silage from mold or rotting. My cattle prefer fermented grass” - Lò Văn Thương a farmer from Thailand. Lường Văn Yêu

4. Discussion

The baseline results from the CLEANED assessment were useful for examining the current environmental The baseline results from the CLEANED assessment were useful for examining the current environmental impacts of both cattle and pig production systems even before implementing Li-chăn interventions in all the systems. Across the five systems, there was a higher dependence of natural pasture than on any other type of feed. About 63% of the total land requirement for the combined livestock systems was associated with natural grass, 23% with crop residues, and the remaining 14% with planted forage crops. Type C systems rely heavily on natural pasture while systems A and B depend mainly on planted forage crops and crop residues for livestock feeding (Figure 5). This is attributed to differences in geographical location and production systems where systems in high altitudes (C1 and C2) have more access to communal grazing lands while those in mid altitudes and lowlands depend entirely on their small portions of land for forage and crop production.

It was observed that feed area/TLU varies significantly in relation to feed crop yields and feed quality across the systems. There are relatively large land requirements per Kg of meat produced across the systems but most in systems C2 and B2 (Figure 6). This is driven by high dependence on natural pasture (system C2) and crop residues (system B2) that are usually associated with low yields. Land use efficiency is relatively high in systems B1 due to high biomass yielding planted forage (elephant grass) and relatively high yielding crop residues (sugarcane tops and banana trunks). Out of the five systems assessed, B1 is the most productive system (Figure 7). Productivity is lowest in system C2 due to low feed efficiency.

CLEANED results illustrated a high nitrogen (N) loss in all systems. System A had the lowest extent of area where nitrogen (N) is mined, i.e., 30% compared to the 64-100% N mining in other production systems (Figure 8). The minimal nutrient mining in Systems A and B are mainly due to high input flows of mineral fertilizer, recycling of organic manure, and better soil health practices such as green manuring and mulching. The extent of nitrogen mining is highest in systems C1 and C2, both of which reported low crop inputs. A complete depletion of nitrogen in these systems can be attributed to low fertilizer flows, burning of crop residues that could otherwise provide the vital nutrients to the soils, and poor recycling of livestock manure due to grazing nature of the systems (most manure is dropped off-farm). In terms of soil erosion, systems B2 and C1 are losing more soil per hectare than other systems (Figure 8). Along with the intense crop cultivation practices, the region's high precipitation levels, limited cover crops and continuous cultivation activities along the slopes, and topographical nature contributes to their significant soil erosion.

Water use corresponds well with rainfall and type of feed crops grown within the region. Accounting for total water use in a year, B1 is the most water efficient system followed by B2 and C1 (Figure 9). High water requirements in system C2 correlate with high livestock numbers and high usage of natural pasture that require a lot of water for growth. However, on relative terms i.e., m3/kg product, C1 is the most water efficient system. Most water is required to produce a kilogram of protein and meat in systems A and B2 (Figure 10).

Enteric fermentation is the major source of GHG emissions in most systems (Figure 11). 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. System A does not experience a high emission of enteric fermentation because of its improved feed efficiency as a result of planted forages occupying a significant portion of the land. Both pigs and cattle consume higher quality feed in System A and therefore generate lower methane emissions. Other major sources of GHGe across the systems include manure use and N20 emissions produced from managed soil, grazing and rice fields. Poor manure management also increases emissions as result a of increased volatilization activity in the soil. System C2 emits more GHG when producing a kilogram of meat and protein than other systems. System A is more carbon efficient when producing a kilogram of meat and protein (Figure 12).

Integrated Li-chăn interventions are likely to result in increased meat production and reduced environmental footprints per unit of outputs in the multi-species production systems (Table 9). Total land requirements are expected to increase by an average of 30% in all systems except in system B2 where area for feed reduces by 53%. The reduced land requirement in system B2 is attributed to its highly improved and yielding feed basket compared to the other systems. Additionally, the area required to produce a kilogram of beef or pork is significantly reducing by an average of 32% across the systems due to improved yielding of the new forages.

Production is also increasing across all systems due to better animal health, improved genetics and increased feed efficiency. In matters soil health, systems B1, B2, C1 and C2 would experience a reduction in soil loss per hectare while in system A erosion is expected to increase by a small fraction. Although nitrogen depletion in the soil is expected to decrease for most systems, B2 is likely to experience an increase in area mining of up to 22%.

The implementation of the integrated package is expected to reduce water use per kg of meat by an average of 33% in all systems, along with 40% reductions in water use per kg of protein in all systems except Xam Ta where it will slightly increase by 3%. Total greenhouse gas emissions are projected to increase by an average of 35% in all systems except B2 where they will reduce by 27%. However, the emission intensity of producing a kilogram of meat is reducing across the systems except C2 where a 10% increase is expected.

Although none of the systems in the integrated package are expected to experience environmental gains across all indicators, the livestock production system in Oi experiences the largest environmental gains. Despite the foreseen total increases in water use and GHGe in almost all systems, a relative reduction i.e., m^3/kg product and kg CO2eq./kg product, shows a greater pathway for an eventual future decrease.

Quàng Thị Thuấn

Lường Thị Dung

Quàng Thị Thuấn feeding her pigs with fermented banana stems mixed with a little bran. She learnt this from Li-chăn (project's) training and comments that her pigs are growing rapidly and healthily. Quàng Thị Nương

5. Conclusion and Recommendations

When it comes to extensive production systems that rely heavily on natural pasture for grazing, land area requirements will always be a challenge. In the NWH, land suitable for agriculture is already a challenge due to environmental constraints caused by steep slopes, uneven grounds, low soil fertility, and high rates of soil erosion. The low energy and crop yields of naturally occurring pastures require a large land mass to sustainably provide enough feed for the cattle and pigs. Farms located in higher altitudes of the NWH such as those in C1 and C2 may not experience an issue with increased land requirements since there is enough land for expansion. However, farms located in mid altitudes (B1 and B2) and lowlands (A) would encounter problems with increased land needs.

Eliminating natural pastures is neither ideal nor environmentally reasonable in the high altitudes. However, further expansion of natural pasture as a feeding strategy without addition of high-quality feed items is not environmentally sustainable due to the associated high emissive diet. A promising solution to prevent further expansion of land particularly in type A and B systems is to further reduce crop residue feeding and encourage farmers to adopt the newly introduced varieties with higher biomass and nutrient yields to support the vision of increased productivity within a small piece of land.

Improved animals that are more energy efficient are more likely to consume less water, produce more, conserve soil and emit less waste in the form of enteric fermentation which is a major source of GHGe in almost all the modeled systems. Production of high-yielding crops and forages can minimize water lost through evapotranspiration and decrease the amount of water required for growth and energy. GHG emissions from manure can also be reduced by proper management and encouraging nutrient recycling in all systems. Improving soil coverage is key especially in the terrain areas to cushion the farmers against both soil erosion and nutrient loss through precipitation or other natural forces down the hills.

Systems A, B1, C1, and C2 are recommended to increase the proportion of improved forages in their diet. For any system to have a complete environmental gain, the proportion of quality feed in the entire feed basket should be greater than the low-quality diet. Along with the adjustment of the feed basket, both systems A and B1 have expanded their herd size in the intervention scenario. The increase in feed demand for animals feeding on poor livestock diet will lead to a direct increase in adverse environmental impacts. Therefore, careful consideration of the feed basket is a prerequisite before physical intensification.

Overall, the Li-chăn integrated intervention package shows synergies as there is an overall environmental efficiency gain per unit of most outputs. However, to boost overall environmental efficiencies and/or achieve absolute reductions, this study recommends greater intake of the improved varieties. A few assumptions were made for the scenario feed interventions during the winter period, and therefore we are yet to know the levels of both adaptation and yielding for the subsequent cuts. We therefore recommend a second assessment next year to validate the scenario results.

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Annex 1: CLEANED Input Data

1. Mon 1 (System A)

Input/Parameter	Value	Source
Herd composition (nr):		
Adult cattle - male	2	G-FEAST report, verified by Huyen and Ngoc
Pigs - growers	7	G-FEAST report, verified by Huyen and Ngoc
Average body weight (kg):		
Adult cattle - male	225	G-FEAST report, verified by Huyen and Ngoc
Pigs - growers	17	G-FEAST report, verified by Huyen and Ngoc
Average annual growth per animal (kg):		
Pigs - growers	40	G-FEAST report, verified by Huyen and Ngoc
Agro-ecological data:		
Annual precipitation (mm/yr)	1570	G-FEAST report
Rainy season (no of months/year)	6	G-FEAST report
Soil type (World Reference Base)	Haplic Acrisols	ISRIC
SoilN (g/kg)	0.45	https://soilgrids.org/
SoilC (g/kg)	7.5	https://soilgrids.org/
Soil clay (%)	42.7	https://soilgrids.org/
Bulk density (g/cm3)	1.33	https://soilgrids.org/
Soil depth (m)	2	https://soilgrids.org/
ET0 (mm/year)	1460	FAO
Crop/forage yields:		
Rice (Oryza sativa) -(DM Yield tonne/ha)	3.64	G-FEAST report, verified by Pham Ngan
Naturally occurring pasture - grazing (DM Yield tonne/ha)	13.10	G-FEAST report, verified by Pham Ngan
Elephant grass (DM Yield tonne/ha)	59.5	G-FEAST report, verified by Pham Ngan
Banana (DM Yield tonne/ha)	4.712	G-FEAST report, verified by Pham Ngan
Maize (Zea mays) - cracked grains (DM Yield tonne/ha)	4.15	G-FEAST report, verified by Pham Ngan
Sugarcane (Saccharum officinarum) (DM Yield tonne/ha)	7.72	G-FEAST report, verified by Pham Ngan
Taro (DM Yield tonne/ha)	7.50	Elizabeth et al. 2020, https://doi.org/10.1016/bs.afnr.2020.06.005
Brachiaria hybrid (t FW/ha), 1st and 2nd cut	47.7	Atieno et al., 2021
Green elephant (t FW/ha), 1st and 2nd cut	83	Atieno et al., 2021
Mombasa Guinea (t FW/ha), 1st and 2nd cut	58.7	Atieno et al., 2021

2. Khoa (System B1)

Input/Parameter	Value	Source
Herd composition (nr):		
Steers/heifers	3	G-FEAST report, verified by Huyen and Ngoc
Pigs - growers	1	G-FEAST report, verified by Huyen and Ngoc
Average body weight (kg):		
Steers/heifers	190	G-FEAST report, verified by Huyen and Ngoc
Pigs - growers	20	G-FEAST report, verified by Huyen and Ngoc
Average annual growth per animal (kg):		
Steers/heifers	50	G-FEAST report, verified by Huyen and Ngoc
Pigs - growers	40	G-FEAST report, verified by Huyen and Ngoc
Agro-ecological data:		
Annual precipitation (mm/yr)	1390	G-FEAST report
Rainy season (no of months/year)	6	G-FEAST report
Soil type (World Reference Base)	Haplic Acrisols	ISRIC
SoilN (g/kg)	0.45	https://soilgrids.org/
SoilC (g/kg)	7.5	https://soilgrids.org/
Soil clay (%)	42.7	https://soilgrids.org/
Bulk density (g/cm3)	1.33	https://soilgrids.org/
Soil depth (m)	2	https://soilgrids.org/
ET0 (mm/year)	1460	FAO
Crop/forage yields:		
Rice (Oryza sativa) - (DM Yield tonne/ha)	3.64	G-FEAST report, verified by Pham Ngan
Natural pasture (Average of grazing + collected forage) - (DM Yield tonne/ha)	13.10	G-FEAST report, verified by Pham Ngan + Expert data
Elephant grass (DM Yield tonne/ha)	59.50	G-FEAST report, verified by Pham Ngan
Banana (DM Yield tonne/ha)	4.71	G-FEAST report, verified by Pham Ngan
Maize (Zea mays) - cracked grains (DM Yield tonne/ha)	4.15	G-FEAST report, verified by Pham Ngan
Green elephant (t FW/ha), 1st and 2nd cut	76.30	Atieno et al., 2021
Mombasa Guinea (t FW/ha), 1st and 2nd cut	48.40	Atieno et al., 2021

3. Oi (System B2)

Input/Parameter	Value	Source
Herd composition (nr):		
Pigs-dry sows	1	G-FEAST report, verified by Huyen and Ngoc
Pigs-growers	4	G-FEAST report, verified by Huyen and Ngoc
Adult cattle-male	1	G-FEAST report, verified by Huyen and Ngoc
Cows local - female	1	G-FEAST report, verified by Huyen and Ngoc
Average annual growth(kg)		
Pigs- growers	40	G-FEAST report, verified by Huyen and Ngoc
Average Body weight (kg)		
Pigs- dry sows	70	G-FEAST report, verified by Huyen and Ngoc
Pig - growers	20	G-FEAST report, verified by Huyen and Ngoc
Adult cattle -male	360	G-FEAST report, verified by Huyen and Ngoc
Cows local - female	300	G-FEAST report, verified by Huyen and Ngoc
Parturition interval (years)		G-FEAST report, verified by Huyen and Ngoc
Cows local - female	1.25	G-FEAST report, verified by Huyen and Ngoc
Agro-ecological data		
Annual precipitation (mm/yr)	1570	G-FEAST report
Rainy season (no of months/year)	6	G-FEAST report
Soil type (World Reference Base)	Haplic Acrisols	ISRIC
SoilN (g/kg)	1.16	https://soilgrids.org/
SoilC (g/kg)	6.4	https://soilgrids.org/
Soil clay (%)	34.7	https://soilgrids.org/
Bulk density (g/cm3)	1.28	https://soilgrids.org/
Soil depth (m)	1.63	https://soilgrids.org/
ET0 (mm/year)	1460	FAO
Crop/forage yields:		
Rice (Oryza sativa) - (DM Yield tonne/ha)	3.64	G-FEAST report, verified by Pham Ngan
Naturally occurring pasture - green fodder (DM Yield tonne/ha)	4.30	G-FEAST report, verified by Pham Ngan
Elephant grass (DM Yield tonne/ha)	59.50	G-FEAST report, verified by Pham Ngan
Banana (DM Yield tonne/ha)	4.71	G-FEAST report, verified by Pham Ngan
Maize (Zea mays) - cracked grains (DM Yield tonne/ha)	4.15	G-FEAST report, verified by Pham Ngan
Sugarcane (Saccharum officinarum) - (DM Yield tonne/ha)	7.72	G-FEAST report, verified by Pham Ngan
Brachiaria hybrid (t FW/ha), 1st and 2nd cut	42.40	Atieno et al., 2021
Ubon Paspalum (t FW/ha), 1st and 2nd cut	42.30	Atieno et al., 2021
Mombasa Guinea (t FW/ha), 1st and 2nd cut	48.40	Atieno et al., 2021

4. Buom Khoang (System C1)

Input/Parameter	Value	Source
Herd composition (nr):		
Pigs-dry sows	1	G-FEAST report, verified by Huyen and Ngoc
Pigs-growers	4	G-FEAST report, verified by Huyen and Ngoc
Adult cattle-male	1	G-FEAST report, verified by Huyen and Ngoc
Cows local - female	1	G-FEAST report, verified by Huyen and Ngoc
Average annual growth(kg)		
Pigs- growers	40	G-FEAST report, verified by Huyen and Ngoc
Average Body weight (kg)		
Pigs- dry sows	70	G-FEAST report, verified by Huyen and Ngoc
Pig - growers	20	G-FEAST report, verified by Huyen and Ngoc
Adult cattle -male	360	G-FEAST report, verified by Huyen and Ngoc
Cows local - female	300	G-FEAST report, verified by Huyen and Ngoc
Parturition interval (years)		G-FEAST report, verified by Huyen and Ngoc
Cows local - female	1.25	G-FEAST report, verified by Huyen and Ngoc
Agro-ecological data		
Annual precipitation (mm/yr)	1570	G-FEAST report
Rainy season (no of months/year)	6	G-FEAST report
Soil type (World Reference Base)	Haplic Acrisols	ISRIC
SoilN (g/kg)	1.16	https://soilgrids.org/
SoilC (g/kg)	6.4	https://soilgrids.org/
Soil clay (%)	34.7	https://soilgrids.org/
Bulk density (g/cm3)	1.28	https://soilgrids.org/
Soil depth (m)	1.63	https://soilgrids.org/
ET0 (mm/year)	1460	FAO
Crop/forage yields:		
Rice (Oryza sativa) - (DM Yield tonne/ha)	3.64	G-FEAST report, verified by Pham Ngan
Naturally occurring pasture - green fodder (DM Yield tonne/ha)	4.30	G-FEAST report, verified by Pham Ngan
Elephant grass (DM Yield tonne/ha)	59.50	G-FEAST report, verified by Pham Ngan
Banana (DM Yield tonne/ha)	4.71	G-FEAST report, verified by Pham Ngan
Maize (Zea mays) - cracked grains (DM Yield tonne/ha)	4.15	G-FEAST report, verified by Pham Ngan
Sugarcane (Saccharum officinarum) - (DM Yield tonne/ha)	7.72	G-FEAST report, verified by Pham Ngan
Stylo (Stylosanthes guianensis), (t FW/ha), 1st and 2nd cut	10.50	Atieno et al., 2021

5. Xam Ta (System C2)

Input/Parameter	Value	Source
Herd composition (nr):		
Cows local - female	5	G-FEAST report, verified by Huyen and Ngoc
Steers/heifers	3	G-FEAST report, verified by Huyen and Ngoc
Calves	2	G-FEAST report, verified by Huyen and Ngoc
Adult cattle - male	2	G-FEAST report, verified by Huyen and Ngoc
Pigs- lactating/pregnant sows	1	G-FEAST report, verified by Huyen and Ngoc
Pigs - growers	6	G-FEAST report, verified by Huyen and Ngoc
Average Body weight (kg):		
Cows local - female	360	G-FEAST report, verified by Huyen and Ngoc
Steers/heifers	70	G-FEAST report, verified by Huyen and Ngoc
Calves	20	G-FEAST report, verified by Huyen and Ngoc
Adult cattle - male	360	G-FEAST report, verified by Huyen and Ngoc
Pigs- lactating/pregnant sows	70	G-FEAST report, verified by Huyen and Ngoc
Pigs- growers	10	G-FEAST report, verified by Huyen and Ngoc
Average annual growth (kg):		
Steers/heifers	130	G-FEAST report, verified by Huyen and Ngoc
Calves	80	G-FEAST report, verified by Huyen and Ngoc
Pigs- lactating/pregnant sows	60	G-FEAST report, verified by Huyen and Ngoc
Pigs - growers	40	G-FEAST report, verified by Huyen and Ngoc
Parturition interval (years):		
Cows local - female	1.25	G-FEAST report, verified by Huyen and Ngoc
Pigs- lactating/pregnant sows	0.5	G-FEAST report, verified by Huyen and Ngoc
Agro-ecological data:		
Annual precipitation (mm/yr)	1390	G-FEAST report
Rainy season (no of months/year)	6	G-FEAST report
Soil type (World Reference Base)	Haplic Acrisols	ISRIC
SoilN (g/kg)	0.45	https://soilgrids.org/
SoilC (g/kg)	7.5	https://soilgrids.org/
Soil clay (%)	42.7	https://soilgrids.org/
Bulk density (g/cm3)	1.33	https://soilgrids.org/
Soil depth (m)	2	https://soilgrids.org/
ET0 (mm/year)	1460	FAO
Crop/forage yields:		
Naturally occurring pasture - grazing (DM Yield tonne/ha)	13.10	G-FEAST report, verified by Pham Ngan
Naturally occurring pasture - green fodder (DM Yield tonne/ha)	4.30	G-FEAST report, verified by Pham Ngan
Cassava (Manihot esculenta) - crop residue (DM Yield tonne/ha)	11.27	G-FEAST report, verified by Pham Ngan
Banana (DM Yield tonne/ha)	4.71	G-FEAST report, verified by Pham Ngan
Maize (Zea mays) - cracked grains (DM Yield tonne/ha)	4.15	G-FEAST report, verified by Pham Ngan
Green elephant (t FW/ha), 1st and 2nd cut	82.10	Atieno et al., 2021
Mombasa Guinea (t FW/ha), 1st and 2nd cut	47.10	Atieno et al., 2021

Notes: Le Thi Huyen (Animal Genetics Expert) and Trần Thị Bích Ngọc (Animal Nutrition Expert) - National Institute of Animal Science, Vietnam; Expert data from Emmanuel Mwema, Research Consultant - Alliance of Bioversity International and CIAT; and Pham Ngan –Environmetrics student at McGill University Canada (She was interning at Alliance of Bioversity International and CIAT – Hanoi office at the time of assessments).

Annex 2: Baseline and scenario results

Farm System Types	Land requirements				Production		Soil impacts					
	Baseline		Scenario		Baseline	Scenario	Baseline			Scenario		
	ha/yr	Ha/kg meat	ha/yr	Ha/kg meat	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)
System A (Mon 1)	1.242	0.007	1.404	0.005	168.000	273.000	30%	12.666	15.735	28%	14.733	20.692
System B1 (Khoa)	0.666	0.007	1.147	0.004	99.000	259.500	64%	7.306	4.863	41%	6.203	7.114
System B2 (Oi)	0.823	0.009	0.390	0.001	96.000	273.000	79%	54.657	44.981	96%	20.101	7.833
System C1 (Buom Khoang)	0.996	0.008	1.245	0.007	128.000	173.000	92%	38.559	38.424	89%	34.801	43.326
System C2 (Xam Ta)	3.637	0.009	3.993	0.008	419.000	471.500	100%	15.834	57.594	80%	12.411	49.561

Farm System Types	Water Impacts						GHG Emissions					
	Baseline			Scenario			Baseline			Scenario		
	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
System A (Mon 1)	1371.533	8.164	38.876	1604.024	5.876	27.979	5.365	31.932	152.055	8.406	30.792	146.627
System B1 (Khoa)	751.924	7.595	30.641	1153.010	4.443	18.712	5.104	51.552	207.972	6.488	25.002	105.291
System B2 (Oi)	925.152	9.637	45.890	484.989	1.777	8.460	4.280	44.581	212.293	3.471	12.715	60.550
System C1 (Buom Khoang)	983.740	7.685	31.857	1134.940	6.560	27.628	5.989	46.791	193.950	7.802	45.100	189.930
System C2 (Xam Ta)	3192.436	7.619	31.378	3580.728	7.594	32.291	29.036	69.298	285.395	36.005	76.362	324.687

Sồng Thị Dụ, a farmer weeding the newly planted Mulato grass which was intercropped in the plum field. When the photo was taken, the grass had been planted only 10 days previously. Some people kill weeds, but we grow weeds. The distance between plum trees is six metres, giving space to grow grass. I plant grass to feed our cattle while creating shade, keeping moisture in the soil and preventing erosion. 📷 Lý A Trống

Farmers harvesting Guinea grass trialled in the Li-chăn project.
📷 (left) Hà Văn Kim, (right) Lò Văn Tân

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