MODELAÇÃO DA SUSTENTABILIDADE DA AGRICULTURA FAMILIAR NO HUAMBO: CENÁRIOS ALTERNATIVOS EXPLORADOS ATRAVÉS DE PROGRAMAÇÃO LINEAR ETNOGRÁFICA (PLE)

MODELING FAMILY FARMING SUSTAINABILITY IN HUAMBO: ALTERNATIVE SCENARIOS EXPLORED THROUGH ETHNOGRAPHIC LINEAR PROGRAMMING (PLE)

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GT 5: Agricultura Familiar e relações de gênero no meio rural

Resumo
O objetivo deste estudo foi construir um modelo etnográfico de programação linear para os agricultores familiares do Huambo, com vista a estimar os seus rendimentos actuais e identificar e testar cenários alternativos de sustentabilidade, nas dimensões económica e social, que tenham em conta as potencialidades e desafios da agricultura familiar. O modelo foi construído em quatro etapas: (i) elaboração do questionário para recolha de informação; (ii) pré-teste do questionário para validação e posterior replicação; (iii) seleção do agregado familiar cuja informação será usada para validar e ajustar o modelo; e (iv) elaboração do modelo PLE. Os resultados mostram que os modelos para os muito pequenos e pequenos agricultores não lhes permitem ultrapassar o limiar de pobreza (são pobres), enquanto os médios e grandes agricultores estão acima da pobreza. A introdução de novas variedades de sementes certificadas com elevado índice de produção e, no caso da pecuária, a introdução de cabritos com dois nascimentos por ano, revelaram-se eficazes e, no que respeita à sustentabilidade económica, o rendimento líquido anual da exploração com novas tecnologias e o rendimento líquido anual per capita com novas tecnologias é positivo para todos os tipos de agricultores identificados.
Palavras-chave: Agricultura familiar, cenários alternativos, pobreza, Huambo.

Abstract
The aim of this study was to build an ethnographic linear programming model for family farmers in Huambo in order to estimate their current incomes and identify and test alternative sustainability scenarios, in the economic and social dimensions, which take into account the potential and challenges of family farming. The model was built in four stages: (i) drawing up the questionnaire to collect information; (ii) pre-testing the questionnaire for validation and subsequent replication; (iii) selecting the household whose information will be used to validate and adjust the model; and (iv) drawing up the PLE model. The results show that the models for very small and small farmers do not allow them to exceed the poverty line (they are poor), while medium and large farmers are above poverty. The introduction of new certified seed varieties with a high production index and, in the case of livestock, the introduction of kids with two births a year, proved to be effective and, in terms of economic sustainability, the annual net income of the farm with new technologies and the annual net income per capita with new technologies is positive for all the types of farmers identified.
Key words: Family farming, alternative scenarios, poverty, Huambo.

1. Introduction

Family farming is a production system primarily focused on family self-sufficiency, with varying degrees of market engagement, and it plays a fundamental role in the rural economy

(Galdeano-Gomez et al., 2017). This system is mainly characterized by the predominance of family labor and specific patterns of land succession, typically passed down from generation to generation (Taveira et al., 2019). Family farming preserves and relies on local knowledge, adaptability, and traditional know-how, which are transmitted across generations.

In many countries, family farming represents a vital sector, both socially and in terms of agricultural production value. Despite its undeniable importance, it faces numerous challenges, including decapitalization, limited access to credit, weak market integration, precarious land tenure, restricted land use, and inadequate access to technical assistance and other support services. Also, family farmers often struggle with low land capitalization and organizational weaknesses.

Family farmers navigate a complex landscape of crises and pressures that affect both their livelihoods and agricultural productivity. These challenges span multiple dimensions, including agricultural production, market access, pricing, and broader socio-economic factors such as aging populations, poverty, labor shortages, and restricted access to essential agricultural technologies and information (Touch et al., 2024). The cumulative effect of these constraints significantly impacts their well-being, economic stability, and long-term sustainability in agriculture.

In response to rising agricultural input costs, many family farmers seek to reduce their reliance on modern inputs but fear potential yield declines. Some have considered adopting organic fertilizers and composting as adaptive strategies but are often discouraged by limited access to raw materials and labor constraints (Milkias & Degefu, 2024).

Given the complex interplay of social, economic, and biophysical factors in smallholder farming systems, it is essential that farmers actively participate in the development of transdisciplinary innovations. This process must fully account for the diverse challenges shaping farming systems, recognizing that farmers are not a homogeneous group and will have varying expectations and priorities in research and innovation efforts (Musvoto et al., 2015).

In this context, the sustainability of family farms depends on their transformation rather than mere preservation, with long-term economic viability as a key focus of rural policies (van Vliet et al., 2015). To enhance income and reduce market and climate-related risks, family farmers may diversify their crop production, while agricultural diversity and income levels can also be influenced by off-farm employment (Ochoa et al., 2019).

Ensuring access to technology for family farmers is an important strategy for promoting both economic and social sustainability. However, evaluating alternative innovation pathways must prioritize the fair distribution of benefits and address inequalities in access to resources and services. This evaluation should be an ongoing process, integrated from the earliest stages of innovation development, to guarantee a broad and equitable distribution of services, benefits, and impacts across farming communities.

The impact of future technological advancements on crop yields remains uncertain, yet the assumptions surrounding these changes are fundamental to the evolution of agricultural areas. Technology enhances access to information and markets while boosting productivity. However, several challenges hinder its widespread adoption (Choruma, 2024). As noted by Souza Filho et al. (2021), technological trajectories —shaped both upstream and downstream of agriculture — create varying opportunities for farmers depending on their position in the production chain, geographical location, scale of operation, and organizational structure.

Across the African continent, small farms dominate the agricultural landscape, playing a decisive role in food production and poverty reduction. However, yields and productivity levels remain low, primarily due to limited access to production technology. The key challenge for these farms is bridging the gap between current and potential yields and incomes (Gassner et al., 2019). African farmers face significant demands, including food insecurity, climate change adaptation, inadequate access to locally suitable technologies, and persistent poverty. Low agricultural productivity and vulnerability to natural disasters, such as droughts, floods, and cyclones, directly impact food security and the well-being of rural families (Marassiro et al., 2021).

Angolan agriculture is marked by diversity and heterogeneity in technology use, with notable regional differences and disparities between family and corporate farming. Despite these challenges, family farming remains the dominant economic activity, currently accounting for approximately 81% of cereal production, 92% of roots and tubers, 89% of legumes and oilseeds, 85% of meat, and 30% of fish production (MINAGRIP, 2020). The average family farm size in Angola is 1.85 hectares, while in Huambo, it is 2.6 hectares. Huambo province has the largest cultivated area in the country, representing about 19% of Angola's total cultivated land (INE, 2022).

In Huambo, family farming systems are diverse and classified into four categories based on farm size: very small (area ≤ 1 ha), small (1 < area ≤3 ha), medium (3 < area ≤ 5 ha), and large (5 < area ≤ 20 ha). Small farms are the most prevalent. Manual cultivation dominates among smaller farms, while the use of animal and mechanical traction, modern inputs, and off-farm labor increases with farm size (Kamutali et al., 2024).

As a result, poverty, hunger, and food insecurity tend to be more severe among smaller farm households. Under current conditions, these systems are not capable of significantly reducing poverty levels. Angola faces high levels of poverty, particularly in rural areas, where the poverty rate stands at 57.2%. Family farmers - the country's primary food producers - struggle with numerous challenges in sustaining agricultural production and ensuring the well-being of their households (INE, 2022).

This article aims to identify solutions to the constraints and poverty affecting family farming systems in Huambo through the application of ethnographic linear programming (ELP). Following this introduction, a literature review examines modeling techniques for family farming systems, with a particular focus on PLE. The methodology section outlines the structure of the PLE model, the alternative technologies assessed, and the key results obtained. Finally, the article concludes with findings and policy recommendations aimed at improving the livelihoods and living conditions of rural families in Huambo province.

2. Literature review

In developing countries, small farmers predominantly operate mixed crop-livestock systems, integrating various agricultural enterprises within their farms. Crops serve both as food for household consumption and as a source of income through cash sales. Likewise, livestock contribute to food and income while also providing draft power for land cultivation and manure for soil fertilization (Herrero et al., 2010). In many tropical regions, particularly in sub-Saharan Africa, small-scale farmers are important in ensuring food security for low-income populations. A key concern is whether these farming systems can sustainably increase household incomes and improve food availability and access for rapidly expanding urban populations in the years ahead. According to Herrero et al. (2014), the future role of smallholder farmers in global food production and food security remains highly uncertain.

The adoption of new agricultural technologies is a critical factor in enhancing productivity, strengthening food security, reducing poverty, and driving agricultural development. However, integrating and effectively utilizing these technologies has long been a complex challenge due to various constraints in the adoption process (Bizimana & Richardson, 2019). For instance, smallholder farm productivity in developing countries is often hindered by policy and structural barriers, leading to slow improvements in crop yields and agricultural stagnation (Norton, 2014).

To accurately capture the idea that small farmers may face vastly different futures, several authors have proposed and developed the use of scenarios. Scenarios are sets of alternative narratives, expressed through words and/or numbers, that describe plausible future outcomes (van Notten et al., 2006; Kok et al., 2007). These scenarios help improve understanding of how systems function, behave, and evolve, while also aiding in the evaluation of future developments under different policy orientations (Kok et al., 2011).

The definition of a multiple or alternative scenarios approach involves blending available technological options with the perspectives of relevant stakeholders, such as policymakers, farmers, experts, and technicians (Biggs et al., 2007; Kinzig, 2006). Scenarios are then tested within agricultural farm models by comparing a baseline scenario with the defined alternative scenarios.

The modeling of rural households initially focused on production aspects and later expanded to include consumption, as well as the presence of a labor market, whether through hired labor or the possibility of family off-farm work. Over time, the social and ethnographic dimensions of rural households were also considered and integrated into farm models.

Chayanov's initial model of self-sufficiency, which assumed no market for family labor, was progressively modified and enhanced by the introduction of markets for resources and products (Ellis, 1988; Hammel, 2005). This led to the development of the Barnum-Squire model, which incorporates the hiring of family labor off the farm and provides a framework for forecasting household responses to changes in household variables (Barnum-Squire, 1979).

The Low model (Low, 1986) diverges from the previous models by focusing on agricultural production within the specific context of African countries bordering South Africa. It incorporates a salaried labor market and wage variation across different categories of work. Additionally, the social and ethnographic dimensions of rural households, explored through rural sociology, were addressed in the work developed by Hildebrand (2003).

The evaluation of these conceptual models under various scenarios can be conducted using two fundamental tools, econometrics or mathematical programming. From a forward-looking perspective, mathematical programming models, particularly linear programming (LP), have been applied to agriculture since the 1950s. These normative models are widely used in agricultural planning to assist farmers in making decisions about resource organization and utilization, thereby improving economic outcomes (Heady, 1958). LP models are also fundamental tools for analyzing both small and large agricultural systems, as well as more complex systems like peasant and subsistence farming. These models can incorporate a temporal dimension through multiperiod models or a spatial one, with aggregate models applied at regional or national levels.

ELP emerged in the 1990s, with Hildebrand as its main proponent (Hildebrand, 2003). ELP integrates not only the productive aspect of households but also the reproductive and socio-cultural dimensions. It combines LP, a quantitative method, with ethnography, a qualitative research approach, to deepen the socio-cultural understanding of households. This integration allows for a comprehensive analysis of the various dimensions of social organization within farming families, particularly those engaged in subsistence agriculture. Hildebrand et al. (2003) highlight the advantages of ELP in simultaneously analyzing production activities and the reproduction of agricultural assets. The ethnographic dimension enables a detailed understanding of what is done, who does it, when, how, and why, considering the multidimensional nature of production, reproduction, and community components of households. The ultimate goal is to maximize household well-being (Wilsey, Gill & Rios, 2012; Deus et al., 2021).

Using PLE to model households and their agricultural systems requires meticulous data collection, storage, management, and processing. This approach allows for the testing of various policies, technologies, reproductive changes, and shifts in social and community norms. It facilitates the exploration of their potential outcomes and the prediction of their consequences for rural households and communities (Deus et al., 2021).

PLE has been applied in several studies across the American continent, including those by Neto (2014), Mello and Hildebrand (2012), and Araújo (2010) in Brazil; Wilsey and Hildebrand (2011) in Mexico; Harper, Granda, Hildebrand, and Messina (2006) in Cuba; Cabrera, Hildebrand, and Jones (2005) and Rios (2010) in Peru; Breuer (2002) in Paraguay; Breuer, Hildebrand, and Cabrera (2004) in Ecuador; Bellow (2004) in Guatemala; Smith (2014) in Costa Rica; and Slaughter (2012) in Haiti. In Africa, notable studies include those by Kamutali (2022) for Angola; Gill (2010) for Kenya; and Thangata, Hildebrand, and Gladwin (2002) and Thangata, Hildebrand, and Kwesiga (2007) for Malawi. In Southeast Asia and the Pacific, the recent application of ELP by Deus et al. (2021) in modeling household farming systems in four districts of East Timor stands out. In this work, the authors identified and analyzed the variables that differentiate households and their farming systems.

The application of ELP in agricultural systems has been contributed to valuable insights into household modeling and the socio-economic sustainability of family farming in different contexts. Kamutali (2022) assessed the suitability of ELP for planning and managing family farming by developing and validating a household model to analyze economic and social sustainability in Huambo, Angola. This study focused on a representative farming household in a region where farming is essential for livelihoods, yet poverty remains high. The objetive was to create a replicable management tool, incorporating multiple dimensions of daily life, such as economic, environmental, social, historical, cultural, educational, health, and organizational factors, all of which reflect the complex relationships between farming households, rural communities, and the market. The results highlighted the effectiveness of ELP as a management tool, demonstrating its potential for broader application despite various constraints.

In a similar vein, Herrero et al. (2014) applied an agricultural simulation model, “FARMSIM” to evaluate alternative technologies in farming systems. Their approach combined the IMPACT tool linked to a LP model, allowing them to generate optimal solutions for farm household management while considering constraints. The model’s objective was to maximize gross margin by integrating sales from agricultural and animal products, income from other sources, and expenses related to agricultural inputs, animal inputs, labor, and other costs. This modeling approach demonstrates the relevance of LP in optimizing farm household operations, similar to Kamutali's use of ELP to integrate various dimensions of farm management.

The work of Gill (2010) examined the intersection of health and food security in rural households in Kenya, focusing on the impact of HIV/AIDS on food insecurity. Gill’s findings showed that the contraction of HIV by an adult male leads to greater food insecurity compared to when a female adult is infected. This study highlighted the importance of considering health-related issues and their socio-economic impacts on rural households, an aspect that can be integrated into household models like ELP to improve the understanding of family farming systems’ vulnerabilities.

Similarly, Thangata, Hildebrand, and Kwesiga (2007) modeled the impact of HIV/AIDS on agricultural adoption and food security in Malawi. Using a dynamic 8-year PLE model, they found that the illness of an adult, regardless of gender, reduces the area available for cultivation, thus exacerbating food insecurity. The results also revealed that gender plays a role in how the illness impacts labor availability and food production, with men’s illnesses affecting the availability of female labor for farming.

In a previous study, Thangata, Hildebrand, and Gladwin (2002) used a 10-year dynamic PLE model to investigate agroforestry adoption in Malawi. They found that adoption decisions were influenced by land and labor availability, with gender having a neutral effect.

Together, these studies demonstrate the utility of ELP and similar models in capturing the multifaceted nature of household farming systems. By integrating various socio-economic, cultural, and health dimensions, these models provide valuable insights into the challenges faced by rural households, and can be used to inform policies and strategies aimed at improving their economic and social sustainability.

3. Methodology

To develop the ELP model for analyzing sustainable family farming systems in the Angolan province of Huambo, it is necessary to construct and validate ELP models for households. These models will enable the measurement of the economic and social performance of farmers, identify and test alternative pathways for household development, and account for the challenges and potential of farming systems in Huambo. The ultimate goal is to enhance the well-being of these farmers, help them overcome the poverty line, and break the vicious cycle of poverty.

Based on surveys conducted with 158 households, farming systems were categorized into four groups, as shown in Table 1. The table summarizes some of the key characteristics of the family farming systems in Huambo that were considered. The farmers interviewed were grouped according to the farm size into four categories, as outlined by Kamutali et al. (2024): very small farms (area ≤ 1 ha, 44.4%), small farms (1 < area ≤ 3 ha, 18.2%), medium farms (1 < area ≤ 3 ha, 20.3%), and large farms (area > 5 ha, 17.1%) (Kamutali et al., 2024).

Table 1 Main characteristics of the farming systems chosen

Item	**Very small**	**Small**	**Medium**	**Large**
Area classes	area ≤ 1 ha	1 < area ≤ 3 ha	1 < area ≤ 3 ha	area > 5 ha
Area (ha)	1	2,25	4,25	32
Vegetable crops	Corn, beans, potatoes, onions	Corn, beans, potatoes, onions	Corn, beans, potatoes, onions	Corn, beans, potatoes, onions
Livestock	Chickens	Chickens	Chickens, goats and cattle	Chickens, goats and cattle
Community Activities	Church, commemorative dates of the country, province and municipality and enthronement of the soba			
Festive activities	Wedding, anniversary, baptism, evamba, harvest and funeral.			

Source: Own elaboration

A household questionnaire was administered through individual interviews with the head of the household responsible for the farm, with their prior consent. The questionnaire was divided into sections covering: (i) the farmer and their family, (ii) family, festive, and community activities, (iii) human nutrition, (iv) farming, plant and animal activities, and technology, (v) marketing, (vi) sources of income, and (vii) monthly household expenditure.

The initial version of the questionnaire was validated by five members from Angola's academic, research, and development sector, including the Faculty of Agrarian Sciences at José Eduardo dos Santos University, the Angolan Institute of Agrarian Research, and the Angolan Institute of Agrarian Development. This validation aimed to ensure that the questions and language used were aligned with the realities of the target audience. Based on their feedback, corrections and additional questions were incorporated. The first round of data collection to build the model began on November 19, 2021, and continued through further interactions with the head of the household from November 30, 2021, to January 15, 2022.

3.1. Description of the ELP Model Used

The model was developed in four stages: (i) designing the questionnaire to gather information; (ii) pre-testing the questionnaire for validation and later replication; (iii) selecting the household whose data would be used to validate and adjust the model; and (iv) constructing the ELP model.

The households selected for data collection to build the model were chosen based on the following criteria: (i) they represented the agricultural systems practiced in Huambo for each farm size class; (ii) the farmer was willing to participate in the study; and (iii) the farmer had access to a cell phone for follow-up contact.

Out of the 158 households (which were categorized into four classes of farmers), a representative farm was selected from each class. This approach was adopted due to the large volume of data collected, as using the average would not effectively capture the extreme values within the dataset.

The PLE model was developed based on several key assumptions: it is static and deterministic, capturing the most relevant aspects of family farming systems across the productive, reproductive, and community dimensions. Its goal is to maximize household well-being by enabling decisions on the composition of activities, guided by the available resources and needs. The model's objective function seeks to maximize the household's margin by subtracting the costs of both productive and non-productive activities, as well as labor, from the household's earnings. Constraints are set to regulate the use of the farm's and family's resources, based on their availability.

Function Objective:

$\text{Max } E(Z) = -C_v X_{(v)} - C_p X_p + R_{(v)} Q_{(v)} + R_p Q_{(p)} - W_b N_{(b)} - W_f Q_f - W_m Q_{(m)} - W_x V_{(x)}$

Subject to restrictions:

Land use restrictions:

$A_{av} X_v \leq T_{(a}$

Restrictions on the use of male labor:

$B_{bv} X_v + B_{bp} X_p + B_{(bf)} Q_f + B_{bm} Q_m + B_{bh} X_h - N_b \leq T_{(b}$

Restrictions on plant production:

$-S_{qv} X_v + S_{qf} Q_f + S_{qm} Q_m + Q_v \leq 0$

Restrictions on animal production:

$S_{tp} X_p + S_{tf} Q_f + S_{tm} Q_m + Q_p \leq 0$

Restriction on festive activities:

$Q_f = 1$

Restriction on community activities:

$Q_m = 1$

Restriction on fixed costs:

$V_x = 1$

where the variables are:

$\mathbf{N_b}$ - column vector (b x 1) of hired labor.

$\mathbf{Q_v}$ - column vector (x x 1) of demand for plant foods for sale.

$\mathbf{Q_p}$ - column vector (z x 1) of demand for animal feed for sale.

$\mathbf{Q_f}$ - column vector (f x 1) of the festivities.

$\mathbf{Q_m}$ - column vector (m x 1) of the communities.

$\mathbf{X_v}$ - column vector (v× 1) of plant production activities, in terms of area occupied.
$\mathbf{X_p}$ - column vector (p× 1) of animal production activities, in terms of heads.
$\mathbf{X_h}$ - column vector (h× 1) of family activities
$\mathbf{V_x}$ - vector (1× 1) for fixed costs
and the parameters are:
$\mathbf{A_{av}}$ - matrix (a× v) of land requirements for plant activities;
$\mathbf{B_{bv}}$- matrix (b× v) of labor *input* coefficients for the plant sector;
$\mathbf{B_{bp}}$- matrix (b× p) of labor *input* coefficients for the animal sector;
$\mathbf{B_{bf}}$- matrix (b× f) of labor *input* coefficients for the festivities;
$\mathbf{B_{bh}}$- matrix (b× h) of labor *input* coefficients for family activities;
$\mathbf{B_{bm}}$- matrix (b× m) of labor *input* coefficients for community activities;
$\mathbf{S_{qv}}$- matrix (q× v) of coefficients relating production to plant activities;
$\mathbf{S_{tp}}$- matrix (t× p) of coefficients relating production to animal activities;
$\mathbf{T_a}$ - column vector (a× 1) of land factor availabilities;
$\mathbf{T_b}$ - column vector (b× 1) of labor factor availabilities;
$\mathbf{C_v}$ - line vector (1× v) of plant activity costs;
$\mathbf{C_p}$ - line vector (1× p) of livestock activity costs;
$\mathbf{R_v}$ - line vector (1× v) of plant product prices.
$\mathbf{R_p}$ - line vector (1× p) of livestock product prices.
$\mathbf{W_b}$ - line vector (1× b) of labor purchase prices
$\mathbf{W_x}$ - scalar for fixed costs;
$\mathbf{W_f}$ - scalar referring to the costs of the festivities.
$\mathbf{W_m}$ - scalar for community costs

Household production systems are developed on five types of land called *épia*, *onaka*, *octhumbo*, *ombanda and elunda*, with *épia* and *onaka* being the most important lands and the ones that contribute the most to the household economy.
The household workforce is made up of male and female members, adults and young members of the household. The supply of labor also includes hired labor. The demand for labor includes plant, animal, domestic, festive and community activities. For crop activities, it is necessary to carry out the tasks of producing maize, beans, reindeer potatoes and onions on the different types of land and the different cultural operations, land preparation, sowing/planting, weeding, fertilizing, plant protection, harvesting and threshing. For livestock activities, demand is split between feeding cattle, goats and chickens. Some tasks have a clear predominance of one gender, such as animal feeding and domestic chores.
The household owns a set of tools and equipment for agricultural production, namely a machete, axe, hoe, plough and cart, which give rise to fixed costs.
The main crops are reindeer potatoes, corn, beans and onions and the animals raised by the household are cattle, goats and chickens. Productivity per hectare for the main crops is low. Maize yields are higher in *Epia*, beans in *Onaka* and potatoes in *Ombanda*. The fertility and prolificacy rate for cattle and goats is 0.75. Cattle give birth every two years, goats once a year and chickens twice. Chickens hatch an average of around 8 chicks in each laying.
The variable costs of plant activities include the purchase of modern inputs, seeds, fertilizers, phytopharmaceuticals and renting animal traction, mainly for larger farms. The animals are fed in the field all year round on land that belongs to the community. There are no costs for goats, sheep and chickens.

Crops are sold and consumed for their own sake, with reindeer potatoes being a designated cash crop. The producer does not usually slaughter cattle for family consumption, but generally sells them, thus helping to increase family income. Goats are used to obtain income to meet emergency needs and are often slaughtered during festive seasons for family consumption. Chickens are used both for sale and for household consumption on special occasions such as festivities

The main domestic activities of the household are carried out mainly by the woman and her children and take place every day of the year. The main festive activities are alambamiento, weddings, birthdays, baptisms, evamba, harvests and funerals. Community activities include the commemorative dates of the country, province and municipality, participation in church activities and the enthronement of sobas.

3.2. Tested scenarios

The productivity of the main crops grown by family farmers in Huambo - maize, beans, onions and potatoes - is low (Kamutali et al., 2022). Suvedi et al. (2017) point out that many small farmers in developing countries have not yet managed to adopt improved agricultural technologies, for example, better high-yielding seed varieties and better agricultural practices that will allow them to increase the productivity of their farms and improve the sustainability of their livelihoods. Technology plays an important role in determining the economic and financial performance of agricultural holdings because, in addition to allowing labor productivity and total factor productivity to rise, it also establishes links upstream and downstream of agriculture that have important negative and positive effects on the sustainability of family farmers' activities (Marassiro et al., 2021).

Thus, the introduction of new technologies to increase productivity has been tested through the introduction of new certified seed varieties with a higher production index and the corresponding modern inputs, new crops such as soya and, in the case of livestock, the introduction of goats with two births a year and an increase in the number of layers for hens.

Depending on the characteristics of the farmers, the introduction of new technologies in the field should be gradual, for very small, small, medium and large farmers.

The scenarios studied are summarized below:

1. **Low technology (baseline scenario, with low input consumption:** use of low quality seed (sourced from the farm or bought locally). Fertilization used is a total of 100 kg 12-24-12 (as background fertilization). No treatment with insecticides or fungicides.
2. **Medium technology:** uses purchased seeds of a medium quality population variety. The fertilizer used is a total of 400 kg of 12-24-12 + 400 kg of dolomitic limestone (as fertilizer and bottom liming in the planting trenches), which is 90 kg of N, 96 kg of P and 48 kg of K. He carries out 1 treatment with insecticide and 2 treatments with fungicide.
3. **High technology:** uses certified seeds of a high quality population variety purchased. The fertilizer used is a total of 400 kg 12-24-12 (as a base fertilizer), and 400 kg of ammonium sulphate after two applications (as a top dressing), 132 kg N, 96 kg P and 48 kg K. He carries out 2 treatments with insecticides and 3 treatments with fungicides.
4. **Goats with high productivity:** use of goats with the ability to appear twice a year.

4. Results and discussion

In this section, the results obtained with the ELP models are presented, both for the baseline and for the alternative scenarios, as well as comparing the well-being of households with indicators of poverty, minimum income and average income.

4.1 Baseline scenario

The results of the PLE model of the areas in terms of surface used and the distribution of crops, in the three types of farmers, show that epia has the largest area used, while the maize*bean consortium is the main crop practiced by the four different types of farmers (very small, small, medium and large).
The main household economic results for the four types of farmers in their current situation are shown in Table 2. The main costs for very small farmers are festivities (35,0%), fixed (33,3%) and agriculture (31,7%) and for small farmers agriculture (51,1%) , followed by festivities (25,1%) and fixed costs (23,8%). Medium and large farmers spend more on crop, 49,9% and 79,1%, respectively, while festivities (32,8%) for medium and contract work (13,9 %) for large, are the second most important cost item.
In the revenues, crops (>80%), are the most important source for the for the four types of farms. In the crop revenues, the sale of maize, beans and potatoes are the main sources of income. Livestock is more releant for small (14,3%) and medium (19,7%) farms.

Table 2 Main household costs and revenues for the baseline scenario (AKZ)

Item	Very small	Small	Medium	Large
Costs				
Crop	14501	32625	1167854	28192000
Livestock	0	0	230000	288000
Offfarm labor	0	0	89808	4962000
Fixed	15225	15225	15905	77902
Festivities	16000	16000	769000	2061500
Community	0	0	70000	40000
Total costs	**45726**	**63850**	**2342567**	**35621402**
Revenues				
Crop	270240	648000	3611338	65232000
Livestock	45000	45000	886400	1748000
Total revenues	**315240**	**693000**	**4497738**	**66980000**
Net Margin	**269514**	**629150**	**2155171**	**31358598**
Net Margin per ha	**269514**	**279622**	**507099**	**979956**

Source: Own elaboration

As can be seen in Table 3, the net margin and net margin per hectare is positive for all farming systems, the last one increasing with farm size. According to Siqueira et al. (2024), if the net margin is positive, the producer will be able to cover all fixed and variable costs, in addition to being remunerated, maintaining his productive activity in the medium or long term; but if it is negative, the fixed costs will not be fully covered, so the producer may enter a process of decapitalization.
In order to situate the well-being of rural households within the Angolan economy, it is important to compare the income obtained per capita with the values of the poverty line, the minimum wage and the average wage. The net income generated is insufficient for very small and small famers to overcome the poverty line for all members of the family, being the situation of these farms dramatic once the net income only covers 17,0% and 39,8% of the poverty line per capita. The medium farms are also unable to achieve the average salary per capita (93,0%). ´Considering the fact that in Angola, approximately 31.1% of the population lives below the poverty line. That percentage represents a significant part of the population facing considerable economic and social challenges (OPSA, ADRA and CINVESTEC, 2024)

Table 3. Income and per capita income in baseline scenario (AKZ)

Item	**Very small**	**Small**	**Medium**	**Large**
Number of household members	5	5	6	8
Net revenue	269 513	629 150	2 155 171	31 358 600
Net revenue per ha				
Monthly income per capita	4492	10 486	29 933	326 652
Monthly poverty line per capita	26353			
Average salary	32181			

Source: Own elaboration

Very small and small-scale farmers face a wide range of complex challenges, crises and pressures that affect both their gricultural production and livelihood. These challenges span several domains, including agricultural production, the sale of agricultural products, pricing and socio-economic factors such as ageing, poverty, shortages of agricultural labor and limited access to essential agricultural technologies and information (Touch et al., 2024).

According to Queiroz & Batalha (2003), in the agricultural context, modeling the cost structure must take into account some of the particular characteristics of managing these environments. For example, seasonality is a particular characteristic of agricultural production, as are spraying, fertilizing and other activities, which are carried out depending on certain variables, such as pest and disease infestations and rainfall rates.

Increasing the potential yield has been achieved through genetic improvement (for example, by improving light capture or the efficiency of converting light into biomass), reducing the yield gap can be achieved by improving crop management practices or genetic improvement (Ewert, F., et al.; 2005).

To improve the effectiveness and efficiency of farms, it would be important to consider an increase in investment, as well as the implementation of training and technical support programs to ensure that beneficiaries have the necessary resources and knowledge to develop income-generating activities in a sustainable and impactful way (OPSA, ADRA and CINVESTEC, 2024).

4.2 Technological improvement scenario

One of the alternatives proposed in this study would be to introduce new certified seed varieties with a high production index and, in the case of livestock, to improve goat production with two births a year. Table 4 shows the results of the models with the new technologies. As can be seen, the net margin of the different family farmers with the new technologies is higher compared to their baseline scenario, indicating a significative improvement of the economic sustainability of the farm size types.

Table 4. Main household costs and revenues with alternative scenario

Item	Very small	Small	Medium	Large
Costs				
Crops	777440	1749000	8604732	68287360
Livestock	75000	0	230000	288000
Contract labor	0	0	377850	4962000
Fixed	15225	15225	15905	77902
Festivities	16000	16000	769000	2061500
Community	0	0	40000	40000
Total	**883665**	**1780225**	**10037487**	**75716762**
Revenues				
Crop	3234900	7318000	23234500	207339008

Livestock	75000	75000	946400	1868000
Total	**3309900**	**7393000**	**24180900**	**209207008**
Net Margin	**2426235**	**5612775**	**14143413**	**133490246**
Net Margin per ha	**2426235**	**2494567**	**3327862**	**4171570**

Source: Own elaboration

Considering the results above, where very small, small and medium-sized farmers have poor levels of well-being, the introduction of new technologies has enabled these family farmers in Huambo to overcome the poverty line and the average salary (Table 5). This overcoming presupposes the adoption by farmers of new technologies, a process that is not immediate for all farmers or all technologies, often requiring gradualism in farmers and technologies and perhaps the production of technologies adapted to very small and small farmers. The value of the average wage for Angola does not allow us to draw certain conclusions about per capita income, but it does allow us to see that urban families with this average wage for the size of the families considered are in an even more fragile situation than rural families.

Table 5. Income and per capita income in the alterantive scenario(AKZ)

Item	**Verysmall**	**Small**	**Medium**	**Large**
Householdmembers	5	5	6	8
Netrevenue	2501235	5612775	14113410	133490200
Monthlyincomepercapita	41687	93546	196020	1390523
Monthlypovertylinepercapita	26353			
Averagesalary	32181			

Source: Own elaboration

Agricultural extension programs play a key role in facilitating the transfer of knowledge, technologies and agricultural practices to farmers, and are increasingly necessary to improve agricultural productivity, ensure food security and improve rural livelihoods (Bhat, P. P. et al., 2024). In addition, it is essential to encourage the emergence of companies providing both mechanization services and technical assistance (to teach good agricultural practices) in order to strengthen family farmers in Huambo.

It should be noted that the technological innovations that are applied in the agricultural sector are not only in the form of agricultural machinery, but can also be in other forms, such as technologies that provide high crop productivity, through cultivation patterns, the use of irrigation systems, pest and disease control, among others (Santoso et al., 2023). It is also necessary to guarantee the supply of certified seeds, fertilizers and agrochemicals, as these are indispensable for desired production. These factors will be indispensable for the development of agriculture in Huambo, since the success of productive activity is directly linked to the availability of these factors of production. The distance in time, caused mainly by the poor state of the access roads to the main consumption centers, represents a major difficulty for the flow of production.

The quest to increase productivity has been the foundation for the development and incorporation of various technologies to increase production (Asunción, 2024). However, aspects related to the environment and natural resources have, in part, been neglected over time, and today agriculture is recognized as one of the main sources of negative impact on the environment, so special attention to these aspects is becoming of paramount importance (Souto Maior et al., 2012).

4.3 Environmental and social sustainability of Huambo farming types

Extensive agricultural activities and monoculture, from the point of view of ecosystems, generate homogenization of the landscape and constant fragmentation and loss of habitats, microclimatic changes and losses of important species and populations of fauna and flora (Liu et al., 2018)

In order to assess the environmental dimension of the agricultural production systems of family farmers in Huambo, it is necessary to look, among other things, at the cultivation practices used and the quantity of inputs used in the production process. Among the inputs, we highlight diesel, nitrogen, phosphorus, potassium, insecticides, herbicides and plastic bags (Table 6).

Table 6. Environmental sustainability of the baseline scenario

	Very small	**Small**	**Medium**	**Large**
Livestock production system	Extensive field animals	Extensive field animals	Extensive field animals	Extensive field animals
Crop production system	Intercropping	Intercropping	Intercropping and monoculture	Intercropping and monoculture
Crop and animal residues	Incorporation into the soil	Incorporation into the soil	Incorporation into the soil	Incorporation into the soil
Fertilization used	Organic	Organic	Mineral	Mineral
Diesel	Without	Without	98 L	
Mineral nitrogen	Without	Without	24 Kg	
Mineral Phosphorus	Without	Without	48 Kg	
Mineral potassium	Without	Without	24 Kg	
Herbicides	Without	Without	Without	
Insecticides	Without	Without	2L	

Source: Own elaboration

According to the results, the positive aspect in the situation of Huambo's family farmers is the quantity of inputs used in the production process, the quantities of diesel, nitrogen, phosphorus, potassium, insecticides, herbicides and sacks, are non-existent or with low levels when compared with intensive ou super intensive agriculture.

The introduction of new technologies causes changes in the environmental factors observed, where the use of modern production factors doubles with the introduction of new technologies, when compared with the baseline scenario, as can be seen in Table 7.

Table 7.Use of modern inputs per ha for Huambo farming types

Name	**Current situation**			**New Technologies**			
	Maize* beans	Potato	Onions	Maize*beans	Potato	Onions	Soy
Nitrogen	24	24	24	48	48	36	48
Phosphorus	48	48	48	96	96	72	96
Potassium	24	24	24	48	48	36	48
Herbicide	0	0	0	2	1	1	1
Insecticide	1	2	1	3	5	3	4
Bags	53	20	20	110	30	30	55
Diesel	60	98	60	162	130	153	141

Source: Own elaboration

In Huambo, agricultural activities play an important role in maintaining the livelihoods of rural households. The household workforce is made up of both men and women, with adults and young members of the household standing out. Most family farms are characterized by the use of family labour, in this sense the members of the household work on the activities of their farm. However, many times, in order to meet some of the basic needs of the household, such as food at certain times of the year, children's education costs, health costs, among others, the members of the household also do paid work outside the family farm of their household. According to INE (2022), in Huambo (40.4%) of the family farms have their members doing paid work outside their farms.

Labor for agricultural activities is used to carry out agricultural production tasks for corn, beans, reindeer potatoes, soybeans and onions. Cultural operations include land preparation, sowing/planting, weeding, fertilizing, phytosanitary treatment, harvesting and threshing. These activities have the same requirements for the different types of plowing (*onaca*, *épia*, *ombanda*, *elunda* and *otchumbo*). The workforce for these activities is essentially from the family, father, mother and children for the many small and very small farmers. The medium and large farmers, on the other hand, rely on hired labor in addition to their own family members, father, mother and children.

As small producers are in a situation of economic and social vulnerability, rural areas offer many alternatives and a diversity of agricultural and non-agricultural activities (Ellis, 2000).

Table 8 shows the farmers' results in terms of the need for and availability of labor.

Table 4. Needs and availability of family labour

Labor	Adult males	Young Men	Total Male	Female Adults	Young Women	Total Female
Very small and small						
Needs						
Crop	82,5		82,5	99,0		99,0
Livestock	45,6		45,6	15,2		15,2
Festivities	11,0	11,0	22,0	11,0	11,0	22,0
Act. Community	29,0	29,0	58,0	29,0	29,0	58,0
Act. Domestic		22,8	22,8	221,6	182,5	404,1
Total TF	168,1	62,8	230,9	375,8	222,5	598,3
Availability						
Number	1	1		1	2	
Days year	365	182,5		365	182,5	
Total availability	**365**	**182,5**	**547,5**	**365**	**365**	**730**
Surplus labor	197	120	317	-11	182,5	132
Medium						
Needs						
Crop	255,1		255,1	147,7		147,7
Livestock	425,0		425,0	30,4		30,4
Festivities	15,0	15,0	30,0	15,0	15,0	30,0
Act. Community	67,0	67,0	134,0	67,0	67,0	134,0
Act. Domestic	0,0	68,4	68,4	143,4	136,9	280,3
Total TF	762,1	150,4	912,5	403,5	218,9	622,4
Availability						
Number	1	3		1	1	
Days year	365	182,5		365	182,5	
Total availability	**365**	**547,5**	**912,5**	**365**	**182,5**	**547,5**
TC			0			74,89
						622,39
Surplus labor	-397,1	397,1	0	-38,5	-36,4	-74,9
Large						
Needs						
Crop	3768,0		3768,0	1632,0		1632,0
Livestock	600,0		600,0	22,5		22,5
Festivities	19,0	19,0	38,0	19,0	19,0	38,0

Act. Community	54,0	54,0	108,0	54,0	54,0	108,0
Act. Domestic	0,0	45,6	45,6	221,6	205,3	426,9
Total TF	4441,0	118,6		1949,1	278,3	
Availability						
Number	1	2		1	4	
Days year	365	182,5		365	182,5	
Total availability	**365**	**365**	**730**	**365**	**730**	**1095**
TC			0			4962,0
						6057,00012
Surplus labor	-4076	246,4	-3829,6	-1584,1	451,7	-1132,4

Source: Own elaboration

On the other hand, it can be seen that for the very and small farmers, there is a surplus of labor (female and male) totaling 132 days, which can be used off-farm. The use of off-farm labor in this case can help improve household incomes. For medium and large farmers, there is only an excess of labor for men. In the latter case, these farmers hire labor to compensate for the lack of labor (Table 8).

Santos et al., (2024), considers that in the presence of an agro-industry, farmers are more likely to protect their soil, use fewer pesticides and adopt agro-ecological production than producers without an agro-industry. In part, this behavior of greater environmental awareness and proactivity is due to the greater relationship that farmers with agro-industries have with the local market and, consequently, reflects consumer expectations in relation to the environment and the consumption of healthier food.

Insufficiently planned and executed agricultural practices can have a negative impact on the environment. In agriculture, soil is essential for the development of crops and, for this reason, knowledge and choice of tillage systems with lower environmental impacts is an important tool when aiming for agricultural sustainability

Family farmers are faced with the constant challenge of rising input costs and small farmers have often expressed the desire to minimize their dependence on agrochemicals. However, they hesitate to do so for fear of a reduction in income. Others have considered adopting organic fertilizers and composting as an adaptive practice, but are often deterred by limited access to raw materials and the necessary manpower (Milkias & Degefu, 2024).

5. CONCLUSIONS

This study has shown that family farming systems in Huambo have distinct and important characteristics in terms of economic, social and environmental performance.

It emerged that under current conditions, farmers' productivity is low and according to the results, the models for very small and small farmers do not allow them to cross the poverty line (they are poor), while medium and large farmers are above poverty.

The introduction of new certified seed varieties with a high production index and, in the case of livestock, the introduction of kids with two births a year, proved to be effective and, with regard to economic sustainability, the annual net income of the farm with new technologies and the annual net income per capita with new technologies is positive for all the types of farmers identified, serves to support all the expenses not included in the model and allows the poverty threshold to be overcome all the family farmer models.

In terms of social sustainability, agricultural activities play an important role in maintaining the livelihoods of rural households. Most family farms are characterized by the use of family labour.

In terms of environmental sustainability, the techniques used in both agriculture and livestock farming are fairly traditional, considering the technological production process used. The positive aspect in this situation for family farmers in Huambo is the quantity of inputs used in the production process, the amount of diesel, nitrogen, phosphorus, potassium, insecticides, herbicides and sacks, which are few in quantity and most of the time non-existent.

As far as public policies are concerned, the first proposal is a land access policy. The aim of this policy is to ensure that family farmers have the facilities to legalize their land, which could serve as a legal guarantee, access to credit, among other purposes.

The second suggestion is rural credit policy. In order to implement new technologies, family farmers must have access to various financial instruments that allow them to acquire the necessary agricultural inputs.

The third proposal is the rural extension policy. This policy should, among several measures, clearly propose Angola's rural extension model, which guarantees technical assistance to family farmers, and develop a career statute for extension workers.

The fourth suggestion is a rural women's policy, which, among other things, would take into account credit lines and other specific financing modalities, access and ease of legalizing land, literacy and technical consultancy programs, encouragement and inclusion of women in rural extension technical teams.

Finally, the fifth suggestion to the public authorities is a policy for cooperatives focusing on training in cooperative management, analysis and control of production costs, marketing and processing of agricultural products.

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