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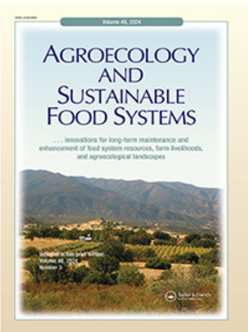


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Agroecology and Sustainable Food Systems

ISSN: (Print) (Online) Journal homepage: www.tandfonline.com/journals/wjsa21

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**To cite this article:** Boko Michel Orounladji, Ollo Sib, David Berre, Mohamed Habibou Assouma, Der Dabire, Souleymane Sanogo & Eric Vall (08 Feb 2024): Cross-examination of agroecology and viability in agro-sylvo-pastoral systems in Western Burkina Faso, Agroecology and Sustainable Food Systems, DOI: 10.1080/21683565.2024.2307902

**To link to this article:** https://doi.org/10.1080/21683565.2024.2307902

AGROECOLOGY AND SUSTAINABLE FOOD SYSTEMS
https://doi.org/10.1080/21683565.2024.2307902

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# Cross-examination of agroecology and viability in agro-sylvo-pastoral systems in Western Burkina Faso

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**ABSTRACT**

This study aimed to examine the correlations between the agroecological status of farms and their viability in agro-sylvo-pastoral systems located in the savannah areas of West Africa. The methodology is based on farm surveys (to assess agroecological farm status) and on farmers' focus group discussions (to assess viability at the farm level). Agroecological farm status was established by considering 15 agricultural practices: 4 on by-products recycling; 4 on soil protection; 4 on industrial inputs limitation; 2 on smart use of natural resources; 1 on cropping diversification; An agroecological (Ae) scoring system was used to establish an Ae ranking by farm type. Farm level viability was established by men and women farmers' focus group discussions: Inventory of viability enhancing and viability-weakening factors; Rating intensity of each viability factor. A scoring system was used to establish Viability ranking by farm type. Four iconic farm types were considered: Small crop-oriented (T1); Medium-size crop-oriented (T2); Large crop-livestock oriented (T3); Livestock-oriented (T4). The findings demonstrate that the viability of agro-sylvo-pastoral systems is not solely dependent on their agroecological status. The ranking of the four farm types, from the first to the last position, is T4, T2, T3, and T1 for agroecology; and T2, T3, T4 and T1 for viability. Our study reveals that T1 farms in Koumbia are not highly agroecological or highly viable. Similarly, farms with the largest cultivated areas (T3) and herds (T4) are not the most agroecological or viable. The best balance between agroecology and viability is struck by T2 farms. We recommend promoting the development of T2 farms that demonstrate the best congruence between agroecology and viability as a model for T1, T3, and T4 farmers. Depending on the agroecological status, one farm could be more or less viable.

**KEYWORDS**
Crop-livestock systems; agroecology; viability; action-oriented research; agricultural practices; Burkina Faso

**SUSTAINABLE DEVELOPMENT GOALS**
SDG 2: zero hunger; SDG 5: gender equality; SDG 12: responsible consumption and production; SDG 13: climate action; SDG 15: life on land

## Introduction

Agroecology (Ae) is a body of knowledge, practices and political movements that aims to support transformation of food and agricultural systems to long-

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term social and environmental sustainability (Wezel et al. 2009). Agroecology is founded on 13 principles that are implemented in diverse ways dependent on local context: recycling, input reduction, soil health, animal health, biodiversity, synergy, economic diversification, co-creation of knowledge, social values and diets, fairness, connectivity, land and natural resource governance, and participation (Wezel et al. 2020). Agroecology's great promise is to bring significant socioeconomic and environmental benefits to farmers and their families, but also to enable countries that embark on this path to provide their citizens with greater food security in a fair and sustainable way (Hatt et al. 2016; Nicholls and Altieri 2018). In other words, agroecology is meant to provide farms with the conditions they need to develop over time, and thus become more viable. This question of the relationship between agroecology and viability is therefore central to any policy promoting the agroecological transition.

The agroecological transition calls for a wide range of factors to be considered, as set out in the 13 agroecological principles suggested by Wezel et al. (2020). This is why, at the farm level, it makes sense to question the impact of agricultural practices related to agroecological principles on the entire production system, the new constraints/opportunities that they can cause to emerge, and therefore ultimately the viability of the farm. We shall first briefly review these agroecological characteristics of agro-sylvo-pastoral systems before clarifying how the concept of viability was considered throughout this study.

Agro-sylvo-pastoral systems in the savannah areas of West Africa are characterized by crop diversity (cotton, cereals, legumes), livestock (cattle, sheep, goats) grazing on various types of land, and the presence of trees on cultivated plots. In this context, based on the synergy principle of agroecology put forward by Wezel et al. (2020), we considered that the stronger and more diversified the synergies were between crops, livestock and trees, the more agroecological the farm was, and we primarily studied the agricultural practices that brought these synergies into play (Vall et al. 2023).

In the field of agronomy, the concept of viability is approached from three main angles: (i) viability reduced to its purely economic dimension; (ii) viability seen as a component of sustainability; (iii) viability viewed as a space for sustainability. In the theory of the viability space, in addition to the economic, social, and environmental dimensions of viability, the viability boundary is also considered.

In most studies, the viability of farming systems is reduced to its economic dimension, and there are many economic indicators available to measure it (Barnes, Thomson, and Ferreira 2020; Neto et al. 2017; Pinheiro et al. 2021; Slavickiene and Savickiene 2014; Somda, Kamuanga, and Tollens 2005; Spencer et al. 2021; Spicka et al. 2019). However, since the 1990s and as part of the concept of sustainable development, the economic viability of farming systems has been considered as one of the components of sustainability alongside social and environmental dimensions (Bhuiyan and Maharjan 2022; Corson et al.

2022; D'Silva et al. 2012; Ehui 1993; Landais 1998). More recently, based on Aubin's viability theory (Aubin 1991), studies have sought to identify the viability kernel of farming systems, in other words the space within which the system finds the internal and external conditions it needs to last and grow (Angeon et al. 2014; Bates et al. 2018; Dumont et al. 2014).

Today, studies looking at the viability of farming systems consider not only economic factors, but also the environmental and social factors that make up the farm environment. These include environmental functions and services (Alary, Gousseff, and Nidumolu 2008; Rivas et al. 2015), human and social factors (Alhamidi, Hakansson, and Gustafsson 2003; D'Silva et al. 2012; Nobrega et al. 2018), and the efficiency of farmers' input management practices (Ehui 1993; Toro-Mujica et al. 2011). The Agricultural Viability Index (AVI) developed by Farmland Trust (https://ag-viability-aft.hub.arcgis.com/) is a good example of this wider concept of viability, with eleven (11) variables taken into account. Economic variables make up 75% of the AVI score, while other variables focus on participation, planning, percentage of elderly and younger farmers, diversity of farmers, and other non-economic components.

As it seemed crucial to consider the economic, social and environmental dimensions of viability, we developed a simple definition of farm viability for the purposes of this study, in order to be able to communicate easily and clearly about this concept with the farmers of the study area: *"A farm is said to be viable if the necessary conditions are in place for it to last and grow. It is therefore a farm that*:

- *Is economically profitable,*
- *Is socially acceptable (complies with local customs and respects people's integrity),*
- *Is beneficial to the ecosystem (preserves water, soil, plants, animals, and air)".*

This study sought to investigate the relationships between the agroecological status of the farms and their viability in agro-sylvo-pastoral systems located in the savannah areas of West Africa.

## Equipment and methods

### *Overview of the study area*

This study was carried out in the municipality of Koumbia which is a representative area of West African agro-sylvo-pastoral territories (Vall, Diallo, and Fako Ouattara 2015; Vall, Dugué, and Blanchard 2006; Vall, Marre-Cast, and Kamgang 2017). Located in the western part of Burkina Faso, in the Tuy province and in the heart of the

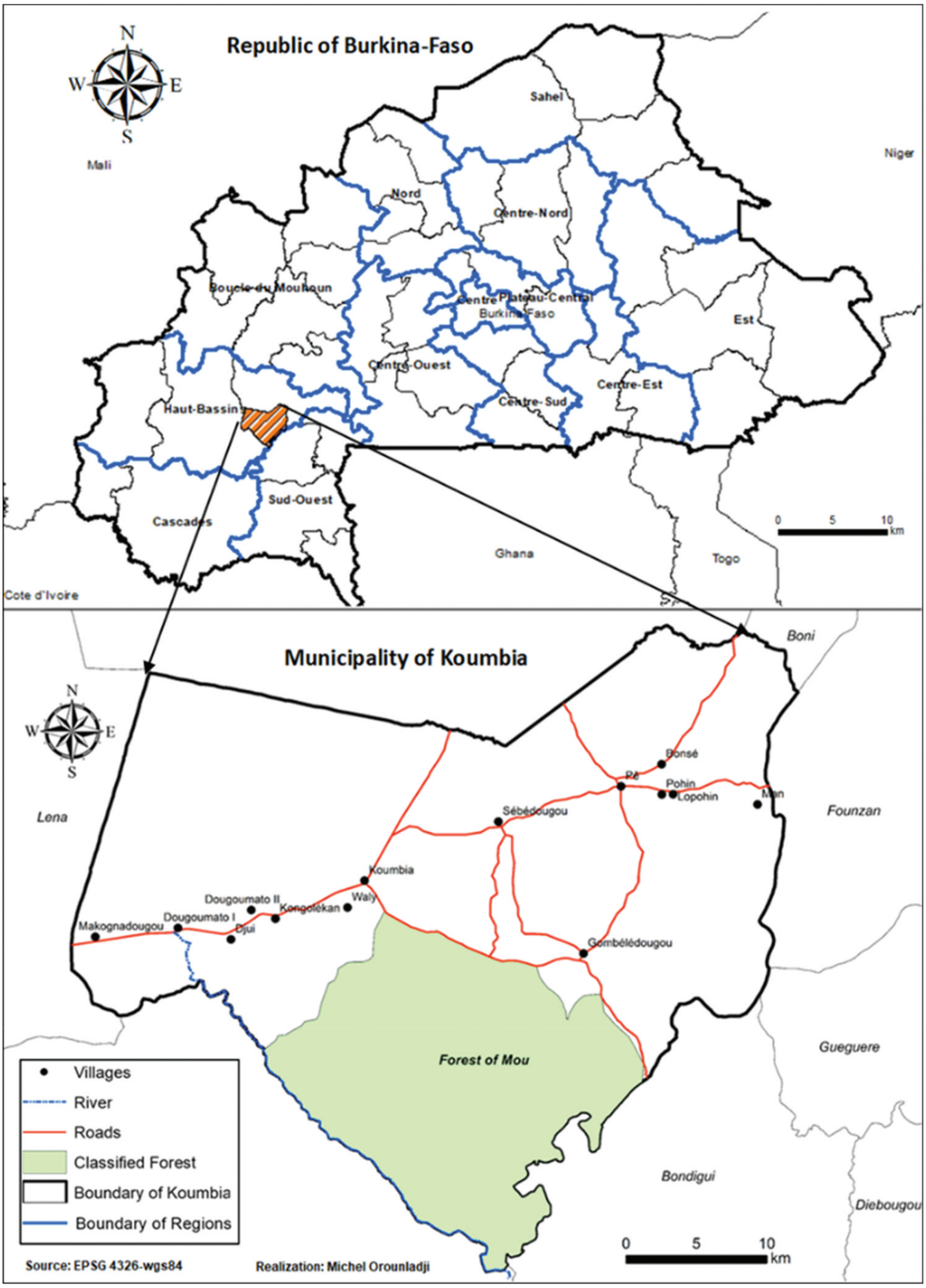


**Figure 1.** Map of the study area.

country's cotton producing area, it comprises 14 villages and several farming hamlets (Figure 1).

It covers an area of 1,358 km$^2$, 30% of which is made up of protected forests. According to the last census, the population is estimated at 46,005 (INSD

2022), on approximately 4,000 farms. The indigenous people belong to the Bwaba socio-linguistic group. Since the 1980s, the municipality has absorbed a large influx of people (Mossi, Fulani, etc.) from the drought-affected central and northern regions of the country in search of land, pasture and more favorable weather conditions (Gonin and Tallet 2012; Gray and Dowd-Uribe 2013; Gray and Kevane 2001) and immigrants, particularly Mossi, contributed to leverage the growth in population into more political clout at the regional and national levels (Gray and Kevane 2001). When they initially started to migrate in large numbers, they were welcomed and were given land by local Bwaba farmers.

The primary economic pursuits within the population encompass agriculture and livestock farming. In addition to these endeavors, the region engages in artisanal gold mining and migration for employment as agricultural laborers on plantations, particularly in southwestern Burkina Faso or Côte d'Ivoire (Gray, Dowd-Uribe, and Kaminski 2018).

The farming system is rainfed under tree cover (*Vitellaria paradoxa, Parkia biglobosa, Faidherbia albida)*, powered by animal traction (with a trend toward motorization), relatively input-intensive for cotton, maize and rice, and with a low level of inputs for other crops (sorghum, millet, groundnut, cowpea, etc.). Cattle, sheep and goat breeding is based on the use of spontaneous pasture, crop residues and a few agro-industrial by-products. Storing crop residues as dry season forage and producing organic manure is becoming increasingly common. In three decades, the population has tripled, resulting in an increase in land being cleared and the end of fallowing, leading to a higher risk of declining soil fertility. As a result of crop expansion, livestock farmers are faced with the shrinking of their traditional pastoral areas. The dramatic growth in population density (+380% between 1985 and 2020, during which it rose from 10 to 48 people/km$^2$ in the legally usable area, i.e. excluding protected forests) has led to fierce competition for agro-sylvo-pastoral resources and is increasingly encouraging farmers to recycle crop and livestock by-products or to practice transhumance with all or part of their livestock.

### General methodology

In order to assess the agroecological status and viability of the farms through the involvement of farmers, and to study the relationship between agroecology and viability, we developed a 4-stage approach as shown in Figure 2.

A meeting was initially held with farmers in Koumbia to introduce the study and explain its purpose, methodology and expected outcomes.

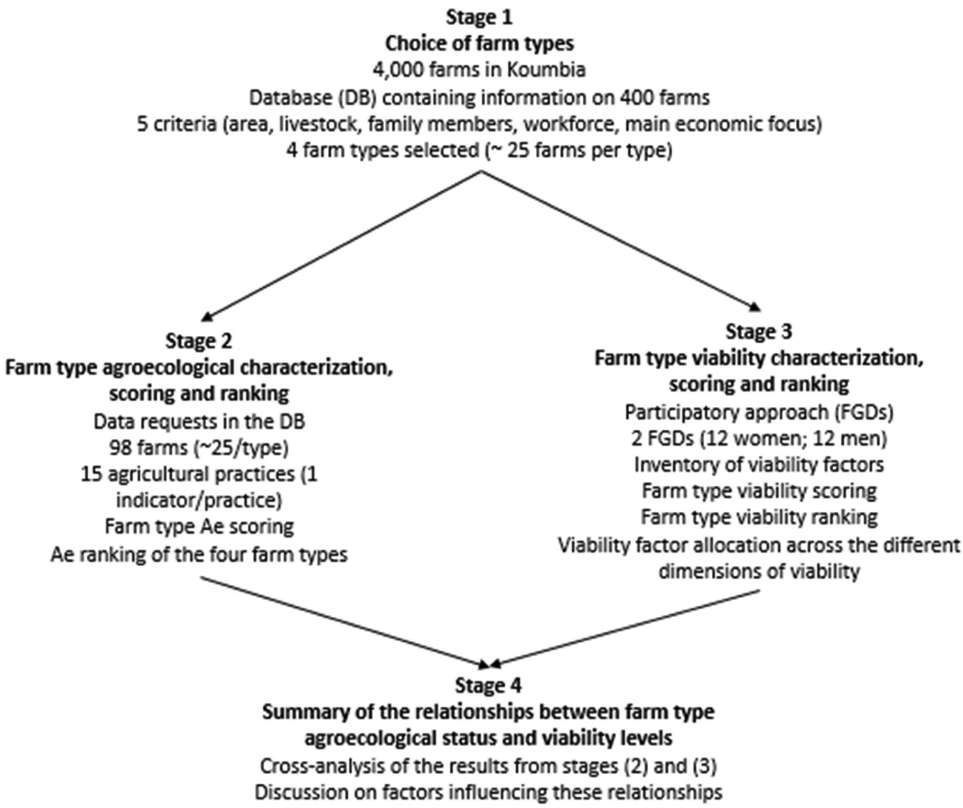


**Figure 2.** Method implemented to study the agroecological status and viability of selected farm types.

### *Choice of farm types (stage 1)*

Farms were selected from a database compiled in 2021, which contains 400 farms spread over the 14 villages making up the municipality of Koumbia (which boasts some 4,000 farms).

We decided to assess four farm types reflecting the diversity of agro-sylvo-pastoral systems in Koumbia, since it was materially impossible to involve more types in the FGDs.

Five criteria were used to select the farms from the four types in the database, with boundaries set on the basis of a typology of farms previously completed in the study area (Vall, Marre-Cast, and Kamgang 2017). Boundaries were chosen for each farm type so that all four types could be clearly distinguished from one another, each being represented by a significant group of farms and reflecting the diversity of agro-sylvo-pastoral systems in Koumbia. A total of 98 farms were selected as a result, with approximately 25 farms per type (Table 1).

**Table 1.** Characteristics of farm types represented in focus groups.

| Farm types | Cultivated area (ha) | Livestock (TLU) | Number of family members (U) | Number of family workers (U) | Economic focus | Number of farms selected (U) |
|---|---|---|---|---|---|---|
| Small crop-oriented farms (T1) | 2 to 7 | 0 | 1 to 17 | 1 to 12 | Agriculture | 24 |
| Medium-size crop-oriented farms (T2) | 10 to 15 | 2 to 10 | 5 to 32 | 3 to 14 | Agriculture | 25 |
| Large crop-livestock oriented farms (T3) | 15 to 50 | 10 to 50 | 9 to 42 | 5 to 38 | Agriculture, Livestock, etc. | 24 |
| Livestock-oriented farms (T4) | 2 to 10 | 30 to 100 | 5 to 30 | 1 to 15 | Livestock farming | 25 |

Keys: TLU: Tropical Livestock Unit (1 TLU = one adult head of cattle with a live weight of 250 kg); U: Unit.

### *Farm type agroecological characterisation, scoring and ranking (stage 2)*

In order to characterize the implementation of agroecology within the four farm types, we selected 15 agricultural practices, each featuring one indicator (Table 2). Data from the 98 farms selected in the database contained the information needed to calculate all 15 indicators for these farms.

As mentioned in the introduction, the majority of these agricultural practices (12/15: 1, 2, 3, 4, 5, 6, 7, 9, 12, 13, 14, 15; Table 2) relate to crop/livestock/tree synergies and are linked to the following agroecological principles put forward by Wezel et al. (2020): (i) crop and animal by-product recycling (animal dung, cotton stalks, cereal straw, legume tops, fodder production and organic manure); (ii) soil protection (ground cover or mulch, stone barriers, grass strips, minimum tillage); (iii) use of spontaneous resources (pastures, wooded areas); (iv) responsible use of industrial inputs (mineral fertilizers, herbicides, animal feed) and internal combustion engine-powered farm equipment; and (v) cropping systems bio-diversification (legumes, combinations). Vall et al. (2023) have highlighted the crucial role of synergies among crops, livestock, and trees, and their by-products recycling in their study conducted in this region. Three agricultural practices unrelated to crop/livestock/tree synergies were also selected (8, 10, 11; Table 2) as they do not only relate to the Ae principles of reducing input levels and soil disturbance as suggested by Wezel et al. (2020), but are also fairly widespread in Koumbia. In those low input farming systems, the smart use of synthetics inputs (indicators 10 and 11) also needs to be considered in agroecological transition in relation to the farm types, and depending on current use patterns and livestock and crop needs. This topic is discussed by Falconnier et al. (2023) for mineral fertilizers considering agronomic aspects, and by Gray and Dowd-Uribe (2013) considering access to inputs and their social impacts. Principles and indicators should not be applied mechanically but nuanced according to the context and the farm type.

**Table 2.** Description of the 15 agricultural practices and indicators used in this study to score the level of agroecology of the four farm types.

| No. | Agricultural practice | Indicators | Calculation methods | Agroecological principles |
|---|---|---|---|---|
| 1 | Maintenance of wooded areas on fields | Number of trees/ha | $\sum_{Fields}$ [Field (ha) x Field tree density (tree/ha)]/Farm's total field area (ha)]; Field tree density estimated with a 6-stage scoring scale from 0 to 25 trees/ha | Soil health, Synergy Biodiversity |
| 2 | Soil and Water Conservation Measures (SWCM; stone barriers, grass strips, manure pits) | Farm land under SWCM practices (%) | $\sum_{Fields}$ [Field with SWCM practices (ha)]/Total area of farm's fields (ha) | Soil health, synergy |
| 3 | Use of agroecological tools and equipment (draft animal power tools and equipment, manure pits, fodder sheds, biodigesters. . .) | Proportion of agroecological tools and equipment (%) | $\sum_{Tools\ and\ Equipment}$ [Value of agroecological tools and equipment (FCFA)]/Total value of farm tools and equipment (FCFA) | Recycling Soil health, Synergy |
| 4 | Organic manure production in pens, pits, biodigesters for cultivated area | OM produced (kgDM)/ cultivated area (ha) | [OM $_{produced\ in\ pens}$ + OM $_{produced\ in\ pits}$ + OM $_{produced\ in\ biodigesters}$ (kgDM)]/Total cultivated area (ha) | Input reduction, Soil health, Recycling, Synergy |
| 5 | Organic manure deposited in cultivated area by night-parked livestock | OM deposited by night-parked livestock (kgDM)/cultivated area (ha) | $\sum_{park\text{-}livestock\ units}$ [TLU of night-parked livestock x Number of nights x 1,4 kgDM.night$^{-1}$]/Total cultivated area (ha) | Input reduction, Soil health, Recycling, Synergy |
| 6 | Organic fertilisation of cultivated area | Cultivated area fertilised with organic manure (%) | $\sum_{cultivated\ plots}$ [Plots that have received OM (ha)]/ Total cultivated area (ha) | Input reduction, Soil health, Biodiversity, Synergy |
| 7 | Maintenance of a mulch (crop residues cover) on cultivated area at the end of the dry season | Mulch density (kgDM/ha) | $\sum_{cultivated\ plots}$ [Plot area (ha) x Mulch density (kgDM/ ha)]/Total cultivated area (ha); Mulch density estimated with a 6-stage scoring scale from: 0 to 6 tDM/ha for maize, rice and pearl millet straws, 0 to 7 tDM/ha for sorghum straws, 0 to 2 tDM/ha for cotton stalks – pulses : not considered | Soil health, Recycling, Input reduction, Synergy |
| 8 | Minimum soil disturbance | Cultivated area under no-till and direct seeding (%) | Cultivated area under no-till and direct seeding (ha)/ Total cultivated area (ha) | Soil health |
| 9 | Legume crops cultivation | Cultivated area under legume crops (%) | Cultivated area under legume crops (ha)/Total cultivated area (ha) | Synergy, Soil health, Biodiversity |
| 10 | Cropping without mineral fertilisers | Cultivated area without any mineral fertilisers (%) | Cultivated area without mineral fertilisers (ha)/ Total cultivated area (ha) | Input reduction |
| 11 | Cropping without herbicides | Cultivated area without any herbicides (%) | Cultivated area without herbicides (ha)/Total cultivated area (ha) | Input reduction |
| 12 | Fodder storage | Stored fodder (kg)/ Cereals and legumes cultivated area (ha) | Quantity of stored plant residues for livestock feeding on the farm (kgDM)/Total cereals and legumes cultivated area (ha) | Synergy, Recycling |

(*Continued*)

**Table 2.** (Continued).

| No. | Agricultural practice | Indicators | Calculation methods | Agroecological principles |
|---|---|---|---|---|
| 13 | Use of pasture to feed livestock | Farm's grazing livestock (%) | Grazing livestock (TLU)/Total farm's livestock (TLU) | Synergy, Animal health, Input reduction, land and NRG |
| 14 | Use of forages to supplement livestock feed (crops residues + cultivated forages) | Farm's livestock receiving forages (%) | Farm's livestock receiving forages (TLU)/Total farm's livestock (TLU) | Synergy, Animal health, Input reduction, Recycling |
| 15 | Nourishing livestock without industrial feeds | Farm's livestock fed without any animal feed (%) | Farm's livestock fed without animal feed (TLU)/Farm's total livestock (TLU) | Synergy, Input reduction, Animal health |

Keys: TLU: Tropical Livestock Unit (1 TLU = one adult head of cattle with a live weight of 250 kg); OM: organic manure; FCFA: CFA Franc; SWCM: Soil and Water Conservation Measures, NRG: natural resource governance

In order to produce an agroecological score and ranking for a given farm type, we proceeded as follows:

(1) For a given indicator (i: 1 to 15) relating to a given farm type (T: 1 to 4), its ($Indic_i^T$) value was compared with indicator i's average for all four farm types ($\overline{Indic_i}$)

(2) A value of + 1, +0.5, −0.5 or −1 was assigned to "i" according to $Indic_i^T$'s position in relation to $\overline{Indic_i}$:

- +1 if $Indic_i^T > 1.05 \times \overline{Indic_i}$
- +0.5 if $\overline{Indic_i} < Indic_i^T < 1.05\ \overline{Indic_i}$
- - 0.5 if $0.95 \times \overline{Indic_i} < Indic_i^T < \overline{Indic_i}$
- -1 if $Indic_i^T < 0.95 \times \overline{Indic_i}$

In this way, it can be defined for a farm type (T) whether an indicator value is significantly above or below a median zone (between 0.95 and 1.05 around the mean).

(1) Ae scoring: For a given farm type (T), the sum of all 15 indicators converted to a score (+1; +0.5; −0.5; −1) produces a score ranging from −15 to + 15, which we interpret as an agroecology score in the sense that it reflects the effort put into implementing those 15 agricultural practices (the closer the score is to 15, the more agroecological the farm is, and the closer the score is to −15, the less it is).

(2) Ae ranking: Based on the Ae score achieved, an Ae ranking was produced for all farm types (from the most Ae to the least Ae).

The method employed in this study is novel and has facilitated the assessment of the socio-economic and environmental viability of agroecological farms. It merits recognition for producing results that accurately reflect the realities of the study area. However, depending on the contexts of each region, it will be necessary to analyze potential adjustments to make it persuasive and relevant. The method could be improved by building with farmers (during FGDs) a weighting of agroecological indicators according to their intensity of impact on the viability of farming systems (viewed by the farmers). Thus, the robustness of the viability assessment approach can be improved.

## *Farm type viability characterisation, scoring and ranking (stage 3)*

### *Composition of farmers' focus groups*

Two focus group discussions (FGDs) were conducted in order to establish the viability factors and levels for all four farm types: one included 12 men (with 3 representatives per farm type) and the other 12 women (with 3 representatives per farm type). Men and women were grouped separately in order to provide women with more opportunities to speak out, as they are less likely to do so around men in Koumbia. FGDs were moderated by a facilitator and transcribed by a secretary during the meeting.

### *Presentation of each farm type*

Before FGDs began, a plenary session was held to check that all participants agreed on the representativeness and characteristics of the four farm types. A representative from each farm type made a presentation on the characteristics of their "farm type" using posters prepared during the study launch meeting (structural features and agricultural practices specific to each farm type; Figure 3). This presentation was followed by a Q&A session: (i) are you familiar with this farm type? (ii) should we change, add or remove anything from the description? (iii) do you agree with the suggested name for this farm type? The process was repeated

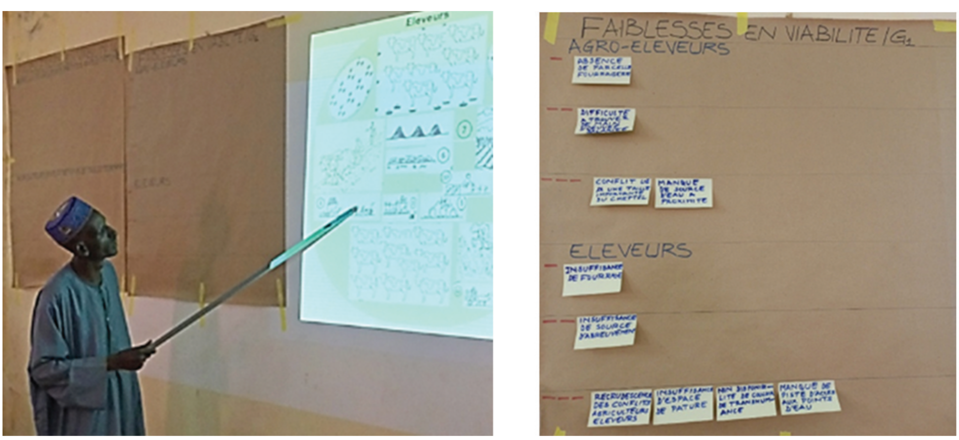


**Figure 3.** Farm type presentation by a participant and display panel showing farm viability factors.

for all four farm types and the presentation posters were displayed in the meeting room for easy reference during both FGDs.

### *Inventory of viability factors for each farm type*

The inventory of viability factors was carried out in two stages during the FGDs: 1) inventory of viability-enhancing factors (expressed as "Viability Strengths", VS+); and 2) inventory of viability-weakening factors (expressed as "Viability Weaknesses", VW-). Both stages were conducted following a 6-step sequence, led by the focus group facilitator. Work began with the T1 farm type (Small crop-oriented farms).

(1) Participants were given a few minutes to think about T1 VS+.
(2) A participant was then invited to share a VS+ with the group. The facilitator then asked if other participants had identified the same VS+. Lastly, the participants agreed on the wording of this VS+ and the session secretary wrote it down on a post-it note.
(3) The VS+ was placed on a board according to its intensity level (+++ for the highest level, ++ for the intermediate level, + for the lowest level). The intensity level was determined by the focus group participants (Figure 3).
(4) The facilitator then asked the group whether that VS+ could apply to other farm types. If yes, a new post-it note was generated and the VS+ was placed in the corresponding box for its intensity and type (T2, T3 or T4).
(5) Participants were then taken back to Step 2 and asked to introduce another VS+ not previously mentioned. Steps 3 and 4 were then repeated, incorporating this new viability factor. Steps 2, 3 and 4 were repeated until all participants' suggestions were exhausted.
(6) We then moved on to the other farm types (T2, T3 and T4) following the same steps (1 to 5).

Once the VS+ and VW- inventory had been completed for all four farm types, pictures of the tables were taken by the secretary for later analysis of the results.

## *Data analysis (stage 4)*

### *Viability scoring and ranking*

The Overall Viability Score (OVS) for a given farm type and a given FGD was calculated using the following elementary score weighting ratios: +3 for VS+ (+++); +2 for VS+ (++); +1 for VS+ (+); −1 for VW- (-); −2 for VW- (–); −3 for VW- (—) and proceeding as follows:

- VS+ Score calculation: "Number of VS+ (+++)" x 3 + "Number of VS+ (++)" x 2 + "Number of VS+ (+)" x 1
- VW- Score calculation: "Number of VW- (—)" x 3 + "Number of VW- (–)" x 2 + "Number of VW- (-)" x 1
- Overall Viability Score (OVS): "VS+ Score" – "VW- Score"

Each farm type was thus assigned an Overall Viability Score (OVS), and a Viability Ranking was ultimately determined for all four farm types.

### *Viability factor allocation across the different dimensions of viability*

Researchers linked each of the viability factors identified to the various dimensions of viability, i.e., economic, social and environmental (each factor could be linked to more than one dimension). A "political" dimension of viability relating to access and use of non-owned agro-pastoral resources (pastures, water points, land, etc.) had emerged during the FGDs, and was therefore added to this allocation exercise. Weighted VS+ and VW- occurrence data were then imported into the R 4.1.3 software (R Core Team 2022). Using the ggplot2 package (Wickham 2016), a figure representing the occurrence of factors (viability strengths and weaknesses) per category and farm type was produced.

## Results

### *Farm type agroecological scoring and ranking*

Agroecological scores and rankings for the four farm types are shown in Table 3. Score calculations based on the 12 agricultural practices common to the four farm types produce the following agroecological rankings: T4 types (Livestock-oriented farms) top the list, followed by T2 types (Medium-size crop-oriented farms), then T3 types (Large crop-livestock oriented farms), and finally T1 types (Small crop-oriented farms). Farm type scores change if a weighted scoring calculation is carried out with all 12 indicators for T1 and all 15 indicators for T2, T3 and T4, but the agroecological ranking does not. Each farm type's position in the agroecological ranking is explained below.

T4 (Livestock-oriented farms) agroecological ranking can be attributed to: 1) a majority of indicators (7/12) with high values (i.e. Ae+: $Indic_i^T$ >1.05 × $\overline{Indic_i}$): Number of trees/ha ; Proportion of agroecological tools and equipment (%); Organic manure produced (kgDM)/cultivated area (ha); OM deposited by night-parked livestock (kgDM)/cultivated area (ha); Cultivated area fertilized with organic manure (%); Cultivated area without any mineral fertilizers (%); Stored fodder (kg)/Cereals and legumes cultivated area (ha); 2) a limited number of indicators (1/12) with average values (Ae neutral:

**Table 3.** Agroecological scoring and ranking of the four farm types considering the 12 common agricultural practices.

| Farm types | Overall average | T1 | T2 | T3 | T4 |
|---|---|---|---|---|---|
| Farm type description | | Small crop-oriented farms | Medium-size crop-oriented farms | Large crop-livestock oriented farms | Livestock-oriented farms |
| Nb. of farms | | 24 | 25 | 24 | 25 |
| **Agricultural practice indicators** | | | | | |
| Number of trees/ha | 12 | 10 | 13 | 11 | 13 |
| Farm land under SWCM practices (%) | 44 | 35 | 52 | 60 | 27 |
| Proportion of agroecological tools and equipment (%) | 52 | 32 | 60 | 52 | 64 |
| OM produced (kgDM)/ cultivated area (ha) | 755 | 1,000 | 488 | 485 | 1,046 |
| OM deposited by night-parked livestock (kgDM)/ cultivated area (ha) | 785 | 718 | 175 | 226 | 2,021 |
| Cultivated area fertilised with organic manure (%) | 55 | 26 | 61 | 63 | 69 |
| Mulch density (kgDM/ha) | 1,433 | 1,074 | 1,603 | 1,578 | 1,475 |
| Cultivated area under no-till and direct seeding (%) | 6 | 22 | 0 | 1 | 0 |
| Cultivated area under legume crops (%) | 18 | 29 | 15 | 14 | 12 |
| Cultivated area without any mineral fertilisers (%) | 30 | 41 | 22 | 17 | 39 |
| Cultivated area without any herbicides (%) | 1 | 1 | 1 | 1 | 0 |
| Stored fodder (kg)/Cereals and legumes cultivated area (ha) | 348 | 70 | 239 | 276 | 805 |
| Farm's grazing livestock (%)* | 93 | X | 94 | 90 | 95 |
| Farm's livestock receiving forages (%)* | 28 | X | 33 | 27 | 23 |
| Farm's livestock fed without any animal feed (%)* | 84 | X | 81 | 84 | 87 |
| **Ae Scores and Ranking (on indicators 1 to 12)** | | | | | |
| Ae+ (+1 coef.) (1) | | 4 | 6 | 4 | 7 |
| Ae+ (+0.5 coef.) (2) | | 0 | 0 | 1 | 1 |
| Ae- (−0.5 coef.) (3) | | 0 | 0 | 1 | 0 |
| Ae- (−1 coef.) (4) | | 8 | 6 | 6 | 4 |
| **Ae Scores (5)** | | − 4.0 | 0.0 | − 2.0 | 3.5 |
| **Ae Ranking** | | **4th** | **2nd** | **3rd** | **1st** |

Keys: Nb.: number; Ae: agroecological; (*) for T1, the last 3 indicators were not assessed as no animals are kept on these farms; (1) Nb. of occurrences $Indic_i^T > 1.05 \times \overline{Indic_i}$; (2) Nb. of occurrences $\overline{Indic_i} < Indic_i^T < 1.05 \times \overline{Indic_i}$; (3) Nb. of occurrences $0.95 \times \overline{Indic_i} < Indic_i^T < \overline{Indic_i}$; (4) Nb. of occurrences $Indic_i^T < 0.95 \times \overline{Indic_i}$; Scoring Formula: Ae+ (+1 coef.) + 0.5 x Ae+ (+0.5 coef.) − 0.5 x Ae- (−0.5 coef.) - Ae- (−1 coef.)

$0.95 \times \overline{Indic_i} < Indic_i^T < 1.05 \times \overline{Indic_i}$): Mulch density (kgDM/ha); 3) a limited number of indicators (4/12) with low values (Ae-: $Indic_i^T < 0.95 \times \overline{Indic_i}$) : Farm land under SWCM practices (%); Cultivated area under no-till and direct seeding (%); Cultivated area under legume crops (%); Cultivated area without any herbicides (%).

T2 (Medium-size crop-oriented farms) agroecological ranking can be attributed to: 1) a more limited number of indicators (6/12) with high values (i.e. Ae+: $Indic_i^T$ >1.05 × $\overline{Indic_i}$): Number of trees/ha; Farm land under SWCM practices (%); Proportion of agroecological tools and equipment (%); Cultivated area fertilized with organic manure (%); Mulch density (KgDM/ha); Cultivated area without any herbicides (%); 2) the lack of indicators with average values (Ae neutral: 0.95 × $\overline{Indic_i}$ < $Indic_i^T$ <1.05 × $\overline{Indic_i}$): 3) a higher number of indicators (6/12) with low values (Ae-: $Indic_i^T$ <0.95 × $\overline{Indic_i}$) : Organic manure produced (kgDM)/cultivated area (ha); OM deposited by night-parked livestock (kgDM)/cultivated area (ha); Cultivated area under no-till and direct seeding (%); Cultivated area under legume crops (%); Cultivated area without any mineral fertilizers (%); Stored fodder (kg)/Cereals and legumes cultivated area (ha).

T3 (Large crop-livestock oriented farms) agroecological ranking can be attributed to: 1) a more limited number of indicators (4/12) with high values (i.e. Ae+: $Indic_i^T$ >1.05 × $\overline{Indic_i}$): Farm land under SWCM practices (%); Cultivated area fertilized with organic manure (%); Mulch density (KgDM/ha); Cultivated area without any herbicides (%); 2) a higher number of indicators (2/12) with average values (Ae neutral: 0.95 × $\overline{Indic_i}$ < $Indic_i^T$ <1.05 × $\overline{Indic_i}$): Number of trees/ha ; Proportion of agroecological tools and equipment (%); 3) a higher number of indicators (6/12) with low values (Ae-: $Indic_i^T$ <0.95 × $\overline{Indic_i}$): Organic manure produced (kgDM)/cultivated area (ha); OM deposited by night-parked livestock (kgDM)/cultivated area (ha); Cultivated area under no-till and direct seeding (%); Cultivated area under legume crops (%); Cultivated area without any mineral fertilizers (%); Stored fodder (kg)/Cereals and legumes cultivated area (ha).

T1 (Small crop-oriented farms) agroecological ranking can be attributed to: 1) a limited number of indicators (4/12) with high values (i.e. Ae+: $Indic_i^T$ >1.05 × $\overline{Indic_i}$): Cultivated area under no-till and direct seeding (%); Cultivated area under legume crops (%); Cultivated area without any mineral fertilizers (%); Cultivated area without any herbicides (%); 2) the lack of indicators with values between 0.95 × $\overline{Indic_i}$< $Indic_i^T$ <1.05 × $\overline{Indic_i}$; 3) a majority of indicators (8/12) with low values (Ae-: $Indic_i^T$ <0.95 × $\overline{Indic_i}$): Number of trees/ha; Farm land under SWCM practices (%); Proportion of agroecological tools and equipment (%); Organic manure produced (kgDM)/cultivated area (ha); OM deposited by night-parked livestock (kgDM)/cultivated area (ha); Cultivated area fertilized with organic manure (%); Mulch density (kgDM/ha); Stored fodder (kg)/Cereals and legumes cultivated area (ha).

## Farm type viability scoring and ranking

### Farm type viability scoring

We will first look at the viability factors and scores of the two farm types deemed to be the most viable (T2 and T3), followed by those of the two types deemed to be the least viable (T4 and T1).

Both FGDs considered the T2 farm type (Medium-size crop-oriented farms) to be viable, with an Overall Viability Score (OVS) of + 26, i.e. the highest among the four farm types (34 for viability factors (VS+) and −8 for non-viability factors (VW-)) (Table 4). Viability scores were consistent between men and women, with an OVS of + 9 (VS+: 14; VW-: −5) and + 17 (VS+: 20; VW-: −3) respectively. Viability factors put forward were mainly economic (3 VS+: availability of farm equipment and animals, significant farm income, low use of hired labor), social (3 VS+: food needs met, observance of customs and traditions, reduced workload thanks to equipment) and, to a lesser extent, environmental (2 VS+: soil protection from erosion, availability of organic manure). Non-viability factors put forward were exclusively economic (3 VW-: shortage of motorized equipment, shortage of labor, lack of dairy animals).

Regarding T3 farms (Large crop-livestock oriented farms), both FGDs deemed this farm type viable with an Overall Viability Score (OVS) of + 16, i.e. lower than T2 farms (VS+: 32; VW-: −16) (Table 4). Viability scores were also consistent between men and women, with an OVS of + 12 (VS+: 15; VW-: −3) and + 4 (VS+: 17; VW-: −13) respectively. Viability factors put forward were mainly economic (4 VS+: high availability of farm equipment, arable land and livestock, and significant farm income), social (3 VS+: food and non-food needs all met, sound work organization, strong family harmony), and to a lesser extent environmental (high availability of organic manure, fields under SWCM practices). Non-viability factors were mainly economic (3 VW-: high workloads, high labor and social costs due to large surface areas, and lack of forage crops), and to a lesser extent social (2 VW-: difficulty in finding agricultural workers, frequent disputes with livestock farmers). No environmental factors were mentioned by either group. In addition, due the size of the herds on T3 farms, non-viability factors related to access difficulties to non-owned grazing resources in the area were highlighted (2 VW-: lack of managed pastures, and shortage of water points in the dry season).

Regarding T4 farms (Livestock-oriented farms), both FGDs deemed this farm type non-viable, with an Overall Viability Score (OVS) of −5 (VS+: 26; VW-: −31) (Table 5). Overall Viability Scores were consistent between men and women, with an OVS of −1 (VS+: 14; VW-: −15) and −4 (VS+: 12; VW-: −16) respectively. Viability factors put forward were mainly economic (4 VS+: large herd including draft animals, significant income from the sale of

**Table 4.** Viability factors and scores for T2 (medium-size crop-oriented farms) and T3 (large crop-livestock oriented farms) types according to men and women focus group discussions (FGDs).

| | Men FGDs | Women FGDs | OVS |
|---|---|---|---|
| T2 | | | |
| +++ | High availability of arable land<br>Significant income from selling part of the production | Good coverage of household food needs<br>Good availability of organic manure<br>Good availability of agricultural equipment (ploughs, ridgers, carts, weeders, dumpers) | |
| ++ | Good soil protection from erosion<br>Good availability of agricultural equipment (ploughs, ridgers, carts, weeders, dumpers)<br>Average availability of organic manure<br>Observance of customs and traditions | Significant income from selling part of the production<br>Low use of hired labour<br>Low reliance on manual labour due to mechanisation<br>Good availability of arable land<br>Good availability of livestock (draught cattle, goats, sheep) | |
| + | | Environmental care and conservation | |
| VS+ | +14 | +20 | +34 |
| - | | No dairy cows | |
| – | Shortage of family and hired labour | Shortage of some equipment (tractor, tricycle, trailer, pick-up truck, motor-driven pump) | |
| — | Shortage of some machinery (tractor, tricycle, trailer, pick-up truck, motor-driven pump) | | |
| VW- | − 5 | − 3 | −8 |
| OVS | +9 | +17 | +26 |
| T3 | | | |
| +++ | Strong family harmony<br>High availability of arable land<br>Significant income from selling a large part of the production | High availability of agricultural equipment<br>High availability of organic manure<br>Good coverage of all household needs (food, health, education, savings, housing)<br>Good organisation of farming activities | |
| ++ | High availability of agricultural equipment<br>High availability of organic manure<br>High availability of livestock (draught cattle, breeding cattle, sheep, goats) | Significant income from selling a large part of the agricultural production<br>Fairly large cultivated areas | |
| + | | Agroecological features in fields | |
| VS+ | +15 | +17 | +32 |
| - | No forage plots | Difficulty in finding hired labour | |
| – | Difficulty in finding hired labour | Frequent disputes with farmers<br>No managed pastures to feed animals during the dry season<br>Shortage of pastoral wells | |
| — | | Significant workload due to large-scale farming activities<br>High costs for hired labour | |
| VW- | − 3 | − 13 | −16 |
| OVS | +12 | +4 | +16 |

Keys : VS+: viability-enhancing factor; VW-: viability-weakening factor; +/++/+++ and -/–/—: viability factor intensity level; OVS: Overall Viability Score.

livestock and milk, good level of transport equipment, forage crop development), to a lesser extent social (1 VS+: strong family harmony) and finally environmental (1 VS+: good soil maintenance thanks to abundant organic manure). Non-viability factors put forward were mainly related to poor grazing resource governance in the area (4 VW-: shortage of secure pastures, cattle tracks and transhumance corridors, pastoral wells, and access trails to water points; frequent blockage of access trails to grazing areas, water points and transhumance corridors; frequent unavailability of veterinarian; increasing number of disputes with farmers), to a lesser extent of an economic nature

**Table 5.** Viability factors and scores for T4 (livestock-oriented farms) and T1 (small crop-oriented farms) types according to men and women focus group discussions (FGDs).

| | Men FGDs | Women FGDs | OVS |
|---|---|---|---|
| T4 | | | |
| +++ | Strong family harmony<br>Good availability of draught cattle<br>Significant income from selling live animals and animal products | High livestock numbers<br>High availability of organic manure<br>Good soil fertility maintenance | |
| ++ | Very high availability of organic manure | High milk availability in the rainy season | |
| + | Good milk availability<br>Ease of transport for crop residues<br>Growing interest in forage production | Income from the sale of organic manure | |
| VS+ | +14 | +12 | +26 |
| - | Insufficient fodder | Difficulty in finding hired labor<br>Frequent unavailability of veterinarian | |
| – | Shortage of pastoral wells | Blockage of access trails to grazing areas<br>Blockage of access trails to water sources<br>Difficulty in finding pasture<br>Cultivated area too small to meet household needs | |
| — | Increasing number of disputes with farmers<br>Insufficient grazing space<br>No transhumance corridors available<br>Lack of access trails to water points | Frequent disputes with farmers<br>Shortage of fodder resources in the dry season | |
| VW- | – 15 | – 16 | – 31 |
| OVS | – 1 | – 4 | – 5 |
| T1 | | | |
| +++ | High time availability for other income-generating activities<br>Adequate maintenance of farmed areas<br>Strong family harmony | No need for hired labor | |
| ++ | Production levels just about sufficient to cover household food needs | Good crop maintenance<br>Production levels just about sufficient to cover household food needs | |
| + | Low workload | Low use of herbicides<br>Low workload | |
| VS+ | +12 | +9 | +21 |
| - | Low availability of organic manure | Poor soil fertility maintenance | |
| – | Limited financial means to tackle unexpected problems<br>Low level of farm income | Low income from selling production<br>Compulsory manual work<br>Difficulty in escaping poverty<br>Inability to meet other household needs (health, education, savings, etc.) | |
| — | No livestock<br>Lack of agricultural equipment | Low availability of arable land<br>No machinery or equipment<br>No draught animals | |
| VW- | – 11 | – 18 | – 29 |
| OVS | +1 | – 9 | – 8 |

Keys: VS+: viability-enhancing factor; VW-: viability-weakening factor; +/++/+++ and -/–/—: viability factor intensity level; OVS: Overall Viability Score.

(VW-: shortage of fodder in the dry season; difficulty in meeting household needs due to small cultivated area), and finally of a social nature (2 VW-: frequent disputes with farmers; difficulty in finding hired labor).

Regarding T1 farms (Small crop-oriented farms), both FGDs also deemed this farm type non-viable, with an Overall Viability Score (OVS) of −8 (VS+: 21; VW-: −29) (Table 5). Women's viability score strongly supports this, with an OVS of −9 (VS+: 9; VW-: −18). However, men's viability score was slightly positive, with an OVS of + 1 (VS+: 12; VW-: −11). Viability factors put forward were mainly economic (4 VS+: no need for hired labor, time availability for all types of activity, good manual crop maintenance, moderate workload), to a lesser extent social (2 VS+: strong family harmony, production levels just about sufficient to cover all household needs), and finally environmental (1 VS+: low use of herbicides). Non-viability factors mentioned were primarily economic (4 VW-: low farm income, insufficient land available, lack of farm equipment, lack of livestock, especially draft animals), then social (3 VW-: inability to meet unforeseen expenses, feeling of being trapped in poverty, feeling of being subjected to hard manual labor due to lack of equipment) and finally environmental (1 VW-: poor soil fertility maintenance due to lack of organic manure).

### *Dimensions of viability and respective weights in viability scores*

An additional dimension of viability, which was not included in the definition provided in the introduction, emerged during the FGDs. This "political" dimension relates to agricultural practices and rules for access and use of non-owned agro-pastoral resources such as pastures and water points. It was therefore considered in the allocation of the 89 VS+ and VW- viability factors listed in Tables 4 and 5.

In the overall viability assessment of the four farm types (Figure 4), economic factors outweigh the others in terms of occurrence, both positively and negatively, whatever the farm type (as shown by the larger red circles in Figure 4). Social factors (green circles) come second in terms of occurrence (smaller circles). Environmental factors (blue circles) rank 3rd in terms of occurrence. Finally, the political dimension of viability stands out in farm types 3 and 4 (purple

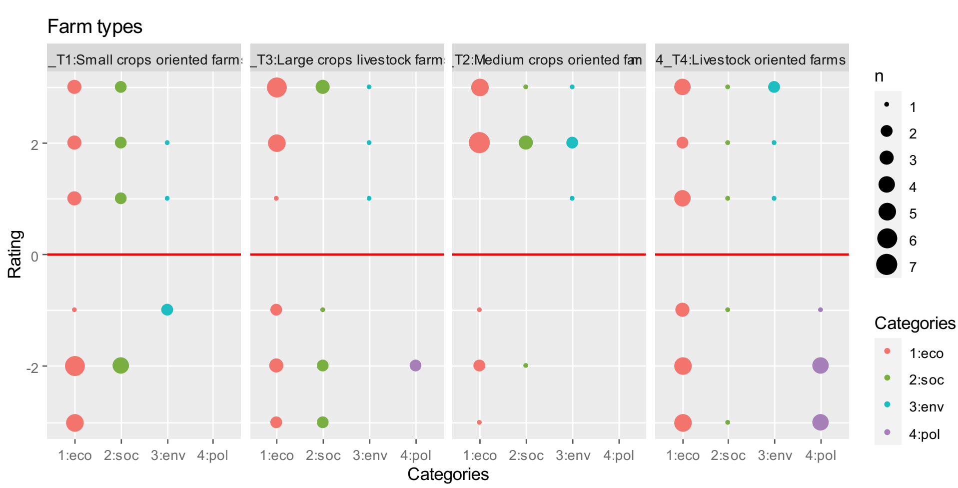


**Figure 4.** Dimensions of viability and respective weights in farms' viability scores. (key: eco: economic; soc: social; env: environmental; pol: political)

circles), where large numbers of livestock are kept and which are therefore heavily reliant on non-owned grazing resources, and where this lack of governance for such spaces is more acutely felt (hence their ranking as VW-).

### *Viability ranking by farm type and gender*

In summary, integrating viability scores from both FGDs (men and women) gives the following ranking in terms of overall viability (OVS): T2s (Medium-size crop-oriented farms) get an OVS score of + 26, followed by T3s (Large crop-livestock oriented farms) with an OVS score of + 16, themselves followed by T4s (Livestock-oriented farms) with an OVS score of −5, and finally T1s (Small crop-oriented farms) with an OVS score of −8 (see Tables 4 and 5).

Viability rankings differ slightly according to gender:

- Both men and women placed T2s and T3s in the most viable farm category, but with a different ranking in the top two positions: women ranked T2s first (Medium-size crop-oriented farms with an OVS score of + 17) while men ranked T3s first (Large crop-livestock oriented farms with an OVS score of + 12).
- Both men and women placed T1s and T4s in the least viable farm category, but with a different ranking in the bottom two positions: women ranked T1s last (Small crop-oriented farms with an OVS score of −9) while men ranked T4s last (Livestock-oriented farms with an OVS score of −1).

### *Farm type agroecology and viability*

Comparing farm types in terms of Ae ranking versus viability ranking does not reveal any causal relationship between agroecological implementation levels (= Ae status) and improved farm viability (Table 6).

This conclusion somehow does not apply to T1s (Small crop-oriented farms) since they rank last in both Ae and viability rankings. As far as viability is concerned, this is not surprising as these farms have very limited resources and are on the verge of survival. The fact that they do not keep any livestock also accounts for their bottom position in the Ae

**Table 6.** Correlation between agroecological ranking and viability ranking for the 4 farm types studied.

| Farm types | Ae Ranking | Viability Ranking |
|---|---|---|
| T4. Livestock-oriented farms | 1st | 3rd |
| T2. Medium-size crop-oriented farms | 2nd | 1st |
| T3. Large crop-livestock oriented farms | 3rd | 2nd |
| T1. Small crop-oriented farms | 4th | 4th |

ranking since they are not in a position to set up the kind of strong crop-livestock synergies that is so important in the Ae scoring process. However, in terms of Ae, these farms stand out for their specific agricultural practices (high proportion of leguminous crops, minimum tillage, very limited use of mineral fertilizers).

T4s (Livestock-oriented farms), which ranked first in the Ae ranking, only came 3rd in the viability ranking. The agricultural practice that seems to be severely undermining their viability is extensive large-scale herding which, today, in a densely populated area with expanding cultivated land and wide-open spaces (no enclosed private property), poses too many problems (multiple disputes between crop-oriented farmers and livestock-oriented farmers: damage to crops, blocked access trails to water points, conversion of pasture land to crops, etc.). On this type of farm, the very high livestock/area (TLU/ha) ratio (13 versus 2 TLU/ha on average) also explains why these farms store more fodder and more readily produce large quantities of organic manure, both of which are agricultural practices that weigh heavily in the Ae scoring system.

T3s (Large crop-livestock oriented farms) rank 3rd in the Ae ranking, but second in the viability ranking. Their strong position in the viability ranking is mainly due to economic factors, as these are large crops and livestock farms providing food security and generating enough income to meet the needs of the many people who depend on them. Their 3rd place in the Ae ranking is mainly due to their greater use of motorized equipment and their more intensive use of mineral fertilizers, given that these are generally large-scale cotton and maize producers.

Lastly, T2s (Medium-size crop-oriented farms) offer the best agroecology/viability balance, with sufficient land and livestock to provide food security and generate enough income for the household, while avoiding the challenges of running large herds and managing crops on very large, scattered plots of land. On these farms, crop-livestock synergies (fodder storage, manure production, etc.) do not involve excessive workloads in relation to requirements, which are commensurate with land area and livestock numbers.

## Discussion

### *Assessment method for agro-sylvo-pastoral systems' agroecology levels*

Results from the agroecological scoring and ranking of the four agro-sylvo-pastoral systems are linked to the 15 agricultural practices selected and included into the scoring system. This approach makes sense in the Koumbia situation, but that it has no universal application as it stands (i.e: in other area, other appropriate sets of agricultural practices should be selected). Several interesting aspects are nonetheless worth noting: 1) it takes into account many crop/livestock/tree synergies, which means that many of the suggested indicators can be re-used for agro-sylvo-pastoral systems (and for crop-livestock systems in general) elsewhere; 2) it is easy to implement since it only requires a survey to collect indicators; 3) it is based on a quantitative approach that makes it easy to rank farm types.

From a theoretical point of view, our conclusion from this work is that the multifactor analysis frameworks for assessing the agroecological character of a farming system put forward by several authors (Côte et al. 2022; Wezel et al. 2020) ultimately serve as guides for selecting the essential agricultural practices that make up the agroecological core of the farming system whose agroecological status is being assessed.

In practice, the essential agricultural practices to consider when assessing the agroecological status of agro-sylvo-pastoral system (and for crop-livestock systems in general) are those that refer to synergies between crops, livestock and trees, as well of by-product recycling, and cropping and livestock system diversification, all core principles of agroecology (Wezel et al. 2020).

### *Few references to the 15 agricultural practices in the viability factors of agro-sylvo-pastoral systems*

Few of the 15 agricultural practices used to assess the Ae status of the four farm types are mentioned by farmers when considering viability-enhancing factors (VS+), with only 5 of them included in the VS+ inventory. The four VS+ practices most often mentioned by all four types, and by both women and men, are the production and use of organic manure, the use of Ae farming equipment and, in particular, the ownership of draft animals. The fifth (agricultural practice relates to soil and water conservation measures), is only mentioned by farm types with the largest cultivated areas (T2s and T3s). Some agricultural practices (3/15), which are either poorly implemented or poorly managed by farmers, are deemed to be VW- factors. They relate to insufficient fodder production and difficulties in gaining access to pasture and water. However, these viability-weakening factors (VW-) are only mentioned by farm types with large herds (T3s and especially T4s).

When determining farm type viability levels, farmers tend to refer to their economic capital (land, livestock, labor), social capital (family harmony, relationship with other users of shared resources), and environmental capital (land and soil fertility).

The theoretical lesson learned from this finding is that methods for assessing agroecology and viability levels of agricultural production systems should better integrate principles of agroecology with elements of economic, social, environmental and political capital (Côte et al. 2022; Wezel et al. 2020).

In practical terms, our study results show that, at the farm level, agroecology makes most sense when it is viewed in the context of the farm's viability in all its dimensions.

### *Impacts of the economic, social, environmental and political dimensions of viability in agro-sylvo-pastoral systems*

The economic dimension of viability is the one that carries the most weight in farmers' opinions, and in this they echo agro-economists whose work places great emphasis on this particular dimension (Neto et al. 2017; Pinheiro et al. 2021; Spencer et al. 2021; Spicka et al. 2019). However, the social and environmental dimensions are also considered by farmers when assessing viability, albeit to a lesser extent, and in this respect, they concur with the proposals made in a number of studies to include such dimensions in viability assessments (Alary, Gousseff, and Nidumolu 2008; Alhamidi, Hakansson, and Gustafsson 2003; D'Silva et al. 2012; Nobrega et al. 2018; Rivas et al. 2015).

The main change brought about by this study, which stems from the use of a participatory approach (FGDs), is the addition of a "political" dimension to viability, which was not initially envisaged in the viability analysis framework. This "political" dimension relates to the difficulties encountered by large herd owners (T3 and T4) in terms of moving around the land and gaining access to pasture and water points, i.e. non-owned land resources.

The theoretical lesson learnt from this finding is as follows. The political capital of a farm, defined as its ability to weigh on and influence the rules governing access to resources and production factors, is a key element that should be included in viability assessment methods, especially when the system relies heavily on access to such resources. This political dimension of viability, which pertains to access and the management challenges of agro-sylvo-pastoral resources, affects the viability of farms. With the specific growth of livestock and the expansion of crops, herders are faced with the reduction and disruption of their traditional pastoral spaces. Poverty and demographic pressure have led to negative effects on the environment (deforestation, land degradation, and watercourses) and conflicts among various stakeholders over the use of these territorial resources (Vall, Diallo, and Fako Ouattara 2015). Regulations on classified forests, protection of riverbanks, and cattle tracks are ignored by the majority of the population or not respected (Vall, Diallo, and Fako Ouattara 2015). As suggested by Gonin and Gautier (2015), policies aimed at enhancing livestock governance in the context of climate change and alterations in land cover and tenure should prioritize the safeguarding of pastoralists' reticular territories, comprising corridors and numerous pasture areas. The co-construction of rules for access and use of agro-sylvo-pastoral resources recognized by the population, through local conventions seems to be a promising path. However, these are complex systems to develop and difficult to implement, as shown by the attempt to establish a land charter in Koumbia reported in the paper by Vall, Diallo, and Fako Ouattara (2015).

The political viability of these farms that integrate livestock is further negatively impacted by the recent influx of Islamist groups to the region, making access to these agro-sylvo-pastoral resources even more challenging. Households of Mossi and Bwaba agro-pastoralists, who mostly have T3 farms, and those of Fulani herders, primarily with T4 farms, are the most affected, to the extent that some have been forced to leave the region in search of feed and water for their animals.

In practice, for farming systems in which part of the activity relies on the use of non-owned land resources, viability assessments should at least consider the economic, social, environmental and political dimensions.

### *Perception of agro-sylvo-pastoral system viability by gender*

In most cases, Overall Viability Scores (OVS) produced during FGDs are consistent between men and women, except for T1s (Small crop-oriented farms). In addition, the analysis of the 89 viability factors does not reveal any trends specific to men or women for either Vs+ or VW-. The only difference is that in the case of T1s, women place more emphasis on factors that keep this farm type trapped in poverty. It was therefore important to conduct both FGDs separately in order to check that there were no gender differences in the way viability was perceived. However, this finding should be treated with caution as it is based on a small sample of farmers (24 men and women farmers grouped in two focus group discussions).

This leads us to draw the following theoretical conclusion. The participatory approach to identifying viability factors through relatively small FGDs and with a limited number of farm types, produced interesting results. However, in order to reach solid conclusions, we recommend holding repeat FGDs of a similar size.

In practice, we feel that any comprehensive viability assessment carried out via a participatory approach should involve repeat FGDs of a limited size in order to collect as many viability factors as possible.

### *Considering agricultural dynamics and synergies between farm types to clarify the link between agroecology and viability*

To meet increasing market demands and ensure food self-sufficiency while limiting economic risks, farmers diversify their production and implement low-input crop-livestock practices. All these changes make their farms dynamic. This dynamic dimension of farming systems must be taken into account over time and space in any discussion addressing the intersections between agroecology and farm viability. For instance in Koumbia, farmers have long favored a strategy of expanding crops and livestock, as long as spaces were available to extend agricultural areas and find new pastures, as shown by the findings of Vall et al. (2018). However, as population and land pressure increase, farmers are adopting new strategies to achieve their goals. This has resulted in the reduction of fallow, the transition to continuous cropping, overgrazing, and an increased reliance on synthetic inputs (Vall, Marre-Cast, and Kamgang 2017). Farmers have also intensified production by strengthening the integration of agriculture and livestock to be more self-sufficient in agricultural energy, fodder, and organic fertilizers. However, the persistent increase in agricultural and pastoral pressure on natural resources has a negative impact on soil fertility, and rangeland availability (Vall and Diallo 2009). The viability of pastoral space is decreasing according to Gonin and Tallet (2012), due to difficulties in accessing pastures, intense agricultural pressure, and various conflicts related to the management of communal pastoral resources (water points, feed resources).

The coexistence of different farm types in the same geographic space also has a direct impact on the viability of farms. These mutual influences between farm types can occur in various ways, such as through a form of economic resilience where T2 farmers may own more livestock but entrust their management to T4 farmers. These T4 farmers can also graze their livestock in the fields of T2 farmers or by night-parked livestock, allowing the livestock to deposit organic inputs for soil fertilization. Thus, each farmer benefits from these synergies where crop residues and animal excrement are valorized. Additionally, the sale of crop residues to livestock-oriented farms (T3 and T4) and organic manure to crop-oriented farms (T1 and T2) plays a role in the viability of the farm types.

### *Links between agroecology and viability in agro-sylvo-pastoral systems*

The agroecological status of agro-sylvo-pastoral systems (and for crop-livestock systems in general), is a widely studied subject around the world, and particularly in Africa where these systems are widespread. Considered to be agricultural systems with high agroecological potential, mixed crop-livestock systems have been the subject of many studies, all over the world, highlighting their potential positive impacts on soil fertilization and carbon sequestration, on the intensification of farm production at minimal cost based on crop-livestock synergies and by-product recycling, on their resilience to climate and economic uncertainties, and on their ability to be implemented by households regardless of their wealth (Gonzalez De Molina and Lopez-Garcia 2021; Herrero et al. 2010; Rufino et al. 2021; Ryschawy et al. 2012).

However, today's agro-sylvo-pastoral systems in West Africa are highly diverse, particularly as regards the relative importance of both activities (size of cultivated area and livestock numbers). The ability of some types of agro-sylvo-pastoral systems to develop over time is an issue for several reasons: movements of large herds are increasingly constrained by the spread of crops, access to crop by-products is increasingly competitive, farmland expansion becomes more difficult as population density increases, and the ability of the most modest systems to really meet the most basic household needs is not guaranteed. This is where the link between the agroecological status of the systems and the issue of viability is revealing. In our study and with regard to Koumbia, our findings lead us to conclude that medium-size farms offer the best balance between agroecology and viability, and therefore the best prospects for sustainability. This finding is interesting as the case of Koumbia and is not isolated, but rather common throughout the savannah area of sub-Saharan Africa. This ultimately leads us to recommend supporting the development of these medium-size forms of family farming, which seem to offer the best prospects for sustainability in that part of the world.

## Conclusion

The viability of agro-sylvo-pastoral systems does not necessarily depend on their agroecological status. As our study shows, very small farms in Koumbia are neither highly agroecological nor highly viable. Similarly, farms with the largest cultivated areas and the largest herds are neither the most agroecological nor the most viable. The best balance between agroecology and viability is struck by medium-size farms. In agro-sylvo-pastoral systems, farms with cultivated areas that are not too small and with livestock numbers that are not too high can be supported in order to make better use of animal dung since ruminants will return almost half of the plant biomass removed to the land, thereby reducing the recurring disputes between farmers and herders over the use of pastoral land to feed livestock.

In assessing farm viability, although greater emphasis is placed on the economic dimension, the social and environmental dimensions also matter, and for farming systems that rely heavily on non-owned resources (such as spontaneous grazing, crop residues and water points), our study showed that a political dimension of viability must also be taken into account in these assessments if they are to be comprehensive.

## Acknowledgments

The authors express their gratitude to the partners of the research and training platform on agro-sylvo-pastoral systems in West Africa (https://www.dp-asap.org/) and extend their appreciation to the farmers and local authorities for their valuable collaboration in this study. They also express their gratitude to the Transformative Partnership Platform (TPP) on Agroecology (bit.ly/AgEc_TPP) that hosted the Viability project "Documenting and Evaluating the Socioeconomic Viability of Agroecological Practices across Africa" where this study was conducted.

## Disclosure statement

No potential conflict of interest was reported by the author(s).

## Funding

This study was carried out thanks to funding provided by the Sustainable Development Department of the French Ministry of Europe and Foreign Affairs and by the Agroecology TPP through the Viability project (Documenting and Evaluating the Socioeconomic Viability of Agroecological Practices across Africa), which was supported by the Government of France and the CGIAR Research Program on Forests, Trees and Agroforestry. .

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## Data availability statement

The data that support the findings of this study are available in Dataverse at https://dataverse.cirad.fr/privateurl.xhtml?token=99409c61-e831-4ced-afd9-93974c7d4368

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