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## Comprehensive Livestock Driven Typology for Food and Nutrition Security in Mali

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# Comprehensive Livestock Driven Typology for Food and Nutrition Security in Mali

Bandiougou Dembele, Moussa Sall, and Cheikh Sadibou Fall

## 1. Introduction

Economic growth in sub-Saharan Africa is projected to remain at 3.2 percent in 2019 and rise to 3.6 percent in 2020 (IMF, 2020). However, globally the continent continues to be the most food insecure. As pointed out by FAO et al. (2020), the prevalence of undernourishment is on the rise in the region. Even though the deterioration has slowed, there are still about 256 million hungry people in Africa. While African countries are making progress towards reducing malnutrition, progress is too slow to meet the six key nutrition targets of the Sustainable Development Goals (SDGs). As a result, the continent is not on track to eliminate hunger by 2030. Moreover, “hidden hunger” is still widespread; about half of all children under five suffer from micronutrient deficiencies, especially in vitamin A, zinc, and iron, which limits their development, health and future working capacity. The effects of micronutrient deficiency can be irreversible. For example, without iodine, children are susceptible to brain damage. Nearly 48 percent of Africa’s population relies on cereals and root staples that lack vital micronutrients (Wawa, 2019). Millions have no access to or cannot afford foods, such as vegetables, fruit, and animal products, that are rich in micronutrients.

According to Adesogan et al. (2019), two billion people suffer from micronutrient deficiencies, 151 million children under five suffer from stunting, and millions more have impaired cognitive development related to poor nutrition. This is partly due to insufficient consumption of animal-sourced foods (ASF), which supply multiple bioavailable nutrients that are lacking in the cereal-based diets of the poor. Indeed, in appropriate amounts, livestock products are valuable sources of complete, high-quality, easily digestible protein and many essential micronutrients, such as iron, zinc, calcium, vitamin A, and vitamin B12 (Schönfeldt, 2013). As pointed out by Fan (2018), livestock plays a critical role in food systems as an important source of income, labor-saving and productive assets. It also contributes to nutrition, as consumption of a diverse array of animal sourced foods is strongly associated with

improved child growth. Downsides of animal production and consumption are its environmental footprint (Steinfeld et al., 2006), overconsumption of ASF in middle- to high-income countries and, as demonstrated by Poore and Nemeck (2018), its contribution to climate change (Steinfeld et al., 2006; Gerber et al., 2013).

In many African countries, population growth, higher incomes, and urbanization, all associated with dietary changes, have increased demand for livestock products (Thornton, 2010; Delgado 2005). Higher demand for livestock products creates new opportunities for public and private investments along livestock value chains.

To guide the selection and design of appropriate interventions for increasing the production and consumption of animal-sourced foods, in this paper we propose a spatial typology based on a comprehensive food and nutrition security (FNS) framework for livestock in Mali. This framework has four dimensions or pillars:

- Potential
- Availability
- Access
- Utilization

Our methodology builds on previous studies by Marivoet et al. (2019), Torero (2014) and Yu et al. (2010). Using data for each of the four dimensions, efficiency and average performance in terms of livestock production, access and utilization are estimated at sub-national levels. Whereas nutritional status will be used to set priority levels, measure of efficiency is used to guide locations where appropriate investments in livestock will produce more benefits in terms of food security, employment and poverty alleviation. To assess production potential for the livestock sector, we use the stochastic frontier framework (SFF) which allows for the estimation of both livestock efficiency and its drivers. As pointed out by Marivoet et al. (2019), the resulting typology is conceptually sound, operationally flexible, and less data intensive than other approaches.

This paper is structured as follows: in Section 2, we discuss the state of food and nutrition security and the role of livestock in the Malian economy. We lay out the conceptual framework to support the proposed typology in Section 3. We present descriptive analyses of the data and variables used in the typology in Section 4. The results of the typology are presented and discussed in Section 5. Lastly in Section 6, we discuss the policy implications of the typology for food security, nutrition, and livestock development planning in Mali.

## 2. Food Security and Livestock in Mali

### 2.1. State of food and nutrition security

Mali is a landlocked and geographically diverse country located in the Sahel region. It is a low-income country with a large rural economy and a rapidly growing population. Crop farming, livestock, and fisheries account for about a third of Mali's gross domestic product (GDP) and contribute to more than 70 percent of rural employment. Cereal production occupies over 80 percent of the total arable land and accounts for about 75 percent of total agricultural production. Cereals are largely produced and consumed on the family farm. A lack of access to the sea means that the country is highly dependent on the ports of Dakar, Senegal and Abidjan, Côte d'Ivoire for its imports and exports. Climate change and human pressure on natural resources present challenges for agriculture in Mali. The population was estimated at 19.1 million in 2018<sup>1</sup>, and poverty remains high mostly in rural areas, with 50 percent living below the poverty line of USD \$1.90 a day. The country ranks 182 out of 189 on the Human Development Index and about 68 percent of the adult population in Mali is illiterate.

The malnutrition rate is high – 28 percent of children under five years suffer from stunted growth. This is mainly due to a poor diet. The share of children with stunted growth is particularly high in the regions of Mopti with 46.5 percent; Segou, 40.5 percent; and Sikasso, 39.9 percent. Moreover, 66 percent of households with poor food supply had at least one child with stunted growth (Eozenou et al., 2013). 74.6 percent of households are food secure of which 26.3 percent with acceptable food consumption and around 48.3 percent of food secure households are borderline (SMART, 2015). Over a quarter of households are food insecure

in rural areas compared to 14.6 percent in urban areas (PoINSAN, 2017). More than 40 percent of households are food insecure, in eleven provinces. – is 74 percent in the province of Youwarou, 73 percent in Gao, 60 percent in Abeibara, 57 percent in Koro, 56 percent in Douentza and Kolokani, 54 percent in Bandiagara, 52 percent in Gourma Rharous, 50 percent in Bankass, and 45 percent in Tominian and Bafoulabe (ENSAN, 2017). In 2016, about 2.5 million Malians were facing food insecurity, around 14 percent of the total population, while 315,000 people suffered from severe food insecurity (NCEA, 2017). Household food expenditures vary across provinces. In Kayes, the budget allocated for food represents 82.5 percent of household expenditures compared to 47.6 percent in Bamako. In Sikasso, a major rainfed agricultural zone in Mali, household food expenditures are estimated at 62.9 percent compared to 70.5 percent in Segou, a major area of irrigated rice production (USAID, 2018).

The Malian government and its technical and financial partners have launched many comprehensive and targeted initiatives to address this food and nutrition insecurity. Among other initiatives, the multisectoral nutrition action plan (2014-2018)<sup>2</sup>, the food and malnutrition control program in the circles of Nara and Nioro du Sahel (2012-2017)<sup>3</sup> and more recently the 2019-2028 Action Plan of the National Food and Nutrition Security Policy (PoINSAN)<sup>4</sup>.

### 2.2. The role of livestock

Livestock production is the backbone for economic growth and the reduction of poverty and malnutrition reduction in rural areas in the Sahel countries. In Mali, in terms of income generation nationwide, livestock is ranked third, with gold and cotton in the lead. Livestock represents an opportunity to create value addition for the many actors in the value chain. In addition, in the case of Mali, the sector has a comparative advantage due to lower costs per animal and greater factor endowments (land and water) compared to regional competitors. Livestock systems and activities differ across the country, with nomadic pastoralists in the northern and agro pastoralists in the south of the country. About 95 percent of cattle farmers are traditional pastoralists or agro pastoralists who sell their livestock in informal “bush” markets and primary markets (USAID-Mali, 2018). Agro pastoral production is generally more

1 Perspective monde, date de consultation : 12/11/2019, source : Banque Mondiale (<http://perspective.usherbrooke.ca/bilan/tend/MLI/fr/SP.POP.TOTL.html>)

2 <https://www.unicef.org/mali/media/2296/file/PLAN%20D%E2%80%99ACTION%20MULTISECTORIEL%20DE%20NUTRITION%202014-2018.pdf>

3 <https://www.fao.org/3/i9626fr/i9626FR.pdf>

4 <http://extwprleg1.fao.org/docs/pdf/MLI192037.pdf>

commercially oriented and satisfies domestic consumption markets. Producers are organized in associations, cooperatives, or unions with varying degrees of specialization. Pastoral livestock farming is generally not business-oriented but oriented towards meeting cash needs. Livestock is used as a “rural bank” by rural households to absorb shocks from the variability of agricultural production. During years of good crop production, households invest and increase their herd size, while during years of poor harvests and rainfall shortage they sell their livestock.

The traditional livestock sector is characterized by its low productivity and the low weight of its carcasses. The average carcass weight is 25 percent to 40 percent below what is possible if proper feeding techniques were applied. Major urban centers like Bamako have seen the development of peri-urban farms, like Afrique Color, that purchase live cattle to fatten and resell to meet local demand. In recent years, livestock has contributed about 19 percent to GDP (World Bank, 2018). In addition, about 85 percent of households rely on livestock for at least part of their livelihoods. Livestock related activities contribute to between 10 and 35 percent of the total cash income generated by rural households (USAID, 2018). The sector contributes to household’s dietary diversity; five percent of household daily protein intake is from animal sources (DNPIA, 2016).

Figure 1 shows the cattle population per province according to data from the Direction Nationale de la Production et Industries Animales (DNPIA, 2016, 2017, 2018) – little change is seen in recent years. The major zones of cattle husbandry include the regions of Mopti, Sikasso, Korolikoro, Segou, Kayes, Timbuktu, Gao, Kidal, and Bamako. Mopti, Sikasso, and Koulikoro represent 28, 16, and 14 percent of cattle ownership, respectively. In terms of herd size, Mopti has the largest herds. Mopti is endowed with significant resources for livestock development, particularly grassland and water, mainly in the Central Delta. Pastoral communities in Mopti region are mostly composed of Fulani who have a long history of rearing livestock. However, livestock production systems are still traditional there. Only 8.1 percent of households sell an average of two or more head of cattle each year (LSMS-ISA, 2019). Offtake remains

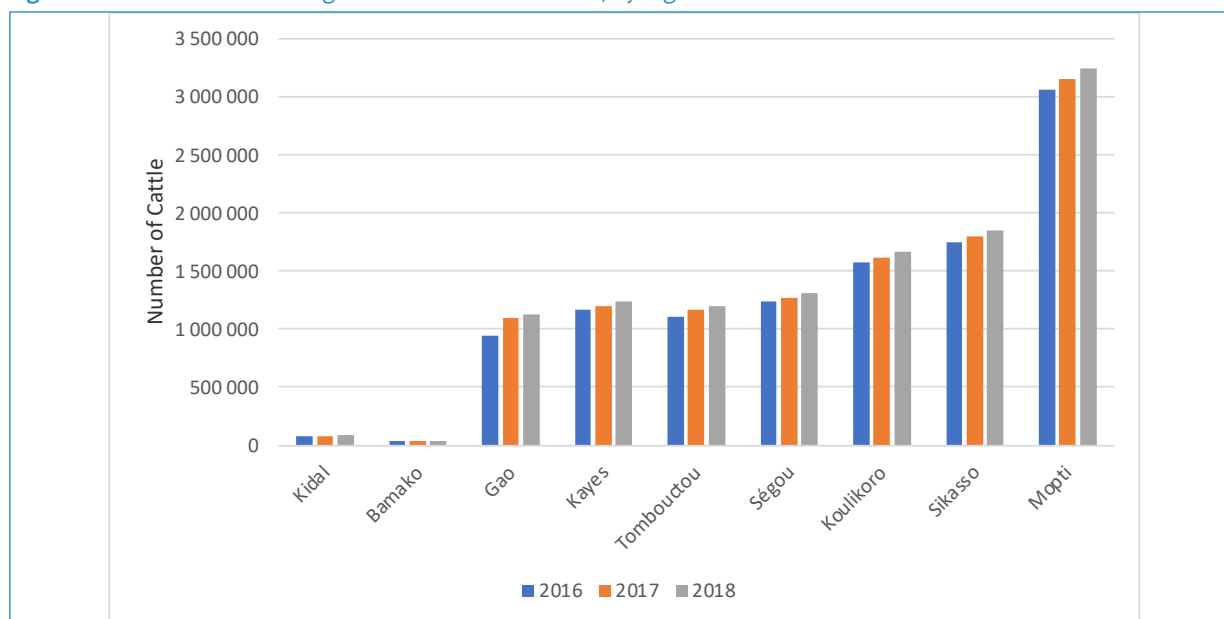
low compared to the number of cattle in the region. Milk production of local breeds is estimated at three liters per day on average. Due to the low productivity of local breeds, the milk value chain is still poorly organized. Genetic improvement programs have been established with the objective to create locally-adapted genotypes capable of producing more milk and meat. To improve the size and productivity of local breeds, the practice of cross-breeding indigenous breeds with breeds imported from Europe has been adopted. Government and donor programs have deployed efforts to promote artificial insemination by importing quality semen from Europe, Morocco, and the US to inseminate local cattle genotypes. Newly trained artificial inseminators are employed to perform in this specific activity. This practice is particularly dominant in the peri-urban dairy value chain.

The health status of the animals is an important aspect of the breeding process and strongly influences livestock productivity. Vaccination campaigns are organized periodically. The Laboratoire Centrale Vétérinaire (LCV) distributed 42.5 million vaccinations. One hundred thirty-seven veterinary posts, 34 veterinary clinics, and 245 veterinary pharmacies are scattered throughout the country. In addition, 162 private agents are accredited with health mandates from government to cover animal health needs. Nevertheless, veterinary and animal health services are geographically dispersed and particularly weak, leading to high rates of cattle disease. The Direction Nationale de Services Vétérinaires (DNSV) faces logistical and manpower constraints which severely restricts their capacity to control animal diseases and the trade in unregistered vaccines and drugs.

Agro-industrial feed for livestock, mostly used by cattle fatteners, are an important part of livestock feeding during the dry season. Some 76 Malian companies transform cotton seed and other agricultural by-products into animal feed, including Grand Moulins du Mali, and Grafax, among others. Animal feed is often in short supply due to seasonal variations in demand. Some of the feed produced is also exported to countries in the region. In 2017, the government granted 1 billion F CFA in subsidies to promote production of crops for use in animal feed to farmers in Bamako, Koulikoro, and Sikasso.



Figure 1: Trends in cattle holdings from 2016 to 2018 in Mali, by region

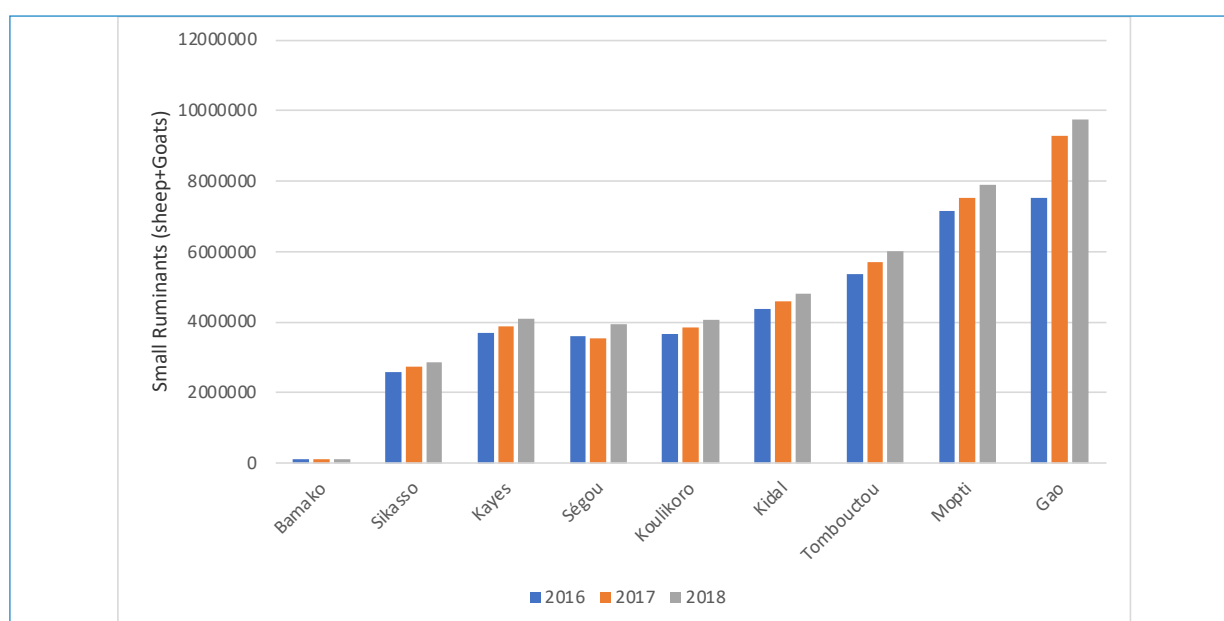


Source: DNPIA, 2016-2018

The number of small ruminants, mainly sheep and goats, per region is presented in Figure 2. Gao, Mopti, and Timbuktu represent 22, 18, and 14 percent of small ruminants in the country, respectively. Numbers of small ruminants are also important elsewhere in Mali. In terms of offtake, the Timbuktu region occupies the first place with 46 percent, followed by Mopti

and Gao. The number of small ruminants sold per year and per household is estimated at seven head for Mopti and Timbuktu and six heads for Gao. Compared to large ruminants, the offtake of small ruminants is more important. National small ruminants' population showed an average growth of 7 percent annually.

Figure 2: Small ruminants' trends from 2016 to 2018 in Mali, by region

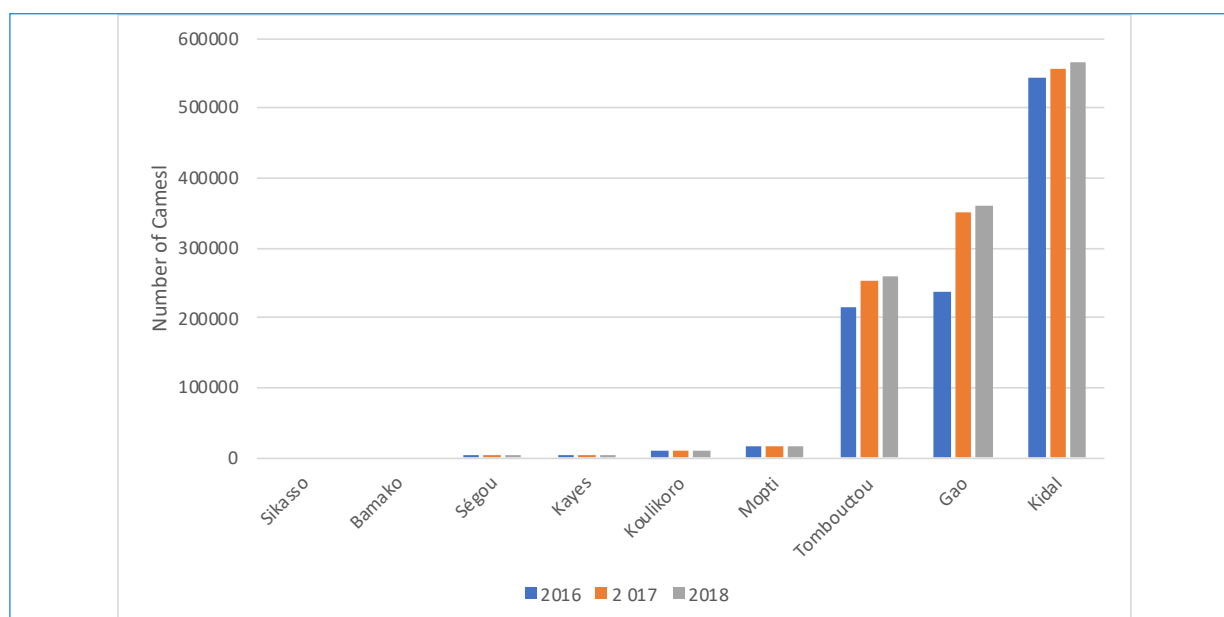


Source: Data (DNPIA, 2016-2018)

The number of camels increased across Mali between 2016 and 2018, except in Sikasso and Bamako regions (Figure 3). The Sikasso region is not well adapted for camel husbandry due to its agroecological conditions and multiple diseases. The three Northern regions

of the country are known as the areas of camel breeding. The bulk of the country's herd is in Kidal, Gao, and Timbuktu. Camel breeding is not yet well integrated in agriculture production systems in the western and southern regions.

Figure 3: Camel trends from 2016 to 2018 in Mali, by region

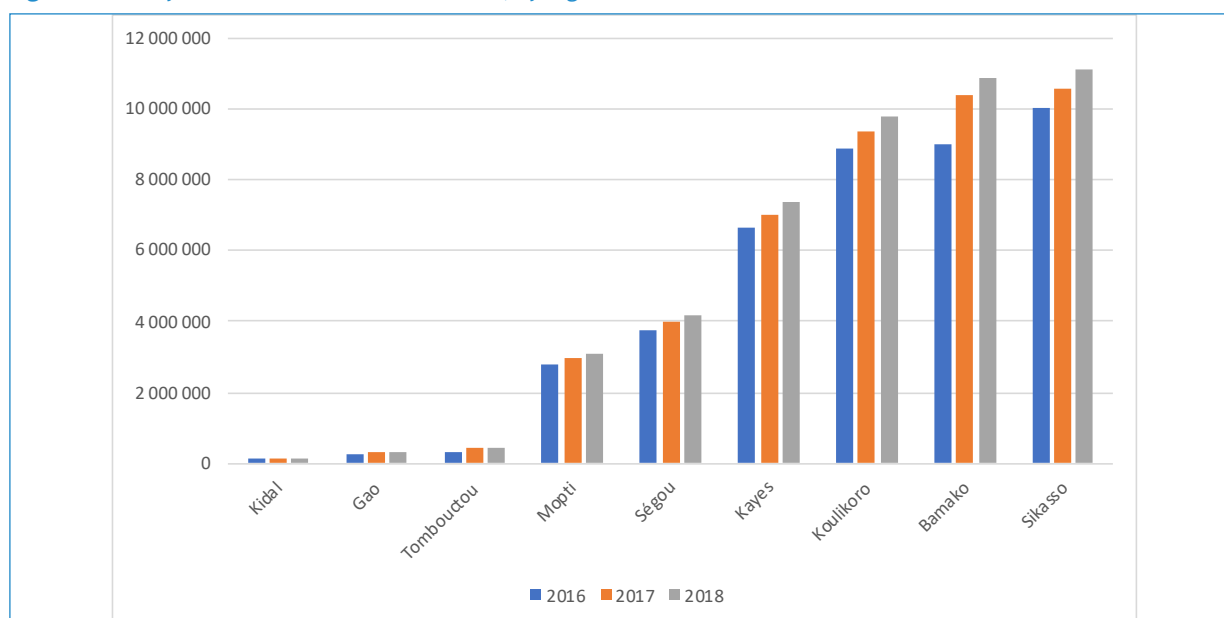


Source: DNPIA (2016-2018)

Mali's poultry sector is developing rapidly, with industrial production being introduced in a number of regions (Figure 4). Population growth and increasing demand are the drivers of poultry growth for both the industrial and the traditional systems. Geographically, the poultry population is concentrated in four regions: Sikasso, Bamako, Koulikoro and Kayes. This could be attributed to high

dietary demand and growing agribusiness around the urban centers in those regions. Poultry production is an important source of revenue and protein for rural households. Even in the traditional system, the market is booming due to increased availability of poultry feed and a better control of poultry feed and diseases.

Figure 4: Poultry trends from 2016 to 2018 in Mali, by region



Source: (DNPIA, 2016-2018)

In least developed countries, many of which are in Sub Saharan Africa (SSA), the livestock sector accounts for nearly 20 percent of agricultural GDP (FAO, 2018). This low contribution from livestock can be attributed to the nature of the production systems (feed, health, care, and genetics, among others) with poor fodder and low complementary feeding. However, in Mali

the livestock production system contributes up to a third of agricultural GDP and for 19 percent of total GDP (Nabarro and Wannous, 2014).

In Mali, livestock contributes significantly to household income, particularly in rural areas, reaching 80 percent in pastoral systems against 18 percent in agropastoral systems (IRAM, 2015). The real GDP

growth rate of livestock increased from 4.4 percent in 2012 to 5.6 percent in 2017. The growth of livestock GDP is mainly driven by the cattle-meat sub-sector – the livestock-meat sub-sector increased from 2.3 percent in 2012 to 2.7 percent in 2016 before dropping to 2.3 percent in 2017, while for milk, the GDP growth rate rose from 0.9 percent in 2012 to 1.8 percent in 2017 (Dembélé et al., 2017). The selection of the best local breeds for reproduction; the development of fodder crops, such as *dolique*, *mucuna sp*, *brachiaria sp*, and double-use sorghum (grains and fodder); promoting local milk production and artificial insemination through programs and projects, and crop-livestock integration, among other factors, have contributed to the growth of the livestock sector in Mali.

The livestock sector is a major source of employment, income, and foreign exchange and occupies a prominent place in the primary sector. Animal husbandry is practiced by more than 80 percent of farmers, making livestock the main source of livelihood for more than 30 percent of the population (Dembélé et al., 2017). However, the modern livestock industrial sector is underdeveloped both in feed-processing and for livestock byproducts due to insufficient and inappropriate equipment. This has led to a low level of exploitation despite the large available potential and strong domestic demand. The development of processing is also limited by poorly respected health standards, which limits the sector's potential for expansion and, particularly, access to external markets.

Livestock is the most common and ubiquitous source of high-quality protein for most people globally. Meat, dairy, eggs, and fish provide 40 percent of the world's protein and 18 percent of its calories. (World Economic Forum, 2019). Meat, milk, and eggs can provide protein and essential micronutrients for nutrition and population health. In Mali, the food situation is characterized by food insecurity affecting 25 percent of households, including 3 percent with severe food insecurity (ENSAN, 2015). The highest share of food-insecure households is found in rural areas.

Total controlled meat production in 2015 was 62,420 tons, all species combined. Red meat production accounted for 90 percent and white meat (poultry) for 10 percent. In terms of consumption, the level of consumption was estimated at 11.5 kg per head per year in rural areas and 15.7 kg in urban areas, i.e. an average of 12.3 kg, compared to the recommendation of 21 kg (Republic of Mali, 2016). Meat production is mainly from cattle (69 percent), with small ruminants contributing 20 percent and poultry 11 percent.

Milk production comes mainly from cattle and camels. The quantity produced in 2015 was 1,773,586 tons, with 31.2 percent from cattle, 28.3 percent from camels, 22.6 percent from goats, and 17.9 percent from sheep (Republic of Mali, 2016). Total annual milk production of around 2 million tons, is poorly valued because of the very low level of collection and processing (IRAM, 2015). The average level of per capita milk consumption is about 44 liters per year, which is far below the FAO recommendation of 62 liters for an adult person. Hence Mali imports considerable amounts of powdered milk (18 billion FCFA in 2019) to cover about 50 percent of milk product consumption.<sup>5</sup> Despite the potential in the livestock sector to support growing demand for dairy products, production remains relatively weak and volatile due to a lack of control of production factors and technical resources for processing units.

Livestock is an integral part of Mali's economy. As a component of agricultural development, the livestock sector, including aquaculture, remains a priority for Mali. However, the sector is subject to threats posed by climate change. These include as gradual depletion of water sources and water points, degradation and disappearance of fodder grass and trees resources, novel animal diseases, and natural disasters, such as floods and droughts. At the same time, there is also concern over livestock as a contributor to greenhouse gases. Challenges also emerge from the shrinking of and increased conflict over grazing resources. The global push towards a diet composed of white rather than red meat poses both challenges and opportunities for Mali's livestock sector.

The sector also faces challenges in production, marketing, and institutional factors, which significantly limit its contribution to Mali's food and nutrition security. There is poor fodder crop adoption resulting in agro-industrial feed being limited in quality and quantity at an affordable price. Animal diseases are still persistent due to limited veterinary services. There is ground and limited access to artificial insemination. In addition, Malian livestock genetics are mainly local and technologically poor. Livestock trading has remained informal with poor access to market information and agricultural credit. Trading also suffers from a low valuation of livestock by-products, such as hides and skins, which influences livestock productivity. As for milk production, there is a limited cold chain infrastructure, resulting in high losses. Livestock keepers also have difficulty accessing formal credit. As a consequence of these challenges and, in order to promote livestock production systems in Mali, the government provides

<sup>5</sup> <http://bamakonews.net/2019/08/importation-du-lait-le-mali-investit-plus-de-18-milliards-fcfa/>

subsidies on livestock inputs and promotes livestock value chain development, among other solutions.

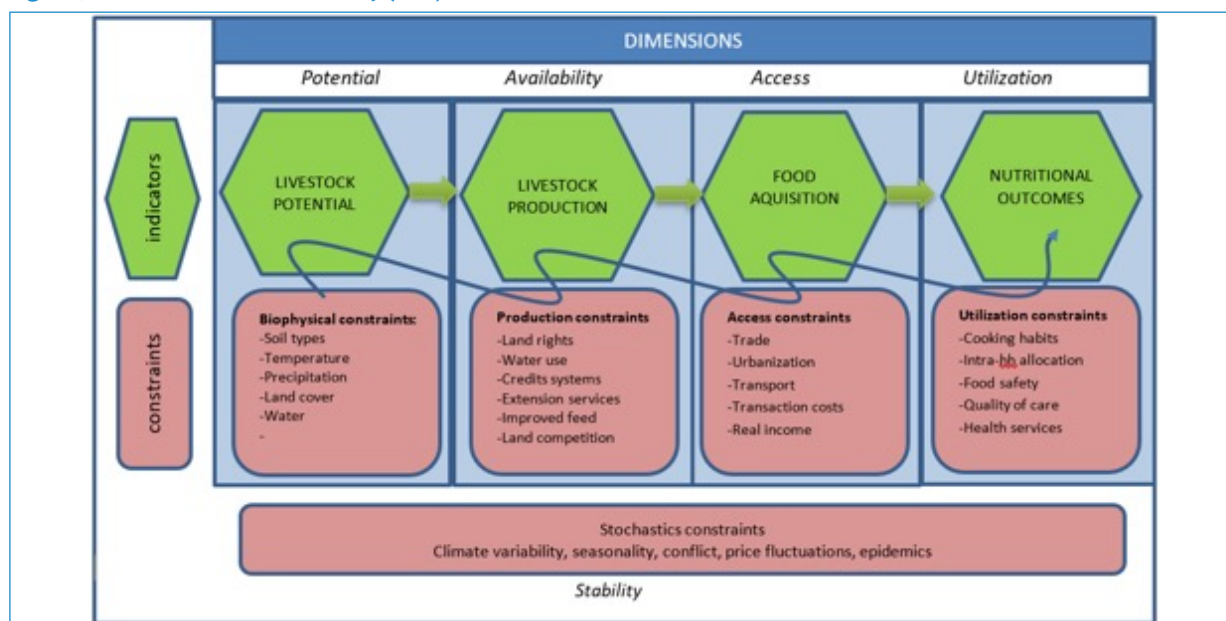
### 3. Conceptual Framework

#### 3.1. Spatial typology

The proposed typology will be developed within the comprehensive food and nutrition security (FNS) framework, as presented in Figure 5. Following Marivoet et al. (2019), using data for each of the four dimensions, efficiency and average performance in terms of livestock production, access and utilization

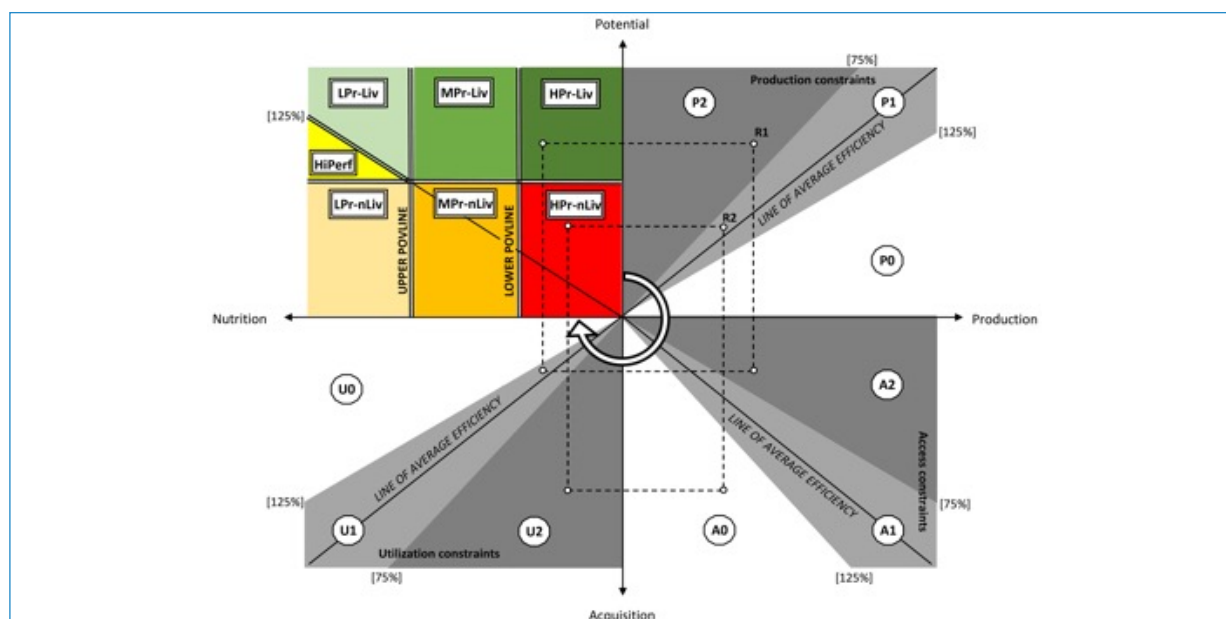
are estimated (see Figure 6). Whereas nutritional status will be used to set priority levels, measure of efficiency is used to identify locations where investments in livestock will produce returns in terms of food security, employment, and poverty alleviation. Depending on the level of priority, other types of interventions might also be suitable, including direct food assistance, cash transfers, nutrition campaigns, or nonagricultural development programs.

Figure 5: Food and Nutrition Security (FNS) Framework



Source: Adapted from Pangaribowo et al. (2013).

Figure 6: Intervention Types and Magnitudes of Production, Access and Utilization Constraints.



Source: Marivoet et al. (2019)

Notes: LPr, MPr, and HPr respectively stand for low-, medium-, and high-priority regions; Liv and nLiv refer to higher and lower livestock potential; and HiPerf stands for high-performance regions. "Povline" refers to the poverty line.

Following Marivoet et al. (2019), the proposed four-dimensional scatterplot depicts two different classifications: the northwest (NW) panel indicates the level of urgency as to whether a focus on the livestock sector is warranted; the second classification, based on the northeast (NE), southeast (SE), and southwest (SW) panels, roughly details where along the pathway from livestock potential to nutritional status the biggest gains can be realized in terms of reducing production, access, or utilization constraints, respectively.

Livestock potential is defined as the maximum livestock production one region/department can attain if performing at maximum capacity. As will be discussed, the procedure for estimating livestock potential involves applying first Stochastic Frontier Approach (SFA) to investigate Technical Efficiency (TE) across the different livestock production zones, which can be considered to be at the regional administrative level in the country. Indeed, the SFA allows for the econometric exploration of the notion that, given fixed characteristics, a livestock owner can make a decision to increase production and income.

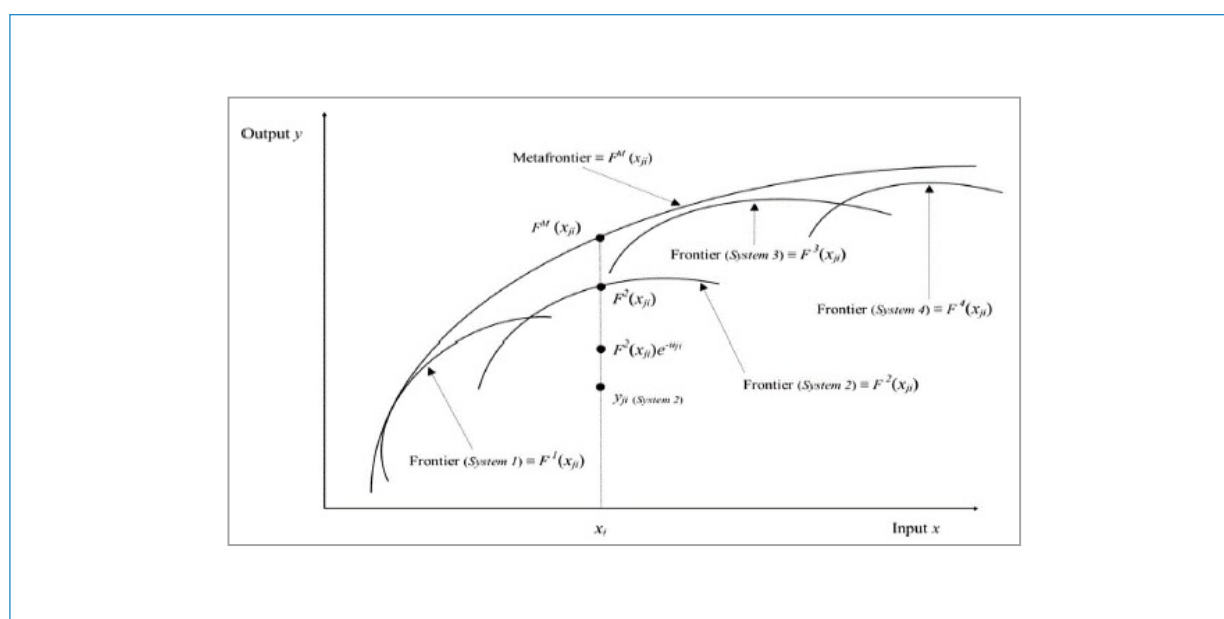
The next step involves estimation of a meta-frontier, an approach proposed by Battese and Rao (2002), to adjust the TE scores from SFA in order to account for differences in technology. In such a context, inefficiency is defined as the loss incurred by operating away from the frontier, given variable and fixed factors faced by the livestock producer. Thus, by estimating where the frontier lies, and how far each producer is from it, the stochastic frontier

approach helps to identify potential and efficiency levels to finally construct the typology.

### 3.2. Livestock efficiency

With respect to livestock, the typology proposed is developed within the comprehensive food and nutrition security (FNS) framework, which includes the four dimensions or pillars, typically identified in the food security literature: availability, access, utilization, and stability. To assess production potential for the livestock sector, we use the stochastic frontier approach (SFA), which allows the estimation of both livestock efficiency and of its drivers. Further, according to Abdulai and Tietje (2007), SFA provides useful information for potential efficiency gains and enhanced competitiveness at existing levels of resources and technology. Considering the fact that livestock performance could vary across farmers within and between groups depending on technology used, management skills, and the external conditions under which they operate, we apply the stochastic meta-frontier model to capture those differences across Mali (Battese and Rao, 2002). To examine the performance of each farm relative to the overall sector, it is necessary to identify the meta-frontier by finding the function that best envelops the deterministic components of the estimated stochastic group frontiers. The meta-frontier, or envelope, is therefore considered as the maximum feasible or potential output that can be attained by a production unit for a given level of inputs and technology. Figure 7 illustrates the concept of the meta-frontier graphically.

Figure 7: Meta-frontier production function with various production systems



Source: Melo-Becerra, Ligia Alba, and Antonio José Orozco-Gallo (2017).

Note: production systems are considered here as regions or other administrative levels within a country.

The meta-frontier framework offers three indicators: technical efficiency (TE), technology gap ratio (TGR), and meta-frontier technical efficiency (MTE), which are defined as follow:

$$TE_i^j = \frac{Y_{ji}}{F^j(X_{ji})e^{v_{ji}}} \quad (1)$$

$$TGR_i^j = \frac{F^j(X_{ji})}{F^M(X_{ji})} \quad (2)$$

$$MTE_{ji} = TGR_i^j * TE_i^j = \frac{Y_{ji}}{F^M(X_{ji})e^{v_{ji}}} \quad (3)$$

Where  $Y_{ji}$  and  $X_{ji}$  denote the scalar output (number of animals produced in terms of TLU) and input vector of the  $i^{\text{th}}$  farm in the  $j^{\text{th}}$  group, respectively.  $F^j$  is the frontier of  $j^{\text{th}}$  group or region and  $F^M$  is the meta-frontier or envelope. MTE (meta-frontier technical efficiency) measures the overall efficiency with regards to the meta-frontier  $F^M(\cdot)$  for each unit of production and is comparable between farms from different technology groups. The MTE is decomposed into two parts – the relative technical efficiency (TE) with respect to the group- $j$  production technology  $F^j(\cdot)$  and the gap between the farm specific technology and the meta-frontier, TGR, expressed as the ratio of the meta-frontier to the group frontier. All these indicators range between 0 and 1. When the score of TE is 1, the selected farm or group of farms are said to be fully efficient with respect to the adopted technology. A TGR score of 1 suggests that there is no gap to fill for the selected group with respect to the meta-frontier technology. In other words, the closer the TGR is to 1, the smaller the technology gap for the group under consideration regarding the economy modeled. An MTE score of 1 is equivalent to full efficiency regarding the meta-frontier production technology. In the current analysis, to determine the country's livestock production potential, we divide the output by the overall efficiency (MTE). Therefore, the potential is given as:

$$Potential_{livestock} = \frac{Y}{MTE} \quad (4)$$

Let

$$Q_{ij} = \sum_r^R y_{ijr} \quad (5)$$

where  $Q_{ij}$  is the annual livestock output of the  $i^{\text{th}}$  farm in the  $j^{\text{th}}$  production system;  $r$  denotes the forms of livestock output considered, i.e., current stock, sales or uses for other purposes in the past twelve-month period; and  $y$  is the number of animals in term of TLU. The total annual improved feed equivalent is computed as:

$$\{\varphi(p_f * d) + S(n_p * W)\} \quad (6)$$

where  $\varphi$  and  $S$  denote, respectively, the ratio of prices of purchased and non-purchased feed to that of improved fodder;  $p_f$  and  $n_p$  represent the average quantities of purchased and non-purchased feeds, respectively, in kilograms per month;  $d$  is the approximate number of dry months (when purchased feeds are mainly used), while  $W$  is the length of the wet season (when farmers mostly use on-farm or non-purchased feeds) in a particular area. The stochastic frontier and technical inefficiency effects model takes the following form:

$$Q_{ij} = \beta_{0j} + \sum_r^R \beta_{rj} \ln X_{irj} - M_i \delta_j + v_{ij} \quad (7)$$

where  $Q_{ij}$  is the annual value of livestock output of the  $i^{\text{th}}$  farm in the  $j^{\text{th}}$  production system and estimated as in (1)  $X_{irj}$  represents a vector of inputs (total feed equivalents, cost of veterinary services, cost of labor, etc.). Labor costs comprise both paid and unpaid labor; the latter valued using the average minimum farm wage in a particular district. The labor costs can be adjusted with the share of livestock income in household income. The vector  $X_{irj}$  also includes a Divisia index calculated as (Boshwabadi et al., 2008):

$$X_i = \prod_{r=1}^R C_{ijr}^{\alpha_{ijr}} \quad (8)$$

where  $\alpha_{ijr}$  represents the share of the  $n^{\text{th}}$  input in the total cost for the  $i^{\text{th}}$  farm in the  $j^{\text{th}}$  production system;  $C_{ijr}$  includes in the case of Mali, veterinary cost, labor cost for keeping, water cost, feed cost, etc. A positive sign of the coefficient of efficiency driver variable ( $\delta$ ) implies inefficiency because the value of  $(u=M\delta)$  would be higher when the farm is farther away below the frontier. On the contrary, a negative sign of the coefficient is interpreted as potentially having a positive influence on efficiency (Brummer and Loy, 2000; Coelli et al., 2005; Delgado, et al. 2008; Otieno et al. 2012).

#### 4. Data and Descriptive Analysis

The data used in this study is obtained from the World Bank Living Standards Measurement Survey (LSMS), 2017-2018, which covered all regions of Mali. The data includes information on livestock holdings, inputs used to livestock husbandry, as well as detailed household characteristics. The sample size for this study was 6,017 household, which covered the entire country. Both continuous and categorical variables were used in this study, including as the level of education, share of household using animal inputs water, and purchased feed, among others.

The level of education was measured using categorical variables as detailed in Table 12. Better educated farmers (households) may be more likely to innovate in their agricultural production. Higher education empowers producers in the effective management to better understand new technologies, and to

implement them more effectively (Teklewold et al., 2014; Sibhatu et al., 2015). As shown in Table 12, about 18 percent of household heads in the seven rural regions had no formal education against eight percent in Bamako.

**Table 1: Level of education of household head by region of Mali, %**

Region	No formal education	Primary	Secondary	Higher	Total (%)
Kayes	1.5	96.7	1.6	0.2	100
Koulikoro	2.4	95.4	1.7	0.4	100
Sikasso	2.0	96.3	1.4	0.3	100
Segou	3.6	94.3	1.7	0.5	100
Mopti	2.1	95.4	1.7	0.7	100
Timbuktu	2.7	97.3	0.0	0.0	100
Gao	3.8	93.2	2.7	0.3	100
Bamako	8.0	34.0	46.0	12.0	100
Total	2.5	95.0	1.9	0.5	100

**Source:** LSMS (2017-2018)

In terms of livestock holdings, Table 2 shows that ruminants, poultry, and donkeys are most present on farms. On average, 73.8 percent of farm households own poultry, the most important animal on farms. Poultry is followed by ruminants, particularly sheep

and cattle, which also play an important role in increasing the household's access to liquidity. These animals allow for coping with major crises. Draft animals, especially donkeys, play a leading role as traction and transport.

**Table 2: Livestock species owned by households in Mali**

Type of animal	Sample households owning, number	Households that own type of livestock, percent	Total number of animals per species
Cattle	4,192	68.3	7,019,481
Sheep	4,197	71.2	6,250,861
Goats	3,158	51.3	4,932,620
Camels	109	1.4	61,129
Equines	416	6.3	85,842
Asins	4,348	68.3	1,258,960
Poultry	4,345	73.8	15,368,606
Pigs	89	1.7	77,548
Rabbits	31	0.7	56,490

**Source:** LSMS (2017-2018)

These data also shows that farming households generally have more than one more animal species depending on financial means, ethnicity (i.e. the Fulani are more oriented towards livestock), and agroecological zone.

To maintain the herd, different inputs are purchased or directly used from rangelands or crop residues (Table 3). Inputs used include water, concentrated feeds, natural feed, and veterinary products. These inputs help to ensure animal welfare. Depending

on the production system, the inputs used may differ. It should be noted that in intensive systems concentrated feed is widely used, whereas in the extensive system natural pastures and crop residues are most commonly used. The use of purchased feeds and veterinary products are mostly observed in the peri-urban production and fattening system. This is due to the need to improve productivity levels to meet growing demand.

**Table 3: Share of household using inputs (in %) in Mali**

Region	Share of households using this input (in %)				
	Water	Purchase feed	Non-purchase feed	Feed	Veterinary
Kayes	3.2	8.0	20.1	21.4	15.9
Koulikoro	1.6	3.4	16.3	17.3	21.7
Sikasso	3.2	6.8	17.2	20.2	26.5
Segou	1.5	7.5	22.3	23.2	25.1
Mopti	1.1	8.0	21.7	25.2	20.2
Timbuktu	2.1	7.3	16.9	19.0	14.2
Gao	0.4	39.8	44.5	47.7	34.2
Bamako	7.9	46.8	37.4	55.2	35.9
Total	2.0	9.2	21.2	23.5	22.8

Source: LSMS (2017-2018)

In Bamako, the cost of purchased feed per TLU can reach 152 298 FCFA against 509 FCFA in Sikasso (Table 4). The same is true for all other types of expenditure —livestock production costs are much

higher in the Bamako area, where production is more intensive compared to other areas, which utilize more extensive production systems.

**Table 4: Average cost for each input per TLU (in FCFA/year) in Mali**

	Water	Purchase feed	Non-purchased feed	Total Feed	Veterinary
Kayes	135.9	3521.3	1,692.4	5,213.7	323.2
Koulikoro	104.6	733.8	1,861.6	2,595.5	414
Sikasso	272.9	509.2	833	1,342.2	588.4
Segou	246.6	1,758.1	2,908.2	4,666.3	411.5
Mopti	155.3	3,138.9	1,864.8	5,003.7	291.6
Timbuktu	83	4,137.5	5,648.6	9,786.1	365.8
Gao	113.5	1,2079.7	1,801.9	13,881.6	1,34.7
Bamako	1,263.4	15,2297.6	14,603.4	16,6901	7,969.4
Average	185.3	3,766.1	2,240.1	6,006.2	458.7

Source: LSMS (2017-2018)

Food expenses are by far the largest expenditure items. The location of animals determines the quality of their diet. Typically this is good only during the rainy season. Costs related to veterinary care and water are very low due to the rearing system. In most of the regions, access to water is free and animals are reared in an extensive livestock system.

Different indicators were used to fully capture the livestock sector in Mali. These indicators are grouped according to spending (cost of inputs and labor); socio-demographic characteristics (family size, age, ethnicity); distance (to roads, markets, to cities); agroecological conditions; population density; and access to credit. Table 5 presents household characteristics, formal schooling, animal inputs (cost of feeding, water, veterinary and labor), institutional factors and agroecological conditions for the households in our survey dataset. Households own 6.7 tropical livestock units (TLU) on average. The mean cost of water per annum expressed in the

mean annual cost for livestock inputs per household (feed, water, labor and veterinary) is estimated at 55,115 FCFA with a maximum cost of 10,000,000 FCFA thus showing a very great variability for the purchase of inputs among livestock producers. The mean age of the household head is estimated at 53 years, and average household size is 12 people. The mean distance from household to the closest population center of 20,000 people is 62 km. The mean distance from the crossing to the nearest border is estimated at 129.5 km.

Descriptive statistics for the independent and dependent variables used in this study are presented in Table 5. The dependent variable is animals produced by the household, measured in Tropical Livestock Units (current stock, sold and slaughter). The independent variables include age of household head, household size, education level, and livestock ownership, all of which could have an important effect on potential of livestock development and



enhance food security. For instance, higher education achievement increases skills, and age may serve as a reasonable proxy for experience in management of household resources and decision-making. Access to credit and shorter distances to roads, markets, or cities are expected to facilitate access to commercial

inputs of livestock, such as feed and veterinary products, among others. As for SFA, the output of livestock produced (TLU) is a function of the set of inputs used including costs of water, labor, feed purchased, and veterinary products.

**Table 5: Descriptive statistics of variables used in the model for a livestock-driven typology of food and nutrition security in Mali**

Variables	Description	Sample	Mean	Std. dev.	Min	Max
Production	# of animals produce (current stock +sold+slaughter): in TLU	6,017	6.7	11.6	0	216.62
Cost of water	Annual cost for watering animals in FCFA	6,017	68787.7	103594.3	56.25	446217.24
Cost of purchased feed	Annual cost for purchasing feed in FCFA	6,017	203766.4	505742.8	600	9672000
Cost of non purchased feed	Annual cost for non-purchasing feed in FCFA	6,017	61513.9	139934.4	100	4900000
Total annual cost for feed	Annual cost for feeding in FCFA	6,017	135146.5	377605.1	325	9837000
Cost for labor	Annual cost for labor in FCFA	6,017	19035.7	39000.9	100	1000000
Cost for veterinary services	Annual cost for veterinary in FCFA	6,017	13708.0	31662.8	50	787500
Total inputs cost	Total annual cost (feed, labor, veterinary, water) in FCFA	6,017	55115.1	206404.8	0	10 000 000
Other costs	Divisia cost	6,017	1441.9	17575.5	1	653862.65
<b>Household characteristics</b>						
HHsize	Household size (number of persons)	6,017	12.3	8.3	1	79
Gender	Sex of household head (1=male)	6,017	1.0	0.2	0	1
Age	Age of household head (years)	6,017	52.6	14.0	19.0	117.0
Age category	The head of household is between 19 and 45 years old	6,017	0.4	0.5	0.0	1.0
Marital status	The head of household is married monogamous	6,017	0.7	0.5	0.0	1.0
Ethnicity	The head of the household is from the Peulh ethnic group	6,017	0.1	0.3	0.0	1.0
Literacy	Education household head (1=literacy)	6,017	0.259	0.438	0	1
<b>Accessibility</b>						
Distance to big cities	Distance from HH to (KM) the center of population the closest with 20,000	6,017	62.01	42.26	0	231
Distance to nearest border	HH Distance in (KM) from the crossing to the nearest border	6,017	129.51	68.58	4	418
Distance to nearest road	HH Distance in km from the nearest road	6,017	14.19	14.44	0	101
Distance to district city	HH Distance in (KM) of Boma from current residency district	6,017	114.62	68.60	0	321

Agroecological conditions						
Humidity	Potential humidity index	6,017	14.63	3.82	11	36
NDVI	Long-term mean NDVI value during the primary growing season	6,017	0.26	0.06	0.12	0.38
Elevation	Elevation (meters)	6,017	611.69	197.88	141	1050
Population density	Density of population in 2009 (inhabitants per km <sup>2</sup> )	6,017	478.51	1746.65	0	11650
<i>Other Variables</i>						
Access to credit	Yes	6,017	0.0565	0.2309	0	1

Source: LSMS (2017-2018)

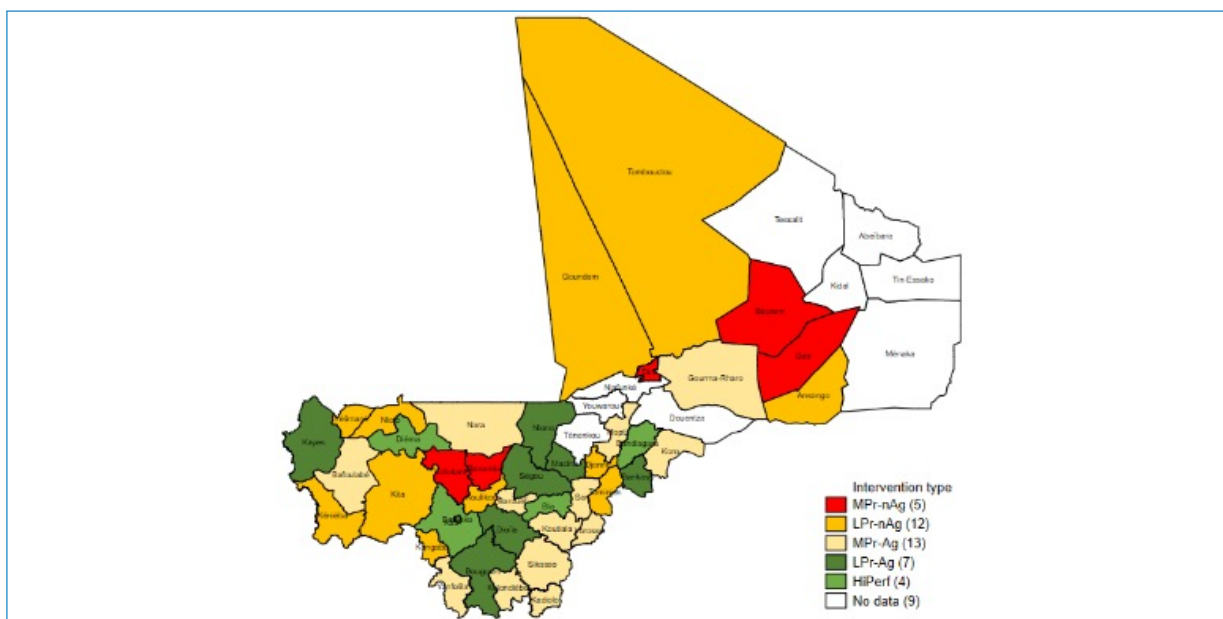
## 5. Results and Discussion

The typology map generated based on livestock sector production is shown in Figure 8. There are five livestock interventions zones in Mali: Medium Priority region with low livestock potential (MPr-nLiv), Low priority region with low potential of livestock (LPr-nLiv), Medium Priority region with high livestock potential (MPr-Liv), Low Priority region with high livestock potential (LPr-Liv), and High performance (Hiperf). The classification of this typology was based on the livestock production potential of the zones and the contribution livestock production might make to local livelihoods.

- The Medium Priority region with low livestock potential (MPr-nLiv) is characterized by low potential livestock production and a diversity of species (cattle, sheep, goats and camels) and covers 10 percent of the country's provinces. Despite availability of abundant grassland with open access, this livestock production system suffers from a lack of natural resources, such as water and grassland. This area includes the western, northern and eastern parts of the country.
- The Low priority area with low livestock potential (LPr-nLiv) covers for 24 percent of the country's area. It covers two contrasting environments in the south and north. The southern part Kita, Kenieba, Kangaba, Koulikoro, and Tominian has N'Dama breed for large ruminants, characterized by their small format, lower weight and resistance to *trypanosomiasis* and lower profitability in terms of cash generation, meat production, and low milk production just to feed the calf. The situation is similar for small ruminants with short sheep and goats with low monetary value. In the western (Yeilimane, Nioro), northern (Goudan and Timbuktu) and central (Djene) parts of the country, cattle and small ruminants (sheep and goats) breeds have the same type of livestock production systems with extensive management.
- Despite abundant grasslands (pasture) and diversification during the rainy season, the feeding system remains challenging. However, the types of breeds of cattle and small ruminants present a good opportunity for cash generation and contribute to poverty reduction and food security.
- The Medium Priority area with high livestock potential (MPr-Liv) covers 26 percent of the country. The livestock production systems in those areas are the major activities for cash generation. There are two major species of cattle (*zebu peulh*, *zebu maure*), plus cross breeds (*N'Dama* and *zebu peulh*). Cattle are used in the main cropping system as animal power. In addition, provinces in this zone constitute the belt of animal husbandry and supply all the main markets and secondary markets with live animals. They have favorable agro-ecological conditions, such as abundant pasture and diversified water availability all year around, particularly in Mopti province. Small unit milk processing is also promoted, resulting in intensification of the livestock production system.
- The Low Priority area with high livestock potential (LPr-Liv) covers 14 percent of the country's area. Herd sizes are large, dominated by the larger *zebu peulh*, with a few small ruminants. This area is different from the MPr-Liv because of the importance of cropping systems. The main provinces in this area are located at the country's borders where demand for livestock is high and livestock rearing (cattle) is the heart of livelihood providing animal power, meat, milk and other services. In terms of feeding systems, the western part (Kayes) benefits from the availability of grass, abundant and diversified water supply in the dry season, in contrast to other provinces.
- About eight percent of the country falls in the high performance (Hiperf) zone. The provinces in this category rely heavily on livestock and each

household possesses one herd of limited large and small ruminants. Livestock production is intensified in the provinces supplying urban centers.

**Figure 8: Type of intervention and nutrition constraint by micro-region (2017)**



Notes: LPr, MPr, and HPr respectively stand for low-, medium-, and high-priority regions; Ag and nAg refer to higher and lower agricultural potential; and HiPerf stands for high-performance regions; Number in parentheses is number of provinces.

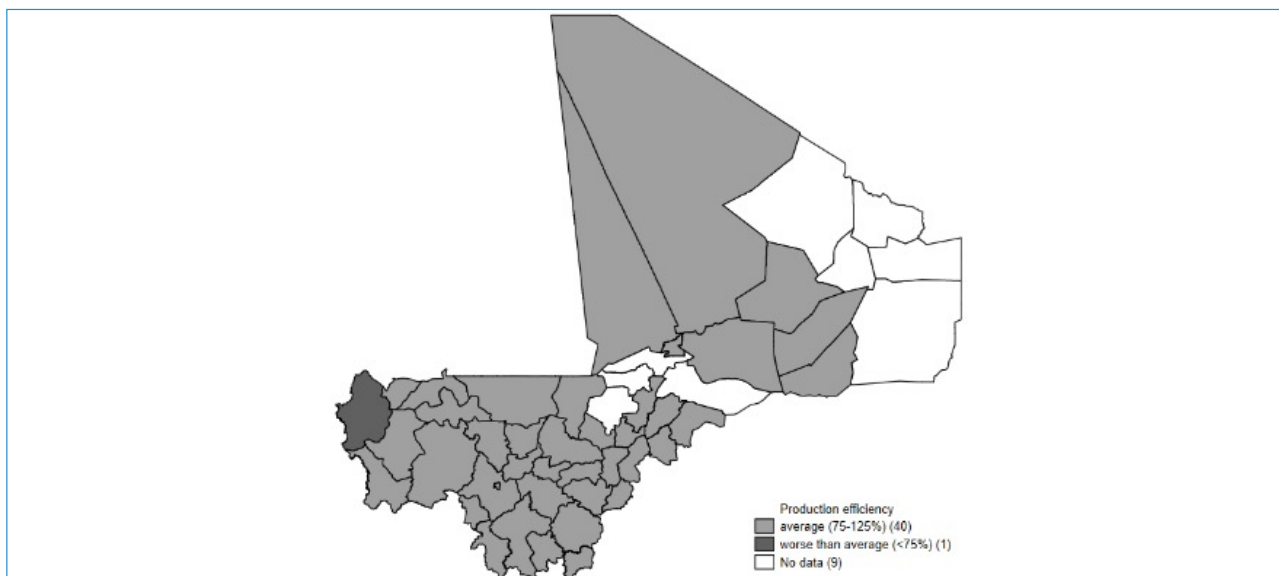
Source: LSMS (Living Standards Measurement Study)

The production efficiency map (Figure 9) shows that average (75-125 percent) production efficiency is around 80 percent. Areas with high average efficiency confirm that the availability and open access to grasslands (pasture), larger areas of land, and access to water play a major role in livestock production in Mali. Other important factors include access to agricultural credit, access to extension services, and training.

The worse than average (<75 percent) category includes only one province in the Western part of the

country. The low performance could be explained by high prices of animal inputs (veterinary products, concentrated feed, processing feed) due to poor road infrastructure. Although, agro-ecological conditions are unfavorable for cropping systems, it is good enough for livestock development (grassland, water, etc.). In addition, livestock is an important contributor to household wealth in that zone, as producers rely more on livestock than crop production. Much of the protein consumed in this area is from animal sources.

**Figure 9: Production efficiency in Mali**



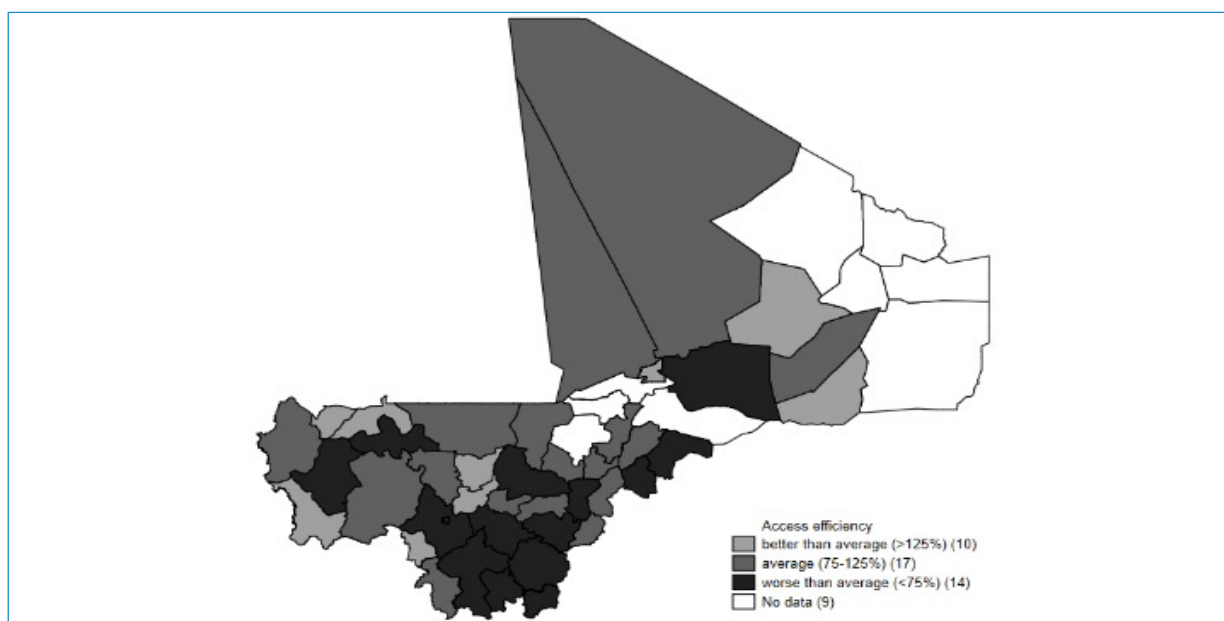
Notes: Number in parenthesis: number of provinces

Source: LSMS (Living Standards Measurement Study)

In terms of access efficiency, as shown in Figure 10, the better than average (> 125) category covers 20 percent of the country's provinces. This high performance in terms of access efficiency could be attributed to the existence of relatively vibrant livestock markets. The area with average (75-125 percent) accessibility covers 34 percent of the country. It is characterized by being close to urban centers where the demand for animal products is

increasing due to population growth and changes to consumption habits. Therefore, the offtake of livestock offers a great development opportunity. The less than average (<75 percent) area is in the Southern part, which is a marginal breeding area because of the strong agricultural intensification. The low average there could be explained by cropping activities replacing marginal livestock activities.

Figure 10: Access efficiency in Mali



Note: Number in parenthesis: number of provinces  
Source: LSMS (Living Standards Measurement study)

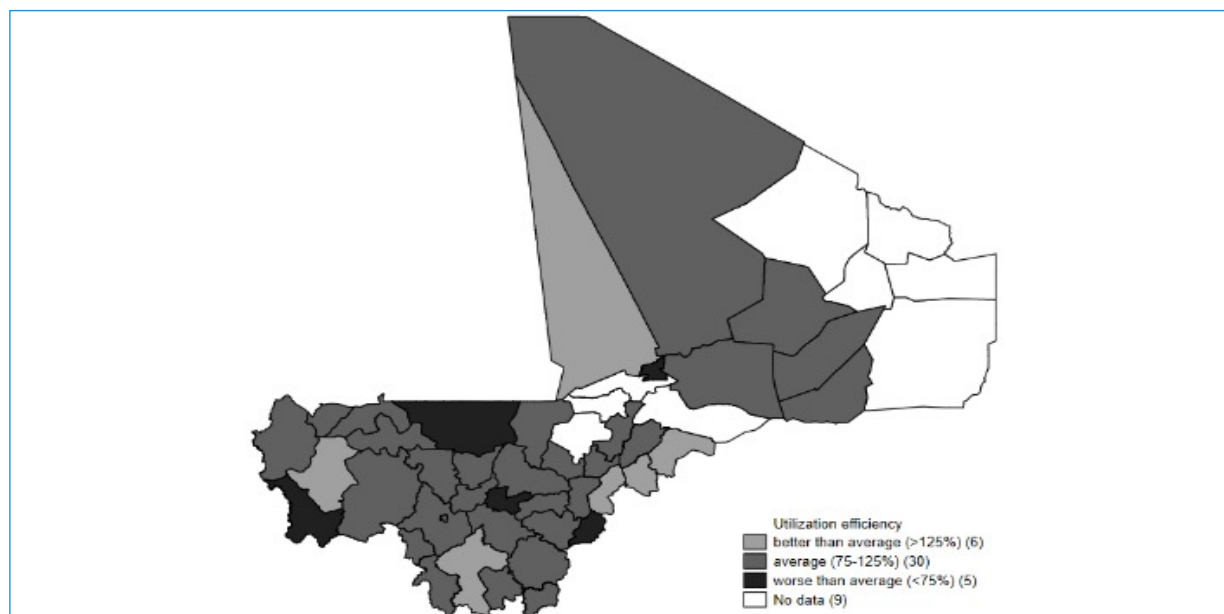
Figure 11 below shows the different levels of utilization efficiency in terms of livestock products. There are three levels of utilization efficiency –namely better than average, average, and worse than average.

- In terms of livestock products, the better than average (> 125 percent) regions are better off in terms of household nutrition status and represent 12 percent of the country. This could be explained by the rational management of animal resources and interventions such as extension services, and the behavior of animal keepers, among others. Therefore, the high efficiency use of livestock products is consistent with the herd size and small ruminants.
- Average (75-125 percent) utilization efficiency areas are scattered across the entire country and

represent 60 percent. Therefore, those areas incorporate the necessary calorie intake, intra-household food allocation. This class rationalizes the nutrient obtained by a given resource and trying to enhance nutritional status.

- The worse than average (<75 percent) provinces fall into the low livestock potential category which might lead to low consumption of animal products and represents 10 percent. This result could be explained by poor management of animal resources and lack of livestock extension services, limited animal health care, and limited allocation of animal products to household food.

Figure 11: Utilization efficiency in Mali



**Note:** Number in parenthesis: number of provinces

**Source:** Source: LSMS (Living Standards Measurement Study)

## 6. Policy Implications

The following policy implications are drawn from this case study. Overall, feed, water, and veterinary services emerged as key elements of livestock production in Mali. Veterinary services have a very high elasticity, implying that if the government were to put more resources in veterinary services, livestock production would increase. Water supply and animal feed are also key components. Provision of subsidies for animal feed as well as policies geared towards increased water supply for livestock production should enhance livestock production efficiency.

The national and regional governments should use more innovative approaches to livestock production through increased automation that offsets the increased demand for labor at the household level. Providing households with appropriate and affordable technologies and skills will enhance livestock production and productivity. Location, household size, and gender are the main factors that significantly enhanced economic efficiency among livestock keepers; —high-potential areas have the potential to develop the sector through entrepreneurial skills and innovation. Government should encourage the installation of small processing units in the high-potential zones for livestock production to improve access and utilization.

Low livestock potential occurs due to the lack of natural feedstock and poor access to commercial feed, which affects the entire livestock value chain. The improvement of livelihood conditions and nutritional status can be achieved by introducing and increasing fodder cropping, encouraging livestock producers to undertake better veterinary practices

for better management of animal health and the development of livestock value chain. Policy makers should consider pathways to promote and scale up fodder crop production, and to facilitate collective marketing of animals and animal products. In terms of production efficiency, interventions should emphasize reducing the costs of livestock inputs and improving livestock-related infrastructure or introducing subsidies for these. In addition, the capacity of livestock keepers could be strengthened through vocational training and networking with animal inputs suppliers. Access inefficiency arises due to missing markets and high transaction costs. To improve tradable livestock potential for economic growth and poverty reduction, food security and nutrition, policy makers should invest in livestock infrastructure, market creation, and capacity building, among others.

For areas with different livestock production potential, different sectoral actions need to be carried out. In areas with low breeding potential, the focus should be on alternative income-generating activities. This implies the existence of adequate infrastructure for distribution, processing, and transport. For areas with high breeding potential, emphasis should be placed on the availability of feed and veterinary inputs over time and space for improved livestock productivity. In addition, fodder and hay production should be encouraged to cope with periods of fodder deficits. It is also necessary to promote limitations on herd size in order to obtain the best potential according to available resources.

In both cases, governments must promote the control and management of water but also facilitate transactions between the various actors in the milk and meat value chains.

Intervention at the production level should target access to equipment for producers, facilitate their access to credit and quality inputs, and subsidize animal inputs, mainly feeding. Strategies should increase incentives to change the behavior of

livestock keepers through the sharing of successful experiences in the intensification of livestock production systems. Public-private partnership should be promoted to increase private investment to modernize slaughterhouses. Policies should be put in place to boost the export of meat, while complying with international standards on meat. Such actions will foster stronger networks among producers, traders, and other agents in the livestock value chain.

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