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Comprehensive Livestock Driven Typology for Food and Nutrition Security in Mali

No.001, February 2022

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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, 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. Eventhough the deterioration has slowed, there are still about 256 million hungry people in Africa, and while many African countries are making progress towards reducing malnutrition, progress is too slow to meet 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 deficiency, 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 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 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 and higher income, and urbanization associated with dietary changes have increased the 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, in this paper we propose a typology based on a comprehensive food and nutrition security (FNS) framework for livestock in Mali, which includes 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). In other words, using data for each of the four dimensions, efficiency and average performance in terms of livestock production, access and utilization are estimated. 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 of 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.

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 analysis of data and variables involved 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 typology derived in section 5.

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 major 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 the primary source 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 and Abidjan 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[1], 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 (UNDP) and about 68 percent of the adult population in Mali is illiterate.

The malnutrition rate is high and over 28 percent of children under five years suffer from stunted growth. This is mainly due to a poor diet which affects physical and mental development. The share of children with stunted growth rates is particularly high in the regions of Mopti 46.5 percent, Segou 40.5 percent and Sikasso 39.9 percent and 66 percent of households with poor food supply had at least one child with stunted growth (Eozenou et al., 2013). About 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 (PolNSAN, 2017). About 40 percent of households are food insecure, with insecurity affecting eleven provinces. The share of food insecure households 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 were facing food insecurity, around 14 percent of 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 agricultural zone in Mali, household food expenditures are estimated at 62.9 percent compared to 70.5 percent in Segou, a major area of rice production (USAID, 2018).

However, 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)[2], the food and malnutrition control program in the circles of Nara and Nioro du Sahel (2012-2017)[3] and more recently the 2019-2028 Action Plan of the National Food and Nutrition Security Policy (PolNSAN)[4].

2.2. The role of livestock

The livestock production system is the backbone for economic growth and poverty and malnutrition reduction in rural areas in the Sahel countries. In Mali, in terms of income generation nationwide, livestock is ranked third, while gold and cotton occupy the first two positions. Livestock represents an opportunity to create value addition for the many actors intervening in the value chain. In addition, in the case of Mali, the sector has a comparative advantage due to a lower cost per animal and greater factor endowment (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 southern areas of country. About 95 percent of cattle farmers are traditional pastor or agropastoral who sell their livestock in informal "bush" markets and primary markets (USAID-Mali, 2018). Agropastoral production is generally more commercially oriented and satisfies the domestic consumption

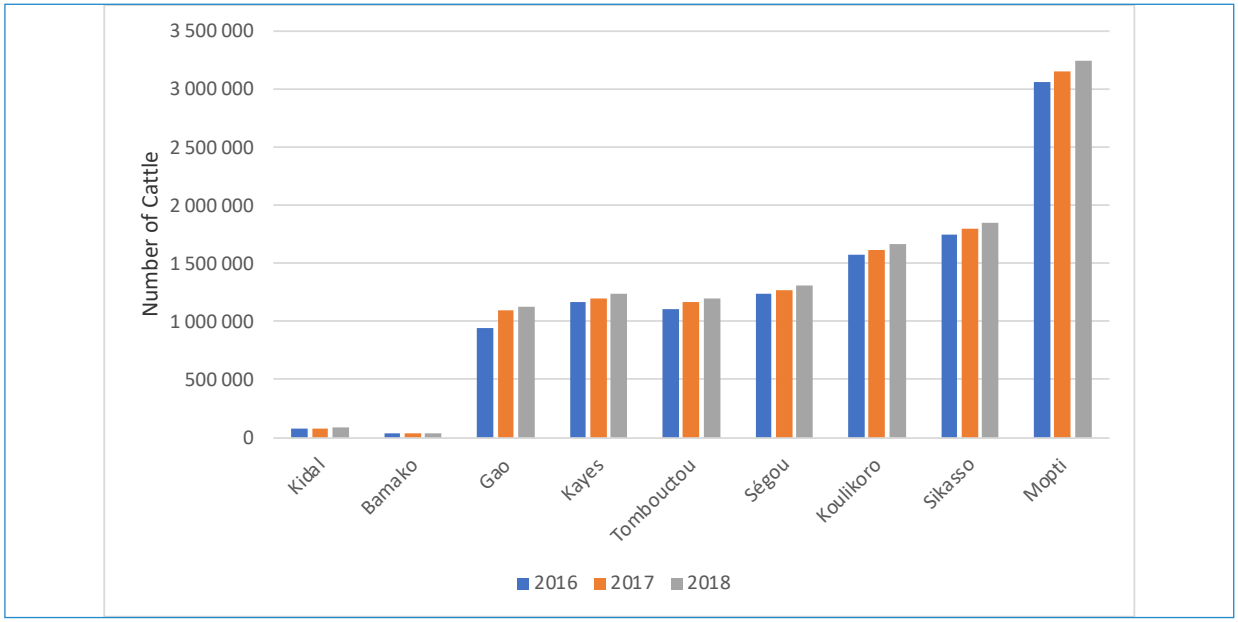
1Perspective monde, date de consultation : 12/11/2019, source : Banque Mondiale (http://perspective.usherbrooke.ca/bilan/tend/MLI/fr/SP.POP.TOTL.html)
2 https://www.unicef.org/mali/media/2296/file/PLAN%20D%E2%80%99ACTION%20MULTISECTORIEL%20DE%20NUTRITION%202014-2018.pdf
3 https://www.fao.org/3/i9626fr/I9626FR.pdf
4 http://extwprlegs1.fao.org/docs/pdf/Mli192037.pdf

market. Producers are organized in associations, cooperatives, or unions with varying degrees of specialization. Pastoral livestock farming is generally not market-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. Livestock related activities contribute to over 10 to 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 Direction Nationale de la Production et Industries Animales (DNPIA, 2016, 2017, 2018); there seems to be little change in recent years. The major zones of cattle husbandry include the regions of Mopti, Sikasso, Korolikoro, Segou, Kayes, Timbuktu, Gao, Kidal and Bamako. The first three regions of Motpi, Sikasso and Kouliroko represent 28 percent, 16 percent, and 14 percent, of cattle ownership respectively. In terms of herd size, Mopti is ahead compared to other regions such as Kayes, Timbuktu, and Kidal. Mopti is endowed with significant resources for livestock development such as grassland and water, mainly in the Central Delta. The community in the region is mostly composed of Fulani who have a long history of rearing livestock. However, livestock production systems are still traditional in Mopti region. Only 8.1 percent of households had sold an average of two herds of cattle each per year (LSMS-ISA, 2019). The offtake remains low compared to the number of cattle in the region. Milk production for local breeds is estimated at three (03) liters per day on average. Due to the low productivity of local breed, the milk value chain is still lagging behind and poorly organized. Genetic improvement programs have been established with the objective to create 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 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. A total of 137 veterinary posts, 34 clinics, and 245 veterinary pharmacies are scattered throughout the country. In addition, 162 private agents accredited with health mandates accompany the activities of the 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. They include companies such as Grand Moulins du Mali, and Grafax, among others. Animal feed is often in short supply due to seasonal variations in demand and production is also exported to countries in the region. In 2017, the government granted 1 billion F CFA in subsidies to farmers in Bamako, Koulikoro, and Sikasso.

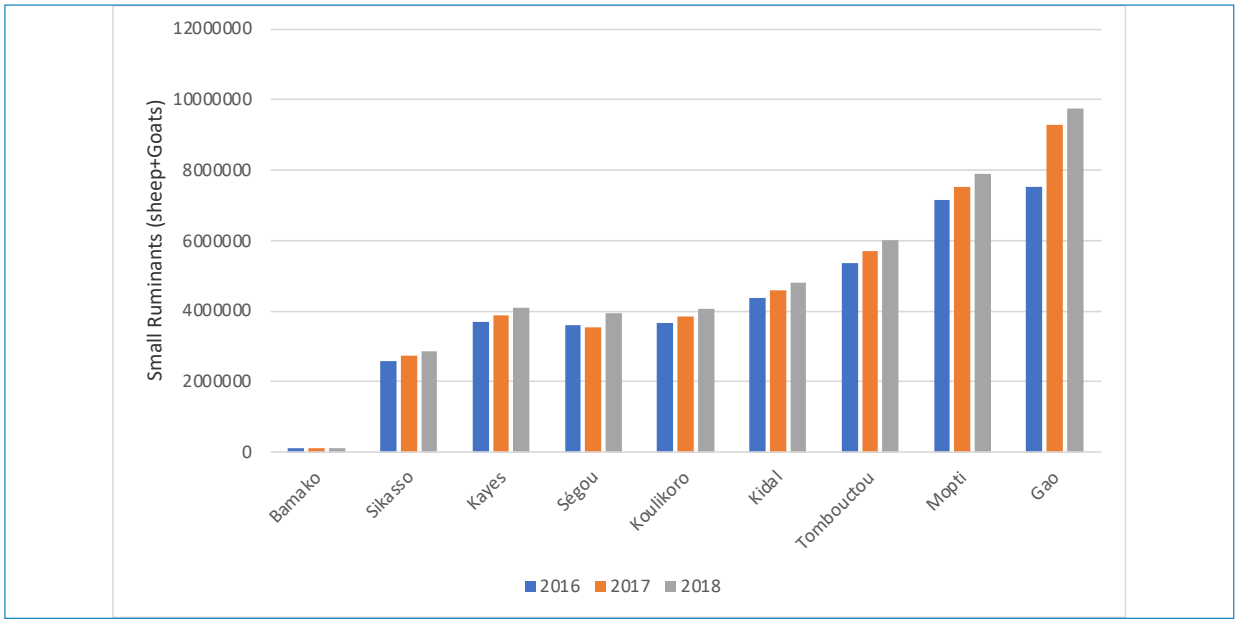
Figure 1: Cattle holdings from 2016 to 2018 in Mali



Source: DNPIA, 2016-2018

The number of small ruminants per region is presented in Figure 2 Gao, Mopti and Timbuktu represent 22, 18 and 14 percent of small ruminants in the country respectively. The number of small ruminants is also important in the rest of region. In terms of offtake, the Timbuktu region occupies the first place with 46 percent, followed by Mopti 21 percent and Gao 19 percent. The number of small ruminants sold per year and per household is estimated at seven heads for Mopti and Timbuktu and six heads for Gao. Compared to large ruminants, their offtake is more important. The national small ruminants' population has shown an average growth rate of 7 percent annually.

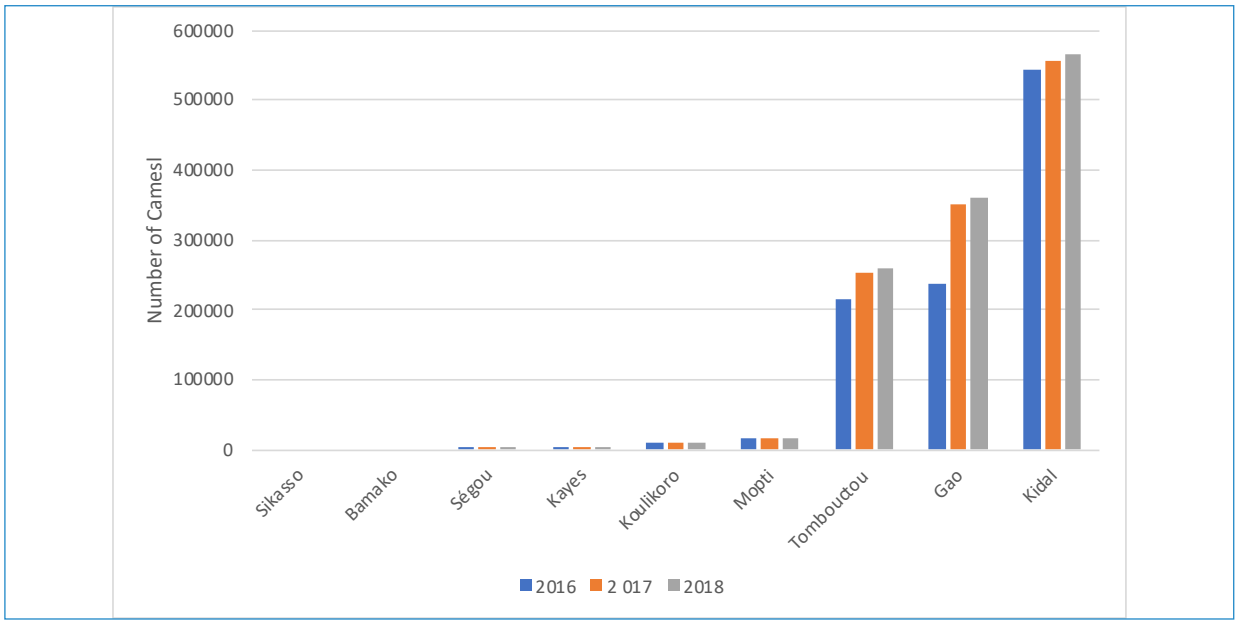
Figure 2: Small ruminants' trend from 2016 to 2018 in Mali



Source: Data (DNPIA,2016-2018)

The number of camels increased across the country between 2016 and 2018 except in Sikasso and Bamako regions (Figure 3). The Sikasso region is not well adapted zone of 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 herd is in Kidal, Gao and Timbuktu. Camel breeding is not yet well integrated in agriculture production systems towards western and southern regions.

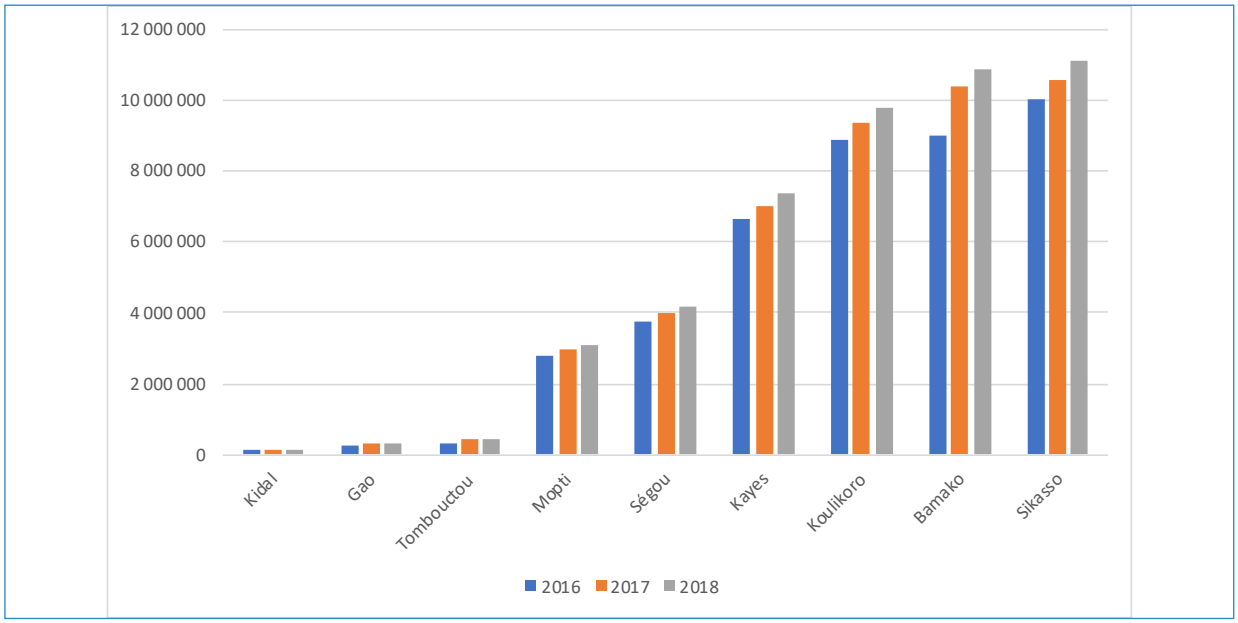
Figure 3: Camel trend from 2016 to 2018 in Mali



Source: DNPIA (2016-2018)

The poultry sector is developing rapidly and continues to be industrialized in a number of regions (Figure 4). Population growth and increasing demand are the drivers of poultry growth either in industrial or traditional systems. Geographically, the poultry population is settled in four regions: Sikasso, Bamako, Koulikoro and Kayes. This could be attributed to high dietary demand and growing agribusiness around the cities. Poultry production is an important source of revenue and protein for women and rural households. Even in the traditional system, the market is booming due to a better control of poultry feed and health.

Figure 4: Poultry trend from 2016 to 2018 in Mali



Source:(DNPIA, 2016-2018)

In least developed countries, most of which are in Sub Saharan Africa (SSA), the livestock sector accounts for nearly 20 percent of agricultural GDP (FAO, 2018). This low contribution can be attributed to the livestock 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 smallholder farmers income (Nabarro and Wannous, 2014).

In Mali, livestock contributes significantly to household income, particularly in rural areas. Livestock's contribution to household income reaches 80 percent in pastoral systems against 18

percent in those of the agropastoral systems (IRAM, 2015). Livestock also accounts for 19 percent of GDP. The real GDP growth rate of livestock increased from 4.4 percent in 2012 to 5.6 percent in 2017, driven by the livestock-meat sub-sector and the milk sub-sector. The growth rate of 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. For milk, the GDP growth rate rose from 0.9 percent in 2012 to 1.8 percent in 2017 (Dembélé et al., 2017). Thus, the growth of livestock GDP is mainly driven by the cattle-meat sub-sector. Therefore, the selection of the best breed local for the reproduction, the development of fodder crops such as *dolique, mucuna sp, brachiaria sp,* sorghum double use (grains and fodder), promoting local milk and artificial insemination through programs and projects, crop integration, among other factors, have highly 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 processing sector is underdeveloped both in feed-processing industries and livestock byproducts due to insufficient and inappropriate equipment, leading 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. 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, 27.7 percent against 14.6 percent in urban areas.

Total controlled meat production in 2015 was 62,419.99 tons, all species combined. Red meat production accounted for 89.6 percent and white meat (poultry) for 10.4 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). In general, meat production is mainly from cattle (69 percent), small ruminants (20 percent) and poultry (11 percent). Milk production comes mainly from cattle and camels, secondarily goats and sheep. The quantity produced in 2015 was around 1,773,586 tons divided as follows: 31.2 percent for cattle, 28.3 percent for camels, 22.6 percent for goats and 17.9 percent for sheep (Republic of Mali, 2016). Total milk production, which fluctuates 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 still far below the FAO standard of 62 liters for an adult person. Hence the strong propensity to import powdered milk (18 billion FCFA in 2019) to cover about 50 percent of milk product consumption.[5] Despite the potential in the livestock sector to support growing demand, 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 such 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 the livestock sector.

The sector also faces challenges in terms of production systems, marketing and institutional factors which significantly limit its contribution to food and nutrition security. There is a lack of zootechnical inputs such as fodder crop adoption and agro-industrial feed in sufficient quality and quantity and at an affordable price. Animal diseases are still persistent due to limited veterinary services on the 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 influence livestock productivity. As for milk production, there is a limited

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

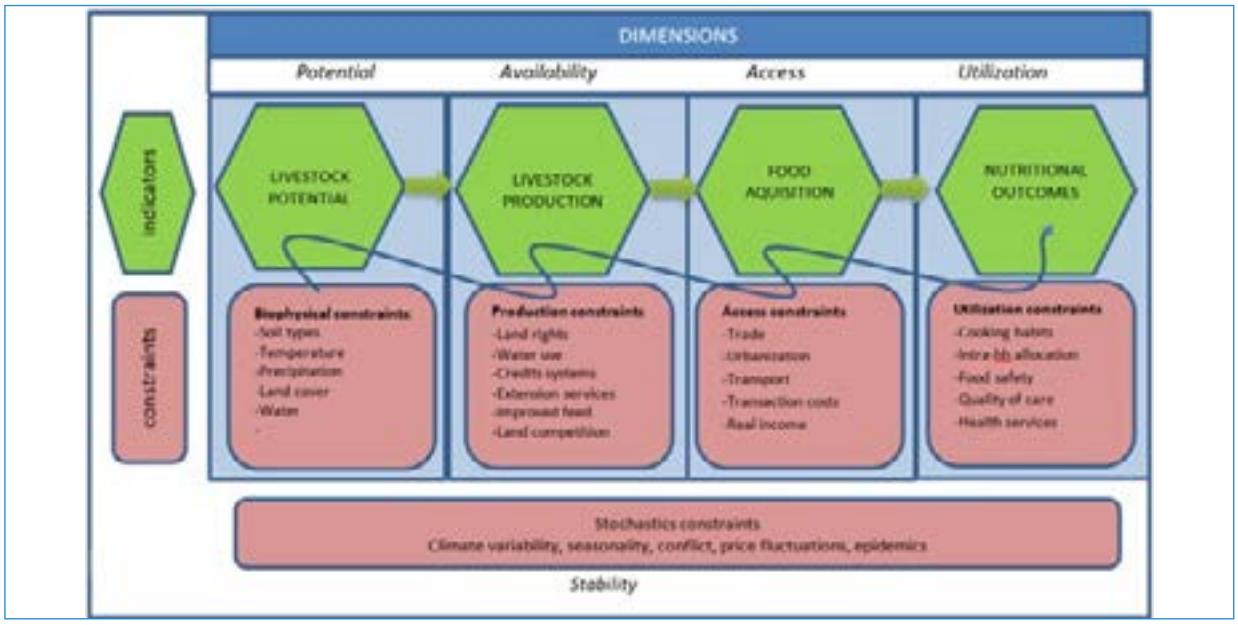
cold chain infrastructure resulting in high losses. Livestock keepers also have difficulty accessing formal credit. Thus, in order to promote livestock production system in Mali and alleviate the problems, the government promotes the subsidy of livestock inputs and livestock value chains development, among other solutions.

3. Conceptual Framework

3.1. Spatial typology

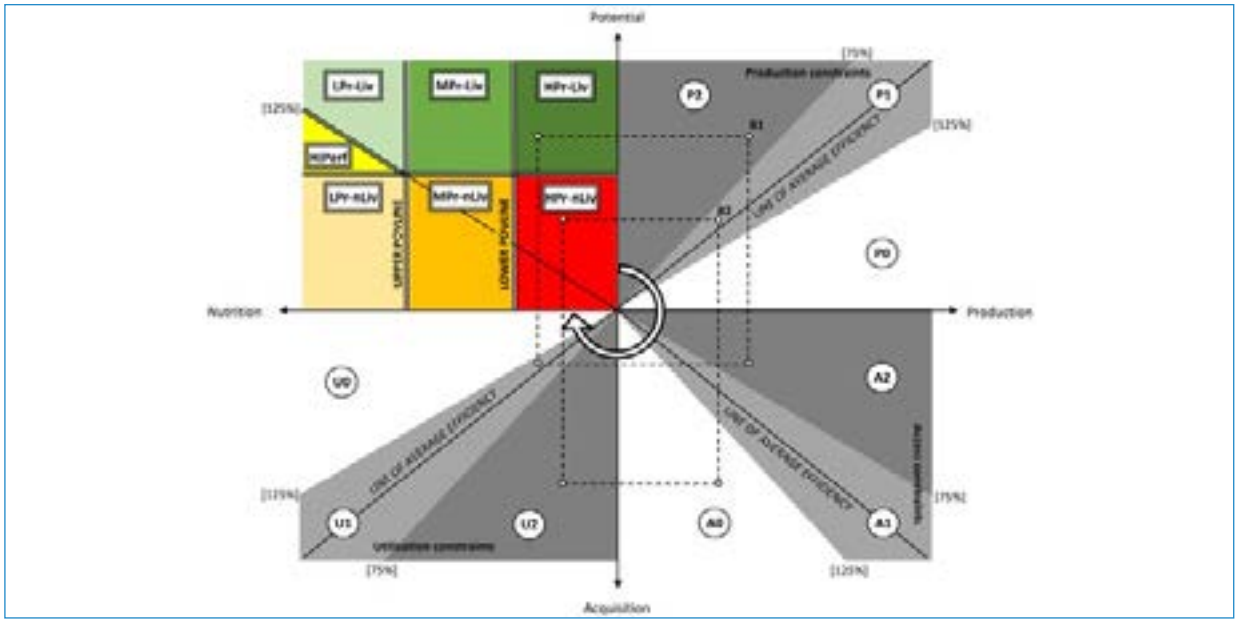
The proposed typology will be developed within the comprehensive food and nutrition security (FNS) framework as presented in Figure 5. Following Marivoet et al. (2019), using data for each of the four dimensions, efficiency and average performance in terms of livestock production, access and utilization 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 more returns in terms of food security, employment and poverty alleviation. Depending on the level of priority, other types of interventions might also be suitable, like 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.

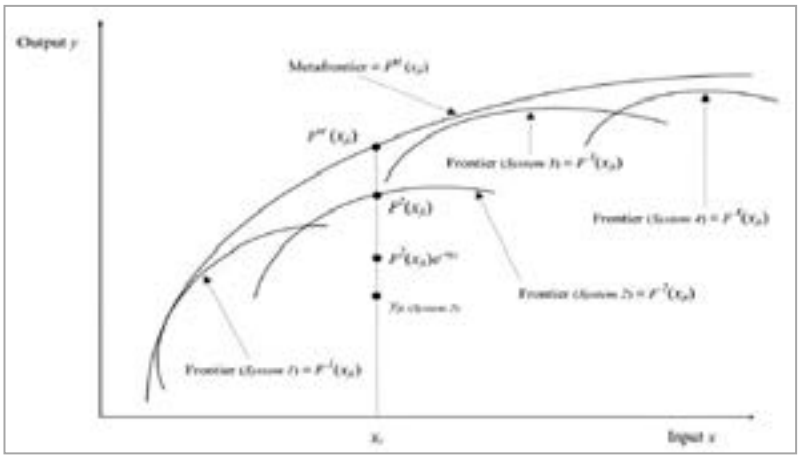
Following Marivoet et al. (2019), the proposed four-dimensional scatterplot depicts two different classifications: the northwest (NW) panel indicates the level of urgency whether a focus on the livestock sector is warranted; the second classification, based on the northeast (NE), southeast (SE), and 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.

Livestock potential is defined as the maximum livestock production one region/department can attain if performing at maximum capacity. As noted below, the potential's estimation procedure involves applying first Stochastic Frontier Approach (SFA) to investigate Technical Efficiency (TE) across the different livestock production systems zones, which can be considered as an 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 four dimensions or pillars, typically identified in the food security literature: availability, access, utilization and stability. To assess production potential for 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 the technology used, management skills and the external conditions under which they operate, we apply the stochastic meta-frontier model to capture those differences across country (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 envelop is therefore considered as a 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} respectively denote the scalar output (number of animals produced in terms of TLU) and input vector of the i[th] farm in the j[th] group. F^j is the frontier of j[th] group or region and F^M is the meta-frontier or envelop. MTE (meta-frontier technical efficiency) measures the overall efficiency with regards to the meta-frontier $F^M(.)$ 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 $F^j(.)$ 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[th] farm in the j[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; 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; φ 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; 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:

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

where Q_{ij} is the annual value of livestock output of the i[th] farm in the j[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 (Boshrabadi et al., 2008):

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

where α_{irj} represents the share of the n[th] input in the total cost for the i[th] farm in the j[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 (δ) implies inefficiency because the value of (u=Mδ) 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 country regions. The data also includes livestock holdings, inputs used to livestock husbandry, as well as detailed household characteristics. The sample size for this study was 6017 household which covered the entire country. The variables used in this study were continuous and categorical, such 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 the table.

Better educated farmers (households) may be more likely to participate in agricultural innovation technologies as the level of education empowers producers in management of new technologies, easy understanding and implementing (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 12: Level of education of household head per region (%) in 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 1 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 1: Type of species owned per household (%) in Mali

Type of animal	Number of house-holds in sample	% of HH who raises this type of animal	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)

It also shows that farms generally have one or 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 2). 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 2: 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 3). The same is true for all other types of expenditure which are much higher in the Bamako area where production is more intensive compared to other areas which are in more extensive production systems.

Table 3: 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	1692.4	5213.7	323.2
Koulikoro	104.6	733.8	1861.6	2595.5	414
Sikasso	272.9	509.2	833	1342.2	588.4
Segou	246.6	1758.1	2908.2	4666.3	411.5
Mopti	155.3	3138.9	1864.8	5003.7	291.6
Timbuktu	83	4137.5	5648.6	9786.1	365.8
Gao	113.5	12079.7	1801.9	13881.6	134.7
Bamako	1263.4	152297.6	14603.4	166901	7969.4
Average	185.3	3766.1	2240.1	6006.2	458.7

Source: LSMS (2017-2018)

Food expenses are by far the largest expenditure items. The location of animals determines the quality of the diet, which is good only during the rainy season, thus significantly decreasing costs on concentrated foods. 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 (in relation to roads, markets, to cities), agroecological conditions, population density, access to credit. Table 16 presents household characteristics, formal schooling, animal inputs (cost of feeding, water, veterinary and labor), institutional factors and agroecological conditions. Households own 6.7 tropical livestock units (TLU) on average. The mean cost of water per annum expressed in local currency is 66,788 FCFA. The annual cost for purchased feed is 203,766 FCFA on average and 61,514 FCFA for non-purchased feed. The mean of veterinary cost is estimated at 13,708 FCFA on average and for labor cost is 19,036 FCFA. The mean annual cost (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 breeders. 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. The mean distance from household to the main road is estimated at 14.2 km. As for agroecological conditions, the mean potential humidity index is evaluated at 14.63 while the average long-term NDVI value during the primary growing season is estimated at 0.26 and average elevation is estimated at 611.69 meters.

The independent and dependent variables used in this study are represented in Table 4. In this study the dependent variable is animal produce (current stock, sold and slaughter), and the independent variables age of household head, household size, education level, and livestock ownership, could have an important effect on potential of livestock development, and enhance food security. For instance, higher education achievement increases skills and age shows an experience in management of household resources and decision-making. Access to credit and distances are expected to be important in accessing commercial inputs of livestock such as feed, veterinary products among authors and small distances facilitate the transaction cost. As for SFA, the output (TLU) is a function of set of inputs used such as costs of water, labor, feed purchased, and veterinary products.

Table 4: Descriptive statistics of variables used in the model 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
Household characteristics						
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
Accessibility						
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

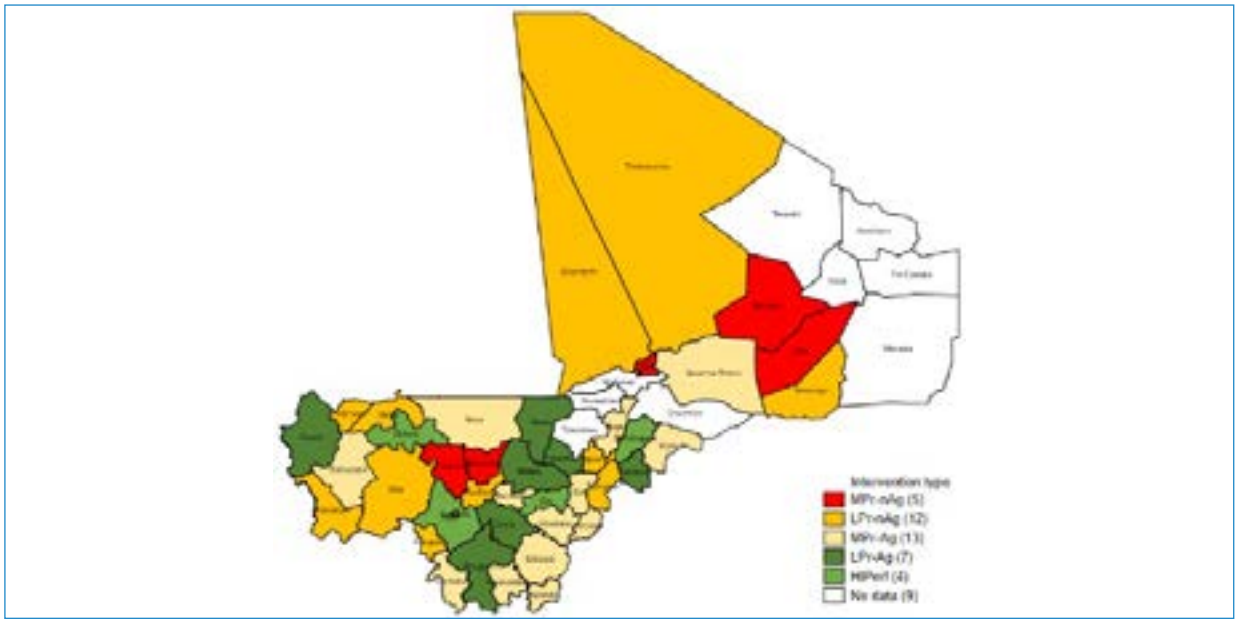
Agroecological conditions						
Humidity	Potential humidity index	6,017	14.63	3.82	11	36
NDVI	Long-term mean NDVI value during the primary growing season	6,017	0.26	0.06	0.12	0.38
Elevation	Elevation (meters)	6,017	611.69	197.88	141	1050
Population density	Density of population in 2009 (inhabitants per km2)	6,017	478.51	1746.65	0	11650
Other Variables						
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 89. 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 potential of livestock zones and its contribution to the livelihood. The Medium Priority region with low livestock potential (MPr-nLiv) is characterized by low potential livestock production and 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, the livestock production system suffers from the lack of natural resources such as water and grassland for almost over 12 months. This area includes the Western, Northern and Eastern parts of the country. The Low priority area with low livestock potential (LPr-nLiv) stands for 24 percent of the country's provinces. It covers two contrasting environments in the south and north. The southern (Kita, Kenieba, Kangaba, Koulikoro, and Tominian in central) part 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 a breed called short sheep and goats with low monetary value. In the western part (Yeilimane, Nioro), northern part (Goudan and Timbuktu) and central Djene 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's provinces. 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*) and cross breeds (*N'Dama* and *zebu peulh*) in the main cropping system used as animal power. In addition, provinces in this category 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 mainly in Mopti province. The small unit of milk processing is also promoted resulting in intensification of livestock production system. The Low Priority area with high livestock potential (LPr-Liv) covers 14 percent of the country's provinces. The herd size is important and dominated by the larger *zebu peulh* and 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 border where the 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 as opposed to other provinces. About eight percent of the country potential is high performance (Hiperf). The provinces in this category rely heavily on livestock and each household possesses one herd of limited large and small ruminants. The livestock production is intensified in the province supplying urban centers.

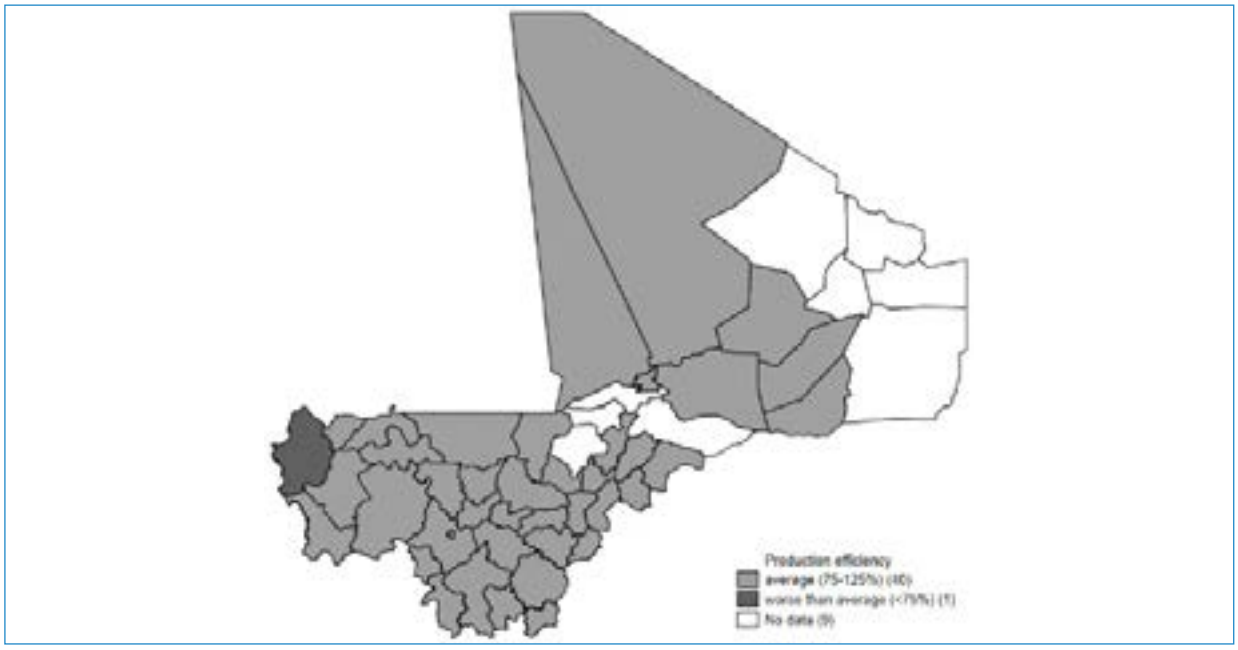
Figure 8: Type of intervention and nutrition constraint by micro-region (2017)



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 the average (75-125 percent) production efficiency is around 80 percent. The high average efficiency confirms that the availability of grasslands (pasture) and open access, larger areas of land, and access to water play a major role in livestock 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, the agro-ecological condition is 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 where producers rely more on livestock than crop production. Much of the protein consumed in this area is from animal sources.

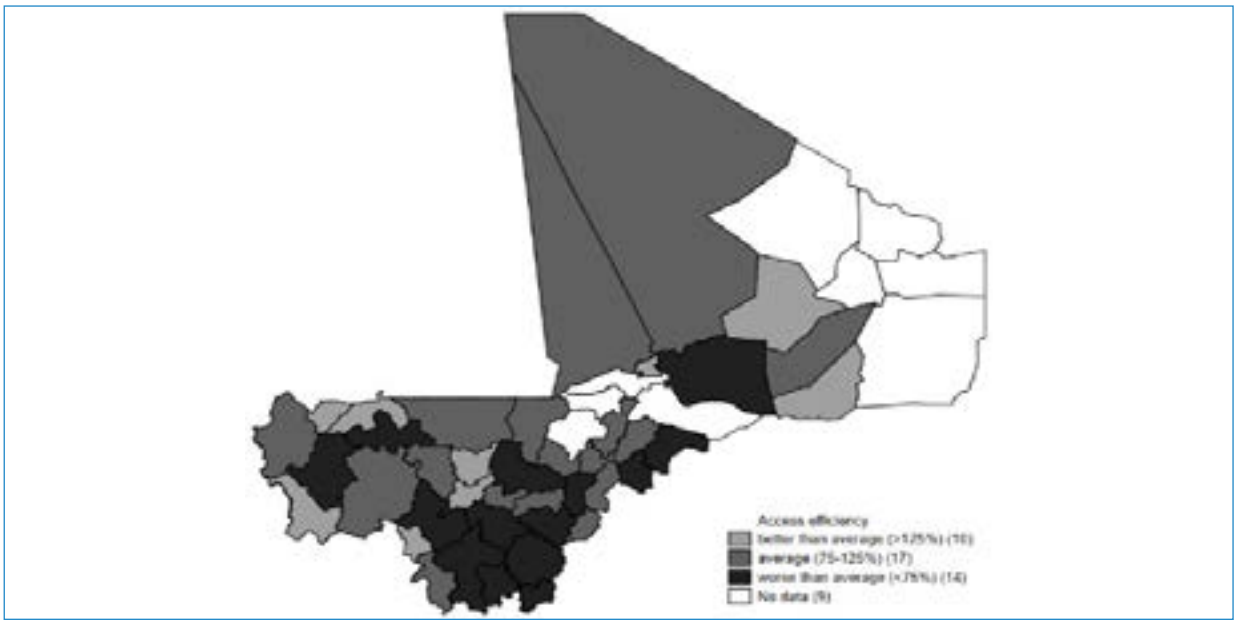
Figure 9: Production efficiency in Mali



Notes: Number in parenthesis: number of provinces
Source: LSMS (Living Standards Measurement Study)

As shown in Figure 11, the better than average (> 125) category covers 20 percent of the country's provinces. The high performance in terms of access efficiency could be attributed to the existence of livestock market. The average (75-125 percent) accessibility area 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 change 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 could be explained by cropping activities replacing marginal livestock activities.

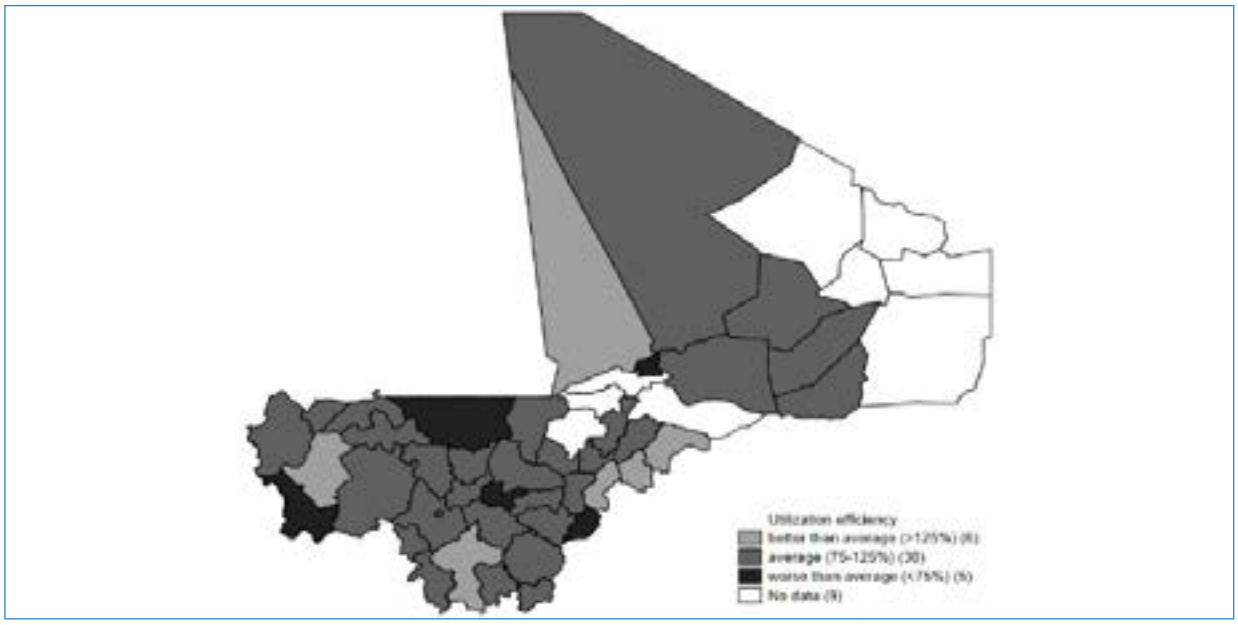
Figure 10: Access efficiency in Mali



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

Figure 12 below shows the different levels of utilization efficiency in terms of livestock products in food security and nutrition dimension. 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 the animal resources and intervention type such as extension service, 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 technical services such as 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 the case study. Overall, feed, water and veterinary services emerged as key elements of livestock production. 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.

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. Locations, household size and gender are the main factors that significantly enhanced the economic efficiency among livestock keepers; such areas have the potential to develop the sector through entrepreneurial skills and innovation. Government should encourage the installation of small processing units in the potential zones of livestock to improve access and utilization.

Low livestock potential occurs due to the lack of natural feedstock and access to commercial feed, which affect the entire livestock value chain. The improvement of livelihood conditions and nutritional status can be achieved by introducing and increasing fodder cropping, encouraging breeders to manage veterinary practices in breeding areas for better management of animal health and development of livestock value chain. Policy makers should consider both pathways to promote and scale up fodder crop production, collective marketing of animals and animal products. In terms of production efficiency, interventions should emphasize prices of livestock inputs and infrastructure or introducing subsidies for these. In addition, 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 different types of areas and depending on the existing breeding 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 food and health 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 the limitation of 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 and 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 and intensification of livestock production systems. Public-private partnership should be promoted to increase private investment to modernize slaughterhouses and put in place a policy to boost the export of meat and comply with international standards on meat and establish strong networks among producers, traders, market and other agents in the livestock value chain.

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APPENDIX

Annex 1: Methodology for projecting future production and consumption

The LSA (2017) made projections of future production and consumption for the major livestock products (meat and milk) without any policy or technology interventions (the 'BAU' scenario) to assess the size of the future supply and demand gaps. The parameters used in demand projections are i) the size of human population and its growth rate, ii) the size and growth in per capita GDP, iii) the baseline consumption levels for meat and milk, and iv) the income elasticities of demand for meat and milk. In the case of the supply projections for meat and milk, the parameters from the herd growth model in LSIPT (Livestock sector and investment policy toolkit)[6] are applied.

Future projection growth rates were calculated assuming the past annual growth rate for real per capita GDP. The CSA 2007–2037 population projection for a medium variant population growth scenario was used to project human population growth. The annual trend growth rate for real per capita GDP of 8 percent was obtained by taking the difference between the GDP and population growth rates over the last seven years (2007–2013). Accordingly, given the income elasticity of demand (η) for a given livestock product, trend annual growth rates (γ) of real per capita GDP, and baseline per capita consumption () of a given livestock product, the projected per capita livestock product consumption () for a given year () is based on the following formula:

$$LC_t = LC_0 * (1 + \eta * \gamma)^t$$

Finally, the projected total consumption of a given livestock product in time period is obtained by multiplying the projected per capita consumption with the projected population for a given time period ()):

$$TLC_t = LC_t * (1 + \eta * \gamma)^t * POP_t$$

The results for projections of the production and consumption of meat and milk over the coming 15 years without any investment interventions.

The projection of future production and consumption of livestock products constitutes the basis for assessing the magnitude of required future investment in livestock research and development interventions (policies and technologies), required to close any production-consumption gaps. The nature and cost of envisaged investments are shown in Table A2 below.

Investment interventions and total investment costs

The total investment costs required to carry out the LMP roadmap are ETB 7762 million. The proportion of investment from the public and private sectors is 57 percent (ETB 4463 million) and 43 percent (ETB 3299 million) respectively.

6The LSIPT consists of a set of tools (mathematical models, format questionnaires, and other aids), that have been field tested and reviewed—most notably in Zambia. It enables in-depth and systematic quantitative analysis of the major constraints facing the livestock sector, and the effects of proposed interventions on economic growth and poverty alleviation (LSA, 2017).

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