



## Light case study: Improving dairy production in Senegal

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WP2 light case study report



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## Abstract

There is a high yield gap in Senegalese milk production. The average milk yield in 2013 was 251 kg per cow per year while in many European countries the yield is between 6000 and 9000 kg per cow per year. Although relative increases in milk yields have been substantial, absolute increase is very low compared to Europe. In Senegal, low-input dairy production produces too little milk and per capita milk consumption is low, less than 30 liters per annum. Due insufficient domestic production, the country is dependent on imported dairy products such as milk powder. Insufficient milk production is partly because of very low milk yields per dairy cow and partly due to missing infrastructure to collect, process and distribute milk.

The purpose of PROIntensAfrica light case studies is to describe intensification pathways at play in the selected agricultural situation, drivers of change and effects of intensification pathways. **This case study focuses on improving dairy genetics and on improving management of livestock farming in Senegal.** It is based on one of the work packages of FoodAfrica programme. The case study is mainly based on the paper by Marshall *et al.* (2016, see Section 3 of this report). Studies **improvements in genetics are mainly related to the choice of breed types which can be summarized by four main types: 1) Indigenous Zebu, 2) Indigenous Zebu × Guzerat, 3) Indigenous Zebu × *B.t. taurus*, and 4) animals with large proportion of improved dairy cattle ancestry (“High *Bos taurus taurus*”; Indigenous Zebu cross × *B.t. taurus*, mainly Montbeliarde and Holstein-Friesian, typically 75% to 100% *B.t. taurus*).** All households were classified as 1) ‘poorer’ or 2) ‘better’ in relation to the level of animal management they applied.

This case study mainly falls under the conventional intensification and sustainable agriculture intensification pathways. Agroecology pathway can be considered as an original intensification pathway. The most intensive scenarios do not fit very well under organic agriculture or agroecology pathways because of several reasons: Firstly, it doesn’t exclude the use of breeds bred for Western high-input dairy farming. Secondly, it tries to aim at good health and welfare status of the animals but it doesn’t exclude the use of chemical inputs or medicines. Thirdly, it aims at finding socio-economically most profitable production practices and breeds or cross-breeds rather than trying to find high-premium markets for dairy products.

Several stakeholders are involved in the livestock value chain. These include farmers, **artificial** insemination (AI) and veterinary service providers, feed suppliers, other input suppliers to the livestock farms, crop farmers, other cattle owners and cattle traders, milk and meat processing companies, consumers and other people who purchase milk and meat, local and national government, and some other stakeholders. Each stakeholder has economic or other interests that affect their (or group that they represent) welfare. The key stakeholders are livestock owners who decide how to use animals, how to develop their activities and whether to utilize artificial insemination, veterinary and other services which may enhance livestock productivity and health. Service providers and input suppliers are also key stakeholder groups. The government of Senegal supports dairy production through the use of genetically improved animals: There is a public AI campaign and local semen production center. However, farmers in low-input dairy production systems lack information on the relative performance of different management and breed-types to be able to make informed decisions.

Several drivers can induce change in the livestock sector so that AI, improved genetics and improved management are adopted by households owning livestock. The drivers include increasing population growth, population density and rise of living standards which increase the demand for milk and may provide opportunities for professional specialization. Urbanization, improvements in the infrastructures and professional specialization may improve farmers’ access to the markets and establishing larger production units may be seen as an attractive option especially near to the cities. Increased human capacity and professionalization

may also improve farmers' understanding of interrelations and issues. Climate change and occurrence of prevalent or novel animal diseases are drivers which increase the need for more robust animals and management. Technological change can also be considered as a driver which makes it easier to retrieve information on improved management practices, and to develop, acquire and use new genetics at the farm. Besides new production potential, they can introduce novel threats as improved animal may be sensitive to stress and diseases.

The main drivers of AI service usage and cross-bred or exotic cattle were farmers' cultural values and wealth. Ethnic group and household's income class were major factors linked with exotic or cross-bred cattle use. The usage of public and private AI service was linked to ethnic group and the mode of acquisition of the first exotic or cross-bred cattle. The usage of mainly public AI service was linked to farm household family size, distance to the market and the mode of being a subsistence farmer. Besides subsistence farming and distance to the markets, the use of mainly private AI service was related to animal health service use and socio-economic parameters (income class, reason for keeping cattle, land owned).

The case study shows that household can benefit significantly profit from keeping different breeds and cross-breeds of dairy cattle in low-input, agro-pastoral systems in Senegal and managing them well. It makes sense for the farmer to intensify milk production by improving the management of animals, which in this case mainly refers to improvements if feeding, but also more generally to caretaking of animals. It helps the farmer to narrow down the yield gap. However, there are several management issues which require more detailed investigation. More research is needed on which actual measures are the most beneficial to the farmers and how the combination of the best-suited genetics and management vary by region.

In the case study, the highest milk yield was obtained for animals with large proportion of improved dairy cattle ancestry. This was 150% more than yield for indigenous Zebu animals under better management. Higher yielding breeds and better management require more intensive animal health care. Higher yielding breeds and better management requires more feed than lower yielding breeds and poorer management. Feed costs per liter of milk produced is however lower for higher yielding breeds and better management than for lower yielding breeds and poorer management. The only exception is animals with large proportion of improved dairy cattle ancestry which had the highest feed cost per liter of milk among studied scenarios. The highest profit was obtained for indigenous Zebu × *B.t. taurus* cross-bred animals under better management. The lowest household profit was for indigenous Zebu under poorer management, showing almost eight-fold difference to the previous scenario.

Sustainable intensification will involve complex mixes of domesticated plant and animal species and associated management techniques, requiring greater skills and knowledge by farmer. The case study suggests that it may be most rational to focus on combining different breeds than using purebred exotic animals which are not adjusted to arid conditions. This is likely to be socially more acceptable, economically rational and resilient-improving strategy than changing completely to exotic animal breeds which have not adjusted to arid conditions.

Future research is recommended on 1) how animals with different genetic backgrounds can cope in various African conditions, 2) how specific management measures (those related to feeding and animal health in particular) can benefit the farming households, 3) which **combinations** of genetics and management result in the best overall outcome when considering productivity, food and nutrition security, economic profitability, environmental footprints and animal health implications of livestock production in Africa, and 4) how various factors influence farmers' willingness to adopt new management and genetics, and 5) what kind of institutional or policy solutions are required to adopt the best solutions.

**Keywords:** Intensification, cattle, milk, cross-breeding, improved management, economics, feeding, animal health

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# 1. Introduction

The purpose of PROIntensAfrica light case studies is to focus on the description of at least two contrasted intensification pathways at play in the selected agricultural situation: the main pathway in force and an innovative emerging pathway. The light case studies should provide for an identification of drivers leading to the observed ongoing intensification pathways. Involved scientists will map out as far as possible with accessible documentation the effects, impacts and outcomes from those intensification pathways, using the proposed criteria as far as they are documented through available literature. Light case studies are not requested to develop the analysis of view-points from stakeholders in the concerned value chains through formal stakeholder's panels as is the case for in-depth case studies.

This case study focuses on improving dairy genetics and on improving management of livestock farming in Senegal. The case study is based on a work package, "Senegal Dairy genetics" project, which was carried out within the first FoodAfrica programme. The work is mainly based on the study report by Marshall *et al.* (2016) and it is represented in more detail in Section 3 of this report. Improvements in genetics are mainly related to the choice of breed or breed mix that would be best-suited for extensive livestock farming in Senegal, and particularly in peri-urban areas. Management aspects mainly focus on improvements in animal feeding, housing and the use of artificial insemination (AI), which is linked to the choice of genetics that are used. This case study mainly covers the conventional intensification and sustainable agriculture intensification pathways. However, agroecology pathway can be seen as an intensification pathway that is linked to cattle production based on the use of indigenous breeds which can cope with scarce housing infrastructures and use local inputs, and do not require excessive use of external inputs such as supplementary feeds, artificial insemination (AI) or veterinary services.

There are multiple reasons which motivate this case study. A wider perspective is that majority of undernourished people in the World live in Sub-Saharan Africa (SSA). The population of Africa is growing rapidly and it is estimated to reach 1.9 billion by 2050 while climate change is simultaneously challenging the food production in SSA. These people need to be fed and livestock can have an important role here. According to Herrero *et al.* (2014), livestock production plays a significant role in the economy of African countries in which it represents on average 20 to 40 % of the contribution of agriculture to GDP. In Senegal, there are approximately 2-3 million undernourished persons (depending on the year). In 2014 they represented 16.7% of population of Senegal (FAOSTAT 2016). Livestock production represented about 35% of the added value of Senegalese agriculture and 8% of GDP in 2013. Milk was the main output of Senegalese livestock sector (World Bank Group, 2014).

At the same time, the population of Africa is concentrating in urban areas. In 2015 about 44 % of Senegal's population lived in urban areas. However, their share is estimated to increase up to 61% by year 2050 (FAOSTAT 2016). Urbanization and the rise of living standards are globally associated with increasing consumption of meat and dairy products. On one hand, urbanization highlights the fact that meat and milk production in Africa needs to be increased to satisfy rising demand. On the other hand, it provides new possibilities to increased livestock production in regions near urban areas as demand for livestock products is increasing.

Livestock has important social, cultural and economic relevance in Africa and improved livestock production can significantly change the livelihoods of households and help small-scale farmers in rural areas out of poverty. There are about 320 million in poor livestock keeping households in Sub-Saharan Africa. In a pastoral society livestock is the prime resource and the responsibility of household head. For many households in a pastoral system livestock is the largest non-land asset they own (World Bank 2007). McDermott *et al.* (2011) argue that public and private investments in smallholder livestock systems would help nearly one billion people use their livestock enterprises as pathways out of poverty.

Demand for milk in Sub-Saharan Africa (SSA) is rising and small scale dairy producers are important suppliers for milk. In Senegal, low-input dairy production produces too little milk and annual per capita milk consumption is low, less than 30 liters. Due insufficient domestic dairy milk production, Senegal is dependent on imported dairy products such as milk powder. Insufficiency of milk production is partly because of very low milk yields per dairy cow and partly due to missing infrastructure to collect, process and distribute milk and dairy products. Furthermore, the type and the genetics of animals that are used and the level of herd management are major contributors to the low milk yield. This case study therefore focuses on the choice of breeds and breed crosses and improvements herd management as means to intensify livestock production in Senegal.

## 2. Context of the case study

### 2.1. Importance of cattle production in Senegal

This section examines briefly market conditions, volume and importance of cattle sector in Senegal. In 2012 there were about 3.43 million cattle animals in Senegal. They produced 173 million kg fresh cow milk and 47 million kg cattle meat. According to FAOSTAT (2016), the gross value of whole fresh cow milk in Senegal in 2011 was 54 million USD (at 2004-6 prices) whereas the gross value of cattle meat production was 126 million USD. About 59% of agricultural area in Senegal is permanent meadows and pastures (FAOSTAT 2016) and thus closely linked to ruminants. In 2013 livestock production represented about 35% of the added value of Senegalese agriculture and 8% of GDP. Milk was the main output of Senegalese livestock (World Bank Group, 2014). This milk production derives mainly from a low-input production system, with a few more intensive operations. According to International Farm Comparison's Dairy Report 2014 (Hemme, 2014) the estimated milk production from about 850,000 dairy cows in Senegal in 2013 was 0.19 million tons of energy-corrected milk. This was well below the estimated national consumption of 0.32 million tons Milk Equivalent (The quantity of fluid milk utilized in a processed dairy product, often expressed on a milk fat foundation), leading to a deficit of almost 0.1 million tons of Milk Equivalent (Hemme, 2014). The value of dairy imports affects significantly to the trade balance of Senegal. The total cost of dairy imports was 43.9 billion FCFA (66.8 million euro) in 2015 (Republique du Sénégal, 2015).

Low national milk production is mainly due to a combination of restricted feed and due to poor performance of indigenous cows with low genetic potential, high level of milk used by the calves which accounts for more than 50% of this production (Dia, 2013) and poor environment including diseases and heat stress (Diop *et al.*, 2004). According to studies, milk production in Senegal is dominated by the use of indigenous breeds and low milk production potential.

Though production is and has been low, dairy milk and cattle meat production appears to have increased during the past decade (Figure 1). The number of animals (Figure 2) as well as the number of animals per hectare of arable land also appears to have increased in the long run (Figure 3). Although milk and meat yields per animal have increased in Senegal during the last two decades, they still are very low when compared to Europe (Figure 4). Increase in meat and milk production is probably linked to apparent increases in yields per animal as well as to increases in the number of animals. Increase in the number of cattle in Senegal is partly related to improvements in infrastructure such as boreholes which increase the carrying capacity of regions in cases where access to water is a limiting factor.

According to our case study, the daily milk offtake is just around 0.7–1.5 liters per dairy cow (excluding milk suckled by calves). According to the production statistics, the annual milk yield per cow in 2013 was 251 kg per cow per year which is substantially lower than in many European countries (6000 kg to 9000 kg per cow per year). Although relative increase in milk yield in Senegal has been substantial (Figure 4), absolute increase is very low when compared to Europe. According to FAOSTAT (2016), the average milk yield in 2011 was 231 kg, in 2012 it was 236 kg and in 2013 it was 251 kg per cow per year. Also cattle meat weight per slaughtered animal was very low, only 151 kg per head in 2011. For instance, in Finland and France the average slaughter weight per animal in 2011 was over 300 kg, and the average milk yields in 2013 in France, the Netherlands and Finland were 6414, 7644 and 8222 kg, respectively (FAOSTAT 2016). Although figures reported by FAO may be somewhat inaccurate, they illustrate very clearly the gap in yields as milk yields in these three European countries is more than 25 times the statistical yield in Senegal. In addition, milk yields per cow have increased in relative terms by 25-45% since early 1990's. Because absolute yields are much lower in Senegal, also yield increases are low, being only 65 kg when compared to 1600 to 2500 kg in Europe.

Figures 5 and 6 represent nominal and deflated producer prices for milk and meat from cattle during years 1991-2011<sup>1</sup>. The data shows that nominal prices have increased over time whereas real prices have remained quite stable since early 1990's. There is also some seasonal and regional variation in agricultural market prices in Senegal. The variation is perhaps more prominent in meat prices than in milk prices because there are for instance seasonal religious festivals which may shift the demand for meat between different species and weather-related factors affecting meat and milk markets. Figure 7 illustrates cattle meat prices for year 2013 in selected regions of Senegal.

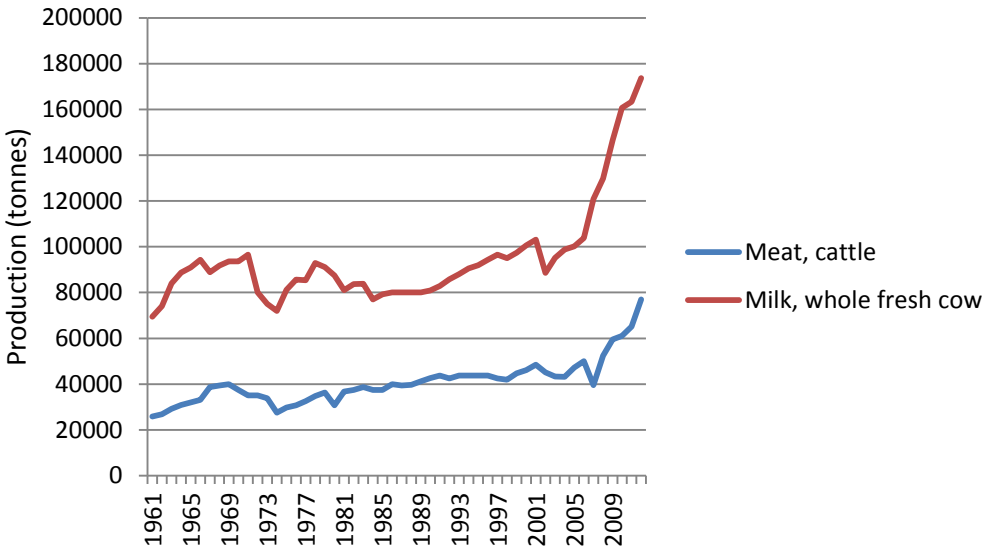


Figure 1. Development of production of meat from cattle and fresh milk from dairy cows in Senegal during 1961-2012 (Source: FAOSTAT)

<sup>1</sup> 1 € is approximately 655 FCFA



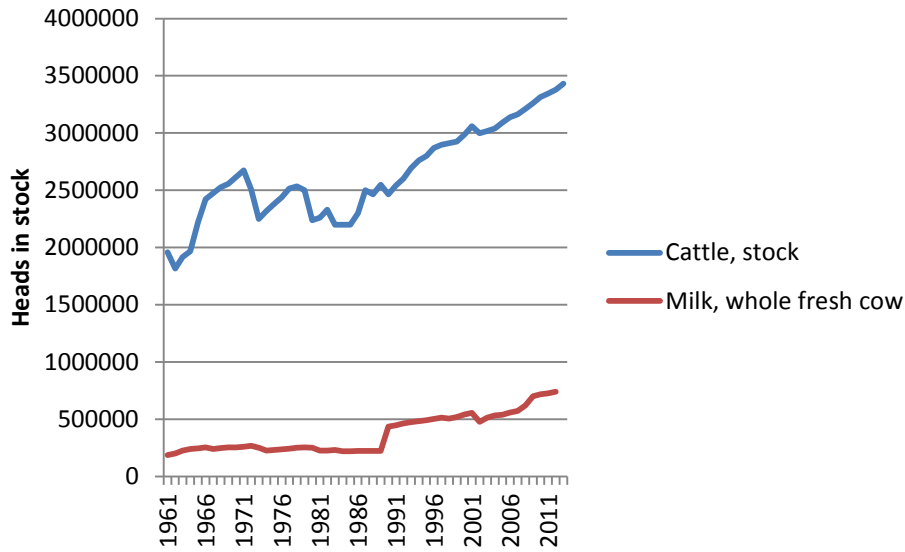


Figure 2. Number of cattle in stock and number of milk animals (heads) in Senegal during 1961-2012 (Source: FAOSTAT)

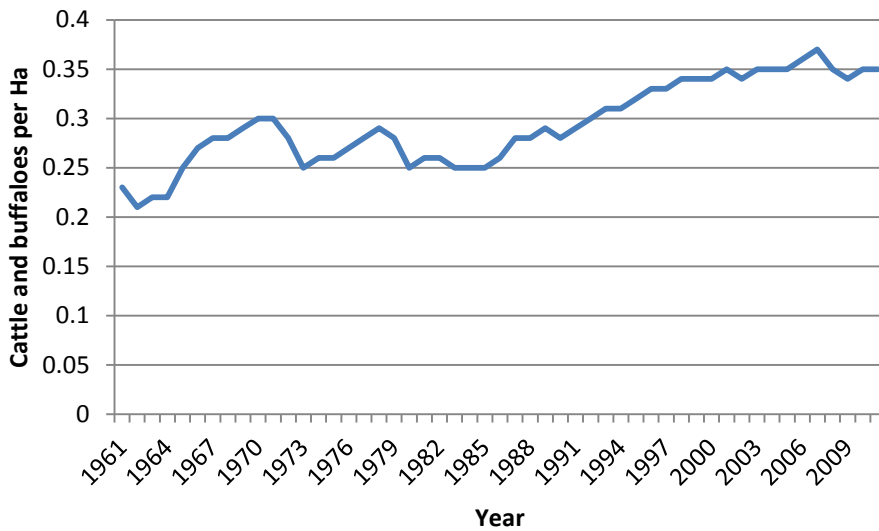


Figure 3. Development number of livestock (cattle and buffaloes in total) per hectare of agricultural area in Senegal during 1961-2012 (Source: FAOSTAT)

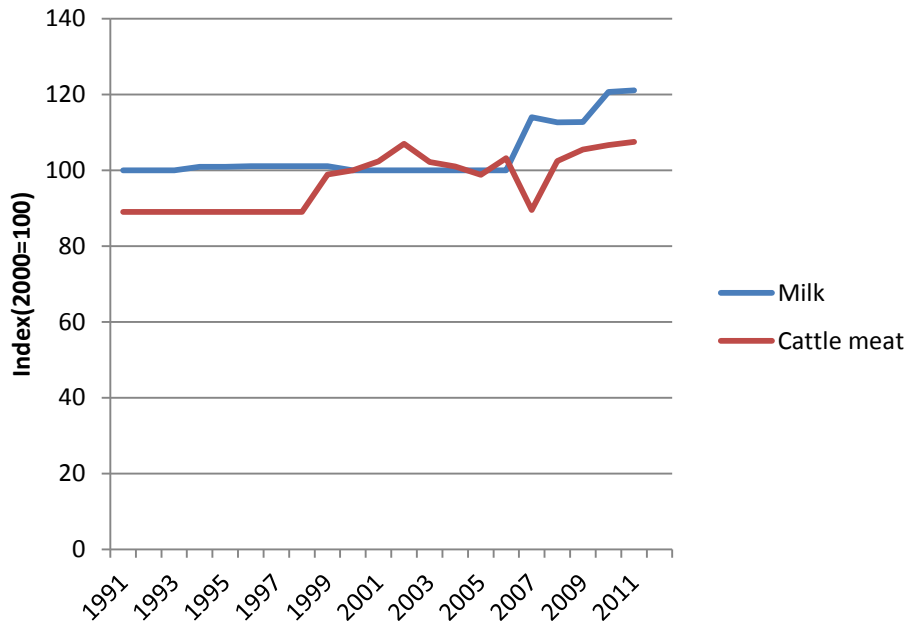


Figure 4. Yield index per head for meat from cattle and dairy milk during 1991-2012 (Source: FAOSTAT)

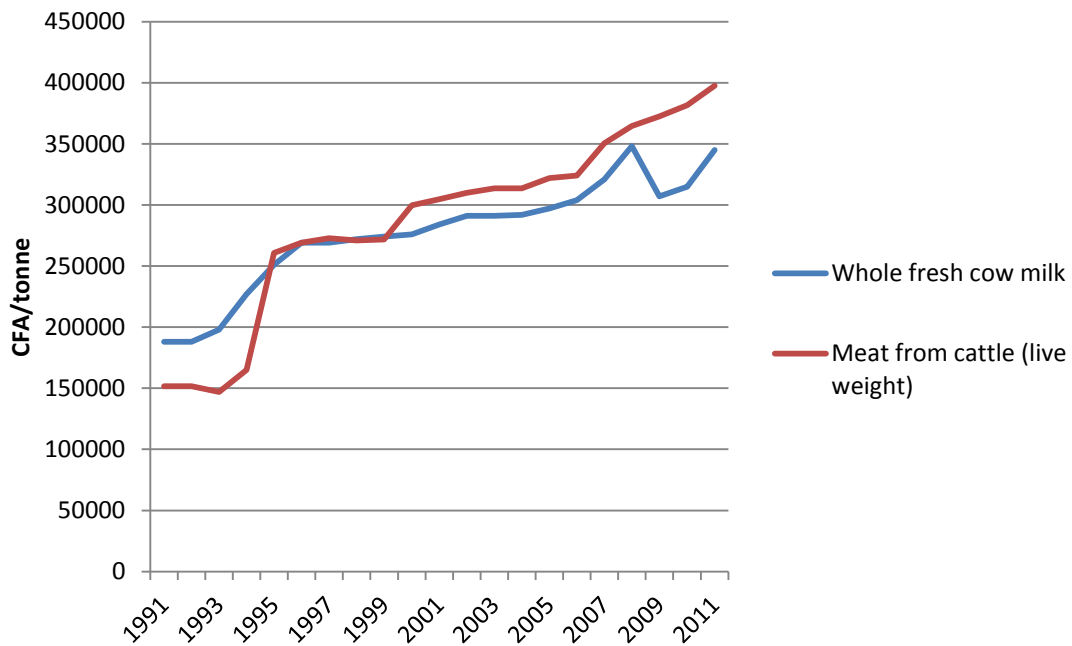


Figure 5. Prices (FCFA per tonne, nominal prices) for meat from cattle and dairy milk in Senegal during 1991-2011 (Source: FAOSTAT).

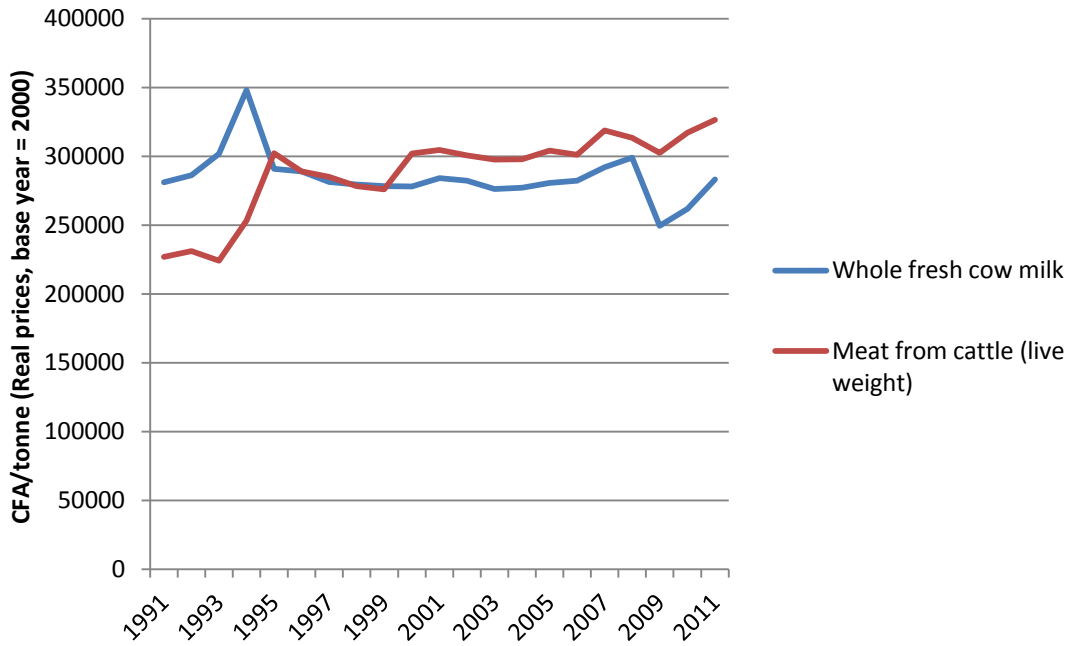


Figure 6. Prices (CFA per tonne, real prices, measured at year 2000 prices) for meat from cattle and dairy milk in Senegal during 1991-2011 (Source: FAOSTAT, World bank).

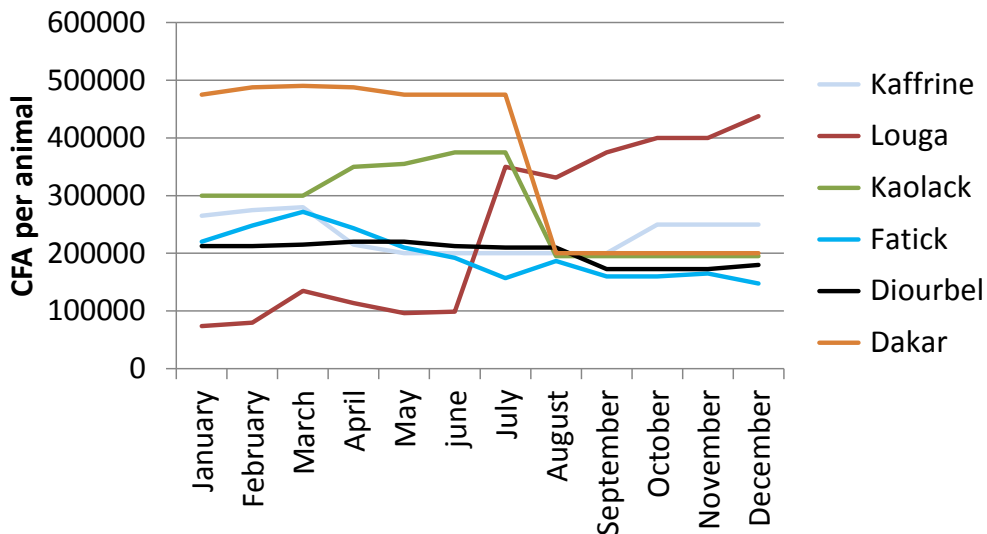


Figure 7. Monthly prices (CFA per animal) of cattle in selected regions of Senegal for year 2013 (Source: CSA).

McDermott *et al.* (2010) examined ways to sustain intensification of smallholder livestock systems in the tropics. One of their examples is about cattle/beef production in West Africa and another is about dairy production in East Africa. They indicate that the potential of dairy to replace import products lies in domestic demand for local products and in future potential exports, including regional trade. For beef, they foresee good opportunities for regional production and possibilities for imports substitution in higher end markets if quality issues can be addressed. It is therefore important how farmers can get their products to the markets and how much value local production adds.

Consumer demand and access to the processing of livestock products are also affecting the livestock sector as summarized below by using information provided by Dieye *et al.* (2005). Senegalese dairy industry has been largely based on the use of imported milk powder (Du-teurtre *et al.*, 2004) and local milk production has been marketed informally (Broutin and Dio-khané, 2000; Ba Diao, 2003). There are several examples indicating difficulties that milk col-

lection near cities or in rural areas have faced and thus they haven't been sustainable (Vatin, 1996; Dieye *et al.*, 2005; Broutin and Diokhané, 2000).

However, there have been successful small-scale milk processing initiatives since 1990 (see *e.g.* Corniaux *et al.*, 2005; Dieye *et al.*, 2005). These have been based on simple equipment and techniques and are found in the Northern and Southern parts of Senegal. Also these systems have faced some challenges such as seasonal imbalance of production and losses in quality (coagulation of milk, acidity of milk, bacterial contaminations (Doumtoum 1995)). However, the development of mini-dairies provides new opportunities for improving market access which has been one of the challenges in African agriculture (see *e.g.* McDermott *et al.* 2010). Although milk production could be boosted by improved herd management and genetics, this may not ease challenges related to seasonal fluctuations in milk supply, because weather and access to feed can be important factor causing seasonal fluctuations in production.

Dieye *et al.* (2005) concluded that the development of improved milk production systems around cities is largely dependent on the emergence of the processing sector. Mini-dairies can be helpful in this process but offering new ways to enter the markets and stimulating innovations in local milk production systems. According to Dieye *et al.* (2005), fermented milk sold by mini-dairies around Kolda has been perceived very well by local consumers and is very well differentiated by packaging, brands and other attributes.

In the consumption side, urbanization provides some new opportunities to scale up dairy production in Senegal. Despite increases in domestic production, milk consumed in Senegal is largely imported. Local production covers only about half of domestic consumption (FAO-STAT, 2016). However, consumers prefer local milk. Broutin *et al.* (2006) found that 90% of households consuming local sour milk would like to increase their consumption but they cannot do so mainly because of the lack of availability. Sissokho and Sall (2001) noted that 79% of the consumers consider that local dairy products are of a higher quality than imported ones. Lefevre (2011) estimated the Senegalese consumers' willingness-to-pay for a fresh (or local) raw material in the composition of sour milk and they found that consumers were willing to pay a premium of 227 CFA (95% CI 104 to 351 CFA) to obtain sour milk made with fresh milk rather than with powder. This can be considered as a high premium given the price of milk at the markets. The willingness-to-pay greatly depends on the characteristics of the households and some niche markets that were identified. Wealthier households and highly educated persons were willing to pay more than the other households or less educated persons, and large households were ready to pay much less than the base category households. Ethnic factors seemed to have no impact of willingness to pay for fresh milk. The existence of a positive willingness to pay for local (fresh) products may have an important impact on local production, if the premium is sufficiently large to compensate the higher production cost of local dairy products. Moreover, Lefevre (2013) concluded that consumers' misinformation regarding the product composition prevents them from allocating a higher price to local milk-based products.

## 2.2. Genetics, management and other measures to improve cattle productivity

ILRI has analysed the livestock yields gaps in developing countries. They highlight that the yield can be seen to have three different levels (see *e.g.* Smith, 2014). **Potential yield** is defined by factors such as breed and climate, **limited below the potential yield** by factors such as the availability of water, feed quality and quantity, and realized, **actual yields** are

even below this limited yield due to reducing factors such as diseases and stress. Hence, the milk yield can be said to be defined by animal's breed, and climatic factors, limited by the availability of water and feed, to be attained under specific conditions laid down by animal's stress and diseases. It can be concluded that the underlying reasons for the yield gap are multiple and they include factors such as poor feed both in terms of quality and quantity, poor genetics, animal health, reproduction and management, as well as stress caused by climatic conditions such as extreme temperature or drought, which is further related to feed availability. In the future intensification of livestock production is likely to be severely constrained by increased droughts.

The most significant constraints to the development of livestock in West Africa are: 1) technological constraints, specifically the persistence of certain epizootic diseases, a shortage of pasture and functioning watering points (because of their high cost, agricultural by-products and stockfeed are often impractical as alternatives for pasture), poor genetics and the low milk and meat yields of the indigenous breeds; 2) economic and financial constraints, such as the small amount of public investment in the livestock subsector and insufficient access to markets and credit for livestock producers. Moreover, farmers in Africa keep animals also for non-economic reasons which may contribute to low productivity and reduce the uptake of new technologies.

An important aspect which influences the development potential of livestock sector is the operating environment of smallholder farmers. Past attempts to close livestock yield gaps have failed to take in account of the realities of the users – the world's small-scale livestock producers: Environment, climate, feeds available, endemic diseases, local market context, state of infrastructure and institutions. Currently mixed systems produce 65% of the beef and 75% of the milk in the developing world as well as almost 50% of global cereals (Herrero *et al.*, 2009a, 2010). Zingore *et al.* (2009) showed that interventions in crop livestock systems at the farm level may have positive or negative impacts on smallholders depending on a host of factors including household wealth, availability of labour and nutrient resources. In some areas, technologies that received limited adoption when initially introduced have become quite viable under changing market conditions.

Intensification of livestock production can be used to reduce the yield gap. It is not completely clear how large dairy milk yield gap there exists in Senegal, but the numbers in the previous section suggest that the yield gap in dairy cows in Senegal is substantial. There is fairly little research on sustainable intensification of livestock production in West Africa. According to Pretty *et al.* (2011), improvements to livestock systems in Africa have focused on better disease management, such as for Trypanosomiasis in West Africa (for disease coverage, see also review by Niemi *et al.*, 2013), new indigenously developed breeds, such as of chickens in Uganda and cross-bred goats in Kenya, and the cultivation on-farm of new sources of fodder. Such fodder (perennial legumes, shrubs and grasses) has been introduced into the typically small farms of East Africa in such a way that maize production has not been negatively affected. This also highlights that livestock in Africa is linked to the surrounding activities.

Using global figures for extensive crop livestock systems, Herrero *et al.* (2009a) estimated that about 98 million dairy cattle producing at 2 liters per day would be required to provide 45 liters milk per capita for the 2000-level population in these systems. Based on estimated population increase and milk demand by 2030, at the same level of productivity, over 166 million dairy cattle would be required. However, if yields could be increased up to 10 liters per day the number of animals required could be reduced to 33 million. Hence, improvements in productivity would be a key to improve food security for households engaged in these production systems. Moreover, improved productivity would also reduce methane emissions by at least two thirds, simply by reducing the number of animals and increasing

feed conversion ratios. Although the example is simplified, it illustrates the role of productivity in this context.

Feed is an important factor for the positive and negative effects of livestock and feed quality can be used to mitigate greenhouse gas (GHG) emissions and natural resource usage in several ways. GHG emissions are often estimated through simplified protocols that are optimized for certain conditions and would need to be adapted to the Senegalese context. In theory, a shift from roughage (high acetate fermentation in the rumen) to concentrate (high propionate rumen fermentation) feeding would reduce the amount of methane produced from 1 kg of feed digested (Tarawali *et al.*, 2011). However, this would increase competition between food and feed production. As an alternative, a general feed improvement (fresher and more digestible feed, e.g. silage) improves animal efficiency (growth and milk production) which has a positive effect on the mitigation of GHG. Moreover, African livestock farmers who are facing very scarce resources may be reluctant to give high-quality feed to the animals if it is suitable for humans. Blümmel *et al.* (2009) estimated for Indian data that increasing per animal milk yield from a national average of 3.6 liters per day to between 6 and 9 liters per day is possible using currently available feed resources.

Soussana and Lemaire (2014) represent a scheme on the effects of grassland intensification by grazing and cutting and by nitrogen fertilizer application on animal production. Their graph illustrates that while intensifying grassland use, the greenhouse gas balance per unit animal production has deteriorated continuously. By contrast soil carbon sequestration and animal production are likely to first increase but as intensification goes far enough, they also will decrease. This has some similarities with the schematic presentation of McInerney (2011) on how intensifying animal production is likely to first increase sustainability in terms of animal welfare, as providing proper care, nutrition and shelter for predators and weather will increase both productivity and animal welfare. However, when the production becomes intensive enough, further increases in the intensity become detrimental to animal welfare, and ultimately also to productivity (e.g. mortality may increase to excessive productivity requirements). This may be the case in so-called conventional intensification pathways.

Tradeoffs need to be considered to define an environmental carrying capacity. These include balancing between maximizing carbon harvest by grazing/cutting for animals and carbon returned to the soil, balancing forage quality to increase digestibility and reduce emissions from enteric fermentation and root and shoot litter decomposability to increase mean residence time of soil organic carbon, and balancing between animal stocking density and enteric CH<sub>4</sub>, urine N<sub>2</sub>O and nitrate emissions.

Sustainable increase in the productivity of Senegalese dairy cattle breeds is needed to meet the increasing demand for milk (Duteutre, 2006). To achieve this AI campaigns have been carried out (Diop, 1993) resulting in co-existence of different crosses between **indigenous cattle** (Gobra, Maure, Ndama, Djakoré) and **exotic cattle** (e.g. Holstein, Guzerat, Montbeliard, Gir, Jersey) some of which have been bred to cope in high-input industrialized production settings. Despite the campaigns, the use of AI and cross-bred or exotic cattle in Senegal remains low.

In certain dairy production systems within Senegal, such as in peri-urban Dakar, the indigenous West African Zebu breeds of cattle (such as the Gobra, Maure and Azaouak) are being crossed with recently introduced dairy breeds from Europe (such as the Holstein-Friesian or Montbeliard), resulting in farmers keeping a wide range of breed types. However, little is known about the relative performance of the different breed-types from a socio-economic viewpoint. Whilst animals with a higher proportion of exotic blood have the genetic potential to produce more milk, they are less adapted to the local environmental conditions and require greater inputs, such as feed, healthcare and shelter, than indigenous animals.

Previously, it has been difficult to quantitatively assess the socio-economic performance of the different dairy breed-types within *in-situ* (peri-urban or village) settings, as the breed-mix of individual animals cannot be determined from phenotypic observation and pedigree records are lacking. New genomic approaches, however, provide a solution to this problem as they enable the breed composition of individual animals to be determined from DNA information. By combining genomic-based breed information with economic and performance information from on-farm monitoring of the same animals (obtained from both baseline and longitudinal surveys), the most appropriate breed/cross-breed type for a particular production environment can be identified. Utilization of the most appropriate breed type is critical to sustainably increase the productivity of the dairy sector.

Breeds such as Holstein are sensitive to lack of feed due to their high milk production. This sensitivity is also increasing with the number of parturitions (Coulon *et al.*, 1994, Gillah *et al.*, 2014). Therefore, in the agro-pastoralist system of Senegal, season of calving and water availability are important factors for milk production (Galukande *et al.*, 2013). Studies have shown that compared to other breed types, crosses between Holstein and indigenous breeds have the highest milk production (Keita, 2005; Millogo, 2010; Galukande *et al.*, 2013).

Indigenous breeds tend to have relatively long calving intervals. Bertrand (2006) reported 18 to 24 months of calving interval in Gobra and N'Dama breeds in sub-Saharan Africa while Tellah *et al.* (2015) reported 477 ( $\pm 119$ ) days of calving interval for Kouri cattle. Similar results have been observed for N'Dama (Sokouri *et al.*, 2010) and Sanga (Apori *et al.*, 2014).

Lactations are also usually long in indigenous breeds. Sokouri *et al.* (2014) found lactation length of 387 ( $\pm 61$ ) days for N'Dama x Montbeliard, which is similar to zebu x *B.t. taurus* crosses in our case study. Indigenous breeds have poorer fertility and so extended lactations occur because farmers are not sure to get cows back into calf early enough to achieve an annual calving interval. Hence cross breeding with taurine breeds, combined with appropriate herd management, remains the easiest and fastest tool to increase the productivity of milk production in Senegal.

Climatic conditions are important for milk production in Africa. It has been estimated that variation in weather/climate explains about 25% of variation in the amount of cattle in Senegal. It matters a lot which type of dry season and rainy season are experienced each year. Rainfall (see e.g. Weikard and Hein, 2011; Niemi *et al.*, 2015) affects the availability of feed and thus the amount of cattle. Hot rainy season and cold dry season decrease the availability of feed and consumption of feed, respectively, and can thus result in resource-scarcity and diminishing cattle stock. In addition, temperature and rainfall are correlated with each other.

A study by Seif *et al.* (1979) showed that Zebu water consumption increased by 58% when temperature increased from 10 to 31 °C. This is only 2.8% increase per degree, if we consider it as a linear process. At higher temperatures, feed consumption decreases (Seif *et al.*, 1979) and fertility increases (Jöchle, 1972). Lower food consumption can be of importance in the dry season. This is in line with the perception of farmers in the savanna zone of central Senegal, who say low temperatures may lead to fodder shortage (Mertz *et al.*, 2009). Western Sahel seems to be especially sensitive to the dry-season temperature. It is likely that the mean precipitation will decrease in parts of Mauritania, Mali and Senegal. Although temperature is important, precipitation shows a more consistent pattern, with a positive effect in the drier countries, and a negative effect in wetter countries.

Only few studies have been previously completed to know the performance of the different cattle breeds (Diop *et al.*, 2004) or the economics of the dairy production under Senegalese production system. Having information on the performance of animals per breed is essential when selecting the best-suited breeds. Moreover, information on individual is vital if one desires to improve the genetic stock and to use AI efficiently. Artificial insemination (AI) is being

used to create indigenous and exotic cross-bred cattle with higher milk yield potential. Artificial insemination helps herd owners to select and use genetic material that is as productive as possible as it makes available different genetic materials. Moreover, heterosis, which is seen in cross-bred animals, can help to achieve even higher production performance than the average performance of breeds when they are used separately.

Animal health remains a challenge for intensification. It is also a challenge, which can be resolved by intensification. The World Organization for Animal Health (OIE, 2016) reports that various severe animal diseases are present in Senegal. These include, for instance, Foot and mouth disease, Peste des petits ruminants, Rift Valley fever, Theileriosis and Trypanosomiasis. Improved control of animal health is therefore essential.

In Mali and Burkina Faso, knowledge on tsetse flies and their symptoms have been improved. Elevating knowledge has increased the use of veterinary drug and thus reduced the prevalence of Trypanosomiasis (Liebenehm *et al.*, 2011). Another success has been the adoption of fodder shrubs in East Africa (Wambugu *et al.*, 2011) which are used to obtain inexpensive and fit-for-purpose feed to dairy cattle. The benefits of the program promoting shrubs have been estimated to benefit farmers by \$4 million (about €3.6 million) per year.

Improving the productivity and profitability of dairy cattle should have positive effects on the livelihoods of dairy cattle keepers and others involved in dairy value chains. The low milk yield of dairy cattle in Senegal is generally attributed to the low genetic potential of the indigenous Zebu breeds. It is also due to harsh environmental conditions and generally poor levels of animal management. In animal science the phenotype of an animal is defined by its genotype, environment and their interactions. In addition, markets, institutions and policies define the setting where smallholders aim to get their best outcome.

Given the diverse production systems in Africa, there is no 'blueprint' of preferred set of interventions to improve livestock productivity. However, one of the options is to identify production systems where breed-change interventions for intensification might be feasible (Marshall, 2014) and try to identify breed and management practices which are best-suited for local conditions. Cross-breeding with often exotic breeds from temperate climates has often been considered inappropriate and worries about the loss of genetic diversity have been raised. However, at least some farmers are aware of higher requirements of crossbred animals, and they are willing to invest in animal nutrition and animal health and accept higher work load as the higher input pays off. Research to support this is needed, and phenotyping of many animals for many traits under farmer conditions is a key task here.

Smallholders are competitive in ruminant systems, particularly dairy, because of the availability of family labour and the ability of ruminants to exploit lower quality available roughage. Smallholders compete well in local markets which are important in agriculturally-based or transforming developing countries (McDermott *et al.* 2010)

Household profit from keeping more productive breeds and cross-breeds of dairy cattle in low-input, agro-pastoral systems in Senegal (Marshall *et al.*, 2016). The government of Senegal supports dairy production through the use of genetically improved animals: A public artificial insemination (AI) program, which promotes the use of exotic breeds, is available to cattle owners at no cost. There is also a local semen production center. In addition, AI to exotic breeds is available through private service providers. This has led to an increase in the uptake of crosses of indigenous breed by exotic breed, as well as the use of pure exotic breeds. However, farmers in low-input dairy production systems lack information on the relative performance of different breed-types to be able to make informed decisions. In addition, they need information on how to better manage their animals, as well as information on the benefits of different animal and management types to make informed choices for the benefit of their household. Since 1994, government-sponsored AI programs (public AI services) and



private veterinarians (private AI services) have continued to provide AI services to farmers. Artificial insemination is being used to create indigenous and exotic cross-bred cattle with higher milk potential. To date, however, the use of AI and cross-bred or exotic cattle in Senegal remains low. There is no formal national production recording programme. Besides AI programme, a number of animals of exotic breeds have been imported to Senegal over the past years.

Past genetic improvement efforts have failed mostly, among other things, due to these reasons: 1) dependence on breed replacement and/or indiscriminate cross-breeding of native with exotic breeds with no plan on how to maintain suitable exotic blood levels and no selection on the dam line; 2) incompatibility of introduced genotypes with producers' breeding objectives, management practices and environmental conditions; 3) lack of comprehensive approach to design simple but effective breeding strategies instead of adopting complex breeding programmes that require many logistics and technologies; and 4) insufficient or no systematic breed evaluation studies ensuring fair comparison of the relative merit of indigenous and exotic breeds under typical environment considering the role of genotype  $\times$  environment interaction. Moreover, smallholder production systems are characterized by small animal numbers per household, single-sire herds, lack of systematic animal identification, absence of performance and pedigree recording, illiteracy, poor infrastructure and ill-functioning institutions. The mobility of pastoral flocks poses additional difficulties in recording and selection of animals (Wurzinger *et al.*, 2014).

Tarawali *et al.* (2011) represent examples on how livestock and water productivity in mixed crop livestock systems could be improved. These measures include:

- Combining feeding, breeding and animal health interventions for better animal productivity. Access to artificial insemination and veterinary services in rural areas and feed interventions.
- Using of improved multi-purpose crops, especially legumes, fodder trees, forages and supplements. This may require resolving tradeoffs in the use of crop residues for soil quality and incorporation of feed value parameters into crop breeding and selection programmes. Some forages or supplements also have high water demands.
- Appropriate grazing management to prevent land degradation. This requires strong institutional arrangements especially for common property.
- Management to increase productive vegetation/cover and integration of livestock with irrigation schemes. These measures may require combinations of biophysical, social and institutional actions.

McDermott *et al.* (2010) examine ways to sustain intensification of smallholder livestock systems in the tropics. One of their examples is about cattle/beef production in West Africa and another is about dairy production in East Africa. They identify a few supply constraints. In terms of dairy genetics, they indicate lack of cost-effective way of adopting cross-bred cows and limited availability, high costs and low conception rates of AI services. For beef genetics, the constraints include lack of improved indigenous sires and proven cross breed as well as missing investments in breeding infrastructure. Genetic improvement, with accompanying changes in feed regimes, can lead to gains of 60% to 300% in milk productivity in cattle.

Regarding management issues, they point out that specific animal diseases such as foot and mouth disease are an issue, and so are issues related to nutrition such as complexities caused by nutrition and health together, under-nutrition of breeding females and poor quality basal diet and low level supplementation, limitations in feed availability during the dry season, resulting in large seasonal fluctuation in milk production. Niemi *et al.* (2015) have also indicated that limitations in feed availability can be a major issue particularly in years of drought.

In terms of market and institutional constraints, McDermott *et al.* (2010) mention that dairy suffers from limited access to formal output market and poor input services, including genetics and feed (quality). For beef, there are very limited input services and there are inefficiencies in output marketing. In these extensive systems with poor infrastructure, access to services is minimal and output marketing relies on itinerant traders and weekly markets, leading to high transactions costs.

Animal disease outbreaks generate a range of economic and non-economic impacts. While significant research has estimated the impacts of various diseases across numerous contexts, synthesizing the differential impacts and implications associated with the introduction of a novel disease in developed versus developing countries remains a rich area for further research. One of the issues is that contagious disease outbreaks can reduce farmer's access to the markets and cause devastating losses to their animal stock (Rich and Niemi, *forthcoming*).

Pretty *et al.* (2011) identify generic requirements for scaling up sustainable intensification. These include:

1. Scientific and farmer input into technologies and practices that combine crops–animals with appropriate agro-ecological and agronomic management
2. Creation of novel social infrastructure that results in both flows of information and builds trust among individuals and agencies
3. Improvement of farmer knowledge and capacity. Farmer engagement and knowledge are essential for the adaptation of innovations to local circumstances and over time.
4. Engage with the private sector to supply goods and services (e.g. AI and veterinary services) and develop farmers' capacity to add value through crop processing and broader business development: farmers wish to make money, not just produce food.
5. Focus particularly on women's educational, microfinance and agricultural technology needs, and build their unique forms of social capital. Women are the primary farmers in many contexts but they are routinely ignored by external agencies.
6. Ensure that microfinance and rural banking are available. Farm families often need small amounts of finance, yet are denied them from conventional banks; lending to farmer groups is low risk.
7. Ensure public support to lever up the necessary public goods for sustainable intensification of agriculture in the form of innovative and capable research systems, dense social infrastructure, appropriate economic incentives (subsidies, price signals), legal status for land ownership and improved access to markets through transport infrastructure.

## 3. Case study

### 3.1. Description of case study

Intensification, by definition, refers to that more of output is obtained per input that is being used. This case study aims to identify the best suited dairy cattle genotypes for the low input dairy systems in Senegal through socio-economic analysis of milk production in urban and peri-urban farms and examines factors driving the choice of breed and AI. The main features of the case study have been reported by Marshall *et al.* (2016). Currently very little developing country livestock production systems are diverse and dynamic, and include those where existing indigenous breeds are currently optimal and likely to remain so, those where non-indigenous breed types are already in common use, and systems that are changing, such as by intensification, where the introduction of new breed types represents significant opportuni-

ties. At present, very little research has focused on optimizing the use of cattle breeds in Sub-Saharan Africa, such that significant knowledge gaps in relation to breed-change interventions remain (Marshall, 2014)

The case study focused on two regions, namely Thies (areas around Thies, Khombole and Tivaouane) and Diourbel (Mbacke and Touba), which are located in the Center-North of the groundnut basin in Senegal (Figure 8). They are part of the Agro-pastoral production system of Senegal. The data were collected during 2013 to 2015. These regions have dairy farms with both indigenous breeds and crossbreeds. Crossbreeds are defined here as a cross between indigenous breeds) and exotic high milk-producing breeds.

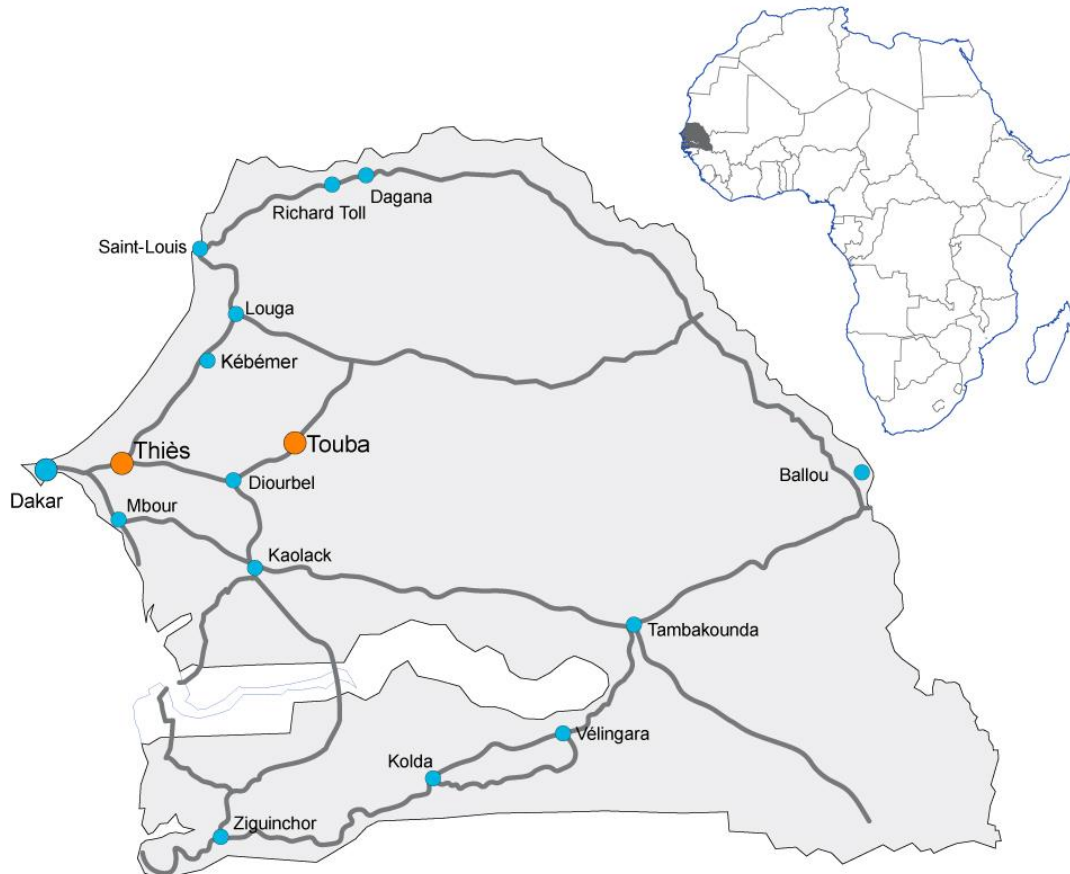


Figure 8. Location of case study areas in Senegal (Image: Natural Resources Institute Finland (Luke)).

The data originates from 239 dairy farming households, ranging from very traditional and more innovative households. These households had altogether more than 3500 heads of dairy animals which represented various breeds and cross-breed types. The average herd size was about 20 animals. The herd size and breed composition differs from small holder dairy farm in East African countries but is comparable to extensive production systems with about 10 cows per herd (see e.g. McDermott *et al.*, 2010; Chagunda *et al.*, 2013).

The climate in the case study areas is characterized by a Sudano-sahelian climate, hot and dry, with a fairly short rainy season of 3 to 4 months and a long dry season ranging from October to June. The average annual rainfall is about 300 to 500 mm. The natural vegetation dominated by the genus *Acacia*, is largely transformed by agriculture into crop plants. The human population consists mainly of Wolof (62%), Serere (33%) and Fulani (4%) (Diop and Gueye, 2008).

Since there is no milk recording scheme in Senegal the first thing was to set up a recording scheme for milk yield and content traits to enable their comparisons between the different breed combinations. On average, only about a quarter of cows in the herd were milked. Data on the breed of cows as well as the basic information of age, parity, insemination and last calving date when the sampling was started were also collected. The daily milk yield was calculated as a sum of morning and evening milking on the test day. This resulted in a unique database on the genetics of dairy cattle in Senegal.

**Breed types which were examined, can be summarized by four main types:**

- 1) Indigenous Zebu (Zebu Gobra, Zebu Maure),
- 2) Indigenous Zebu × Guzerat (Indigenous Zebu cross with Guzerat, typically 25% to 50% Guzerat),
- 3) Indigenous Zebu × *Bos taurus taurus* (Indigenous Zebu cross with *B.t. taurus*, mainly Montbeliarde and Holstein-Friesian *B.t. taurus*, containing typically 25% to 50% *B.t. taurus*), and
- 4) animals with large proportion of improved dairy cattle ancestry (“High *B.t. taurus*”; Indigenous Zebu cross with *B.t. taurus*, mainly Montbeliarde and Holstein-Friesian, containing typically 75% to 100% *B.t. taurus*).

The case study supports intensification of livestock production because strengthening the dairy germplasm supply system improves farmers’ access to dairy breed-types which are suited to local conditions. This can have the potential to decrease environmental impacts of cattle production as well.

Genetic improvements have to be developed together with other interventions at farm level. Besides genetics, information dissemination is therefore important in our case study: Enhanced management and decision-making is examined in combination with breed types. **All households were classified as 1) ‘poorer’ or 2) ‘better’ in relation to the level of animal management they applied.** For this purpose milk yield was used as a proxy test-day milk yields (expressed in standard deviation units from the breed-group mean) were averaged across all animals in a household, and the top 50% of households classified as ‘better management’ and the bottom 50% as ‘poorer management’. Please note that this means that poorer or better management for one breed-group is not necessarily the same level of management as poorer or better for another breed-group.

## 3.2. Intensification pathways

PROIntensAfrica has identified **four intensification pathways** which are conventional, sustainable agriculture, agroecology and organic intensification pathway. These pathways and the relevance of our case study to these pathways are presented briefly in what follows.

**Conventional intensification pathway** is dominated by high use of external inputs, notably breeding, pesticides and mineral fertilizers and the extensive use of irrigation and mechanization. It is also identified as the “neo -conventional green revolution” pathway for Africa, mostly supported by large agribusiness firms of agricultural supplies (mechanization, water management, chemicals, etc.). It targets all kind of farms but implicitly encourages large scale farming as a natural consequence of desired high productivity gains. It still dominantly refers to maximizing production in the short term, through an artificialization of the production conditions. Scientific literature on SSA’s agriculture rarely refers to the so-called “high input” pathways. This pathway is based on the conviction that artificial physics, chemistry and biotechnologies can produce technologies able to substitute the natural processes, while increasing land productivity. Three other pathways defined below refute this conviction.

**Sustainable Agriculture Intensification (SAI)**, for which the “Montpellier panel” has given a wide theoretical framework, is based on three pillars: Genetic intensification, ecological intensification and social intensification. This pathway considers more explicitly local knowledge and ecological services while using external inputs, biotechnology, irrigation and mechanization. It aims to increase the productivity of land and labour and income. This pathway shares the main objective of the conventional pathway of maximizing the potential for increasing production’s volume, but it also requests dedicated research to correct externalities and mistakes of the conventional pathway, and excessive use of natural resources as this can reduce environmental and social sustainability. Private investments and public-private partnership are highly compatible with this pathway.

**The agroecology pathway** combines social and technical movements all along the agri-food chain or food system. Maximization of input productivity or increasing production volume is not the (main) goal of this pathway. It is requested only when needed. This pathway is subordinated to welfare and food justice maximization. The goal is rather to maximize natural processes involved in the agricultural production to diminish the use of external inputs. Autonomy of the production systems from chemical inputs and agronomic infrastructures are also key objectives. Therefore it mainly targets small-scale farms and local and national markets.

**The organic agriculture pathway** refrains from the use of pesticides and mineral fertilizers and emulates ecological systems and cycles. The main objective is to improve quality which should allow better prices. This is why the pathway ruled by the definition of market’s conditions, certified in different ways. Intensification is a more recent concern in this pathway. There is evidence that the yield gap between conventional and organic practices could be reduced. Although short circuits and local anchorage should be promoted, this pathway doesn’t exclude long-distance inputs procurements as long as they are organic.

**Our case study**, which focuses on improved dairy breeding and improved management of livestock farming in Senegal, **mainly falls under the conventional intensification and sustainable agriculture intensification pathways**. Agroecology pathway can be considered as an original intensification pathway. Although our case study aims at finding the breeds and cross-breeds of dairy as well as herd management practices which are best-suited for conditions of peri-urban dairy production in Senegal, improved management and breed scenarios mostly do not fit very well under organic agriculture or agroecology pathways because of several reasons: Firstly, it doesn’t exclude the use of breeds bred for Western high-input dairy farming. Secondly, it tries to aim at good health and welfare status of the animals but it doesn’t exclude the use of chemical inputs. Thirdly, it aims at finding the socio-economically most beneficial production practices and breeds or cross-breeds. Economic return is an important criteria in this respect, but socio-economically most preferred option may imply the same as the most intensive production, rather than trying to find high-premium markets for dairy products. However, it is highlighted that the (fresh) dairy product markets in Senegal can be considered to be high-premium markets where milk prices are rather high whereas products manufactured by using milk powder are “conventional” markets.

Herrero *et al.* (2009) describe livestock systems based on some characteristics intensification. The systems covered in our case study could mainly fall under the following systems: 1) Agropastoral systems with low population densities, low agricultural potential and poor market access. These areas are characterized by livelihood systems depending mostly on ruminant livestock. 2) Extensive crop–livestock systems with medium population densities, where there is crop cultivation but low yields, extensive livestock production mainly for meat production, low input use, and poor connectedness to markets. 3) Intensive crop–livestock systems with high population densities, high agricultural potential including the use of irrigation sometimes, high input use, intensive livestock rearing predominantly for dairying, and good market access.

Each PROIntensAfrica case study should provide information on different aspects of sustainability. Our case study provides good data on productivity (measures particularly by milk yields) and viability (measures primarily by economic profit per dairy cow). Environmental sustainability is clearly related to our intensification options but the case study doesn't provide exact quantitative data on it. However, there is data about veterinary medications costs which is one of the measures for environmental sustainability. It can also be argued that, in our case, improved productivity is likely correlated with the amount of greenhouse gas emissions (see Soussana and Lemaire 2014). Positive correlation with per kg milk produced and positive correlation with per animal is expected. Moreover, it can be argued that in the cases of better management animal health and welfare are improved when compared to poorer management as differences between these two management patterns mainly relate to fulfilling some basic needs of the animals. The data doesn't provide accurate metrics for social well-being/social sustainability and resilience impacts of intensification pathways although economic differences between intensification scenarios can be regarded to represent one form of resilience.

### 3.3. Stakeholders and the value chain

There are several stakeholders and actors involved in the livestock value chain. Figure 9 illustrates key stakeholders from the perspective of this case study. These include cattle farmers, AI service providers, veterinary services, feed suppliers, other input suppliers to the livestock farms, crop farming, other cattle owners and cattle traders, milk and meat processing companies, consumers and other people who purchase milk and meat, local and national government, and some other stakeholders. Each stakeholder has economic or other interests that affect they (or group that they represent) welfare.

The central stakeholders are livestock owners (*i.e.* farmers) who decide on how to use animals and how to develop their activities. Livestock owners decide whether to utilize artificial insemination (AI), veterinary and other services which may enhance livestock productivity and health. They pay to service and input providers and receive the service or good in exchange. Through purchases of animals they also decide which types of animals they will be using in the future. Actions taken by livestock owners can be based on their economic interests or other values such as cultural or social aspects.

Public and private animal breeding organizations can have multiple roles. They can collect information on the traits of animals from the farms and use this information to improve animal genetics. They may also be involved in providing advice to the farms on how to take care of the animals, and they may be involved in the trade (purchases and sales) of live animals and semen. Public and private AI service providers can be a stakeholder group operating between animal breeding organizations and livestock farmers. They can sell semen and genetics on behalf of animal breeding organizations. Potentially, also other services such as consultancy and advice on animal nursing practices can be incorporated in their operations. The motives of action for animal breeding organizations and AI service providers may vary depending on whether they are public or private organizations. Public organizations should operate for the best interest of society whereas private organizations are likely to aim at maximizing their economic benefits. However, also private organizations are likely to aim at maintaining permanent customer relationships to livestock owners.

Veterinary service providers are an important stakeholder group who can collaborate with all stakeholders operating with live animals or food derived from the animals. In other words, they can provide veterinary treatments (preventive and curative) and advice to livestock

owners and animal breeding organizations. They can provide advice on e.g. hygienic practices to prevent the spread of livestock diseases as well as how to ensure that the food is safe to eat and free from zoonotic pathogens, which is an action that provides a public good. Feed suppliers, in the event that feed is purchased to the animals, are also an important stakeholder group. They are stakeholders who can collect the feed and deliver it to the livestock farms. Feed supplied can be a main product of a feed company, a side stream of another industry such as ingredients derived upon processing peanuts (which are commonly used as feed), crop of a farm or a household involved in the cultivation of fodder crops, or some other types of stakeholders. The role of feed suppliers is usually to supply feed which helps to improve economic or physical production results of livestock. Besides these stakeholders, there may also be other input suppliers as important stakeholders. One of these stakeholder groups are logistics service providers. Although animal logistics in Senegal are not generally well developed, logistics can play an important role in some farms.

Other cattle owners and cattle traders are an important part of the value chain. They can act as stakeholders who are buying livestock as well as stakeholders who are selling more animals to the livestock owner. In Senegal, livestock is often sold to other households for food use or for breeding. The trade of animals also commonly occurs through market places. Animal trade is usually a bargaining process which aims at finding the best compromise on animal's price. The prices can vary by market place and season and the season of peak prices can vary by region as shown by statistical data.

Milk and meat processing operators, including butchers/slaughterhouses and dairies are a stakeholder group which can purchase meat (or live animals) or milk from the farm or from traders, process it and sell it further to the retailers, restaurants or to final consumers. These operators can be also households seeking for food as consumers frequently purchase milk and live animals directly from livestock owners. Finally, consumers who purchase milk or meat are the stakeholder group which will benefit from the final product originating from livestock.

Local and national governments are also important stakeholders. They can impose rules and regulations which aim at ensuring good animal husbandry practices, food safety or animal health. They can also initiate information and support programs to promote or prevent intensification of livestock production. Public investments can have a role in overcoming the constraints through knowledge and technologies that deliver quality feed, animal health, breeding, technical advice and other services. Government has also a special role as it has the power to control how land is used (particularly in rural areas where the land is owned by the government).

Institutional issues can be particularly important in the context of animal health and animal breeding, because these operations often require investments in data collection and analysis or to service provision. If intensified production is more susceptible to extreme weather events, supportive institutions and policies may also be needed to help farms in managing risks (e.g. index based livestock insurance; investments in rural infrastructure).

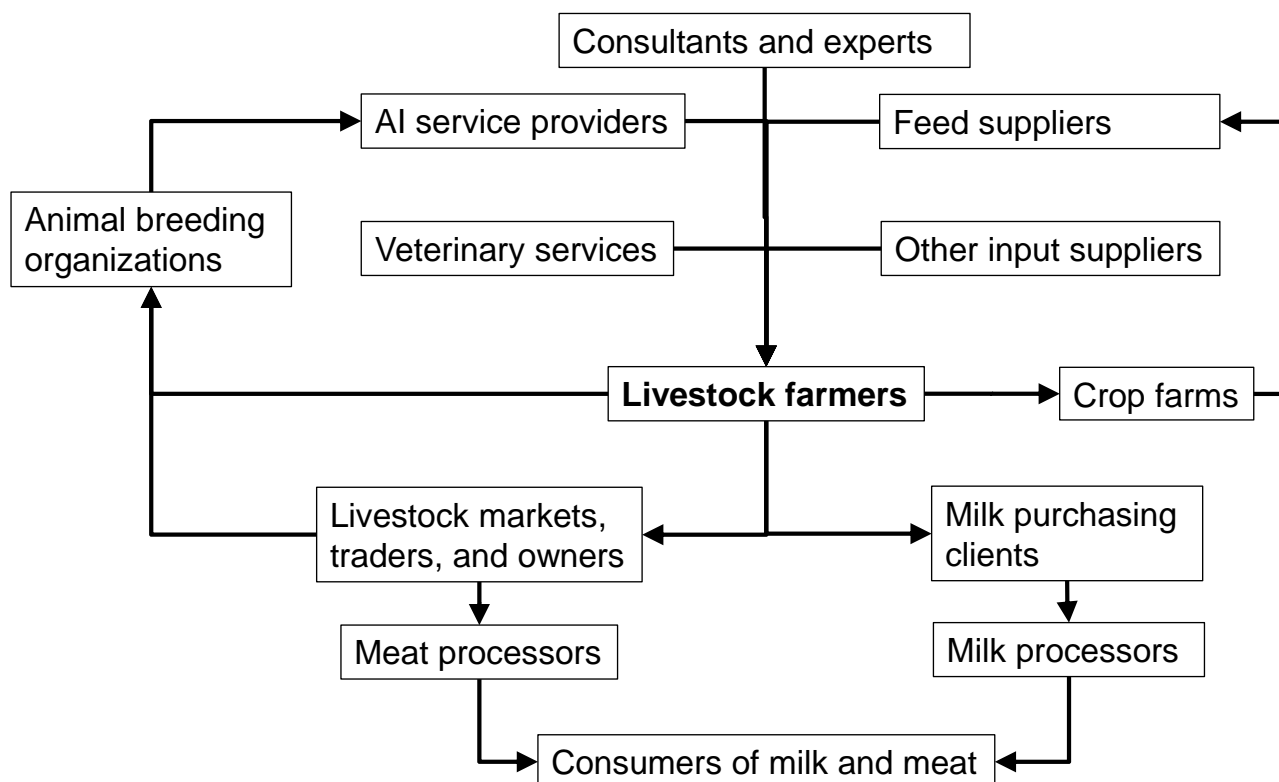


Figure 9. Illustration of links between some of the key stakeholders in our case study.

### 3.4. Drivers of change

The most significant constraints to the development of livestock are: 1) technical constraints, specifically the persistence of certain epizootic diseases, a shortage of pasture and functioning watering points (because of their high cost, agricultural by-products and stockfeed are impractical as alternatives for pasture), and finally the low milk and meat yields of the indigenous breeds; 2) financial constraints, owing to the small amount of public investment for the livestock subsector and lack or insufficient credit availability for livestock producers.

There are several drivers which can induce change in the livestock sector so that AI, improved genetics and improved management are adopted by households owning livestock. **The drivers include increasing population growth and population density** which increase the demand for milk and may create opportunities for professional specialization. **Urbanization, improvements in the infrastructures** (especially logistics and roads) **and professional specialization** may improve farmers' access to the markets and establishing larger and specialized production units may be seen as an attractive option especially near to the cities. **Increased human capacity and professionalization of livestock farming** may also improve farmers' understanding of interrelations and issues.

Urbanization, population growth and **growth of living standards** and climate change are megatrends which will shape the livestock sector in SSA. As McDermott *et al.* (2010) argue, demand drivers can be associated with increasing consumer concerns about food safety and a trend toward highly intensive livestock production systems, often in vertically integrated food chains. However, in the SSA setting the change is more likely to be driven predominantly by population growth, urbanisation and the exploration of livelihood options.



**Climate change and animal health challenges**, such as introduction of new animal diseases, are drivers which increase the need for more robust animals. Rapid population growth and slow changes in the quality of the resource base due to land degradation or climate change is causing stagnation, loss of livelihood opportunities, and conflict over resources in livestock systems as well. Because the region is quite arid, future animals should be robust to the weather conditions. Over the past fifty decades, the Sahelian region and its' livestock system has faced increasing environmental pressure as population has more than tripled and the amount of rainfall has decreased (Ickowicz *et al.*, 2012). These changes pose substantial challenges to pastoral livestock management, which is a prevalent economic activity in the area.

Population growth is expected to increase demand for meat. Prices of milk and meat can increase in the future also due to globally increasing demand (OECD-FAO, 2014). Moreover, climate change can decrease the average annual rainfall and also increase the variability of weather. For instance, McSweeney *et al.* (2010) projected that the rainfall in Senegal can decrease by approximately 3% per decade by 2060. This will have major impacts on the availability of vegetative local biomass for the animals.

Other “stressors” that may guide the future development of livestock production and which may influence the intensification, include rangeland degradation, increased variability in access to water, fragmentation of grazing areas, changes in land tenure from communal towards private ownership and hence restricted mobility, in-migration of non-pastoralists into grazing areas, lack of opportunities to diversify livelihoods, conflict and political crisis, weak social safety nets, and insecure access to land, markets, and other resources. Possible other consequences of climate changes are, in addition to scarcity of feed, a higher prevalence of diseases and parasites and more and longer droughts. Therefore, disease and parasite tolerance need to be included in future breeding programmes. Heat stress and tolerance of salty water might be other traits to be considered.

**Technological change** can also be considered as a driver which makes it easier to retrieve information on improved management practices and acquire new genetics to the farm. Genetic changes in the cattle can provide new production potential, but also introduce novel threats as more productive animal may be sensitive to stress and diseases. **Structural changes** in the regional economy, such as increasing cultivation of cash crops may also drive farmers to intensify production as for example by-products which are suited for feed may become available. In addition, **changes in economic conditions** such as improved access to credit, increasing livestock prices, increased competition or the rising importance of food quality may also encourage farmers to adopt more effective genetics and management.

Some drivers may also have conflicting effects. For instance, climate change and introduction of new animal diseases may make investments in animal stock less attractive as the risk of losing the animals may increase, and urbanization and population growth (animals and people) may increase competition on land resources and conflicts between cattle owners and other stakeholders.

A preliminary statistical analysis of factors which affect farming households' choices regarding the use of AI has been conducted (Tebug *et al.*, 2014) in our case study data and is summarized here. **Use of AI and non-indigenous** cattle breeds varies with farmer's characteristics. The main drivers of AI service usage and cross-bred or exotic cattle were **farmers' cultural values and wealth**. It matters how different traits are valued by the herd owner. Ethnic group and income class of the farm household were major factors linked with exotic or cross-bred cattle use.

Irrespective of AI service provider, farmers were less likely to use AI if they belong to the traditional Fulani ethnic group and if the first non-indigenous cattle was not acquired via AI. Farmers with large families, who depend on crop production for subsistence, and those located farther from AI service providers, were more likely to rely on public AI services. The use of private AI services depends positively on wealth indicators such as monthly income earnings and land owned. Similarly, adoption of non-indigenous cattle depends on farmer's ethnicity and monthly income earnings. On the other hand, adoption of AI and non-indigenous crossbred cattle rearing was independent of farmer's education, labour availability, herd size and duration of dairy farming. The results highlight the need to focus on farmer's ethnicity and wealth in future programs promoting AI and / or non-indigenous cattle breeds (Tebug *et al.*, 2014). The role of ethnic factors is rational. Milk production is a key element of the pastoral tradition of Fulani people. Milk is consumed by agropastoral populations and might represent the food basis for several months of the year. This self-consumption is economically very important, but milk is also the most direct source of external revenue for Fulani livestock keepers (Vatin, 1996; Dieye *et al.*, 2005).

### 3.5. Impact of intensification options considered in the case study

Milk yields in the case study differed substantially between different management and breed types as indicated by Figure 10. Lactation milk off-take per cow for a 365 day lactation was 100% to 193% higher under better than poorer management, depending on which breed or cross breed was in question. In terms of annual milk offtake, the differences between the two management types were even larger, ranging from 159% to 225%.

The highest milk yield, 2251 kg for a 365 day lactation or 1422 liters per year was obtained for animals with large proportion of improved dairy cattle ancestry. The difference between the two parameters is due to taking into account the duration of lactation. This was 150% more than yield for indigenous Zebu animals under better management. Lactation milk yields for Indigenous Zebu × Guzerat animals were 101% to 133% (depending on the management type) and lactation milk yields for Indigenous Zebu × *B.t. taurus* animals were 107-203% higher than yields for Indigenous Zebu animals. Hence, this suggests that switching from indigenous Zebu animals to more productive animals or switching from poorer to better management improved milk yield and food security of farming households substantially. However, the maximal yields were still substantially lower than those obtained in intensive production in Europe. Crossing indigenous zebu cows with other zebu types at 25 to 50 % level did not increase the milk yield considerably.

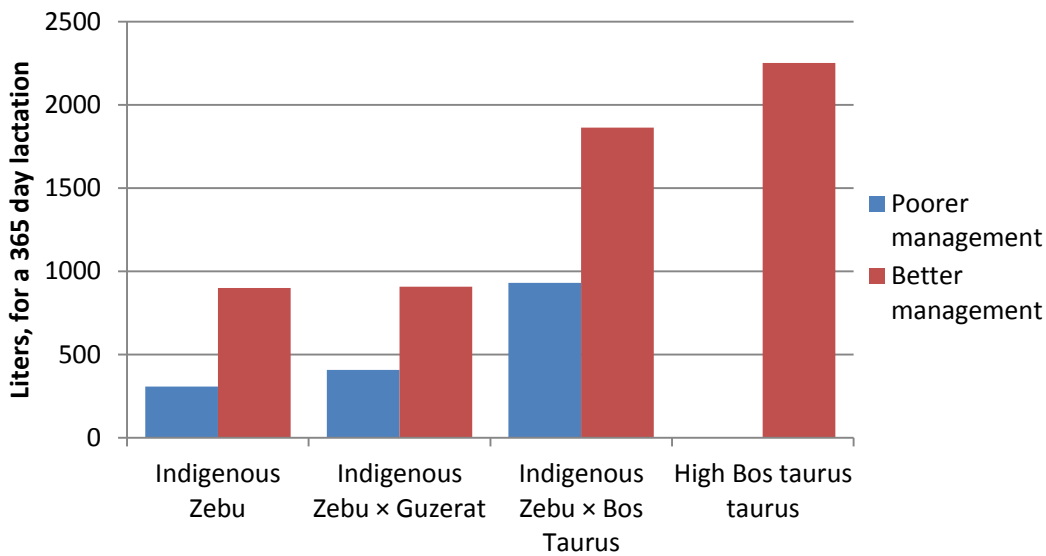
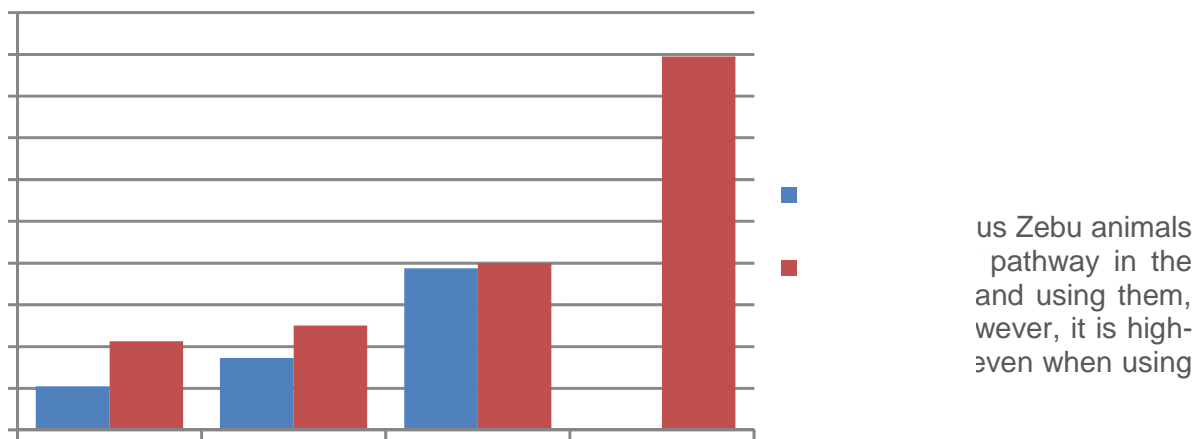


Figure 10. Lactation milk off-take per cow, in liters, for a 365 day lactation under two management types and four breeds or breed-crosses (source: Marshall *et al.*, 2016).

As Marshall *et al.* (2016) indicate, some of the price parameters also varied by animal type. Although milk was costed at the sale price of 500 FCFA per liter, live animal prices and costs associated to animals varied by animal type. For instance, young male animal sale prices varied from 176500 FCFA per indigenous Zebu to 933000 FCFA per animals with large proportion of improved dairy cattle ancestry. Feed costs were usually more than 50% of production costs under better and less than 50% under poorer management. The difference in feed costs between the management scenarios was substantial which highlights the fact that an important proportion of the management impact was likely due to improvements in the quality and quantity of feed fed. For instance, for Indigenous Zebu the feed costs under poorer and better management were 72500 FCFA and 193000 FCFA per mature female animal and for Indigenous Zebu x *B.t. taurus* animals they were 198500 FCFA and 394500 FCFA per mature female animal, respectively (Figure 12). Other important cost items included labour and the value of milk suckled by calves.

Indigenous Zebu x *B.t. taurus* animals under better management and animals with large proportion of improved dairy cattle ancestry faced housing costs of 112500 FCFA per herd as opposed to only 2000 FCFA per herd for Indigenous Zebu or Indigenous Zebu x Guzerat animals. This also highlights that the production in the two highest yielding scenarios were much more intensive and the production in Indigenous Zebu or Indigenous Zebu x Guzerat scenarios, and that high yields can be obtained with (and it may also require) a better housing, healthcare, feeding, and other herd management. Figure 11 illustrates that higher yielding breeds and better management require more animal health care effort. However, the data does not indicate cause and effect, *i.e.* it doesn't indicate whether increased health care costs are due to increased yield or whether increased yield is because of improved health care. The productivity of dairy cattle in Senegal could be improved by shortening the average calving interval. This requires good heat control and, that adequate amount of feed is available for the cow to enable earlier return to heat after calving.

Figure 12 illustrates that that higher yielding breeds and better management requires more feed than lower yielding breeds and poorer management. Feed costs per liter of milk produced is however lower for higher yielding breeds and better management than for lower yielding breeds and poorer management. The only exception is animals with large proportion of improved dairy cattle ancestry which has the highest feed cost per liter of milk among studied scenarios. The cost of animal housing was higher for breed-types involving improved *B.t. taurus* ancestry as they need shade. The highest yielding scenarios therefore fall under



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better management and for animals with large proportion of improved dairy cattle ancestry, while for Indigenous Zebu or Indigenous Zebu × Guzerat under poorer management at about 100000 FCFA or less. The milk consumed by the calf can be up to 50% of the daily milk production (Duteutre, 2006). This should be noticed when comparing milk production levels to studies in industrialized countries. Indigenous Zebu × *B.t. taurus* animals under better management and for animals with large proportion of improved dairy cattle ancestry (high European taurine animals; *i.e.* High *B.t. taurus* taurus in Figure 9-13) also benefited from increased value of animal sales. The results also show that Indigenous Zebu × *B.t. taurus* animals have the shortest calving interval than three other animal types, which implies that they produce more calves than other animals. Animals with large proportion of improved dairy cattle ancestry, by contrast, had by far the longest lactation period.

The data indicate that the highest household profit was for indigenous Zebu × *B.t. taurus* crossbred animals under better management (479525 FCFA per cow per year). The lowest household profit was for indigenous Zebu under poorer management (60235 CFA per cow per year), which almost eight-fold difference to the previous scenario (Figure 13). Within a breed-group, moving from poorer to better management resulted in a 2.85–2.03 fold increase in profit per cow per year, depending on the breed-group. The difference can mainly be attributed to the provision of better feed. The data could not fully partition the effects of better genetics from the effects of better management, as management levels applied in the real farms were not consistent across the breed groups. Marshall *et al.* (2016) indicate that if artificial insemination costs are applied to the use of *B.t. taurus* males, household profit is slightly reduced (by an average of 9% of the values shown in Figure 5), but Zebu × *B.t. taurus* crossbred animals under better management still remain the most profitable (at FCFA 445585 per cow per year) animals.

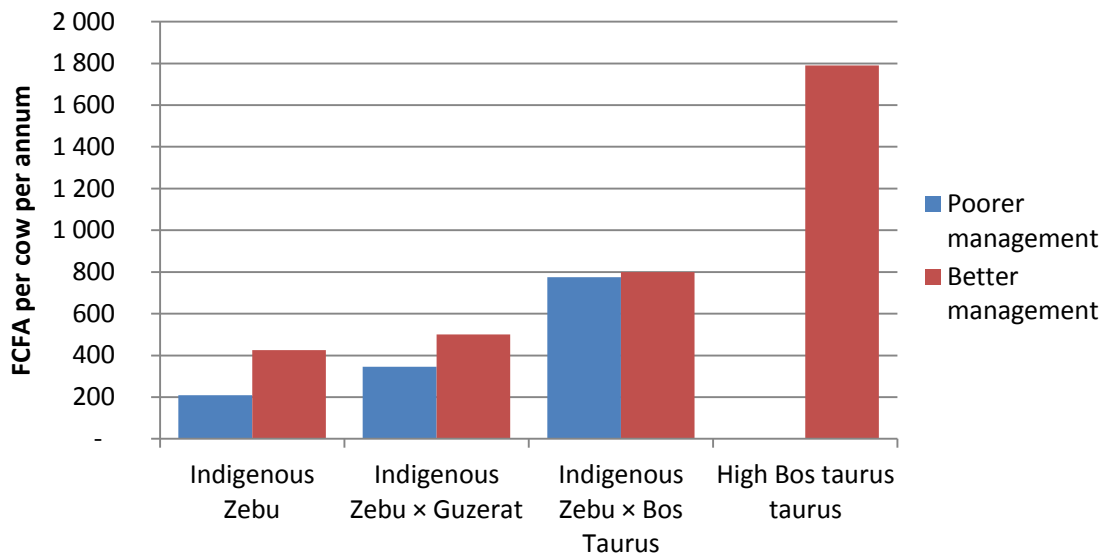


Figure 11. Mature female cow health care cost (FCFA per cow per year) under two management types and four breeds or breed-crosses (source: Marshall *et al.*, 2016).

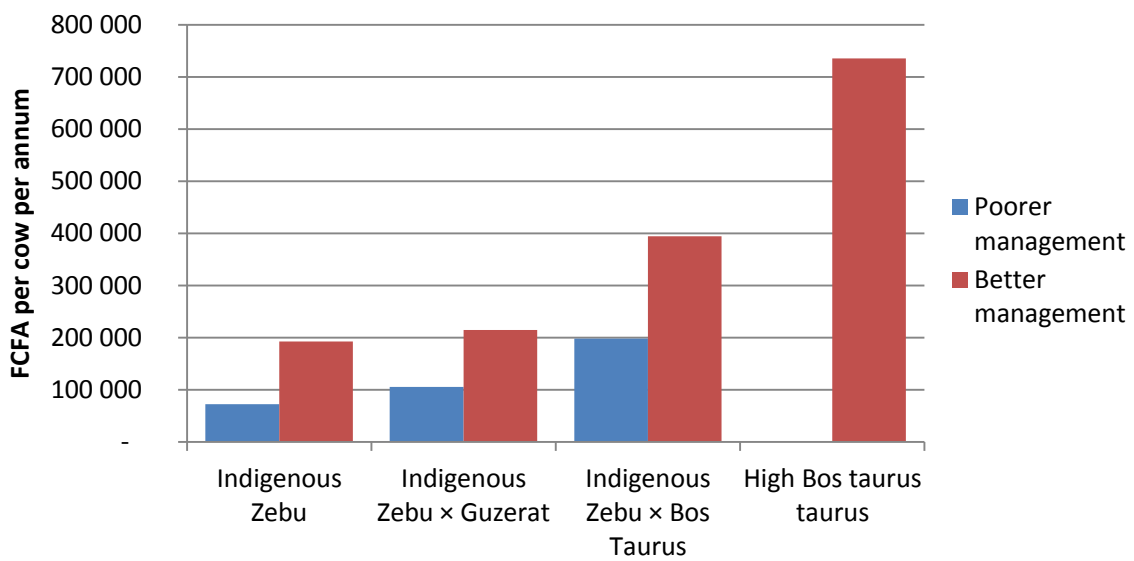


Figure 12. Mature female cow feed cost (FCFA per cow per year, assumes zero cost for grazing pasture) under two management types and four breeds or breed-crosses (source: Marshall *et al.*, 2016).

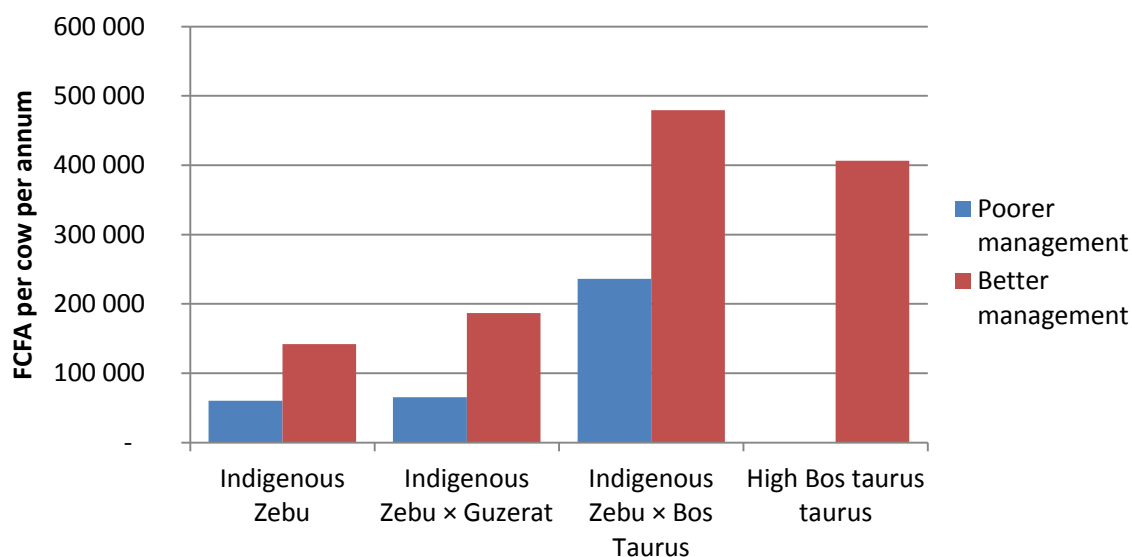


Figure 13. Profit (FCFA per cow per year) when breeding bulls are “used for free” (born in the herd or fully subsidized AI) under two management types and four breeds or breed-crosses (source: Marshall *et al.*, 2016).

## 4. Conclusions for future research agenda

Productive and sustainable agricultural systems make the best use of livestock resources. Sustainable intensification will often involve complex mix of domesticated plant and animal species and associated management techniques, requiring greater skills and knowledge by farmer. A sustainable production system would achieve the best overall sustainability for given parameters. This case study examined a few optional measures which can be used to improve the sustainability of milk production in Senegal. The case study suggests that improvements in management, especially in feeding, animal health care and the use of AI, have the potential to improve productivity and economic profitability of small-scale farming households. In addition, the case study suggests that the choice of breed and cross-breed can have substantial impacts on productivity and economic profitability of dairy production. However, other aspects of sustainability may be deteriorated in some cases. For instance, the use of veterinary drugs may be increased which may not be sustainable in some cases. The validity of GHG emission estimation protocols would need to be validated to ensure the most cost-efficient mitigation options can be prioritized

The case study shows that it makes sense for the farmer to intensify milk production by improving the management of animals, which in this case mainly refers to improvements in feeding, but also more generally to care-taking of animals. It helps the farmer to narrow down the yield gap. There are several management issues which require more detailed investigation in the future. More research is needed on which actual management measures are the most beneficial to the farmers as surprisingly little research exists on this important topic.

Maximizing productivity may not yield the best overall result. It may be more rational to focus on combining/mixing different breeds than using purebred exotic animals which are not adjusted to arid conditions. This is likely to be socially more acceptable, economically rational and resilient-improving strategy than changing completely to exotic animal breeds which have not adjusted to arid conditions. This is an area which has been studied very little.

Improving sustainability of livestock sector in Senegal requires simultaneous improvements in management and genetics. There is a need to choose robust techniques because of arid conditions and challenges posed by climate change. Research on trade-offs between different pillars of sustainability is needed. Future research agenda is recommended to study how animals with different genetic backgrounds can cope in African conditions and which genetics and which combinations of genetics and management practices yield the best overall outcome when considering productivity, food and nutrition security, economic profitability environmental footprints and animal health implications of livestock production in Africa. Animal production has not really been studied from this perspective. There is much potential to ensure livelihood, reduce poverty and increase food security by improving the sustainability and intensity of livestock production.

In Senegal, as in the entire Africa, there are different climatic conditions and zones. Research on how to best manage should take into account differences between regions. The management measures as well as the best-suited genetics may depend on the climatic conditions because for instance the importance of heat stress, water requirements and susceptibility to animal diseases, such as Trypanosomiasis, varies by climate zone. Hence, the drivers of change and solutions to sustainability challenges can vary by region.

The case study shows that improved management and genetics benefit the farmers. However, it is not entirely clear why production levels are still so low and cross-bred animals are not utilized more than they are, and why such a small proportion of cows is being milked daily. This may be associated with inadequate extension and capacity building activities, unavailability of inputs, services and financial resources as well as to missing private incentives to adopt improved production practices and to share information with other farmers. Besides productivity and economic values, it is important to pay attention to cultural values and aspects related livestock as part of the ecosystem.

The breeding goals should take into account traits which are important to local smallscale farmers. These traits may include productivity parameters but also other traits such as the appearance of animals which may have socio-economic value. Some breeds (such as N'Dama and zebus) have traditionally been used for meat production. Research may be needed to examine whether milk and meat would be best produced by the same breeds (as opposed to separated production) and how milk and meat traits should be weighed when selecting the breeds. A practical challenge for developing an animal breeding programme is that it is challenging to monitor animals systematically. Animals may enter and exit the monitoring system and their genetic background may sometimes be unclear. Hence, solutions to conduct monitoring efficiently and robustly are needed.

Livestock production in Africa is challenged by arid conditions. Climate change is expected to put further pressure towards it. Climate change is expected to reduce feed production capacity and the availability of water. Moreover, it is expected to have animal health implications through nutritional impacts, heat stress and evaporation. Climate change may also introduce new animal diseases and increase the risk of parasites and vector-borne diseases spreading among the animals. Active animal trade may also have negative effects such as increased risk of spreading animal diseases (cf. Pokou *et al.*, 2010; Pagabeleguem *et al.*, 2012). Research on ways to improve animal health in socio-economically sensible manner along the intensification of production is therefore essential.

The measures included in the case study have a large potential for upscaling. However, research is needed on how to induce the change. This could involve research on factors which can motivate stakeholders to choose preferred measures. It could involve research on the roles of infrastructures, private incentives and public-private partnerships as some measures may require public involvement or may involve heavy initial investments.

Research on optimizing the use of breeds can help to improve the livelihood of the world's poor, increase food and nutrition security and enhance environmental sustainability. Marshall (2014) has suggested that research on breeds would include assessing the impact of differing breed types in developing country livestock production systems, from a range of viewpoints including intrahousehold livelihood benefit, food and nutrition security at different scales, and environmental sustainability; identification of specific livestock production systems within developing countries, and the type of livestock keepers within these systems, that are most likely to benefit from new breed types; and identification of new breed types as candidates for in-situ testing within these systems, such as through the use of spatial analysis to identify similar production environments combined with community acceptance studies. Our case study agrees with this view. Results of such studies would help stakeholders, including policy makers and livestock owners, to make informed decisions on the potential use of new breed types.

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