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Contribution of cattle breeds to household livelihoods and food security in southern Mali

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DECLARATION

I hereby declare that this doctoral thesis is a result of my personal work and that no other than the indicated aids have been used for its completion. All quotations and statements that have been inferred literally or in a general manner from published or unpublished sources are marked as such. Furthermore, I assure that the work has not been used, neither completely nor in part, for achieving any other academic degree.

Sékou Amadou Traoré,
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LIST OF ACRONYMS AND ABBREVIATIONS

AFC	Age at first calving
ASF	Animal source food
BCS	Body condition scoring
CI	Calving interval
DAAD	German Academic Exchange Service
ECOWAS	Economic Community of West African States
FAO	Food and Agriculture Organization
FCS	Food consumption score
GM	Gross margin
HDDS	Household dietary diversity score
HFIAP	Household food insecurity access prevalence
HFIAS	Household food insecurity access scale
ILRI	International Livestock Research Institute
IFAD	International Fund for Agricultural Development
LSM	Least square mean
mHFIAS	Modified household food insecurity access scale
NB	Net benefit
OECD	Organization for Economic Co-operation and Development
ONDY	Opération N'Dama de Yanfolila (Yanfolila N'Dama Project in Mali)
PATTEC	Pan-African Tsetse and Trypanosomiasis Eradication Campaign
PCA	Principal Component Analysis
PROGEBE	Regional Project on Sustainable Management of Endemic Ruminant Livestock
SAS	Statistical Analysis System
SSA	Sub-Saharan Africa
SWAC	Sahel and West Africa Club
WFP	World Food Program

1 GENERAL INTRODUCTION

1.1 Background and research objectives

Reducing poverty and achieving food security is a significant and growing challenge in the developing world, especially in Sub-Saharan Africa (SSA) where the majority of the more than one billion food insecure people are living. Although the prevalence of extreme poverty in developing countries has been reduced from 42% in 1990 to 26% in 2005 (World Bank**,** 2007), the incidence of extreme poverty had remained at 41% in SSA by 2013. Countries in SSA are the most affected by undernourishment, with a prevalence of 23.2%, and an increasing number of undernourished (FAO, IFAD and WFP, 2015). Therefore, ending poverty in all its forms and ending hunger, achieving food security and improving nutrition, and promoting sustainable agriculture remain important goals of the United Nation's (UN) 2030 Agenda for Sustainable Development, which succeeded the Millennium Development Goals (UN, 2015).

In order to reduce poverty and hunger, priority must be given to sectors where the poor work, like the agricultural sector, which employs about 60% of the whole population worldwide. Agriculture, especially in SSA, has proved its ability as a leading sector for initiating rapid economic development and, in doing so, has the potential to reduce poverty more than other sectors (FAO, IFAD and WFP, 2015). Livestock is an important part of agriculture, contributing to 40% of the agricultural gross domestic product in SSA (Steinfeld et al., 2006). From the 1.3 billion people relying on livestock for their livelihoods, about 600 million are considered to be poor farmers (HLPE, 2016). The expeditious growth of demand for animal products in developing countries due to fast urbanization, rising incomes and human population growth has been labeled as the "livestock revolution" (Delgado et al., 1999). Hence, it offers an opportunity for poor livestock keepers to improve their income and food security.

Livestock can contribute to all four pillars on which food security is built: availability, access, utilization and stability (FAO, 2011). Randolph et al. (2007) highlighted the diverse pathways by which livestock is impacting the socio-economic and food security status of rural households. In addition to the supply of high-quality food for home consumption, the income generated from the sale of animal products can be used to access a more diversified diet (Haddad, 2000). Animal source foods (ASF) are relatively high in protein, but also have a higher micronutrient density (vitamin A and B12, riboflavin, calcium, iron and zinc), with a

better bioavailability compared to plant source foods (Murphy and Allen, 2003). More than 50% of the cash income of farmers in the crop-livestock production systems of SSA is generated from the sale of livestock products (ECOWAS-SWAC/OECD, 2008). Indeed, although crops make up the larger part of total farm production they are used mainly for home consumption (Waters-Bayer and Bayer, 1992). Sales of products such as milk provide a regular flow of cash income, while sales of animals like sheep, goats and cattle occur occasionally, when a larger amount of cash is required (Kitalyi et al., 2005).

In mixed farming systems, livestock is crucial for providing manure and draught power. Livestock manure is an important input for soil fertility, especially for poor farmers who cannot afford mineral fertilizer, and thereby it contributes to higher crop yields for food and income (Powell et al., 2004). Moreover, for many farmers livestock constitutes a saving, which can be used to cope with a loss of income and food insecurity. This saving and insurance function is very important given that the financial services of banks and insurance companies still remain inaccessible to many rural farmers (ECOWAS-SWAC/OECD, 2008). Livestock additionally provides a robust hedge against inflation (Bosman et al., 1997; Moll, 2005). In many societies, livestock plays a considerable role in the culture through its use as a dowry and the exchange of animals strengthening social bonds between families (Kitalyi et al., 2005).

However, livestock husbandry in developing countries can also have negative impacts on household food and nutrition security. With crop farming, competition for limited water and land and labor resources can reduce food availability and income from crops under certain conditions. Livestock husbandry and products may also involve important health hazards, especially regarding water pollution and food-borne (e.g., brucellosis, salmonella, *Escherichia coli*, etc.) and emerging diseases, which can impact on individual nutritional status due to the resulting poor absorption of nutrients (Randolph et al., 2007; HLPE, 2016). These negative effects might be more or less severe, depending on the production system.

In Mali, the prevalence of poverty and hunger has been reduced over the past decade, but the country stays among the poorest worldwide. The national poverty rate was estimated to be over 43% in 2010 and chronic food insecurity and malnutrition persist throughout the country. The Sikasso region, despite being known as the country's cereal basket and a center of cotton production, one of Mali's major export commodities, has often been reported as the country's poorest region and most affected by malnutrition (Eozenou et al., 2013). Cattle are significant

for the national economy of Mali, being the third main export commodity after gold and cotton and contributing to 80% of rural household income in pastoral systems and 18% in mixed crop-livestock systems (Alary and Dieye, 2006). In the mixed farming systems of southern Mali, where about 90% of the households own at least an ox and 60% have a cattle herd, cattle play an important role in the livelihoods of farmers through their strong integration into crop production (Poccard-Chapuis et al., 2007). Nevertheless, cattle and in general the livestock sector do not often receive due attention in national policies as no detailed livestock-oriented measures have been recommended for poverty reduction (Blench et al., 2003). The difficulty of properly evaluating the contribution of livestock to household economies leads to underestimation of its contribution and to an extensive scientific discussion regarding the nature of livestock products, the value of the asset, and the use of the monetary unit as stated by Alary et al. (2011).

In recent decades, there has been a rapid shift in livestock breeds used in developing countries due to global drivers, such as an increasing demand for livestock products and market-oriented production, as well as technological and environmental changes (Tisdell, 2003). Local breeds are increasingly being replaced and crossbred with exotic breeds, leading to a loss of genetic resources (Rege et al., 2011). The introduction of more productive but less adapted exotic livestock breeds might offer opportunities, but also pose threats to the livelihoods of poor farmers (Rege et al., 2011; Roschinsky et al., 2015). The debate around the comparative advantages of the use of local and crossbred or exotic livestock breeds is on-going (Leroy et al., 2016).

The relationship between locally adapted breeds and food security has been emphasized in the second State of the World's Animal Genetic Resources for Food and Agriculture (FAO, 2015). Livestock populations with greater genetic diversity can offer livestock keepers more options to overcoming an extreme event. This is illustrated through the example of the Red Massai sheep, which is native to Kenya and renowned for its resistance to endoparasites and tolerance to drought, and which has been indiscriminately crossbred with the Dorper breed introduced from South Africa because of its better growth potential. The upgrading towards the Dorper breed, however, resulted in low herd survival rates when a severe drought occurred (König et al., 2016), thus affecting farmers' food security. Therefore, maintaining a diverse animal genetic resource can be considered as a way of ensuring future developments and ease the adaptation to climate change (Hoffmann, 2013). Although the conservation of farm animal

genetic resources is very important, this alone should not be a reason to limit the introduction of exotic breeds into a system that may benefit from it (Marshall, 2014).

One alternative to conserving local breeds includes their use as crossbreeding partners to intensify production (Valle Zárate, 1996). The adoption of improved breeds with a higher production performance, even when requiring more input, may be advantageous for food security as it can lead to more food and cash availability in comparison with the lower output but more adapted breeds (Marshall, 2014). At a higher level, Karugia et al. (2001) calculated that crossbreeding in dairy benefited the Kenyan economy, increasing the country social welfare by nearly 37 million USD annually. However, the use of exotic breeds and crossbreds does not necessarily improve farmers' livelihoods, as highlighted in an economic efficiency analysis of goat flocks carried out by Ayalew et al. (2003) in Ethiopia. The analysis showed that increased net benefits were mainly due to better management and not due to the ownership of crossbred goats. The efficiency of a breed depends mostly on production and the environmental condition (Valle Zárate, 1996; Kahi et al., 1998). Thus, households shifting from a low to a high output breed, while minimizing risk and improving management, have better prospects to improving their livelihoods. Under limited resources, especially increasingly limited access to feed and grazing lands, farmers should take advantage of all available animal genetic resources in order to raise the productivity of their livestock per unit of limited resource.

In southern Mali, different cattle breeds are raised by farmers. These are the taurine N'Dama breed (*Bos taurus*), which is endemic to the southern region of Mali, the Fulani Zebu breed (*Bos indicus*), which originated from the northern part of the country, and their crosses. The N'Dama breed remains productive under the trypanomiasis challenge, is tolerant to heat and resistant or resilient to helminths and tick-borne diseases (Murray et al., 1991; Dwinger et al., 1992), as well as having low nutritional and husbandry demands (Grace, 2005), which could be thought of as the preferred pro-poor option. Despite their multiple adaptive attributes, N'Dama cattle are considered by farmers as less productive than Zebu because of their relatively small size and therefore the breed faces serious threats through crossbreeding with the larger trypano-susceptible Zebu breed (Agyemang, 2005). Fulani Zebu cattle are valued by many livestock keepers in West Africa for their milk yield, body size and ease of handling (Jabbar and Diedhiou, 2003).

There is a lack of studies on the evaluation of different livestock breed types in developing countries, their use in the actual production systems in which they are found, and their impact on household income and food security. Most studies have compared the breed performance based on animal output, recording phenotypic traits. Few studies took into account the complexity of the production system in which livestock are raised and compared performance from a socio-economic and food security perspective of the farmers (Marshall, 2014). There is a need to understand farmers' perceptions of the traits of the different livestock breeds they keep, but also generally the reasons why farmers keep these breeds (Anderson, 2003). A systematic comparison of livestock breeds under similar management conditions is required to correctly evaluate them. A systematic comparison of the endemic N'Dama cattle, Fulani Zebu cattle and their crosses under the same farming conditions in western Africa is required to reveal whether farmers benefit from the introduction of Zebu cattle or are negatively affected by the replacement of N'Dama purebreds.

The overall objective of this study was to evaluate and compare N'Dama cattle with Fulani Zebu and their crossbred based on their performance and contribution to household economic benefits and food security, taking into account the production environment and farmer breeding strategies.

The overall objective of this study was addressed through the following specific objectives:

(1) Investigate the production objectives, trait and breed preferences of cattle keepers and comparatively assess the suitability of N'Dama and Fulani Zebu cattle breeds and their crosses for different production objectives.

(2) Evaluate and compare the productive and economic performances of N'Dama cattle, Fulani Zebu cattle and their crossbreds in order to assess the comparative advantages of these breed groups for farmers.

(3) Examine households' food security and coping strategies with particular emphasis on the contribution of different cattle breed groups.

1.2 Study area and methodology

This study was conducted in the communes of Sibirila and Garalo, which are located within the district of Bougouni in the Sikasso region of southern Mali, from October 2012 to April 2013. The Sikasso region has a sub-humid climate, with an annual rainfall of between 1,000

and 1,200 mm. The rainy season extends from May to October. Crop farming and livestock husbandry make the main contributions to the livelihood of households in the study area. The major crops cultivated are maize, sorghum, millet, rice, groundnuts, beans and yam. The main cash crops are cotton and cashew nuts. In southern Mali, like in other neighboring countries, cattle are kept in a traditionally extensive production system, with grazing on natural pasture. The feed availability depends on the season, with a declining quantity and quality of pasture from the wet (May to October) to the end of the dry season (Umutoni et al., 2015).

Within the study area, two farmer groups were differentiated: a) local farmers, who have lived in their villages for many generations, and b) settled transhumants, who had previously been migrating and then settled in a particular village. Local farmers in the study area are mainly from the Bambara ethnic group, and, to a limited extent, from the sedentary Fulani group, who are locally known as 'Wassoulouké' and are culturally very close to the Bambara since they immigrated more than 200 years ago into this region (Amselle, 1987). Local farmers rely on crop farming, with a strong integration of livestock production. The settled transhumants are all from the Fulani ethnic group and arrived within the last 30 years from the northern region of the country. Besides raising cattle, they also practice crop farming and are therefore considered agro-pastoralists.

The study area was part of one of the three intervention sites in Mali within the project 'Sustainable management of globally significant Endemic Ruminant Livestock of West Africa', PROGEBE, which was designed to conserve and improve the productivity of the N'Dama cattle, the Djallonke sheep, and the West African dwarf goat in the Gambia, Guinea, Senegal and Mali (UNDP, 2007). The field research was carried out in cooperation with PROGEBE Mali.

Both communes – Sibirila and Garalo – and four villages in each of the communes were purposively selected based on the presence of N'Dama, Zebu and their crossbreds (Fig. 1). A stratified random sampling based on cattle and breed ownership was applied for the selection of 258 households. Households with a herd were grouped into four herd categories based on breed composition. The first three categories comprised of herds with more than 75% of N'Dama, Zebu or crossbred cattle, respectively. Herds with less than 75% cattle from a single breed were designated as mixed herds, forming the fourth category. Households with only oxen and those without cattle represented two additional herd categories.

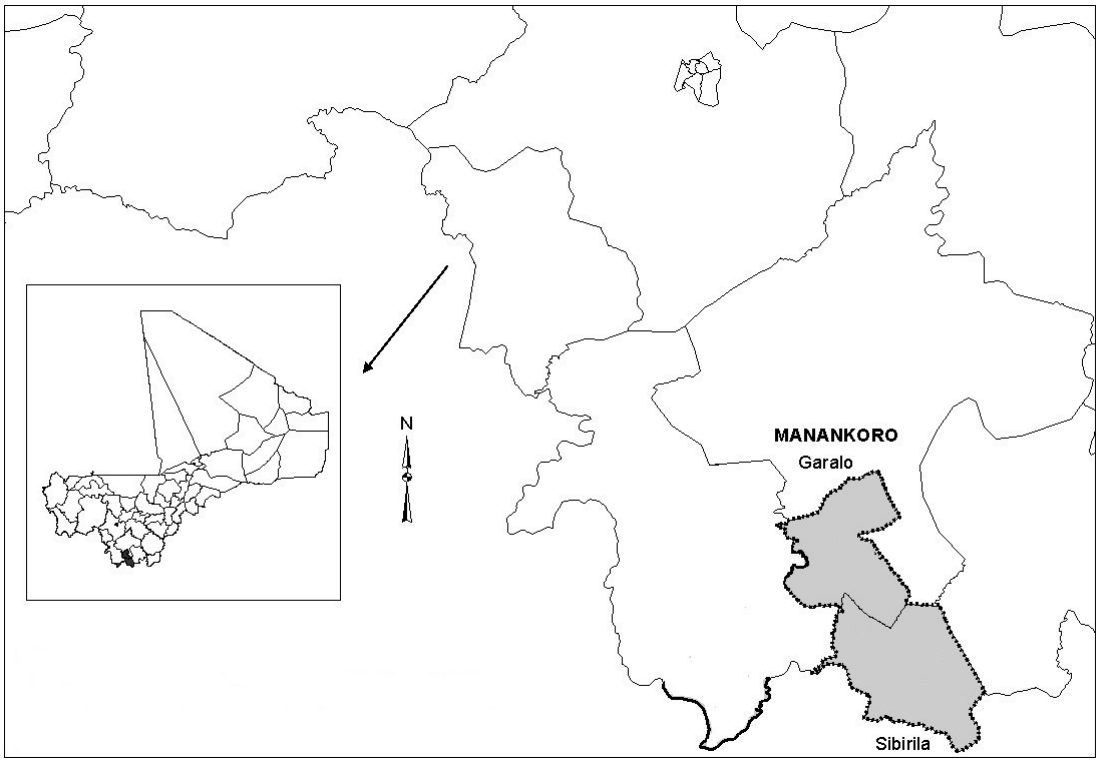

Figure 1.1 Map of study area and study site (Source: PROGEBE, modified)

Data collection methods encompassed household interviews using structured questionnaires, herd surveys, focus group discussions and key person interviews. The household questionnaires focused on the socio-economic data of the households, cattle husbandry practices and herd biological performances. Data on inputs and outputs of animal and crop production, as well as marketing and the use of animal products, were collected for the previous 12 months. The dietary pattern of the households for the past 24 hours and the week before the interviews, and the households' food insecurity situation for the past month and during the month of August were investigated. Times of food shortage (month in the year) and corresponding coping strategies were identified. Moreover, the risk perceptions of farmers associated with keeping different cattle breeds were investigated.

The herd surveys were carried out in 120 households with one household member who was in charge of the herd and the herder of the cattle herd. These were used to assess individual cows' performances using a cow history survey and body condition scoring (BCS). Breed and herd inventory were crosschecked during the herd survey.

A focus group discussion with eight to ten farmers who had previously participated in the household survey was carried out in each of the eight villages to obtain information on when the Zebu had been introduced and the onset of crossbreeding in the villages, the preferred breed type for breeding males and females, the main attributes considered by traders when purchasing cattle, and whether there was any difference regarding the taste of the milk and meat of N'Dama compared to Zebu. Key person interviews were conducted with representatives of institutions that had dealt with the management, breeding program and formulation of policies related to the endemic N'Dama cattle.

Besides descriptive statistics, data were analysed using an exploded logit model (Allison and Christakis, 1994), mixed linear models and non-parametric tests using the Statistical Analysis System (SAS) software.

1.3 Structure of the thesis

Chapter 1 presents the background and objectives of the study and the methodological approach. Chapter 2 addresses "Production objectives, trait and breed preferences of farmers keeping N'Dama, Fulani Zebu and crossbred cattle and implications for breeding programs". This chapter evaluates farmers' production objectives as well as trait and breed preferences, and their relationship to household and farm characteristics using a ranking approach. Implications for breeding strategies were derived and the comparative advantages of the three breed groups (N'Dama, Fulani Zebu and crossbreds) raised in the study area were identified.

Chapter 3 corresponds to the "Productive and economic performance of endemic N'Dama cattle in southern Mali compared to Fulani Zebu and their crossbreds". This chapter evaluates and compares the productive and economic performances of N'Dama cattle, Zebu cattle and their crossbreds and contributes to the on-going debate about the comparative advantages of local and crossbred cattle elsewhere.

Chapter 4 focuses on the "Contribution of different cattle breed groups to household food security in southern Mali". The study examines household food security with particular emphasis on the contribution of cattle and specifically the different breed groups. Factors affecting food security and household coping strategies were examined and different indicators of food security compared.

Chapter 5 discusses the findings of the preceding three chapters. It examines the relationship between farmers keeping different cattle breeds, traits and breed preferences, the economic benefits for farmers, and the food security of their households. The findings for each of the specific research objectives are compared with scientific literature and conclusions are drawn regarding the general objectives. This chapter also reflects on the strengths and limitations of the applied research method. Chapters 6, 7 and 8 provide extensive summaries of the thesis in English, German and French.

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2 PRODUCTION OBJECTIVES, TRAIT AND BREED PREFERENCES OF FARMERS KEEPING N'DAMA, FULANI ZEBU AND CROSSBRED CATTLE AND IMPLICATIONS FOR BREEDING PROGRAMS

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2.1 Abstract

Many local livestock breeds in developing countries are being replaced by exotic breeds, leading to a loss of genetic resources. In southern Mali, for the past two decades, a trend towards increasing crossbreeding between the trypanotolerant N'Dama cattle and the trypano-susceptible Fulani Zebu cattle has been taking place. A survey with 160 farmers owning a cattle herd was carried out in southern Mali to investigate their production objectives, as well as trait and breed preferences and correlated socio-economic determinants in order to understand farmers' breeding decisions and to identify comparative advantages of three breed groups (N'Dama, Fulani Zebu and crossbreds) raised in the study area. Data were analyzed using an exploded logit model. The reasons for raising cattle, as well as trait and breed preferences reflected the multiple objectives of the farmers. Draught power and savings were the most important production objectives. Productive traits were ranked highest; farmers reported large body size as the most preferred trait, followed by fertility, draught ability and milk yield. Crossbreds were the favored breed group. Breed preferences were mainly explained by 'resistance to disease' for N'Dama cattle and 'high market price' for Fulani Zebu and crossbred cattle. Production objectives, trait and breed preferences were mainly influenced by farmer group (local farmers and settled transhumants). Local farmers put comparatively more emphasis on livestock functions linked to crop production such as draught power. They had a higher preference for traction ability as a selection trait and preferred N'Dama over Fulani Zebu cattle. Settled transhumants emphasized milk yield as a selection trait and preferred Fulani Zebu over N'Dama. The results indicate that the trend towards more crossbreeding will continue putting the N'Dama breed under high risk of genetic dilution in southern Mali. The N'Dama cattle remain a valuable breed due to their adaptive traits such as disease and drought tolerance and their good traction ability, fulfilling the diverse objectives of local farmers. Crossbreeding was found to be a promising breeding strategy, which might contribute to the maintenance of the local breed, provided that breeding schemes are thoroughly planned and organized.

Keywords: Breed preferences, Crossbreeding, N'Dama, Production objectives, Trait preferences

2.2 Introduction

In recent decades, there has been a rapid shift in livestock breeds used in developing countries due to global drivers, such as an increasing demand for livestock products and market-oriented production. Local breeds have been replaced by exotic breeds, leading to a loss of genetic resources (Rege *et al.*, 2011). Changes in economic, social and environmental factors affecting the population of local livestock breeds might offer opportunities, but also pose threats to the livelihoods of poor farmers (Rege *et al.*, 2011). The trypanotolerant N'Dama cattle breed (*Bos taurus*) is endemic to the southern region of Mali. It is productive in tsetse-infested areas, tolerant to heat, and resistant or resilient to helminthes and tick-borne diseases (Murray *et al.*, 1991). The breed also has relatively low nutritional and husbandry requirements, which, along with the previous features, can be considered as advantageous for poor livestock keepers with limited capital to invest in better feeding and health care. However, trypanotolerant taurines are often perceived as inferior in terms of meat and milk output as well as draught power, and thus fetch lower prices on the market compared with Fulani Zebu (*Bos indicus*) breeds (Kamuanga *et al.*, 1999; Agyemang, 2005). Where Fulani Zebu can be raised, trypanotolerant cattle have been continuously replaced, suggesting that farmers regard the advantages of trypanotolerant breeds to be less important than their disadvantages (Jabbar and Diedhiou, 2003).

In the past 30 years, more and more transhumant pastoralists have settled with their Fulani Zebu in the south of Mali due to repeated droughts in the north since the 1970s (Ayantunde *et al.*, 2014). Along with this sedentarization, bush clearing for agriculture, implementation of tsetse control programs, and a widespread use of trypanocides have been observed. These changes have favored crossbreeding between the N'Dama and the Fulani Zebu breeds (Agyemang, 2005). In 1985, the N'Dama breed was estimated to represent 6% of the total cattle population in Mali, with an estimated 409,000 heads (Shaw and Host, 1987). The number of purebred N'Dama was reported to have declined in inland Sahelian countries like Mali (Agyemang 2005); however, the extent to which the current N'Dama population is affected by crossbreeding in Mali is not known. The future role of trypanotolerant breeds as a unique animal genetic resource depends on the changes occurring in the production systems in which they are kept, the availability of other options for tsetse and trypanosomiasis control, and the farmers' perceived value of these breeds relative to other breeds (Agyemang, 2005).

A number of studies have been carried out on production objectives, and trait and breed preferences of farmers for cattle in West Africa. Most of these studies were conducted within the scope of conservation and improvement of trypanotolerant cattle breeds. Tano *et al.* (2003) investigated trait preferences of farmers in Burkina Faso using conjoint analysis. Jabbar and Diedhiou (2003) examined breed preferences in Nigeria based on the rating of breed traits and market data using hedonic pricing. Ejlertsen *et al.* (2013) and Benison *et al.* (1997) assessed the production objectives and selection criteria of livestock owners in The Gambia, also using a rating matrix. Few studies have taken into account the heterogeneity of farmers and the factors that influence their production objectives and trait preferences for cattle (Benison *et al.*, 1997; Tano *et al.*, 2003; Ouma *et al.*, 2007; Ndumu *et al*., 2008).

A long-term international project for pure breeding N'Dama cattle, the "Regional Project for Sustainable Management of Endemic Ruminant Livestock in West Africa" (UNDP, 2007), was set up to prevent genetic dilution and improve the productivity of N'Dama cattle. Breed improvement programs should take into account production aims, breeding interests, and selection criteria of livestock keepers to reduce the risk of being unsustainable (Ouma *et al.*, 2007; Ndumu *et al.*, 2008). Understanding the production objectives of farmers and how they value different livestock traits is regarded as a prerequisite for enabling them to make best use of the animal genetic resources available (Anderson, 2003). This paper evaluates farmers' production objectives as well as trait and breed preferences, and their relationship to household and farm characteristics using a ranking approach. The aim of the present study was to better understand farmers' breeding preferences in order to consider them in breeding programs and to comparatively assess the suitability of N'Dama and Fulani Zebu cattle breeds and their crosses for different production objectives in southern Mali.

2.3 Materials and methods

2.3.1 Study area

The study was conducted in the communes of Sibirila and Garalo in the Bougouni district, within the Sikasso region of southern Mali and covered an area of 363 700 km^2 (UNDP, 2007). Within the study area, two farmer groups were differentiated: a) local farmers, who have lived in their villages for many generations, and b) settled transhumants, who had previously been migrating and then settled in a particular village. Local farmers in the study area are mainly from the Bambara ethnic group, they rely mainly on crop farming, while

livestock production remains a secondary activity. The settled transhumants are all from the Fulani ethnic group, they mainly raise cattle and crop farming is less important to them.

2.3.2 Sampling

The communes Sibirila and Garalo and four villages within each commune were purposively selected based on the presence of the three breed groups N'Dama, Fulani Zebu and their crossbreds. A stratified random sampling scheme based on cattle breed ownership was applied for the selection of the households. In total, 160 households out of an estimated 2200 households owning a cattle herd in both communes were selected. Household herds were grouped into four categories based on breed composition: The first three categories were comprised of herds with more than 75% of N'Dama, Fulani Zebu or crossbred cattle, respectively. Herds with less than 75% cattle from a single breed were designated as mixed herds, hence forming the fourth category. From the 160 sampled households, 34 N'Dama, 31 crossbreds, 34 Fulani Zebu and 61 mixed herds were identified. A focus group discussion with eight to ten farmers, who had previously participated in the household survey, was carried out in each of the eight villages.

2.3.3 Data collection

Interviews comprised sets of semi-structured and structured questionnaires and were conducted to collect data on household characteristics, herd composition, history of the cattle breeds kept, reasons for changing breeds, and intended breed choice for the next five to ten years. The following four ranking procedures were applied to assess farmers' production objectives, trait and breed preferences: 1) the household heads were asked to rank reasons for keeping cattle from a list of the following nine predetermined production objectives: draught power, savings, use for ceremony and dowry, manure, sale of animals, milk for home consumption, milk for selling, meat for home consumption, and prestige associated with the owning of cattle; 2) household heads were asked to state and rank the three most important traits they considered when selecting breeding animals; 3) respondents were asked to rank the following six predetermined traits with respect to the suitability of each of the three breed groups (Fulani Zebu, N'Dama and crosses of Fulani Zebu and N'Dama): body size, milk yield, fertility, draught ability, drought tolerance, and disease resistance; 4) they were then asked to rank the three breed groups from most preferred to least preferred. In addition, the

main reason for ranking a certain breed first as well as the main disadvantage of each breed group were requested. The focus group discussions aimed at obtaining information on the time of the introduction of Fulani Zebu and the onset of crossbreeding in the villages.

2.3.4 Data analysis

Descriptive statistics were used to present information on household characteristics, stated reasons for preferences, and reported disadvantages of N'Dama, Fulani Zebu and their crossbreds. Ranked data for the production objectives, trait and breed preferences were analyzed using an exploded logit model (Allison and Christakis, 1994). The exploded logit model can be conveniently implemented using proportional hazards regression as implemented, e.g. in the PHREG procedure in SAS, Version 9.3 (SAS Institute Inc. 2012). This is described in detail by Allison and Christakis (1994). In this model, a respondent i derives a certain utility U_{ij} from each item (cattle production objective, trait or breed) j, which is modeled as the sum of a systematic component μ_{ij} and a random component $e_{ij,}$ i.e., $U_{ij} = \mu_{ij}+e_{ij}$. The error term e_{ij} is assumed to be independently and identically distributed with an extreme value distribution. The systematic component can be modeled as: $\mu_{ij} = \beta_j x_i$, where β_j is a row vector of coefficients, the values of which vary over the cattle production objectives, traits or breeds j, and x_i is a column vector of predictor variables that describe the i^{th} respondent. As utility is modelled on a latent scale, corresponding to the log-odds scale, one of the β_j must be set equal to 0 for an arbitrary chosen item (reference production objectives, traits or breeds) to achieve identification of all parameters. Each of the β_j vectors then describes how characteristics of the respondent affect the log-odds of choosing item j rather than the reference item. The exponential difference between coefficients of two items provides the odds of preference of one item over the other item. As predictor variables, several household characteristics were investigated, i.e., farmer group, age and education of the household head, farm size (area for crop production), cattle herd size, and herd category.

Several exploded logit models were estimated. First, the ranks for the production objectives, traits and breeds were examined for significant differences. For this purpose, a model that allowed for differences among the production objectives, traits and cattle breeds, but not for differences among respondents, was used. This can be written as:

$\mu_{ij} = \beta_j$, for all i and j

where β_j is a scalar.

Second, heterogeneity across respondents was taken into account using the following model for production objectives, traits and cattle breed preferences:

$$\mu_{i(klmno)j} = \beta_{0j} + G_{jk} + \beta_j a_i + E_{jl} + F_{jm} + S_{jn} + H_{jo}$$

where G_{jk} = effect of k-th farmer group (k = 1, 2; local farmer, settled transhumant), β_j = coefficients of regression on age, a_i = age of the i-th household head in years, E_{jl} = effect of l-th category of education of the household head (l = 1, 2; no formal education, primary school), F_{jm} = effect of m-th farm size category in hectare (m = 1, 2, 3; < 6.5, 6.5-13.5, > 13.5), S_{jn} = effect of n-th herd size category in head (n = 1, 2, 3; < 22, 22-50, > 50), and H_{jo} = effect of o-th herd category (o = 1, 2, 3, 4; N'Dama, crossbreds, Fulani Zebu, mixed).

The model for production objectives, trait and breed preferences was selected using a backward elimination procedure, and explanatory variables retained by the models were significant at α = 0.1. The interaction terms farmer group x herd category were not significant in the models for production objectives, traits and cattle breed preferences and based on small group sizes n<7. Therefore these interaction terms were not included in the final model and partial confounding between farmer group and herd category was accepted. The Wald chi-square statistic was computed to test the significance of model terms. The SAS macro %MULT was used to display significant mean differences by a letter display (Piepho, 2012), with a common letter indicating non-significance of a difference between means at the 5% level by a Wald-test.

2.4 Results

2.4.1 Household characteristics

From the sampled households, 30% of the total cattle were N'Dama, 38% were crossbreds, and 32% were Fulani Zebu. The breed distribution of adult breeding bulls was 11% for N'Dama, 24% for crossbreds, and 65% for Fulani Zebu, indicating a wider use of Fulani Zebu bulls in the breeding herds. In the Fulani Zebu herd category, only Fulani Zebu bulls were used for breeding. Fulani Zebu bulls were further used in 29%, 52% and 72% of the N'Dama, crossbred and mixed herd categories, respectively. Table 2.1 summarizes household and farmer characteristics for the two farmer groups. No female household head was encountered. For the settled transhumants, none of the household heads attended primary school, and 95%

reported livestock husbandry as their main activity. Only a few local farmer household heads (18.3%) attended primary school, and 88.3% reported cropping to be their main activity. The age of the household heads, the household sizes, and the farm sizes were significantly lower for settled transhumants than for local farmers. The breed composition of the herds was also different between the two farmer groups: of the local farmers, 45% had a mixed herd, 27.5% had N'Dama, and 24.2% had a crossbred herd, while only 3.3% had a Fulani Zebu herd, compared to 75% of the settled transhumants.

Table 2.1 Characteristics of surveyed households for local farmers and settled transhumants

Characteristic		Local (n=120)			Settled transhumants (n=40)		
		Percent	Mean	SD	Percent	Mean	SD
Commune	Sibirila	50.0			50.0		
	Garalo	50.0			50.0		
Herd category	N'Dama	27.5			2.5		
	Crossbred	24.2			5.0		
	Fulani Zebu	3.3			75.0		
	Mix	45.0			17.5		
Ethnicity	Bambara	72.5			0.0		
	Fulani	27.5			100.0		
Education of household head	None	81.7			100.0		
	Primary school	18.3			0.0		
Main activity	Cropping	88.3			5.0		
	Livestock	11.7			95.0		
Age of household head (year)			54.1[a]	14.2		46.9[b]	10.6
Household size (member)			16.3[a]	8.2		12.4[b]	6.8
Farm size (hectare)			13.6[a]	8.7		4.6[b]	3.5
Cattle herd size (head)			35.7[a]	29.5		40.1[a]	22.6

[a,b] Means within a row with different superscripts differ significantly at $P<0.05$.

2.4.2 Production objectives

In general, farmers have different preferences for production objectives. The provision of draught power was the most important reason for keeping cattle, with cattle being 4 times more likely to be kept for draught power than for home consumption of milk. The odds of

keeping cattle as a saving, for manure and sale, were 2.60, 2.21 and 1.51 times, respectively, the odds of keeping cattle for home consumption of milk. Milk for selling, meat for home consumption, and prestige were of less importance with 0.60, 0.23 and 0.07 times, respectively, the odds of keeping cattle for home consumption of milk. Considering farmer characteristics, farmer group ($P < 0.0001$) and farm size ($P = 0.02$) had a significant effect on the ranking of the production objectives (Table 2.2). Local farmers had a clear hierarchy for their production objectives, with high importance of livestock functions linked to crop production, such as draught power, savings and manure. The same was observed for medium to large farms. In contrast, the six first production objectives of settled transhumants did not differ significantly, indicating the multifunctional role of cattle for this group. Keeping cattle for sale was more important for small farms compared to large farms, while savings were less important.

Table 2.2 Odds ratios of estimated production objective preferences by farmer group and farm size

Production objective[1]	Farmer group (n)		Farm size (n; mean in hectare)		
	Local (120)	Settled transhumants (40)	Small (55; 3.8)	Medium (52; 9.7)	Large (53; 21)
Draught power	8.58 [a]	1.27 [ab]	1.79 [ab]	5.16 [a]	3.94 [a]
Savings	3.22 [b]	1.75 [a]	1.20 [bc]	3.39 [ab]	3.29 [ab]
Ceremonial and dowry	3.56 [b]	1.11 [ab]	1.93 [a]	2.48 [b]	1.63 [cd]
Manure	3.06 [b]	0.99 [ab]	1.26 [bc]	2.10 [bc]	1.99 [bc]
Sale of live animals	1.88 [c]	0.87 [b]	1.48 [ab]	1.40 [cd]	1.00 [de]
Milk for home consumption[2]	1.00 [d]	1.00 [ab]	1.00 [c]	1.00 [d]	1.00 [de]
Milk for selling	0.47 [e]	1.05 [ab]	0.57 [d]	0.75 [de]	0.87 [e]
Meat for home consumption	0.25 [f]	0.12 [c]	0.09 [e]	0.24 [f]	0.24 [f]
Prestige	0.07 [g]	0.03 [d]	0.02 [f]	0.06 [g]	0.07 [g]

[1]Production objectives with different superscripts in a column differ significantly at $P<0.05$, while alphabetical order of superscripts indicates the relative importance of production objectives.
[2]Milk for home consumption was used as the reference

2.4.3 Trait preferences

The left-hand column of Table 2.3 shows that in general, the trait most preferred by farmers was body size, followed by fertility, traction ability and milk yield. The odds of preferring

body size were 7.92 times the odds of preferring coat color (reference) when selecting a breeding animal. Regarding coat color, red was the most preferred. According to farmers, cattle with red coats are less affected by insect bites.

Considering farmer heterogeneity, only farmer group (P = 0.0126) had a significant effect on the ranking of the trait preferences. Both local farmers and settled transhumants ranked body size first. Milk yield was ranked second by settled transhumants and only fourth by local farmers, who gave more importance to fertility and traction ability. Disease resistance was ranked least important by settled transhumants (Table 2.3).

Table 2.3 Odds ratios of estimated trait preferences by total sample and farmer group

Trait[1]	Total sample (n=160)		Farmer group			
			Local (n=120)		Settled transhumants (n=40)	
Body size	7.92	a	8.58	a	6.55	a
Fertility	4.71	b	5.81	b	2.59	bc
Traction ability	3.35	c	4.44	bc	1.39	cd
Milk yield	3.10	c	3.00	c	3.42	b
Coat color[2]	1.00	d	1.00	d	1.00	de
Beauty	0.95	de	0.98	de	0.87	df
Teat size	0.84	de	0.89	de	0.78	df
Docility	0.90	de	0.58	df	1.17	cd
Disease resistance	0.76	df	0.76	de	0.12	f
Conformation	0.48	ef	0.41	ef	0.64	df
Fast growing calves	0.23	f	0.23	f	0.24	ef

[1]Traits with different superscripts in a column differ significantly at $P<0.05$, while alphabetical order of superscripts indicates the relative importance of traits.
[2]Coat color was used as the reference.

2.4.4 Breed preferences, aptitude and trends

Based on the total sample, crossbreds were ranked significantly higher than N'Dama and Fulani Zebu cattle (Table 2.4). When heterogeneity across respondents was considered, farmer group (P = 0.0017) and herd category (P = 0.0001) had a significant effect on the ranking of the breed preferences. Local farmers had a higher preference for crossbreds and N'Dama over Fulani Zebu, while settled transhumants preferred Fulani Zebu and crossbreds over N'Dama. Farmers with crossbred and mixed herds had a higher preference for crossbreds

compared to N'Dama and Fulani Zebu breeds. Farmers with N'Dama and Fulani Zebu herds preferred the main breed they kept as well as crossbreds (Table 2.4).

Table 2.4 Odds ratios of estimated breed preferences by total sample, farmer group and herd category

Breed group[1]	Total sample (n=160)	Farmer group		Herd category			
		Local (n=120)	Settled transhumants (n=40)	N'Dama (n=34)	Crossbred (n=31)	Fulani Zebu (n=34)	Mix (n=61)
Crossbred	2.23 [a]	2.97 [a]	0.96 [a]	3.25 [a]	2.64 [a]	0.59 [a]	1.90 [a]
N'Dama	1.36 [b]	2.75 [a]	0.22 [b]	4.76 [a]	0.85 [b]	0.18 [b]	0.49 [b]
Zebu[2]	1.00 [b]	1.00 [b]	1.00 [a]	1.00 [b]	1.00 [b]	1.00 [a]	1.00 [b]

[1]Breeds with different superscripts in a column differ significantly at P<0.05, while alphabetical order of superscripts indicates the relative preference for breeds.
[2]Zebu was used as the reference.

Table 2.5 shows that the ranking of the selected traits significantly differs for each breed group. Differences in trait valuation were more pronounced for Fulani Zebu cattle compared to crossbreds. Fulani Zebu cattle were more appreciated for milk yield and body size and much less valued for traction ability, drought tolerance and disease resistance than crossbreds. In contrast, N'Dama cattle were valued for disease and drought tolerance, while body size and milk yield were the least valued traits. The ranking of the selected traits for each breed group was not affected by any of the farmer characteristics.

Table 2.5 Odds ratios of estimated selected trait preferences according to cattle breed group

Trait[1]	N'Dama (n=156)	Crossbred (n=151)	Fulani Zebu (n=139)[2]
Body size	0.13 [e]	1.62 [a]	2.66 [a]
Milk yield	0.36 [d]	1.31 [a]	3.53 [a]
Fertility[3]	1.00 [c]	1.00 [b]	1.00 [b]
Traction ability	1.01 [c]	0.61 [c]	0.23 [c]
Drought tolerance[4]	2.27 [b]	0.48 [cd]	0.17 [c]
Disease resistance	4.62 [a]	0.41 [d]	0.03 [d]

[1]Traits with different superscripts in a column differ significantly at *P*<0.05, while alphabetical order of superscripts indicates the relative importance of traits.
[2]n: number of farmers who completed the ranking of the six predetermined traits for the respective breed group. [3]Fertility was used as the reference.
[4]Refers to breed ability to cope with reduced quantity and quality of forage during the dry season.

As presented in Table 2.6, preferences for the N'Dama breed were explained mainly by their resistance to diseases, low raising costs, and tolerance to feed shortages. The main reasons for preferring crossbreds were their high market price, followed by their disease resistance. High market price was also the most frequent reason for preferring Fulani Zebu, followed by milk yield. To a lesser extent, draught ability was also stated as a reason for preferring N'Dama and crossbreds. Regarding undesirable features for each breed group, the most mentioned disadvantages of N'Dama cattle was their handling difficulty followed by their small size and low selling price. The lack of tolerance to feed shortages and disease susceptibility were the most cited disadvantages of crossbreds and Fulani Zebu, respectively.

Table 2.6 Reported main reason for preferring a cattle breed group

Main reason for preference[1] (%)	Preferred cattle breed group		
	N'Dama (n=57)	Crossbred (n=48)	Fulani Zebu (n=55)[2]
Market price	0	35	49
Disease resistance	30	18	0
Body size	0	15	16
Low raising cost	27	0	0
Milk yield	0	6	18
Tolerance to feed shortage	18	2	0
Draught ability	7	8	0
Easy to raise	7	4	2
Easy to handle	0	4	5
Well known	5	0	4
Hardiness	4	2	0
Fertility	2	4	0
Beauty	0	2	2
Easy to sell	0	0	2
Growth rate	0	0	2

[1]Farmers were only asked to give the main reason for the breed group they ranked first.
[2]n: number of farmers reporting N'Dama, crossbred or Zebu as their top preferred breed.

During the group discussions, farmers additionally reported that, when starting to raise cattle, a farmer without experience in cattle husbandry usually preferred to start with the N'Dama breed because of lower input costs and risks. Many farmers mentioned that N'Dama cattle

were the animal of the poor, since they can afford to keep them. Of the total respondents, 70% had introduced a new breed into their herd in the past. Among the 115 households, who had changed the breed composition of their herd, 95% included crossbreds or Fulani Zebu, while only 5% introduced N'Dama. The most common change occurred through the purchase of Fulani Zebu bulls for mating with N'Dama cows. It was reported during the group discussions that the practice of crossbreeding started approximately 13 years ago (range: 5-30 years).

2.5 Discussion

2.5.1 Farmers' production objectives and trait preferences

The production objectives and trait preferences for cattle found in this study reflect the multiple objectives of the farmers in southern Mali, and are comparable to the findings of similar studies conducted previously in Kenya (Bebe *et al.*, 2003; Mwacharo and Drucker, 2005). The importance of draught power, saving and manure functions, underline the strong integration of crop and cattle production in the study area, especially among local farmers. As noted by Bosma *et al.* (1993), these functions became more important with the development of cotton cultivation in Mali, while the traditional prestige function of cattle has lost its significance.

In our study, farmers ranked productive traits such as large body size, high fertility and milk yield (Table 2.3) higher than adaptive traits such as disease resistance for the selection of breeding animals. These results are in line with Wurzinger *et al.* (2006) who found that milk yield, fertility and body size were ranked highest by Ankole cattle breeders in different production systems in Burundi, Rwanda, Tanzania and Uganda. These traits were also scored higher by goat, sheep and cattle keepers as selection criterion in recent findings of Ejlertsen *et al.* (2013) in The Gambia. Contrary to our results, Tano *et al.* (2003) found that disease resistance was among the most important traits, while body size was among the traits ranked lowest in West Africa. More research is needed to know if differences between our results and Tano *et al.* (2003) findings are due to changes of farmer traits preferences over time. The preference for a large body size in both farmer groups in our study was mainly driven by a higher market price for larger cattle. Duguna *et al*. (2011) also found large body size to be an important trait across different sheep production systems in Ethiopia. Milk yield was of less importance for local farmers than for settled transhumants, probably because the milk offtake was usually kept by the herders hired by the local farmers as in-kind payment in addition to

their salary. In contrast, settled transhumants, who rely mostly on their own family members as herders, benefited directly from the milk for home consumption or sale.

The low rank given to disease resistance (Table 2.3) might be explained by the lower prevalence of tsetse flies in the study area (Bocoum *et al.*, 2012), or the widespread use of subsidized trypanocidal drugs (Grace *et al.*, 2009). This is a concern, knowing that farmers in West Africa are confronted with the development of widespread resistance of trypanosomes against trypanocidal drugs (Grace *et al.*, 2009).

2.5.2 Farmers' breed preferences

Similar to previous studies across several sites in West Africa (Kamuanga *et al.*, 1999), our study shows a higher overall preference for crossbreds. The most important reason for preferring crossbreds was high market price followed by disease resistance (Table 2.6). The latter result is inconsistent with the result in Table 2.5, which indicates low importance of disease resistance for crossbreds. This contradiction might be partly explained by productive traits such as body size and milk yield being valued through high market price (Table 2.6). A further explanation is that farmers probably tend to prefer N'Dama when disease tolerance is important to them. However, when they chose crossbreds, they take it for granted that they lose disease tolerance, but this loss is outweighed by higher market value. Also it is important to note that the results for the most important reason for preferring a certain breed group (Table 2.6) were only based on the farmer who ranked that breed first, unlike the ranking of breed aptitude done by each farmer. The less pronounced differences in trait valuation for crossbred compared to N'Dama and Fulani Zebu (Table 2.5) suggest that the combination of adaptive and productive traits is more relevant for the farmer than any particular trait in this breed group.

Similar to findings of Jabbar and Diedhiou (2003), the lack of disease resistance and the disability to cope with dry season stress were clearly perceived as disadvantages for Fulani Zebu, but this was out-weighted by a high recognition of their size and milk yield (Table 2.5). Next to market price, milk yield as the second most important reason for preferring Fulani Zebu (Table 2.6) indicates its suitability for farmers for whom milk production is an important production objective.

No farmer reported draught ability as a reason for preferring Fulani Zebu, compared to 7% and 8% of the farmers preferring N'Dama and crossbreds, respectively (Table 2.6). Though Agyemang (2005) and Kamuanga *et al.* (1999) reported a low draught power for N'Dama, the fairly good traction ability reported by farmers as a reason for preferring N'Dama cattle in this study might not be determined by draught power, which is linked to animal size, but by endurance, as suggested formerly by Steglich (2006). During group discussions, farmers reported that Fulani Zebu was not able to plow fields as long as N'Dama cattle. This suggests the adequacy of N'Dama cattle for local farmers for whom draught power was the most important production objective.

In accordance with Steglich (2006), approximately 10 years ago for The Gambia, disease resistance and drought tolerance were the most preferred traits for the N'Dama in our study (Table 2.5). Low raising costs were the main reason for preferring N'Dama (Table 2.6), making it the breed of choice for poorer farmers. Similar to results of Jabbar and Diedhiou (2003), difficulty in handling, small size, and low market price were identified as the main disadvantages of the N'Dama breed. In this study, however, more farmers were concerned about the difficulty in handling this breed than about its small size, which might explain the preference for crossbred and Fulani Zebu in this respect. Interestingly, ranking of the relative aptitudes of the different breed groups (Table 2.5) was not influenced by the farmer group, suggesting that local and settled transhumants had a common perception of the breed aptitudes.

In the context of climate change and pro-poor development, the comparative advantages of the N'Dama breed in terms of adaptive traits such as coping with feed shortages and disease resistance are expected to become more relevant for the prospects of its conservation and for ensuring a sustainable contribution of livestock breeds to farmer livelihoods (Hoffmann, 2013). As stressed by Zander and Drucker (2008), local breeds are an important genetic resource that may be used to develop new breeds that will be able to adapt to unforeseen future changes. This may also apply to the situation in our study.

2.5.3 Implications for breeding strategies

Farmers are well aware of the aptitudes (Table 2.5 and 2.6) and weaknesses of the different breeds, and therefore, crossbreeding is a decision made by the farmer, rather than just taking place randomly. Steglich (2006) noted in the case of The Gambia that a considerable number

of cattle owners were very knowledgeable about crossbreeding strategies and their prerequisites. Following socio-economic and parasitological studies attesting the productivity of the N'Dama cattle, policy has been in favor of its use in the whole sub-humid zone of West Africa and genetic improvement programs for the N'Dama cattle were initiated in The Gambia and Mali (Agyemang, 2005). The clear preference for crossbreds in our study shows the need to design a breeding program, which does not only focus on N'Dama pure breeding, but includes crossbreeding as a breeding strategy (Leroy *et al.*, 2016). This would additionally contribute to the conservation and further promotion of pure breeding N'Dama, since it would require a continuous supply of purebred females (FAO, 2015; Scholtz and Theunissen, 2010). Under favorable conditions and when properly implemented, crossbreeding can result in better animal performance and a higher income for the farmer (Roschinsky *et al.*, 2015). Crossbreds combine advantages of both breeds, but in order to assess and maximize the potential benefits, an organized crossbreeding scheme would be required (Herold *et al.*, 2010). So far, no organized crossbreeding between the N'Dama and Zebu cattle has been implemented at village level, which would require a thorough planning and long-term organization (Leroy *et al.*, 2016) to sustainably contribute to farmers' livelihoods. Farmers need to be better informed about the effects of crossbreeding, especially in terms of the possible loss of adaptive traits, and researchers should consider farmers' experience in crossbreeding. Only crossbreeding between European breeds and the Fulani Zebu or N'Dama cattle was done in peri-urban areas and on-station to test the performance of the different crossbreds (Tamboura *et al*. 1982).

As advised by Mapiye *et al.* (2009) for the Nguni breed in South Africa, the government should create multiplication farms and formulate policies to ensure the conservation and future supply of N'Dama breeding stock. The low appreciation of productive traits of N'Dama cattle in our study highlights the need for their improvement. An open nucleus breeding scheme could be considered (Bosso *et al.*, 2009) in order to achieve this and prevent genetic erosion of the N'Dama breed. Multiplier herds managed by individuals or farmer groups specialized in the breeding of pure N'Dama cattle could also allow for a sustainable production of heifers that could partly be mated to Fulani Zebu bulls to produce crossbred cattle for the market. A rotational crossbreeding scheme could then be applied to avoid animal with more than 1/2 Fulani Zebu blood. Crossbred dams would alternatively be mated to improved N'Dama bulls and Fulani Zebu bulls.

Regarding breed improvement, a three-tier breeding program, with the breeding objective defined as 'improvement of milk and meat without loss of disease resistance and other adaptive traits', was implemented for N'Dama cattle in The Gambia by the International Trypanotolerance Centre (Dempfle and Jaitner, 2000). A similar selection strategy could be implemented for the N'Dama in Mali; however, large body size should receive the highest weight. An additional trait that could be considered is the reddish coat color, which is preferred by farmers (Table 2.3). Using a uniform coat color will help in the branding of the breed.

2.6 Conclusion

This study emphasizes the multiple production objectives, traits and breed preferences of livestock keepers in southern Mali. N'Dama cattle remain a valuable breed due to their favorable adaptive traits and also their relatively good traction ability, thereby fulfilling the diverse objectives of local farmers. However, with increasing demand for livestock products and a decrease in the tsetse fly population, it is expected that more Fulani Zebu cattle will be kept and the trend in crossbreeding will probably continue, putting the N'Dama breed under high risk of genetic dilution. Crossbreeding should be seen as an opportunity for farmers to improve their livelihoods, and can be considered as a way to maintain locally adapted breeds. There is a need to monitor crossbreeding and to develop appropriate policies that aim to minimize the risk of genetic erosion of the N'Dama breed, such as sensitizing and supporting farmers with appropriate breeding information and implementing a national or regional within-breed improvement program.

2.7 Acknowledgments

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3 PRODUCTIVE AND ECONOMIC PERFORMANCE OF ENDEMIC N'DAMA CATTLE IN SOUTHERN MALI COMPARED TO FULANI ZEBU AND THEIR CROSSBREDS

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3.1 Abstract

In recent decades, there has been a rapid shift in livestock breeds used in developing countries, leading to a loss of local genetic resources. The introduction of livestock breeds might, however, offer opportunities to improve the income of poor livestock keepers. In southern Mali, where cattle play an important role in farmers' livelihoods, the Fulani Zebu, an improved local breed, is increasingly replacing the endemic N'Dama cattle breed. This study aims to evaluate the productive and economic performance of endemic N'Dama, Fulani Zebu and their crossbreds in southern Mali in order to assess the comparative advantages of these breed groups for farmers. Data collection methods comprised interviews with 34, 31, 34 and 61 households keeping N'Dama, crossbreds, Zebu and mixed herds, respectively, and a cow progeny history and body condition scoring (BCS) (n=770). Data were analyzed using linear mixed models and a non-parametric test. A higher BCS was recorded for N'Dama compared to the crossbred and Zebu cattle, while cow milk offtake was higher for Zebu cattle. Calving and offtake rates were higher for the Zebu and crossbred herds. The gross margin per cattle and the benefit-cost ratio were highest in the Zebu herd, followed by the crossbred herd, whereas the net benefit per cattle, including non-market benefits, such as traction, manure, insurance and home consumption, was similar between the herd categories. The N'Dama cattle remain a valuable breed for subsistence-oriented crop-livestock farmers for whom non-market benefits from cattle play a considerable role. Zebu and crossbred cattle were the most favorable options for market-oriented local and settled transhumant farmers, given their higher price and increased profitability.

Keywords: N'Dama, Fulani Zebu, Productive performance, Economic performance, Mali

3.2 Introduction

Crossbreeding local tropical cattle with exotic western cattle, as well as between tropical breeds, is, today, a widely used strategy by farmers in developing countries to increase the milk and meat output of their herd, and, thereby, increase their income (Leroy et al., 2016; Roschinsky et al., 2015). Crossbreeding and breed replacement are mainly due to economic globalization and change in consumer preferences, as well as technological and environmental changes (Tisdell, 2003). An increased proportion of exotic breeds or crossbred groups in livestock populations might offer opportunities, but could also pose a risk to the livelihoods of poor livestock keepers through the loss of adaptive traits of their animals, such as disease resistance and hardiness (König et al., 2016; Rege et al., 2011), as well as possibly leading to the loss of farm animal genetic diversity. Similar impacts are to be expected when introducing an improved tropical breed for crossbreeding or replacement of the endemic breed. The loss of biodiversity by losing an endemic breed might be accompanied on the local level by either increased profitability of cattle production or by a threat to livelihoods that rely on endemic breeds in low input systems. Only a few studies have undertaken economic comparisons of different breed groups in developing countries, taking into account the complexity of the production system in which they are kept (Marshall, 2014), and the value of non-market benefits achievable from livestock, such as traction, manure or insurance (Leroy et al., 2016).

The local taurine N'Dama breed (*Bos taurus*), which is endemic to the southern region of Mali, the Fulani Zebu breed (*Bos indicus*), which originated from the northern part of the country, and their crosses are raised by farmers in southern Mali. The N'Dama cattle are well-known for their trypanotolerance and resilience to helminthes and tick-borne diseases (Dwinger et al., 1992; Murray et al., 1991). Additionally, the low nutritional and husbandry requirements of N'Dama cattle (Grace, 2005) make it an interesting breed for extensive cattle production systems in western Africa. Many studies have indicated that trypanotolerant breeds possess a relatively good level of productivity when compared to Zebu and, therefore, support the need to preserve them. Decades ago, the productivity of N'Dama cattle was shown to be only marginally lower than that of Zebu (ILCA/FAO/UNEP, 1979) or even higher (Agyemang et al., 1991). Only ten years ago, Agyemang and Rege (2004) reported that output per head of cattle in tsetse-infested environments was on average 39% higher in trypanotolerant herds than in transhumant Zebu-dominated herds, and 26% higher than in sedentary mixed herds. The reported values referred to a range of production systems in

different locations of West and Central Africa. In spite of these favorable results for N'Dama cattle, there has been an increasing trend of crossbreeding between N'Dama cattle and the larger trypano-susceptible Zebu breed (Agyemang, 2005), suggesting that farmers might gain from the introduction of Zebu cattle.

A systematic comparison of the productive and economic performances of endemic N'Dama cattle, Fulani Zebu cattle and their crosses under the same farming conditions in western Africa may show whether farmers benefit from the introduction of Zebu cattle or are negatively affected by the replacement of N'Dama purebreds. This study aims to compare and evaluate the productive and economic performances of N'Dama cattle, Fulani Zebu cattle and their crossbreds in southern Mali, and, through this, contribute to the on-going debate on the comparative advantages of endemic breeds for local farmers in western Africa and elsewhere.

3.3 Materials and methods

3.3.1 Study area and sampling

In southern Mali, like in other neighboring countries, cattle are kept in a traditionally extensive production system, with grazing on natural pasture. The feed availability depends on the season, with declining quantity and quality of pasture from the wet (May to October) to the end of the dry season (Umutoni et al., 2015). This study was conducted in the communes of Sibirila and Garalo, which are located within the district of Bougouni in the Sikasso region of southern Mali, from October 2012 to April 2013. Both communes and the four villages contained within each of them were purposively selected, based on the presence of N'Dama, Zebu and their crossbreds. Stratified random sampling within the villages in regard to cattle breed ownership was applied for the selection of the households. In total, 160 households were chosen and subsequently classified into four herd categories, according to the main breed group present in the herd. The first three categories comprised of herds with more than 75% of N'Dama, Zebu or crossbred cattle, respectively; herds with less than 75% cattle from a single breed were designated as mixed herds, forming the fourth category. The cattle herds of 120 households were visited to assess individual cows' performances. In each herd, up to 10 cows that had already calved at least once were randomly selected. In total, data on 770 cows were collected. The study area and household selection have been described in detail by Traoré et al. (2017).

3.3.2 Household survey

Interviews with sets of semi-structured and structured questionnaires were used to collect socio-economic data on the households. This was followed by data collection on the herd inventory and cattle husbandry practices (feeding, herding, veterinary treatments), and herd productive performance (number of calves born and dead, average daily milk offtake per milked cow (DMO) for the dry and rainy season). The interviewee was also asked to recall all herd entries (births, purchases, gifts) and exits (sales, slaughters, deaths) of cattle that had occurred over the last 12 months. Data on inputs and outputs of animal and crop production, as well as marketing and use of animal products, were also collected for the previous 12 months.

3.3.3 Individual cow performances

Body condition scoring and a cow progeny history survey were applied to investigate the performance of randomly selected cows. Body condition was assessed based on a nine score scale in which each of the three main conditions (fat [F], medium [M] and lean [L]) were subdivided into three categories. The given scores ranged from 1 (L-) to 9 (F+) (Nicholson and Butterworth, 1986). Data on a cow progeny history comprised of the age at first calving (AFC), calving interval (CI) (the period between the date of birth of the last and previous calf), current age of the cow, number of lactations, number of calves born alive, number of stillbirths, number of abortions, number of calves dead before weaning, and cow lactation stage. The lactation stage was classified as not lactating, early stage (first 6 months) and late stage (after 6 months). The breed group of the cow (N'Dama, Fulani Zebu and crossbred) was recorded, based on the morphology, coat color and information on the pedigree of each animal.

3.3.4 Economic performances

The following parameters indicated the economic performance and efficiency of cattle production:

Gross margin (GM) = cash revenue – variable cash cost

Net benefit (NB) = (cash revenue + non-market benefit) – (variable cash cost + labor opportunity cost)

Benefit-cost ratio 1 (BCR1) = (cash revenue) / (variable cash cost)

Benefit-cost ratio 2 (BCR2) = (cash revenue + non-market benefit) / (variable cash cost + labor opportunity cost)

Return to herd capital (NB / herd capital) = net benefit / average value of the herd

GM and NB were calculated per farm and per head of cattle. Different revenue and cost components were calculated per head of cattle to account for differences in average herd sizes between herd categories. The currency used in this study was the Franc CFA, with an exchange rate of 1 EURO = 650 FCFA (2012-2013).

The cash revenue comprised the sale of cattle, milk and renting oxen out. The non-market value comprised the meat and milk offtake for home consumption, cattle given away as a gift, value of draught power, and manure used on-farm, as well as the change in stock value. Cattle given away as a gift was valued based on the price of the cattle sold. The value of milk offtake was based on the average milk offtake for the rainy and dry season multiplied by the market price of the milk for the respective season.

The value of the draught power was derived from the total working days per year multiplied by 2000 FCFA, which is the daily price charged to hire a pair of oxen without equipment and labor costs. The non-market benefit of manure was derived from the total cattle manure used for crops based on the fertilizer equivalent. A chemical equivalence of the manure was determined with respect to nitrogen and phosphorus and related to current unit prices of these key nutrients in two frequently applied inorganic fertilizers: urea and NPK (nitrogen-phosphorus-potassium). The nitrogen and phosphorus content were assumed to be 1.5% and 0.4% of manure dry matter, respectively (Amadou et al., 2015). Change in stock value was derived from the value of purchased cattle and animals born in the herd during the last year minus the value of the cattle that had been sold, given away or died in the same period. For all calves born in the herd within the last 12 months, a weight at 6 months of 64, 71 and 80 kg for N'Dama, crossbred and Fulani Zebu, respectively, was assumed (Ahamefule et al., 2007). This weight was multiplied by the price of 1 kg live weight of the respective adult animals for each breed type, using data from this study.

An estimation of the intangible benefits of the cattle was based on Bosman et al. (1997), Moll (2005) and Moll et al. (2007), and comprised financing and insurance benefits. The benefit of financing was estimated as: $B_F = V_C \times F$, where B_F is the benefit of financing, V_C is the total

monetary value of live cattle sold on a farm in one year, and F is the financing factor. The latter value was taken from the formal interest rate of credit in the study areas (0.1) (Kafo Jiginew, 2013). The intangible insurance benefit was estimated as: $B_I = V_H$ x I, where B_I is the insurance benefit, V_H is the monetary value of the average of the cattle herd, and I is the insurance factor. Since functional insurance systems do not exist in rural areas of Mali, estimates suggested by Moll (2007) were used, ranging from 0.05 for favorable weather conditions to a factor of 0.20 for unfavorable conditions. Accordingly, considering the good annual rainfall in the study sites, a conservative insurance factor of 0.05 was applied.

Variable cash costs included costs for the purchased feed, animal health care, hired labor and purchased cattle. The cost for animal health care was based on preventive treatments (curative treatments and veterinary consultation costs that had occurred during the past year as reported by the farmers). The labor cost was calculated using the salary of a herder or the monetary value of their payment in kind (milk or a male calf). For households using their own family members for herding, a labor opportunity cost of 500 FCFA per cattle and month wasassumed, which corresponds to the rate paid to herders for each cattle they take care of. For feed costs, only the cost of purchased feed was taken into account. Fixed costs, such as the depreciation of housing, were not considered since the cattle were mainly kept in simple enclosures overnight that were constructed out of bushes and branches.

3.3.5 Data analyses

Data analysis was performed using SAS 9.3 (SAS Institute Inc. 2012). Descriptive statistics were applied to characterize the households and husbandry practices. Analysis of variance (ANOVA), t-tests and chi-square-tests were used to compare the productive and economic performances of the different breed groups. Normal distribution and homogeneity of the variance of residuals were tested. For quantitative variables that were not normally distributed, a pairwise comparison using the non-parametric Kruskal-Wallis test was performed. For all the models described, main effects and interactions were tested. Non-significant effects and interactions were removed by backward elimination, and only variables found to satisfy a $P<0.1$ significance level were retained in the final models.

Individual cow performances (BCS, AFC, CI) were analyzed using linear mixed model procedures, with commune, village (nested within commune) and household (nested within village) as random effects. The cow breed group, availability of the grazing area, provision of

crop residues during the dry season, and herd size were used as explanatory variables. Additionally, the lactation stage and season were included as explanatory variable for BCS.

BCS was analyzed using the following full model:

$$y_{ijklmxyza} = \mu + B_i + G_j + R_k + \beta h_z + L_l + S_m + u_x + v_{xy} + f_{xyz} + e_{ijklmxyza}$$

where

$y_{ijklmxyza}$ = BCS of the ath cow; μ = overall mean; β = regression coefficient; B_i = breed group (i = 3; N'Dama, crossbred, Fulani Zebu); G_j = grazing area (j = 2; limited, abundant); R_k = crop residue (k = 2; not used during the dry season, used during the dry season); h_l = herd size (heads of cattle) of the household as covariate; L_l = lactation stage (l = 3; not lactating, <6 months, >6 months,); S_m = season (m = 2; dry, rainy); u_x is the random effect of the commune (x = 2; Sibirila, Garalo); v_{yx} is the random effect of the village (y = 8; 1, 2, …, 8) nested within the commune, f_{xyz} is the random effect of the household (z = 160; 1, 2, …,160) nested within the village and commune, and $e_{ijklmxyza}$ is the residual error, $N(0, \sigma^2 e)$.

AFC and CI were analyzed using the following full model:

$$y_{ijkxyza} = \mu + B_i + G_j + R_k + \beta h_z + u_x + v_{xy} + f_{xyz} + e_{ijkxyza}$$

With factors defined as described above.

The calving rate and average daily milk offtake per milked cow for the dry and rainy season were analyzed at the herd level using the following mixed full model, with commune and village (nested within commune) as random effects:

$$y_{ijklxyz} = \mu + C_i + G_j + R_k + \beta_1 h_z + \beta_2 p_z + M_l + u_x + v_{yx} + e_{ijklxyz}$$

where

$y_{ijklxyz}$ = observation of the zth household; μ = the overall mean; β_1-β_2 = regression coefficients; C_i = herd category (i = 4; N'Dama, crossbred, Fulani Zebu, mixed); G_j = grazing area (j = 2; limited, abundant); R_k = crop residue (k = 2; not used during the dry season, used during the dry season); h_z = herd size (head of cattle) of the household as covariate; p_z = number of preventive treatments as covariate; M_l = distance to the main market (l = 2;<15 km, >15); u_x is the random effect of the commune (x = 2; Sibirila, Garalo); v_{yx} is the random effect of the village (y = 8; 1, 2, …, 8) nested within the commune, and $e_{ijklxyz}$ is the residual error, $N(0, \sigma^2 e)$.

GM/cattle for each herd category was analyzed using the following mixed full model, with commune and village (nested within the commune) as random effects:

$$y_{xyz} = \mu + \beta_1 h_z + \beta_2 o_z + \beta_3 p_z + \beta_4 c_z + u_x + v_{yx} + e_{xyz}$$

where

y_{xyz} = observation of the zth household; β_1-β_4 = regression coefficients; o_z = offtake rate as covariate; c_z = calving rate as covariate; and with other factors defined as described above.

3.4 Results

3.4.1 Household characteristics

Table 3.1 summarizes household and farmer characteristics for the different herd categories. Farmers of the Zebu group clearly stand out from the other groups: they were mainly settled transhumant farmers (88%), had the lowest formal education, had the lowest average age (45 years), had the smallest household and farm size, and derived their livelihood mainly from livestock rearing (79%). For all other herd categories, crop production was the main activity of the household head. The Zebu herd category had the largest herd size, while the N'Dama herd category had the smallest herd size. In each herd category, adult cows represented the largest share of the herd. The share of castrated males for traction was highest in N'Dama and lowest in Fulani Zebu herds (Table 3.1).

Table 3.1 Characteristics of households by herd category

Characteristic	Herd category							
	N'Dama (n=34)		Crossbred (n=31)		Zebu (n=34)		Mixed (n=61)	
Farmer group, %								
Local	97.1		93.6		11.8		88.5	
Settled transhumant	2.9		6.5		88.2		11.5	
Education of hh head, %								
None	85.3		87.1		97.1		80.3	
Primary school	14.7		12.9		2.9		19.7	
Main activity of hh head, %								
Cropping	85.3		83.9		20.6		85.3	
Livestock	14.7		16.1		79.4		14.8	
	Mean	S.D	Mean	S.D	Mean	S.D	Mean	S.D
Age of hh head (years)	57.9[a]	16.9	53.7[a]	13.9	44.7[b]	10.5	52.6[a]	11.5
Household size (members)	15.9[ab]	6.7	15.3[ab]	7.3	12.4[b]	7.4	16.6[a]	9.1
Farm size (hectare)	13.1[a]	6.8	12.3[a]	7.7	5.2[b]	4.1	13.4[a]	10.4
Cattle (head)	26.0[b]	24.5	36.4[ab]	35.3	44.2[a]	22.2	39.2[a]	27.2
Breed group (%)								
N'Dama	91.8	8.4	8.7	7.8	1.3	3.1	35.4	18.6
Crossbred	6.6	7.8	87.2	9.1	4.5	7.1	49.4	14.8
Zebu	1.7	2.7	4.0	5.1	94.2	8.4	15.2	17.5
Herd structure (%)[a]								
Adults: -males	6.2	5.5	7.0	7.1	8.2	5.5	6.8	5.6
- castrated males	17.6	9.6	12.1	11.6	6.2	5.2	12.4	8.9
-cows	32.5	9.3	32.5	7.5	35.6	7.3	32.2	8.1
Young: -males	10.0	7.0	10.8	4.7	11.5	5.2	12.6	5.7
-females	15.7	10.8	17.3	7.9	16.1	6.1	15.4	7.1
Calves	18.1	8.7	20.4	5.9	22.4	4.3	20.6	5.1

n: number, S.D: standard deviation, hh: household.
[a]: Adults > 3 years; 3 years ≥ Young ≥ 1 year; Calves < 1 year.
[a,b] Means within a row with different superscripts differ significantly at $P < 0.05$ (Lsd t-test).

3.4.2 Cattle management

Feeding management was similar between the different herd categories. Cattle were mainly grazing on natural pasture. Almost all herds (95%) received salt as a supplement. After a crop harvest, 75% of the herds had access to crop residues (maize, sorghum and rice stover;

cowpea and groundnut hay) in the field, while 40% were supplemented with collected crop residues during the dry season. Only 20% of the herds were supplemented with concentrate or cereal brand during the dry season. During the dry season (January – May), 22% of the herds went on transhumance, with the highest share among the Fulani Zebu herds (55%). Regarding health management, herds received on average 6.1 preventive treatments per year, including vaccinations. Zebu and crossbred herds received slightly more preventive treatments against trypanosomiasis, with 3.0 and 2.9 treatments/year, respectively, compared to N'Dama herds (2.1 treatments/year) (χ^2 = 6.92 and P = 0.0743 Kruskal-Wallis test). Trypanosomiasis was considered to be the most serious disease affecting the herds: 50.0, 38.7 and 47.5% of the Fulani Zebu, crossbred and mixed herd received a curative treatment against trypanosomiasis, respectively, while only 14.7% of the N'Dama herds were given curative treatment (χ^2 = 11.97 and P = 0.0075 Chi-square test) (results not shown).

3.4.3 Productive performance

3.4.3.1 Individual cow performance

The results for individual cow performance are presented in Table 3.2. BCS and AFC were significantly affected by the breed group. N'Dama cows had the highest BCS and the earliest AFC. BCS was mainly affected by the season and by the lactation stage of the cow. AFC was also significantly affected by the availability of the grazing area. CI was similar between the cattle breed groups, with an overall mean CI of 15.6 months (n = 526, results not shown).

Table 3.2 Body condition score (BCS) and age at first calving (AFC) of cattle by breed group, lactation stage, season and grazing area

		BCS (scores)			AFC (years)	
Variable	n	LSM	SE	n	LSM	SE
Breed group		***			**	
N'Dama	297	5.25[a]	0.20	282	3.47[a]	0.06
Crossbred	257	5.02[b]	0.20	248	3.63[b]	0.06
Zebu	216	4.76[c]	0.21	210	3.61[b]	0.06
Lactation stage		***				
Dry	183	5.27[a]	0.20			
Early	288	4.94[b]	0.20			
Late	294	4.82[c]	0.20			
Season		***				
Rainy	520	5.69[a]	0.20			
Dry	250	4.33[b]	0.21			
Availability of grazing area					*	
Limited				559	3.68[a]	0.05
Abundant				211	3.47[b]	0.08
r_c		0.58			0.47	

LSM: least squares mean; SE: standard error of the mean; n: number of cows; r_c: degree of agreement between the observed values and the predicted value (BCS, AFC); * $P<0.05$, **$P<0.01$, ***$P<0.001$. LSMs in column followed by different superscripts differ significantly at $p<0.05$.

3.4.3.2 Herd performance

The mean calving rate for all of the herds was 70.3%, while the offtake rate was 8.2%. DMO per milked cow was higher during the wet season (1.2 liter) compared to the dry season (0.8 liter). Calf mortality was high (9.7%) compared to young (3.3%) and adult (1.6%) mortality.

As shown in Table 3.3, the herd category had a significant effect on the calving rate and the (DMO) per milked cow during the wet season ($P<0.05$). The calving rate was lowest for the N'Dama herd category. It was also affected by the interaction between the availability of the grazing area and the herd category ($P<0.01$). The calving rate for the crossbred herd category was significantly higher in abundant grazing areas compared to limited ones, while no significant difference was found for the other herd categories. DMO during the dry season increased by 0.15 liter with the use of crop residues ($P<0.05$). DMO during the dry and wet seasons increased by 0.24 and 0.25 liters, respectively, with the abundant grazing area

(P<0.05). With a shorter distance to the market, DMO increased by 0.22 and 0.23 liters in the dry and wet seasons, respectively (P<0.05). DMO during the wet season increased by 0.04 liters for each additional preventive treatment (P<0.05).

Table 3.3 Calving rate and milk offtake by herd category

	Herd category											
	N'Dama (n=34)			Crossbred (n=31)			Zebu (n=34)			Mixed (n=61)		
Parameter	N	LSM	SE	N	LSM	SE	N	LSM	SE	N	LSM	SE
Calving rate (%)	34	60.3^{b}	4.9	31	72.1^{a}	5.2	34	69.4^{ab}	4.8	61	74.2^{a}	4.0
Milk offtake cow/day (liter)												
Dry season	16	0.7^{b}	0.08	17	0.8^{ab}	0.09	26	0.9^{a}	0.07	38	0.7^{b}	0.06
Wet season	24	1.1^{c}	0.11	23	1.3^{bc}	0.11	31	1.6^{a}	0.10	57	1.4^{ab}	0.07

LSM: least squares mean; SE: standard error of the mean; N: number of households; LSMs within a row followed by different superscripts differ significantly at p<0.05.

The Kruskal–Wallis tests revealed significant differences for cattle offtake between the herd categories, while no significant difference between calf mortality rates was found (Table 3.4). The mean cattle offtake rate was almost two times higher for the Zebu and crossbred compared to the N'Dama herd category.

Table 3.4 Cattle offtake rate and calf mortality rate by herd category

	Herd category							
	N'Dama (n=34)		Crossbred (n=31)		Zebu (n=34)		Mixed (n=61)	
Parameter	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Cattle offtake rate (%)	5.9	4.7^{c}	10.1	7.1^{ab}	11.5	10.5^{a}	6.3	5.5^{bc}
Calf mortality rate (%)	11.2	0.0	13.8	9.1	8.6	8.5	7.5	0.0

Difference between herd category at χ^2 = 12.8 and P < 0.01 for cattle offtake rate (Kruskal-Wallis test). Medians within a row followed by different superscripts differ significantly at p<0.05.

3.4.4 Economic performance

3.4.4.1 Benefits of cattle production

A large share of the benefits realized from the households was non-cash, except for the Zebu herd category in which cash revenue had a share of more than 50% of the total benefits. The

highest benefit from keeping cattle in the surveyed households was from live sales of the cattle, followed by intangible insurance and financing benefits. Home meat consumption had the lowest share in all herd categories (Figure 1).

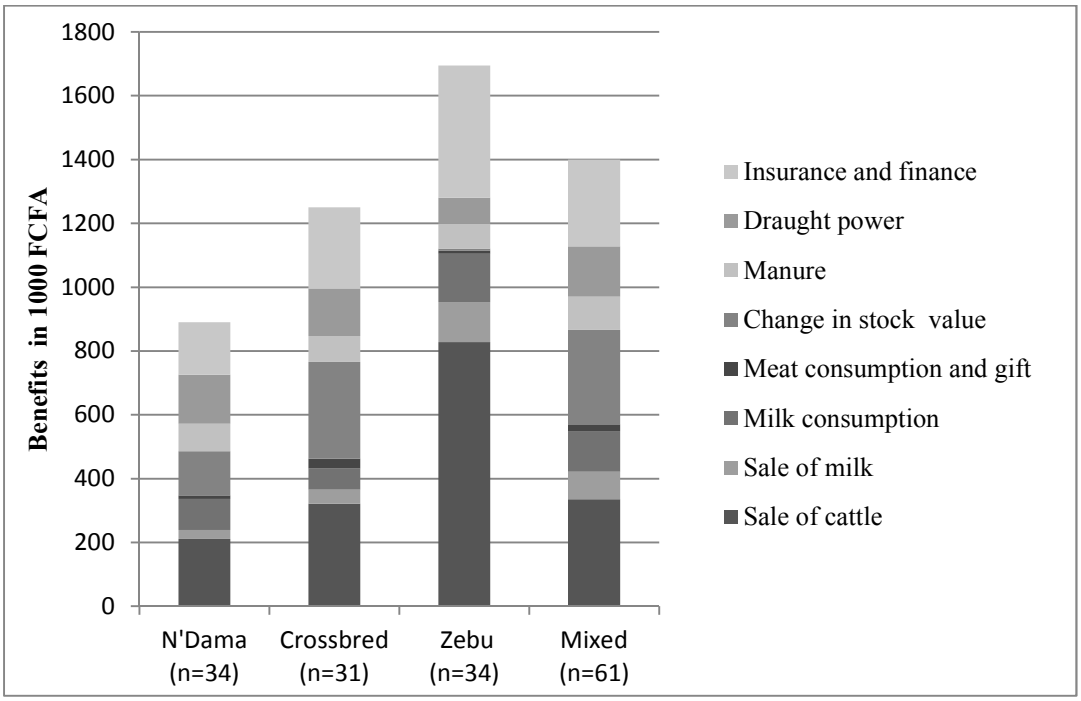

Figure 3.1 Composition of benefits of cattle production per household by herd category (Arithmetic means)

Households with Zebu had the highest total cash revenue per cattle, followed by crossbred, mixed and N'Dama herds (Table 3.5). The higher cash revenue from sale of Zebu and crossbred compared to the N'Dama herd ($P<0.05$) resulted from higher offtake rates (Table 3.4) and selling prices (Figure 2). The cash revenue from selling milk was higher for Zebu and mixed herds compared to the N'Dama and crossbred herds ($P<0.05$). Non-market benefits were significantly lower for the Zebu herds, since households with Zebu benefited less from manure and draught power ($P<0.05$) given that they had less cropping land (Table 3.5). The insurance and financing benefits of crossbred, mixed and Zebu herds were higher than for N'Dama cattle ($P<0.05$), given their higher selling price. Thus, crossbred and Zebu cattle present a higher capital asset value than N'Dama cattle for farmers.

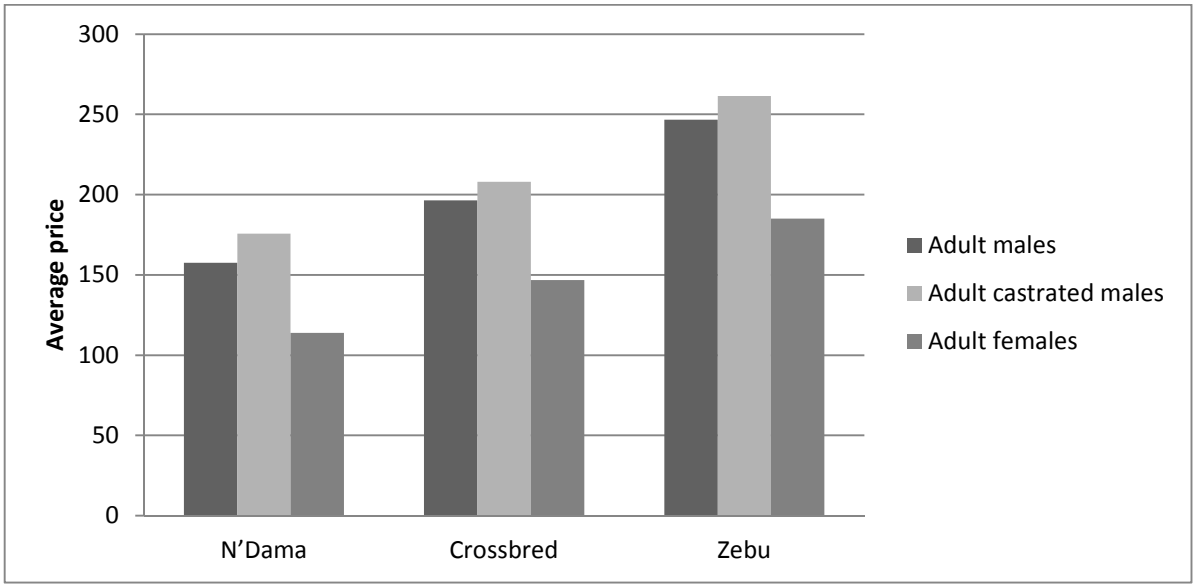

Figure 3.2 Average selling price of cattle by breed group (in 1000 FCFA)

3.4.4.2 Variable costs of cattle production

An overview of the variable cost per cattle in the different herd categories is presented in Table 3.5. The main variable cost was the labor cost (including the labor opportunity cost), followed by purchase of cattle, veterinary costs and feed costs. When costs were calculated per cattle, hired labor, curative treatment and supplementary feeding costs were significantly different between herd categories. The cost for hired labor per cattle was significantly higher for N'Dama, since they relied more on hired herders (67%) than family members, and consisted of a smaller herd size. Curative treatment costs were significantly lower for N'Dama compared to the other herd categories. Salt cost represented 79.7% of the feed cost and was similar between herd categories, while cost for concentrate (cereal brans and seed cake) was significantly higher for Zebu herds compared to the other herd categories. The total variable cash cost was similar between the herd categories.

Table 3.5 Benefit and cost components per cattle by herd category (in 1000 FCFA)

	Herd category							
	N'Dama (n=34)		Crossbred (n=31)		Zebu (n=34)		Mixed (n=64)	
Variable	Mean	Median	Mean	Median	Mean	Median	Mean	Median
Total cash revenue	8.4	4.8^{c}	15.6	10.4^{b}	23.5	19.8^{a}	12.2	11.3^{b}
Sale of cattle	7.6	3.8^{c}	13.8	9.6^{b}	20.5	15.4^{a}	9.7	8.6^{bc}
Sale of milk	0.8	0.0^{b}	1.5	0.0^{b}	3.0	2.6^{a}	2.3	0.0^{a}
Total non-market benefit	33.3	30.3^{a}	25.4	25.6^{ab}	18.6	22.5^{b}	28.0	26.6^{a}
Milk consumption	5.0	3.6^{ab}	2.4	1.4^{b}	4.3	3.5^{a}	4.4	2.6^{a}
Meat consumption and gift	0.5	0.0	0.7	0.0	0.2	0.0	0.7	0.0
Change in stock value	6.7	10.1	3.7	5.1	-0.4	3.2	6.8	8.9
Manure	4.4	2.8	2.9	2.6	2.1	2.0	3.3	2.7
Draught power	9.8	6.5^{a}	7.5	4.6^{ab}	2.4	1.6^{c}	5.1	4.1^{b}
Insurance and finance	6.8	6.5^{c}	8.3	8.0^{b}	10.1	9.6^{a}	7.7	7.5^{b}
Total benefit	41.8	39.3	41.0	38.1	42.1	42.7	40.2	40.1
Total variable cash cost	9.7	7.9	9.7	7.8	7.3	4.6	8.4	6.2
Hired labor	3.5	3.6^{a}	1.9	0.0^{b}	1.6	0.0^{b}	2.8	2.5^{ab}
Preventive treatment	1.6	1.6^{b}	2.0	1.9^{a}	1.6	1.6^{ab}	1.6	1.5^{b}
Curative treatment	0.1	0.0^{b}	0.4	0.2^{a}	0.2	0.1^{a}	0.2	0.1^{a}
Salt	1.3	1.1	1.3	1.1	1.0	0.8	1.4	1.2
Concentrate	0.2	0.0^{b}	0.2	0.0^{b}	0.8	0.0^{a}	0.2	0.0^{b}
Purchased cattle	3.0	0.0	3.9	0.0	2.1	0.0	2.3	0.0
Labor opportunity cost	1.7	0.0	2.8	4.4	2.8	4.6	2.0	0.0
Total variable cost	11.4	10.2	12.5	9.3	10.1	7.9	10.5	8.9

Medians with different superscripts within a row differ significantly ($P<0.05$) (Wilcoxon-Mann-Whitney test).

3.4.4.3 Economic success of cattle production

The GM per farm was, on average, 3.2 and 18.5 times higher for the crossbred and Zebu herd categories, respectively, than for the N'Dama herd. The GM per farm and cattle were significantly affected by the herd categories and were the highest for Zebu, followed by mixed and crossbred, and lowest for the N'Dama herd category. The NB per farm was significantly higher for the Zebu and mixed herd compared to the N'Dama herd; it was insignificantly higher for the crossbred than for the N'Dama herd category. The NB per cattle was similar between the herd categories (Table 3.6).

Table 3.6 Gross margin (GM)/farm and net benefit (NB)/farm, GM/cattle and NB/cattle from cattle production by herd category (in 1000 FCFA)

	Herd category							
	N'Dama (n=34)		Crossbred (n=31)		Fulani Zebu (n=34)		Mixed (n=64)	
Parameters	Mean	Median	Mean	Median	Mean	Median	Mean	Median
GM/farm	37.1	27.4[c]	119.7	120.8[b]	689.2	638.4[a]	183.4	93.4[b]
GM/cattle	-1.2	-2.2[c]	5.9	2.9[b]	16.2	15.4[a]	3.8	4.5[b]
NB/farm	659.8	496.7[c]	929.3	565.8[bc]	1336.7	1224.6[a]	1095.7	810.1[b]
NB/cattle	30.4	27.0	28.5	27.0	32.0	33.9	29.7	29.1

Medians with different superscripts within a row differ significantly (P<0.05) (Wilcoxon-Mann-Whitney test).

Considering the efficiency, the BCR1 was highest for the Zebu herd category and higher for the crossbred and mixed herds compared to the N'Dama herd category (Table 3.7). However, the BCR2 (including non-market benefits) and the return to herd capital were similar between the herd categories (Table 3.7).

Table 3.7 Benefit-cost ratio (BCR) and NB in relation to herd capital by herd category

	Herd category							
	N'Dama (n=34)		Crossbred (n=31)		Zebu (n=34)		Mixed (n=61)	
Parameter	Mean	Median	Mean	Median	Mean	Median	Mean	Median
BCR1	1.6	0.8[c]	2.4	1.3[b]	5.4	4.1[a]	2.2	1.6[b]
BCR2	5.2	3.9	3.9	3.6	5.1	4.9	4.7	4.2
NB/Herd capital	0.26	0.24	0.21	0.19	0.21	0.22	0.23	0.23

Medians with different superscripts within a row differ significantly (P<0.05) (Wilcoxon-Mann-Whitney test).

3.4.4.4 Factors affecting the economic performance of cattle production

GM/cattle was significantly positively correlated with cattle offtake rates in all of the herd categories. Herd size was positively correlated with GM/cattle in all of the herd categories except for N'Dama. The number of preventive treatments was significantly positively correlated with GM/cattle for the crossbred and mixed herd categories. Calving rate had a positive effect on GM/cattle only for the N'Dama herd category (Table 3.8).

Table 3.8 Estimates of determinants of gross margin (GM) per cattle by herd category (in 1000 FCFA)

	N'Dama (n=34)		Crossbred (n=31)		Zebu (n=34)		Mixed (n=64)	
Variables	Estimate	SE	Estimate	SE	Estimate	SE	Estimate	SE
Intercept	-15.73	3.36	-20.38	4.34	-15.71	6.17	-20.38	4.34
Herd size			0.06*	0.04	0.17**	0.08	0.06*	0.04
Offtake rate	1.74****	0.17	1.37***	0.13	2.13***	0.20	1.05***	0.13
Number of preventive treatment			1.27**	0.49			0.96**	0.49
Calving rate	0.10*	0.05						

*P<0.1, **P<0.05, ***P<0.01

3.5 Discussion

Differences in farm size, main activity, herd size and structure indicated that farmers from the different herd categories had different production objectives concerning cattle production. Settled transhumant farmers' primary objective was the generation of cash income, mainly through the sale of Zebu cattle, as indicated by the higher offtake rate in the Zebu and crossbred herds. As observed by Boutrais (2007), settled transhumant farmers in West Africa avoid crossbreeding their Zebu cattle with smaller trypanotolerant cattle such as the N'Dama, except when they notice that Zebu cattle cannot survive in a new environment. Zebu and crossbred cattle with a higher market price might be more suitable than N'Dama cattle for settled transhumant farmers and local farmers for whom raising cattle is their main source of income. In contrast, local farmers' primary income activity was crop production. They kept mainly N'Dama, crossbred and mixed herds as a secondary activity. The N'Dama breed seems favorable for local farmers for whom traction and manure are among the most important production objectives for keeping cattle (Traoré et al., 2017).

The average offtake rate in the Zebu and crossbred herd categories in our study was similar to the offtake rate (11%) reported by Ba et al. (2011) for a medium sized herd (35 cattle) in southern Mali. The calf mortality rate in our study was similar between the herd categories and relatively low (8.2%), comparable to the findings of Ba et al. (2011) and Wymann et al. (2006). The relatively low values found in our study could be explained by sufficient disease prevention measures (Ba et al., 2011). The higher share of herds among Zebu and crossbred herd categories that received curative treatment against trypanosomiasis indicates a lack of resistance to disease and the need for regular treatments, which was stated as a main

disadvantage of these breed groups by farmers (Traoré et al., 2017). In our study, the overall calving rate (70.3%) was higher than the 54% reported for southern Mali by Ba et al. (2011), but similar to the calving rate of 60.3% (Table 3.3) found for N'Dama. The absence of breeding bulls in 32% of the N'Dama herds might explain the lower calving rate in this herd category. The significantly increasing DMO during the wet season with an increasing number of preventive treatments (vaccination and trypanocide) supports the importance of preventive treatments, especially during the wet season (Table 3.4) when the incidence of diseases, particularly trypanosomiasis, is highest (Bocoum et al., 2012). The higher BCS recorded for N'Dama, compared to the crossbred and Zebu, suggests a better adaptation of the N'Dama breed to the husbandry conditions in the study area. This is in line with farmers' experiences, that N'Dama is more tolerant to drought conditions than Zebu (de Jode, 1989; Traoré et al., 2017). Similar to our study, Ezanno et al. (2003) and Leloup et al. (1996) found the season to be the main factor affecting cow BCS, with best conditions in the wet season. The earlier AFC for N'Dama compared to Zebu was in line with the results of Sokouri et al. (2010) in the Ivory Coast. A younger AFC is expected to increase herd productivity.

The higher cash revenue from milk for Zebu and the mixed herd compared to the N'Dama herds ($P<0.05$) was in line with the finding of Somda et al. (2005) in The Gambia which showed that the introduction of Zebu breed in N'Dama dominated herds increased the amount of milk produced and farm revenue. The higher cash revenue for the sale of cattle in crossbred and Zebu herds was explained by the higher offtake rate in these two herd categories and a 25 and 60% higher selling price for crossbred and Zebu, respectively, than for N'Dama cattle (Figure 3.2). The higher veterinary costs per cattle of crossbred herds compared to N'Dama herds were largely compensated by their cash revenue (Table 3.5). Interestingly, the preventive treatment cost per cattle was not significantly lower for N'Dama compared to the Zebu herd category. This might be explained by the fact that all of the categories received similar numbers of preventive treatments per year, indicating that farmers indiscriminately treat or vaccinate irrespective of the breed. Under such a health management scheme, the assumed savings in veterinary costs by raising the more disease resistant N'Dama breed compared to Zebu, as stated by Agyemang (2005), is not sufficient to have a positive effect on the GM. Nevertheless, the lower costs for curative treatment of the N'Dama herd category can be considered as advantageous for poor farmers with limited capital to invest in better health care.

The negative GM per cattle and the BCR1<1 (median = 0.8) for the N'Dama herd category indicates that keeping this breed was not profitable for the farmers. Indeed, 59% of farmers keeping N'Dama had a GM<0. For the other herd categories, GM per cattle was positive and the BCR1 indicates that their cash revenue largely exceeded their variable cost. The low GM in N'Dama herds (Table 3.6) was due to a low calving (60.3%) and offtake rate (5.9%) found in this herd category, and the higher labor cost of hired herders. A large share of the benefits from keeping cattle was non-cash, particularly for the N'Dama, which was up to 70%, in contrast to Fulani Zebu herds, which was less than 50%. The similar BCR2 (including non-market benefits) and NB per cattle for all of the herd categories (tables 3.6 and 3.7) indicate that smallholders keeping N'Dama cattle are relatively competitive and efficient when non-market benefits, such as milk and meat for home consumption, manure, draught power and change in stock value, are taken into consideration. This illustrates, as stated by Lemke and Valle Zárate (2008) that the economic performance of breeds depends on the choice of evaluation parameters. The coexistence of market and subsistence-oriented farmers in our study area justified the valuation of both market and non-market values of cattle production.

The cattle offtake rate was the strongest determinant of GM/cattle for all of the herd categories, and can be considered as an important indicator of cattle production profitability. The positive correlation between GM/cattle and herd size can be explained by the economy of scale: with an increasing herd size, the cost per cattle decreases. Increased numbers of preventive treatments only positively affected the GM/cattle of the crossbred and mixed herds, suggesting the importance of good veterinary care for these herd categories (Table 3.8).

According to many studies, a major objective of crossbreeding local with exotic breeds was to increase farmers' incomes (Roschinsky et al., 2015; Udo et al., 2011). In fact, Patil and Udo (1997) found that farms with crossbred cattle had a higher GM than farms without crossbreds in India. Lemke et al. (2007) found higher revenues for crossbred rather than local pigs under smallholder production conditions in Vietnam. Our results even show that crossbreeding between two tropical breeds leads to a higher revenue for the farmer (Table 3.6). The importance of cash availability for buying inputs for cropping makes the Zebu and crossbred more attractive to the farmer. Since economic performance based on the GM calculation clearly does not favor the endemic breed, farmers' adoption of the Zebu breed or its crosses with N'Dama are justified as a means by which to intensify their production and improve their livelihoods. Along the same lines, Mendelsohn (2003) stated that economic forces have been

the major cause for farmers to shift from traditional breeds to new ones. Furthermore, the environment in the study area favors Zebu, given the low prevalence of tsetse flies in the study area (Bocoum et al., 2012) and the availability of subsidized trypanocidal drugs (Grace et al., 2009). The findings in this study explain the high preference for crossbreds and Zebu by local farmers (Traoré et al., 2017). However, it is important to consider that the profitability of the breed group might change with the potential development of a widespread resistance of trypanosomes to trypanocidal drugs or detrimental impacts of climate change on local farming conditions.

3.6 Conclusion

Fulani Zebu and crossbred cattle were the most favorable options for market-oriented farmers under the prevalent farming conditions. N'Dama cattle remain a valuable breed for subsistence-oriented smallholders in crop-livestock systems, given their limited investment capacity in better health care in southern Mali. However, unless the national governments or the international community invests in the genetic improvement of the endemic breed and/or making its use economically profitable by direct transfer payments for the conservation of biodiversity, local farmers will follow their obvious economic interests and further replace the endemic breed by genetic options that suit them better.

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4 CONTRIBUTION OF CATTLE OF DIFFERENT BREEDS TO HOUSEHOLD FOOD SECURITY IN SOUTHERN MALI

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4.1 Abstract

Cattle husbandry plays an important role in the livelihoods of many households in southern Mali where the endemic N'Dama and Fulani Zebu breeds and their crosses are raised by farmers. This study examines food security, its determinants and the coping strategies used among 258 households in southern Mali, with particular emphasis on the contributions of cattle keeping and specifically different breed groups, i.e. N'Dama, Zebu, crossbreds and mixed herds, to food security. The main aim was to investigate whether the replacement of the endemic N'Dama breed threatens or improves household food security. A linear mixed model was used to analyze the effects of household characteristics on food security using the household dietary diversity score (HDDS), food consumption score (FCS), and a modified household food insecurity access scale (mHFIAS) as indicators. Results revealed that cattle ownership and breed group were important determinants of all household food security indicators. Households keeping Zebu and mixed herds had the highest FCS. HDDS and FCS were positively correlated with crop diversity and wealth, while negatively correlated with cotton cultivation. During the food shortage period, households raising Zebu were better off and had significantly lower mHFIAS than those keeping N'Dama, crossbreds or mixed herds. In times of food shortage, selling livestock was the main coping strategy for households with a cattle herd, while households without a cattle herd relied mostly on borrowing cash. In conclusion, the ongoing displacement of native N'Dama cattle by Zebu cattle and their crosses is contributing to improved household food security.

Keywords: Cattle breeds, Dietary diversity, Food security, Mali.

4.2 Introduction

Livestock husbandry can contribute directly to household food security through the home consumption of livestock products, and indirectly through the provision of cash income, manure and draft power (Smith et al. 2013). The animal source food (ASF) is known for its high nutritional value due to its high energy density, high quality protein and diverse essential micronutrients, such as vitamin A, vitamin B-12, riboflavin, calcium, iron and zinc. However, a considerable share of poor farmers in sub-Saharan Africa does not have adequate access to ASFs, and they depend on starchy and plant protein based diets, which, alone, hardly fulfill their nutrient requirements (Kidoido and Korir 2015; Murphy and Allen 2003). While the potential role of livestock in contributing to better nutrition for households keeping livestock is often stressed, few studies reveal this link and show the conditions under which it occurs (Azzari et al. 2015). Moreover, the relative contribution of different livestock breeds to household food and nutrition security in developing countries has hardly been studied, even though such research is particularly relevant under changing environmental conditions and when comparing exotic with local breeds in the tropics (Marshall 2014). On the one hand, the replacement of locally adapted breeds by exotics or crossbreds might affect farmers' food security through livestock losses in the event of drought or disease outbreak (König et al. 2016). On the other hand, the adoption of more productive breeds may be advantageous for food security as it can lead to more food and cash availability in comparison with the lower output but more adapted breeds (Marshall 2014).

The Sikasso region in southern Mali is the country's poorest region and most affected by malnutrition (Eozenou et al. 2013), although this region is regarded as the country's cereal basket and known for cotton production, its first export commodity. Cattle production plays an important role in the livelihoods of many farmers in this region, where about 90% of the households own at least an ox and 60% have a cattle herd (Poccard-Chapuis et al. 2007). The endemic N'Dama breed and the more productive Fulani Zebu breed, as well as their crosses, are raised by farmers mainly for draught power, as a saving and source of income (Traoré et al. 2017). The N'Dama cattle are well known for their trypanotolerance and resilience to helminthes and tick-borne diseases as well as their low nutritional requirements (Murray et al. 1991; Grace 2005). Zebu and Zebu-N'Dama crosses are valued by many farmers for their high market price, large size and high milk yield (Jabbar and Diedhiou 2003; Traoré et al. 2017). There has been an increasing trend of crossbreeding between N'Dama cattle, as well as

other West African Shorthorn trypanotolerant breeds and the larger trypano-susceptible Zebu breed in West Africa (Agyemang 2005), putting the first under risk of genetic erosion. The shift towards crossbreds and Zebu might benefit farmers in terms of food security, even implying the loss of farm animal genetic diversity.

The multidimensional character of food security makes its measurement challenging. Nevertheless, it is well recognized that food security is built on four pillars: availability, access, utilization and stability (FAO 2011). The household dietary diversity score (HDDS), food consumption score (FCS) and household food insecurity access scale (HFIAS) have been often utilized to measure different aspects of food security (Becquey et al. 2010; Kennedy et al. 2010; Regassa and Stoecker 2012) and were found to be suitable in estimating diet adequacy and assessing household food security (Arimond and Ruel 2004; Becquey et al. 2010). This study examines household food security using HDDS, FCS and HFIAS, its determinants and coping strategies used in response to food shortages in southern Mali, with an emphasis on the contribution of cattle and specifically different breed groups. The main aim is to investigate whether the displacement of the endemic N'Dama breed is a threat or an opportunity to farmers' food security.

4.3 Materials and methods

4.3.1 Study area

The study was conducted in the communes of Sibirila and Garalo in the district of Bougouni within the Sikasso region of southern Mali from October to December 2012. The region has a sub-humid climate, with an annual rainfall of between 1,000 and 1,200 mm. The rainy season extends from May to October. Crop farming and livestock husbandry make the main contributions to the livelihood of households in the study area. The major crops cultivated are maize, sorghum, millet, rice, groundnuts, beans and yam. The main cash crops are cotton and cashew nuts. Food shortage generally occurs from July to September (lean period, reaching a peak in August). The harvest period usually starts in October and ends in December.

4.3.2 Sampling

The communes, Sibirila and Garalo, and four villages in each of the communes were purposively selected based on the presence of N'Dama, Zebu and crossbred cattle. A stratified

random sampling based on cattle and breed ownership was applied for the selection of 258 households. Households with a herd were grouped into four herd categories based on breed composition: the first three categories were comprised of herds with more than 75% of N'Dama, Zebu or crossbred cattle, respectively. Herds with less than 75% cattle from a single breed were designated as mixed herds, forming the fourth category. Households with only oxen and those without cattle represented two additional herd categories. Farmers of the Zebu herd category were mainly settled transhumant farmers from the Fulani ethnic group whose culture, livelihood and diet are centered on cattle (Glew et al. 2010). Farmers of all other herd categories were mainly local farmers affiliated to the Bambara ethnic group who rely mainly on crop farming as their source of livelihood.

4.3.3 Data collection and definition of food security indicators

Interviews with sets of semi-structured questionnaires were used to collect socio-economic data on households, livestock holding, cropping, household assets, and inputs and outputs of animal and crop production for the previous 12 months. Household dietary intake data were recorded for 12 food groups: cereals, white roots and tubers, vegetables, fruits, legumes, meat, eggs, fish, dairy, oils and fats, sweets and condiments during the previous day according to the FAO guidelines for measuring household and individual dietary diversity (FAO 2011). Household heads and their wives were interviewed in order to list and qualitatively describe food items prepared at home and consumed by household members. Similarly, FCS data were generated from household food consumption patterns (i.e. dietary diversity and food frequency information) over the past seven days. All food items consumed during the past seven days were grouped into eight specific food groups and a weighting system designed by the World Food Programme was applied to the different food groups based on their energy, protein and micronutrient densities (WFP 2008). This makes FCS a blended score of dietary diversity, consumption frequency and relative nutritional value of different food groups.

Additionally, household food insecurity situations were retrospectively assessed for the past 30 days before the interviews, distinguishing between two periods: 1) October to December as corresponding to the harvest period and 2) during the month of August, which is considered to be the most critical period for food security (lean period) in the study area. A modified household food insecurity access scale (mHFIAS) was derived from a guideline proposed by Coates et al. (2007). The six food insecurity-related conditions were whether or not household

members had to do any of the following because of a lack of resources or food: 1) eat a kind of food they did not like; 2) eat a smaller meal; 3) eat fewer meals in a day; 4) stay a whole day without eating anything; 5) borrow food; 6) or purchase food on credit. If the response was yes to a condition, the frequency was asked to determine whether the condition occurred rarely (1 = once or twice), sometimes (2 = three to 10 times), or often (more than 10 times) during a four week time span. The mHFIAS score is the sum of the frequency of occurrence during the four weeks for the six food insecurity-related conditions. Finally, a Household Food Insecurity Access Prevalence (HFIAP) status, which categorizes households into four levels of household food insecurity, i.e. food secure and mildly, moderately and severely food insecure, was also computed. Households were categorized as increasingly food insecure as they experienced more severe conditions and/or suffered those conditions more frequently. In this study, the mHFIAS and HFIAP were based on only four of the nine questions suggested by Coates et al. (2007), since some of these conditions were considered as redundant and not relevant. Furthermore, household heads were asked which months their household members experienced food shortages and which coping strategies they used.

4.3.4 Data analyses

Data analysis was performed using SAS 9.3 (SAS Institute Inc. 2012). Descriptive statistics were used to characterize households, their food consumption, food insecurity indicators and coping strategies. t-test, $\chi 2$-test and Fisher's exact test were applied to identify significant differences between herd categories. HDDS, FCS, mHFIAS and food shortage length were used as dependent variables and analyzed using linear mixed model procedures with commune and village (nested within commune) as random effects. Higher values of HDDS and FCS indicate a better household food security status, while higher values for mHFIAS and the food shortage length reveal a situation of food insecurity. Continuous explanatory variables included in the models were: 1) food crop species' diversity as defined by the number of species cultivated by the household; 2) the wealth index, which was computed using a Principal Component Analysis (PCA) based on the number of motorcycles, phones, radios, ploughs, total livestock units and total revenue of the household; and 3) the dependency ratio, which is defined as the ratio of household members with an age of between 0 and 14 and above 65 years, to the productive age group (15–65 years). The herd category was a categorical variable with six levels (defined above). The cultivation of cotton, education

of the household head and off-farm income were all dichotomous variables. The effects of socioeconomic factors on food security indicators (HDDS, FCS, mHFIAS and food shortage length) were modeled as follows:

$$y_{ijklxya}=\mu + F_i + \beta_1 n_z + \beta_2 w_z + \beta_3 d_z + C_j + E_k + O_l + u_x + v_{xy} + e_{ijklxya}$$

where

$y_{ijklxya}$ = observation of the ath household; μ = overall mean; F_i = herd categories (i = 6; N'Dama herd, crossbred herd, Zebu herd, mixed herd, only oxen, without cattle); β_1-β_3 = regression coefficients; n_z = number of crops cultivated as covariate; w_z = wealth index as covariate; d_z = dependency ratio as covariate; C_j = cultivation of cotton (j = 2; cultivation, no cultivation); E_k = education of the household head (k = 2; no formal education, primary school), O_l = off-farm income (l = 2; no off-farm income, off-farm income); u_x is the random effect of the commune (x = 2; Sibirila, Garalo); v_{xy} is the random effect of the village (y = 8; 1, 2, …, 8) nested within commune, and $e_{ijklxya}$ is the residual error, assumed to be normally distributed.

Before data analyses, multi-collinearity of the explanatory variables was checked; normal distribution and homogeneity of the variances of the residuals were tested. Non-significant effects were removed by backward elimination, and only variables found to satisfy a $P<0.1$ significance level were retained in the final model. The strength of the correlation between the food security indicators was examined using Pearson correlation.

4.4 Results

4.4.1 Household characteristics

Table 4.1 summarizes household characteristics stratified by herd category. Zebu and mixed herds were significantly larger than N'Dama herds. Farm size was lowest for households with Zebu and no cattle and similar between households with mixed, crossbred and N'Dama herds. Food crop species diversity was significantly lower for Zebu herds compared to mixed and crossbred herds. The wealth index was highest for households with mixed herds, followed by those with Zebu, crossbred and N'Dama herds. Households without cattle had the lowest wealth index after households with only oxen. The household dependency ratio was similar between herd categories, with more dependent members than active ones in all herd

categories. The share of households involved in cotton cultivation and those whose household head had an off-farm income was lower for Zebu compared to the others herd categories.

Table 4.1 Means and (standard deviation) of socioeconomic characteristics of surveyed households by herd category

Socioeconomic characteristic	Herd category					
	Zebu N=34	Mixed N=61	Crossbred N=31	N'Dama N=34	Only oxen N=45	No cattle N=53
Cattle (head)	44.2[a]	39.2[a]	36.4[ab]	26,0[b]	2.4[na]	0.0[na]
	(22.2)	(27.2)	(35.3)	(24.5)	(1.1)	(0.0)
Farm size (hectare)	5.2[c]	13.5[a]	13.1[a]	13.2[a]	9.6[b]	6.5[c]
	(4.1)	(10.3)	(8.2)	(6.6)	(5.6)	(4.8)
Food crop species diversity (n)	2.9[b]	3.6[a]	3.6[a]	3.3[ab]	3.6[a]	3.4[ab]
	(1.4)	(1.5)	(1.7)	(1.3)	(1.5)	(1.4)
Wealth index[1]	0.2[b]	0.7[a]	0.3[b]	0.3[b]	-0.4[c]	-0.9[d]
	(0.8)	(1.2)	(0.9)	(0.8)	(0.5)	(0.4)
Household size (number members)	12.4[bc]	16.6[a]	15.3[ab]	15.9[a]	12.3[bc]	9.5[c]
	(7.4)	(9.1)	(7.3)	(6.7)	(4.4)	(3.5)
Dependency ratio[2]	1.1[a]	1.3[a]	1.4[a]	1.4[a]	1.1[a]	1.4[a]
	(0.7)	(0.7)	(0.7)	(0.8)	(0.7)	(1.3)
Cultivation of cotton [+#]	0.2	0.5	0.7	0.6	0.7	0.4
	(0.4)	(0.5)	(0.4)	(0.5)	(0.5)	(0.5)
Education of household head [+#]	0.0	0.2	0.1	0.1	0.2	0.1
	(0.2)	(0.4)	(0.3)	(0.4)	(0.4)	(0.2)
Off-farm income [+#]	0.3	0.5	0.6	0.5	0.5	0.7
	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)	(0.5)

[+]Indicates dummy variables (yes = 1, no = 0).
[1]Based on number of motorcycles, phones, radios, ploughs, total livestock units and total revenue.
[2]Ratio of household members,who are aged 0–14 and above 65 years to the productive age group (15–65 years).
[a,b,c,d] Means within a row with different superscripts differ significantly at P <0.05. (Lsd t-test).
[#]Statistically significant relationship with herd category at P <0.05, (χ2/Fischer's exact test for dummy variables).

4.4.2 Dietary patterns

All households consumed cereals, and most of them also had meals with vegetables during the past 24 hours (Fig. 1). Households differed mostly in their milk consumption and to a lesser extent in their legumes, meat and fruit consumption, depending on the herd categories. Milk consumption clearly depended on herd category: the majority of the households with a Zebu

(97.1%) and mixed herd (80.0%) and half of the households with N'Dama (58.8%) and crossbred herd (54.8%) consumed milk. However, only 35.6% and 24.5% of the households with only oxen and without cattle consumed milk, respectively. Average daily per capita milk consumption was 222, 140, 84, 115, 56 and 57 ml, for Zebu, mixed, crossbred, N'Dama, only oxen and no cattle herd categories (data not shown), respectively. Households without cattle also had the lowest consumption of legumes and fruits. Approximately 80% of the households in all herd groups consumed fish, which was mainly consumed as dried fish. Meat and legume consumption followed the same pattern between herd categories, except for N'Dama. Both were highest for households with mixed herds, and were lowest and similar for households with Zebu, with only oxen and without cattle. Except for the mixed herd category, consumption of fruit, which are a good source of vitamins, was low, particularly for households without cattle. Eggs were not consumed by almost all of the households.

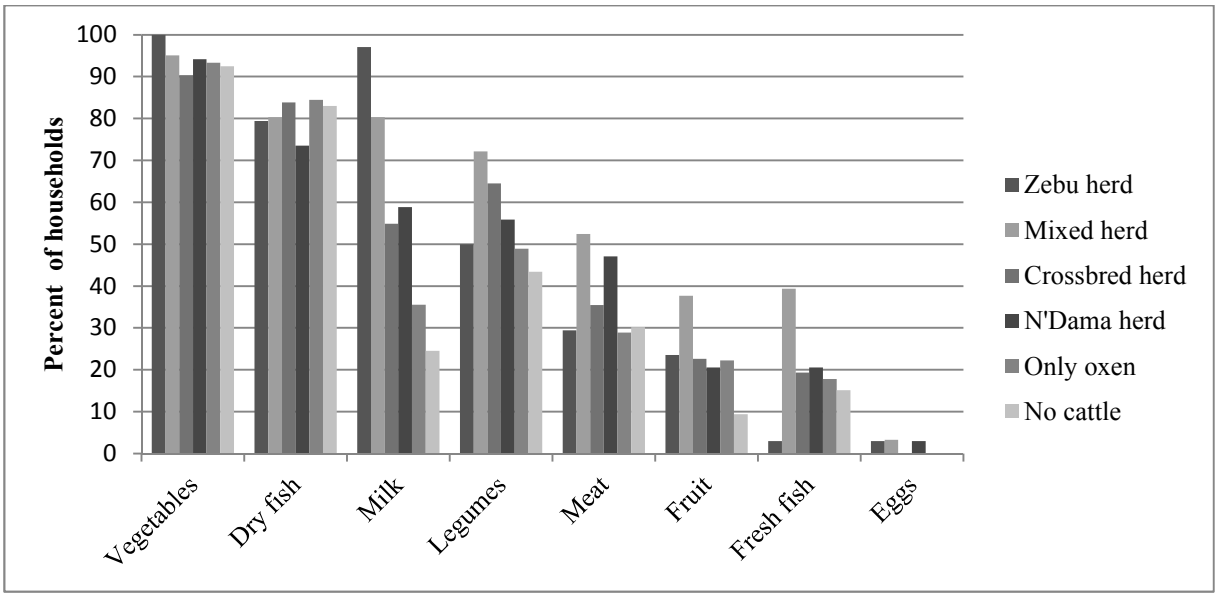

Figure 4.1 Proportion of households that consumed micronutrient rich food groups in the past 24h by herd category

The frequency of consumed ASF for the past seven days is presented in Fig. 2. Herd categories differed mostly in the consumption frequency of milk, fresh fish, beef, the meat of small ruminants and poultry. Households without cattle had the lowest consumption frequency of all these three food groups, which are known to have high protein content and to be rich in vitamins A and B12, calcium, iron and zinc. All milk consumed during the week

before interview by households with Zebu herds originated from their own herds, while 76.5, 73.7 and 78.3% of the households with mixed, crossbred and N'Dama herds which consumed milk, sourced it from their own herd, respectively. Households with only oxen and without cattle consumed milk on average once a week and had to purchase it. Dry fish was consumed more often than fresh fish by all herd categories, and the frequency of consumption of the latter differed between herd categories. Of the households that consumed beef, goat and sheep meat in the week before the interview, 96.9, 97.7 and 100% purchased it, respectively. In contrast, consumed poultry originated mainly from own production (88.5%).

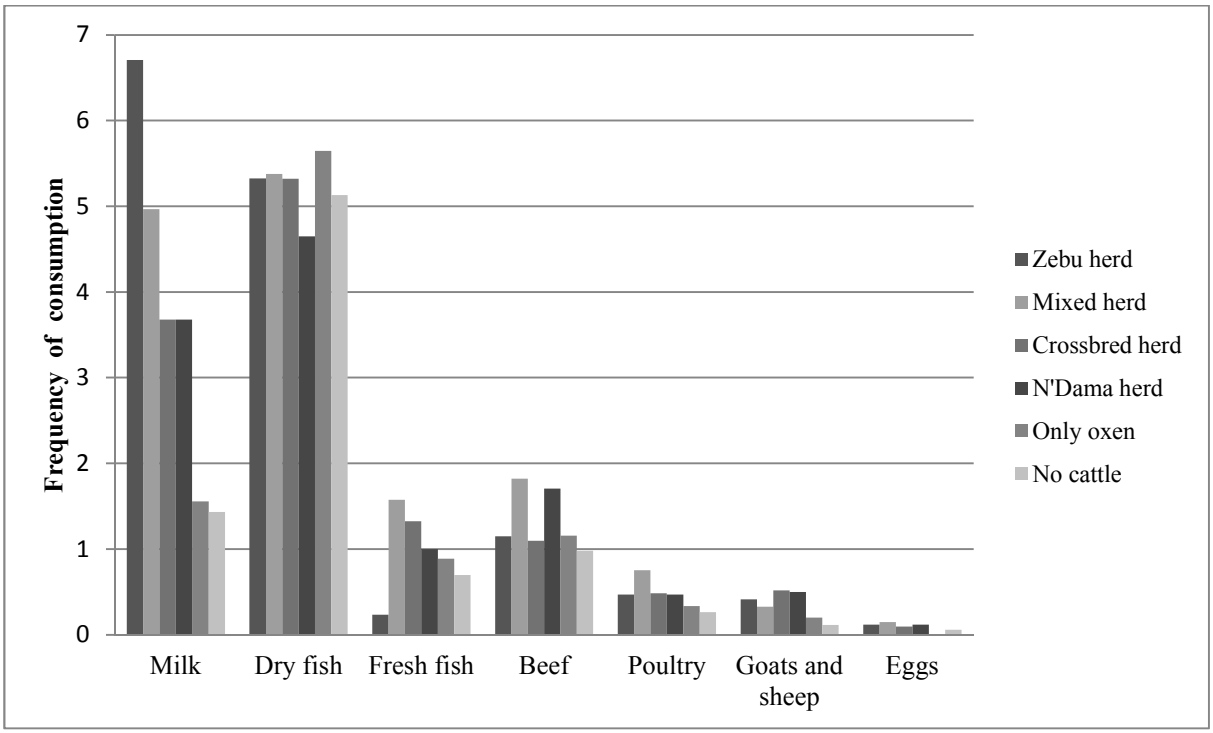

Figure 4.2 Frequency of consumed animal source food in the past seven days by herd category

Study households had a mean HDDS of 7.7 and FCS of 75.7, indicating intakes of good dietary diversity and a high food consumption score. Estimates of factors influencing the two indicators of food security, FCS and HDDS, are presented in Table 4.2. Herd category was a key determinant of FCS, while it was a weak determinant of HDDS. The FCS of the Zebu herd category was 11 scores higher compared to the N'Dama herd and 21 scores higher compared to households without cattle. For HDDS, only households without cattle were significantly different from those with Zebu herds, consuming on average 0.9 food groups

less. Both indicators of food security were significantly and positively associated with the diversity of food crops species cultivated. FCS was significantly associated with the wealth index, while HDDS only had a weak link to wealth. Surprisingly, cultivation of cotton was negatively correlated with HDDS and FCS.

Table 4.2 Regression analysis of determinants of FCS and HDDS

Effect	FCS[1]			HDDS[2]		
	Estimate	SE	P-value	Estimate	SE	P-value
Herd category (ref. = Zebu herd)						
Mixed herd	-3.05	3.70	0.4114	0.52	0.32	0.1002
Crossbred herd	-8.52	4.36	0.0517	0.01	0.37	0.985
N'Dama herd	-11.17	4.17	0.008	-0.11	0.36	0.7505
Only oxen	-18.01	4.13	<.0001	-0.53	0.35	0.1348
No cattle	-20.89	4.06	<.0001	-0.91	0.35	0.0089
Food crop species diversity	1.47	0.73	0.0420	0.29	0.06	<.0001
Wealth index[3]	3.06	1.33	0.0223	0.19	0.11	0.0868
Cultivation of cotton (1: yes)	- 5.13	2.28	0.0256	- 0.52	0.19	0.0086

Estimates were presented only for household characteristics found to satisfy a P<0.1 significance level.
[1]Food consumption score.
[2]Household dietary diversity score.
[3]Based on the number of motorcycles, phones, radios, ploughs, total livestock units and total revenue.

Table 4.3 presents least square means of FCS and HDDS by herd categories, showing how herd categories differ from each other for these two indicators. HDDS was less differentiated among households with a herd, compared to FCS. Households keeping Zebu cattle had higher FCS than those of other herd categories, except for those with mixed herds. Households keeping Zebu and mixed herds had a significantly higher FCS compared to households keeping N'Dama herds, only oxen and without cattle. Considering HDDS among households with a herd, only households with a mixed herd had a significantly higher score than households keeping an N'Dama herd. The non-cattle keepers had the lowest FCS and HDDS.

Table 4.3 Least square means (LSM) and standard errors of FCS and HDDS by herd category

Indicator		Herd category					
		Zebu N=34	Mixed N=61	Crossbred N=31	N'Dama N=34	Only oxen N=45	No cattle N=53
FCS[1]	LSM	86.5[a]	83.5[ab]	78.0[bc]	75.3[cd]	68.5[de]	65.6[e]
	SE	3.5	2.9	3.5	3.4	3.1	3.1
HDDS[2]	LSM	7.9[ab]	8.4[a]	7.9[ab]	7.8[b]	7.3[bc]	7.0[c]
	SE	0.3	0.2	0.3	0.2	0.2	0.2

[abcde]Least square means with different superscripts within variable levels in a row vary significantly ($p < 0.05$). [1]Food consumption score. [2]Household dietary diversity score.

During the lean period (August), a higher proportion of households were affected by different conditions of food insecurity compared to the harvest period (October to November). During the lean period, a large proportion (43.5%) of households had to eat a kind of food they did not like because of a lack of resources or other food; 36.9 % had to reduce the size of their meals; and 20.9% had to reduce the number of meals they had per day. Some households (9.4%) reported going a whole day without food, indicating hunger. Many households either borrowed food (23.5%) or had to take credits to buy food (27.5%), which might put them in permanent indebtedness (data not shown). Households without cattle purchased food on credit the most during the lean period (41.5%), putting them at greater risk of indebtedness. Households without cattle and those with only oxen were most affected by food insecurity conditions compared to households with a herd (Table 4.4).

Table 4.4 Summary of mHFIAS related conditions for the lean period by herd categories

Condition (%)	Herd category					
	Zebu N=34	Mixed N=61	Crossbred N=31	N'Dama N=34	Only oxen N=45	No cattle N=53
Eat a kind of food they do not like	15.2	23.0	41.4	38.2	64.4	71.7
Smaller amount of food per meal	12.1	21.3	37.9	32.4	51.1	60.4
Reduced number of meals per day	0.0	9.8	3.5	14.7	33.3	47.2
Spending the whole day without eating any food	3.0	4.9	0.0	2.9	13.3	24.5
Borrowing food	3.0	11.5	27.6	14.7	35.6	43.4
Purchasing food on credit	3.0	24.6	31.0	23.5	33.3	41.5

Values are given in percentages of households affected.

During the lean period of August, 50.6 % of the study households were food secure, while of those that were food insecure, 7.6% were mildly, 25.4 % were moderately and 16.3% were severely (Table 4.5). Households without cattle had the highest proportion of severe food insecurity (30.2%), followed by households with only oxen (26.7%). Among the households with a cattle herd, those with an N'Dama herd had the highest proportion of severe food insecurity (14.7%).

Table 4.5 HFIAP categories by herd category in the lean period of August

	Herd category						
HFIAP category (%)	Zebu N=34	Mixed N=61	Crossbred N=31	N'Dama N=34	Only oxen N=45	No cattle N=53	All groups N=258
Food secure	81.8	68.9	51.7	52.9	31.1	24.5	50.6
Mildly food insecure	6.1	4.9	10.3	14.7	4.4	3.8	6.7
Moderately food insecure	6.1	16.4	34.5	17.7	37.8	41.5	26.3
Severely food insecure	6.1	9.8	3.5	14.7	26.7	30.2	16.5

Statistically significant relationship between HFIAP categories and herd category; P<.0001 (Fisher's exact test).

An analysis of household food insecurity indicators showed that an increase in the wealth index was significantly associated with a decrease of the mHFIAS score for the harvest period (P=0.0085) as well as the lean period (P=0.0008). An increase of a household's wealth index was also significantly (P=0.0001) associated with a reduced period of food shortage. Furthermore, the herd category had a significant effect on all food insecurity indicators (Table 4.6). In the harvest period, only households without cattle were significantly more food insecure compared to the other herd categories. Households keeping a Zebu herd were significantly less food insecure in the lean period and had a significantly shorter food shortage length compared to the other herd categories. The N'Dama herd category had the highest values for mHFIAS for the lean period and food shortage length among households with a cattle herd. These two indicators were significantly higher for N'Dama and the crossbred compared to the Zebu herd category.

Table 4.6 Least square means (LSMs) and standard errors of mHFIAS and food shortage length by herd category

Food insecurity indicators		Herd category					
		Zebu N=34	Mixed N=61	Crossbred N=31	N'Dama N=34	Only oxen N=45	No cattle N=53
mHFIAS for harvest period[1]	LSM	0.42[a]	0.66[a]	0.75[a]	0.58[a]	0.73[a]	2.27[b]
	SE	0.38	0.3	0.39	0.38	0.33	0.33
mHFIAS for lean period	LSM	0.68[a]	2.04[b]	2.44[b]	2.59[bc]	3.68[cd]	4.23[d]
	SE	0.58	0.47	0.6	0.57	0.51	0.51
Food shortage length[2]	LSM	0.30[a]	0.60[ab]	0.74[bc]	0.84[bc]	1.07[cd]	1.26[d]
	SE	0.17	0.15	0.18	0.17	0.16	0.16

[1]Modified food insecurity access scale (mHFIAS) ranging from 0 to 18 (i.e. the larger the scale, the higher the food insecurity).
[2]Food shortage length in months per year.
[3]Weighted mHFIAS ranging from 0 to 24 based on the severity of indicators.
Least square means with different superscripts within variable levels in a row vary significantly ($p < 0.05$).

4.4.3 Coping strategies during lean period

Fifty-four percent of the households experienced food shortage for at least one month (range 1 to 4 months), of which most (66.4%) experienced one month of food shortage. August was the month in which the largest number of households (51.6%) experienced a food shortage followed by September (12.8%) and July (10.5%). Household coping strategies during the lean period were found to vary among different herd categories as shown in Table 4.7. Households without cattle were the most affected by food shortage (84.9%), followed by the one with only oxen (73.3%). As a result, borrowing cash was found to be the main coping strategy of these two groups, followed by working on other farms as daily labor. For farmers with a cattle herd, selling livestock was the major strategy to ensure food for their families during a food shortage. Farmers with a Zebu herd sold mostly only their cattle, while farmers in other herd categories used more coping strategies besides selling cattle.

Table 4.7 Households' coping strategies by herd category

Coping strategies (%)	Herd category						
	Zebu N=7	Mixed N=21	Crossbred N=16	N'Dama N=17	Only oxen N=33	No cattle N=45	All groups N=139
Borrowing cash	14.3	28.6	31.3	11.8	45.5	33.3	31.6
Selling livestock	85.7	38.1	37.5	58.8	9.1	8.9	26.6
Working on others farms	0.0	0.0	0.0	5.9	12.1	26.7	12.2
Borrowing food	0.0	0.0	18.8	17.7	15.1	4.4	9.4
Off farm activity	0.0	9.5	0.0	0.0	9.1	8.9	6.5
Remittances	0.0	4.8	6.3	0.0	6.1	11.1	6.5
Early growing of crops	0.0	19.0	6.3	5.9	3.0	6.7	7.2
Food shortage[1]	20.6	34.4	54.8	50.0	73.3	84.9	54.3

[1]Proportion of households experiencing a food shortage for at least one month in each herd group.

Statistically significant relationship between coping strategies and herd category; P<.0001 (Fisher's exact test).

4.4.4 Relationship of the indicators

Table 4.8 gives an overview of the Pearson's correlation coefficients between the food security indicators, and also shows which correlations are significant and at which level. HDDS and FCS are negatively correlated with the mHFIAS score and length of food shortage. This is expected since a higher HDDS and FCS indicate better a food security status, while a higher HFIAS score and longer food shortage length means the household is more food insecure. All the correlations between the indicators were significant at the p=0.01 level, except between HDDS and mHFIAS during the harvest period, which was weak and only approaching significance at the 0.1 level.

Table 4.8 Pearson's correlation coefficients for food security indicators

	HDDS	FCS	mHFIAS for lean period	mHFIAS for harvest period	Food shortage length
HDDS	1.00				
FCS	0.76***	1.00			
mHFIAS for lean period	-0.27***	-0.37***	1.00		
mHFIAS for harvest period	-0.12*	-0.19***	0.51***	1.00	
Food shortage length	-0.29***	-0.37***	0.86***	0.37***	1.00

*10 % significance level, **5 % significance level, ***1 % significance level.

4.5 Discussion

This study provides findings on the role of cattle production and keeping different cattle breeds in ensuring a good dietary intake and household food security in southern Mali where the endemic N'Dama cattle is gradually being replaced by Fulani Zebu and their crosses (Traoré et al. 2017).

Cattle production appeared to be an important source of livelihoods for most farmers in the study area and contributed significantly to improved dietary intake and household food security. A positive association between cattle ownership and food security has also been found in other studies across Africa (Desiere et al. 2015; Rawlins et al. 2014). The revealed higher FCS among Zebu cattle and mixed herd keepers compared to N'Dama keepers was mainly explained by their higher milk consumption (Fig. 1). This also coincides with our previous observation (Traoré et al. forthcoming) in which the values of milk consumed and sold, as well as milk offtake per cow, were higher for households keeping Zebu and mixed herds compared to N'Dama and crossbred herds. In addition to the direct contribution of milk for own consumption, higher milk off-take in Zebu and mixed herds might have contributed indirectly to improve food security through the increased daily cash income, which allows households to access a more diversified diet as also reported by Kidoido and Korir (2015). More milk for home consumption and increased income through the sale of animals and milk also resulted in better nutrition in households that upgraded their indigenous goats to crossbreds in the frame of the FARM Africa Goat Improvement Project (Peacock 2008). Moreover, owing to the larger body size of their Zebu and crossbred cattle fetching higher market prices (Traoré et al. forthcoming), Zebu and mixed herd owners would see their purchasing power and food access enhanced compared to households with N'Dama cattle. In addition to milk, the households keeping mixed herds had a higher quality diet through an increased intake of meat (Fig. 1). However, none of the cattle keepers slaughtered cattle at home and, thus, all beef consumed was purchased, suggesting that cattle ownership did not directly increase home consumption of beef, but could improve their access to meat. Regarding the comparison of animal species with respect to their contribution to food security, Romeo et al. (2016) found evidence that poultry had the strongest correlation with household diet diversity followed by goats and sheep, while keeping cattle did not affect diet diversity although associated with more milk consumption. A reason given by the authors was that poultry and small ruminants did not only lead to more meat consumption, but were also

more likely to be sold in order buy more diverse food items. In our study, however, we found cattle keeping to be associated with both milk consumption and dietary diversity, suggesting that cattle ownership could contribute to home milk consumption and dietary diversity through an income effect. During the food shortage period, the higher proportion of severely food insecure households were observed in the N'Dama herd category compared to households with Zebu and crossbred herds (Table 4.5), suggesting that cattle breed had an impact on the food security status of a household. The mHFIAS were more differentiated between the different herd categories during the lean period than during the harvest period (Table 4.6), indicating the seasonal patterns of food insecurity and suggesting a difference in the coping ability of the different herd categories. As also observed in their coping strategy, the Zebu cattle keepers mainly used animal selling as major mechanism to ensure household consumption during the lean period (Table 4.7). The fact that households are increasingly interested in raising Zebu cattle and their crosses (Traoré et al. 2017) could be due to economic reasons and the greater role Zebu cattle plays in ensuring household food security, although endemic N'Dama cattle are more adapted to the local environment through their disease tolerance and hardiness (Grace 2005; Kim et al., 2017). This shows that the non-endemic Zebu cattle and its crosses with the endemic N'Dama breed are the most suitable breed groups to improve food security. Under the aspect of food security, the keeping and thus conservation of the endemic breed is not justifiable unless large investments from governmental or non-governmental bodies would enable the genetic improvement of milk and growth performances of the N'Dama cattle as proposed by Traoré et al. (2017).

Cereals and vegetables were the common food groups consumed by the majority of the surveyed households, as also shown by other studies in the region (Hatløy et al. 2000; Torheim et al. 2004). Dried fish was a frequently used source of animal protein since it was cheap and easy to store; indeed, dried fish was by far the main source of ASF protein for households without cattle, households that were also the poorest (Table 4.1). Although dried fish contributed to increasing food security indicators, i.e. HDDS and FCS, in this study, the small quantity consumed (1kg/week/household) might not alone provide the household members with the adequate amount of protein and micronutrients. However, this could not be determined in the frame of our study. In our study, ethnicity is likely to have affected household diet as dietary patterns often follow well-established local cultural codes (Sougou and Boëtsch 2016). On the one hand, Zebu keeping households who were mainly Fulani consumed milk on a daily basis (Fig. 2); households with a mixed herd of similar size who

were mainly Bambara consumed milk on average five days a week. On the other hand, Zebu keeping households diet included less legumes, meat and fruit (Fig. 1) in their diet compared to households keeping a mixed herd. The almost non-existing egg consumption observed was due to the low egg production of the local hens, which were reserved for brooding, as also found in a study in central Mali by Kuit et al. (1986). We observed a higher average HDDS (7.7) compared to a previous report of 5.9 food groups from the same study area (Dury and Bocoum 2012). The higher HDDS in our study could be attributed to the interview period that took place during the harvest season, during which households' diet diversity may be above the annual average. In particular, the diversity of plant source foods consumed from their own farms, such as cereals, pulses, vegetables and fruits, would be expected to increase in this season.

In our study, HDDS and FCS were positively associated with the diversity of food crop species cultivated. Similarly, a wider variety of crops planted were also found to be associated with higher food diversity in Malawi (Jones et al. 2014) and in a study based on household-level data from Indonesia, Kenya, Ethiopia, and Malawi (Sibhatu et al. 2015). In general, increasing crop diversity grown on their own farms is the most feasible strategy to improving dietary diversity and nutrient intake for the majority of rural households that consume legumes, vegetables and fruits. Homestead production of fruits and vegetables thus provides the households with important nutrients that may not be readily available otherwise or within their economic reach. Cotton cultivation, despite being an important source of income that could be expended on food items, was found to disfavour the food security status of households. This is in line with the result of a study carried out by DNSI (2007), which showed that cotton producers had the highest poverty rate (77.8%) in the Sikasso region compared to 47.4% for other farmers. It supports the so-called "Sikasso paradoxe" situation in which poverty rates are unexpectedly high in a fertile region dominated by cash crop production (Eozenou et al. 2013). Indeed, Delarue et al. (2009) noted that cotton generates a low profit, especially for the smallest producers, and that the main reason for continuing cotton cultivation was access to credit and inputs as a member of the cotton cooperative. Anderman et al. (2014) also found a negative relationship between the extent of cash crop farming and food security in Ghana. mHFIAS and food shortage length (Table 4.6) were not affected by crop diversity or cotton cultivation unlike the other food security indicators (FCS and HDDS). This might be explained by the fact that mHFIAS and food shortage length reflect to a greater extent a situation of insufficient access to food during an extended time

period than diet diversity, which gives a snapshot of consumption information. In fact, mHFIAS and food shortage length were more affected by household wealth than HDDS. Like herd category, household wealth was found to be associated with all indicators of food security. The wealth index had a significant and positive effect on FCS, but the effect was insignificant on HDDS (Table 4.2). The most probable explanation is that higher FCS mirrors consumption of more nutrient dense food such as meat and milk, which are also more affordable for richer households if not produced on the farm. Therefore, FCS better reflects the monetary value of the food consumed by a household compared to HDDS.

In our study, no significant associations were found between the indicators of food security and the household dependency ratio, as well as the education level of the household head. This is unlike the findings of Eozenou et al. (2013) for Mali and De Cock et al. (2013) for South Africa, which showed that food insecure households had a higher dependency ratio and were more likely to have a household head with no primary education. The reason may lie in the low variation of education level of household heads and the dependency ratio, in spite of considerable variation in household sizes found in our study. In addition, Torheim et al. (2004) did not find any significant relationship between the dependency ratio and HDDS in rural Mali. Households without cattle and with only oxen had detrimental coping strategies, such as borrowing cash and working on other farms. Working on other farms decreases labor available for their own farm and may weaken their ability to produce enough food, while taking credits increases the risk of poor households being trapped in permanent indebtedness, which might result in a vicious cycle of food insecurity (Maxwell 1996). Cattle ownership seems to have a stabilizing effect on household food security status.

The strong correlation (0.74) between FCS and HDDS found in this study was similar to the value (0.73) found by Kennedy et al. (2010) in Burkina Faso. We found also that FCS displayed higher correlation coefficients with other food security indicators (mHFIAS; length of food shortage) compared to HDDS, which was in line with Kennedy et al. (2010). The high correlation coefficients between HDDS and FCS and between mHFIAS for the lean period and the food shortage length (Table 4.8) showed good agreement between these indicators and thus validates their use as food security (HDDS and FCS) and insecurity (mHFIAS for the lean period and the food shortage length) measurements. The lower correlations between indicators of diet diversity (HDDS and FCS) and indicators of food access and availability

(mHFIAS and the food shortage length) may indicate complementarity of these different indicators, thus enriching information on food security.

FCS was a better indicator than HDDS when assessing the special contribution of livestock, since it is not only based on dietary diversity but also takes into account consumption frequency and the relative nutritional value of different food groups, for which animal source food has the highest weight (World Food Programme 2008). Thus, FCS is more sensitive to dietary quality such as the intake of animal source foods compared to HDDS, which is a better measure of household access to food and dietary diversity. Measuring FCS is, however, slightly more time demanding as it poses a recall burden on the respondents during data collection due to its longer reference period and integration of consumption frequency (Kennedy et al. 2010).

4.6 Conclusion

Cattle ownership, breed group, diversity of food crops cultivated and household wealth were important determinants of food security. Households keeping Zebu cattle and mixed herds had the highest diet diversity. Zebu cattle ownership had the strongest impact on food access, reducing household food insecurity, especially during the lean period. FCS provides a more fair representation of households' food consumption than HDDS, especially when assessing the contribution of livestock to dietary quality. In general, our results show that the ongoing replacement of native N'Dama cattle by Zebu cattle and their crosses is contributing to improved household food security. However, since cause-effect relationships could not be established, our results may also reflect the fact that only more food secure households shift and profit from higher yielding Zebu and crossbred cattle.

4.7 Acknowledgements

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5 GENERAL DISCUSSION

The N'Dama breed, which is endemic in West Africa, is an internationally striking example of an important genetic resource that has unique features in terms of trypanosomiasis tolerance. Therefore, many international projects have already been undertaken to research this breed and promote it. However, for decades now the N'Dama breed has increasingly been replaced and crossbred with the larger and more milk yielding Fulani Zebu cattle. This suggests that farmers might gain from the introduction of Fulani Zebu cattle.

The main objective of the study was to evaluate and compare N'Dama cattle with Fulani Zebu and their crossbreds, based on their performance, and contribution to household economic benefits and food security, taking into account the production environment and farmer breeding strategies. In order to achieve our main objective, the following research questions were investigated:

(1) What are the production objectives, trait and breed preferences of farmers keeping N'Dama, Fulani Zebu and crossbred cattle in southern Mali? Which household and farm characteristics affect these preferences?
(2) What are the productive and economic performances of N'Dama cattle, Fulani Zebu cattle and their crossbreds?
(3) What are the comparative advantages of these breed groups for which type of farmers?
(4) What is the contribution of different cattle breed groups to household food security?

This chapter starts with the discussion on the main findings of the three publications in the general study context (Chapter 5.1 to 5.4). Then, potentials and limitations of the applied methodological approaches are discussed (Chapter 5.5) and general conclusions are drawn regarding the general objective (Chapter 5.6).

5.1 Breeds and productive performance

Zebu cattle were ranked highest in this study and preferred for milk yield, body size and ease of handling (Section 2.4.4), similar to the findings of Jabbar and Diedhiou (2003). This was concordant with the significantly higher reported milk offtake in herds composed mainly of the Zebu breed (Section 3.4.3.2). N'Dama is recognized as a beef breed, while Fulani Zebu as

a dual purpose breed for meat and milk production (Payne and Hodges, 1997). Zebu and herds of mixed breed composition had significantly higher milk offtake per cow with 1.6 and 1.4 liters respectively, compared to N'Dama herds (1.1 liters) (Section 3.4.3.2). The milk offtake per cow for herds dominated by crossbreds and N'Dama were similar, although crossbreds' milk yield was perceived as higher than N'Dama cattle by farmers (Section 2.4.4). The reported high market price for crossbreds and the fact that body size was the most valued trait of crossbreds (Section 2.4.4) indicated their suitability for beef production. The higher calving rate found for Fulani Zebu (69%) and crossbred herds (74%) compared to N'Dama herds (60%) (3.4.3.2), was in contrast to the higher calving rate in N'Dama (83%) compared to Zebu (60%) found by Sokouri et al. (2010) in Côte d'Ivoire. The absence of breeding bulls in 32% of the N'Dama herds might partly explain the low calving rate and consequently low offtake rate in N'Dama herds in the present study.

The farmers' perception that the N'Dama breed has a good ability to cope with a reduced quantity and quality of forage during the dry season (Section 2.4.4) was consistent with this breed's higher body condition score compared to the Zebu and crossbred cattle (Section 3.4.3.1). These results are in line with the finding of de Jode (1989), which found that farmers appreciated the N'Dama cattle for its reduced weight loss during the dry season. The non-selective grazing behavior of N'Dama, also reported by de Jode (1989), might contribute to the breed's higher body condition score and its ability to maintain body weight during the dry season. As presented in section 2.2.4, preferences for the N'Dama breed were explained mainly by their resistance to diseases, while disease susceptibility was reported by farmers as the main weakness of Zebu. The superiority of the N'Dama in terms of disease tolerance and resistance over the Zebu was also demonstrated in many trials in West Africa (Murray et al., 1991; Dwinger et al., 1992). More recent findings based on genome sequencing confirm the superior ability of N'Dama to maintain body weight and resist apathy and emaciation following trypanosome infection (Kim et al., 2017). Considering that the lack of pasture and diseases were identified by farmers as the main risks during the dry and rainy season, respectively (own unpublished result), the N'Dama cattle, due to its hardiness, remain a valuable breed for poor farmers with a limited capacity to improve feeding and ensure full trypanosomiasis prevention in the study area.

5.2 Breeds and economic performance

Crossbreds were kept mainly for the sale of live animals, as body size was ranked by farmers as their most important attribute, while high market prices were reported as the main reason for their preference (section 2.4.4; Jabbar and Diedhiou, 2003). This can clearly be seen in Chapter 3, which shows higher off-take rates and revenues from selling cattle in the crossbred herd category. Similar to crossbred cattle, reasons given by farmers for preferring Zebu were high market values, large body sizes and high milk yields (Table 2.6). Zebu and crossbred cattle with a higher market price (Figure 3.2) proved to be more suitable than N'Dama cattle for settled transhumant farmers for whom raising cattle is the main source of cash income. Settled transhumants were from the Fulani ethnicity and have a long tradition of cattle breeding (Boutrais, 2007), with some cropping on smaller areas. In contrast, local farmers were mainly from the Bambara ethnic group. Their primary income activity was crop production and they mainly kept cattle as a secondary activity. They traditionally raised N'Dama cattle, but were increasingly shifting to crossbreds and Zebu, building herds of mixed breed composition (Section 2.4.4). Among local farmers, some are more market-oriented, especially those keeping crossbred herds, as suggested by the higher offtake rate in this herd category. Cattle production was found to contribute 20.3% of sedentary local farmers' total revenue (including off-farm incomes and remittances), while contributing 81.6% of settled transhumant farmers' total revenue (own unpublished result). Alary and Dieye (2006) reported similar figures for rural households in mixed crop-livestock and pastoral systems in Mali. The N'Dama breed seems favorable for sedentary local farmers for whom traction and manure are among the most important production objectives for keeping cattle (Chapter 2), and who are used to the less docile character of this breed (Jabbar and Diedhiou, 2003). This is reflected in the higher non-market values compared to the alternatively available breed groups (Chapter 3).

The importance of the non-market value for cattle production systems in the study area is shown in Chapter 3. When only cash benefits are taken into consideration, Zebu, crossbred and herds of mixed breed composition have a clear advantage over the N'Dama cattle. When, however, non-market benefits such as manure, draught power and change in stock value are also taken into account, net benefits per cattle and benefit-cost ratio including non-monetary value (BCR2) were similar between herds with different breeds (tables 3.6 and 3.7). Therefore, N'Dama cattle herds were still efficient when considering their non-market value,

even though about 59% of N'Dama herds had negative gross margins. With the ongoing transition from a subsistence-oriented production system towards a more market-oriented system, the importance of cash revenue is expected to increase, as well as the importance of performance traits for farmers, making the Zebu and crossbred more attractive to the farmer. Furthermore, in the assessment of the economic performance, it is important to consider that the cattle offtake rate was the strongest determinant of gross margin for all of the herd categories (Table 3.8).

In the study area, farmers perceived trypanosomiasis as the main disease affecting their herd, and its treatment represented 65% of the total health cost. Farmers applied preventive treatments, irrespective of the breed they kept. This is reflected by similar costs per cattle for preventive trypanosomiasis treatment and general preventive treatments between herd categories (Section 3.4.4.2). Corsius (2012) also noted that farmers gave a similar number of preventive treatments to the N'Dama, crossbred and Zebu, even if the N'Dama were trypanotolerant. Therefore, farmers keeping the N'Dama breed did not take advantage by substantially decreasing the cost for animal health. However, given that Zebu herds are larger and that certain costs like paying for veterinary visits are fixed, cost per cattle was reduced in Zebu herds. Although trypanotolerant cattle such as N'Dama can survive without regular treatment, strategic treatment occasionally with trypanocidal drugs can improve their productivity and thus be economically well founded, as discovered by Karbe and Freitas (1981) in Togo. Trypanocidal drugs are easily available and affordable for many farmers in SSA (Clausen et al., 2010).

Regarding the replacement of the endemic cattle breed, Eisler et al. (2014) argued that the additional cost of drugs necessary for the survival of larger exotic cattle, or Zebu breeds in tsetse infected areas of West Africa, often outweighs the increase in revenue due to their higher output. We could not find support for this (Section 3.4.4.2): unless misguided, farmers do not take the risk of changing their breed unless the prospect of a better income is substantiated. This is reflected in the higher gross margins per farm and cattle of farmers keeping crossbreds, than of those raising N'Dama cattle (Section 3.4.4). For crossbred herds, the gross margins per cattle even rose with increasing preventive treatments and thus so did veterinary costs (Table 2.8). The perceived improved resistance to disease, low raising costs (Section 2.4.4) and calculated lower costs for curative treatment and feed supplementation (Section 3.4.4.2) of the N'Dama breed can be considered as advantageous for poor livestock

keepers with limited capital to invest in better feeding and health care. Therefore, the trend toward more crossbreeding, although benefiting most farmers, might not bring benefits for the poorest cattle keepers, who consequently stay with N'Dama as long as it is available in the area. However, as long as no efforts are made for maintaining or improving the genetic quality of N'Dama, access to good quality N'Dama bulls will fall short as a consequence of advancing crossbreeding.

The better taste of N'Dama milk and meat, compared to Zebu, was reported during the group discussions. Farmers agreed in seven out of the eight focus group discussions that N'Dama milk tastes better, while only one group did not perceive any difference in taste. For meat, farmers agreed on the superior taste of N'Dama meat in four of the groups, one group did not experience any difference, and three did not know (own unpublished result). In a study carried out by de Jode (1989) in Nigeria, farmers also mentioned better quality milk and meat among the advantages of the N'Dama compared to Zebu cattle. The better taste of N'Dama milk might be linked to its higher fat content (6.5-7%) compared to Zebu milk (average 4.8%) (Payne, 1970). The better taste of its meat might be associated with higher intramuscular fat, which is responsible for the juiciness and flavor of meat and a recognized feature of most taurine breeds (Strydom et al., 2011). These special characteristics, if properly labeled and marketed, e.g., through cooperatives, could add value to the N'Dama cattle (Kocho et al., 2011; Papachristoforou et al., 2013). The potential to use N'Dama products as niche products needs to be further researched; special characteristics of its milk and meat quality will require further investigation. Exploitation of these qualities, however, will depend on opening reliable market channels for these products, which does not seem in reach under the current conditions. Without heavy investments from governmental or non-governmental institutions in the conservation and improvement of the N'Dama, farmers will further follow their economic interests and replace N'Dama by Fulani Zebu and their crossbreds.

5.3 Breeds and food security

The link between raising cattle and household food security is multiple. Households with a cattle herd had direct access to milk for home consumption (Chapter 4; Rawlins et al., 2014), which can particularly benefit children's nutritional intake and development (Hitchings, 1982). Households keeping the Zebu breed or a mixed herd consumed more milk (Chapter 4) as Zebu cows gave higher milk yields (Chapter 3). Indeed, the average daily per capita milk

consumption varied considerably, with 222, 135, 73, 103, 51 and 33 ml, for farms with Zebu, mixed herds, crossbreds, N'Dama, only owing oxen and without cattle at all categories, respectively (Section 4.5.2) as being determined by significant differences in the daily milk offtake per milked cow between the herd categories during the wet season (Section 3.4.3.2). Cattle ownership did not affect home consumption of beef, however: only 7% of the households with a herd slaughtered cattle during a whole year (Chapter 3). Farmers' production objectives indicated that milk was used for home consumption as a first priority and then for selling as a second priority (Chapter 2). This was confirmed by the higher value of milk consumed at home compared to milk sold (Section 3.4.4). Furthermore, households with Zebu and mixed herds had a higher cash revenue from surplus milk sales (Section 3.4.4) and also had more diverse diets. Therefore, we infer that cash income generated by milk sales contributed to diversifying household diets, as observed by Kidoido and Korir (2015) in Tanzania. Our results suggest that cattle ownership has a stabilizing effect on household food security, as selling livestock was the major coping strategy during food shortage periods for households with a cattle herd (Chapter 4). In contrast, households without cattle were strongly affected by food shortages (84.9%) during the lean period and had to rely on detrimental coping strategies, such as borrowing cash. This is in agreement with the important role of cattle within savings and insurance (Chapter 2; Romeo et al., 2016).

5.4 Trends in breed and trait preferences and implications for breeding strategies

In our study, about 77% of the local sedentary farmers included Zebu or crossbreds in their N'Dama herd over the past three decades, suggesting a poor attachment to their traditionally kept N'Dama breed, which could justify its conservation, and indicating a strong trend away from smaller trypanotolerant N'Dama and toward the Fulani Zebu and crossbreds (Section 2.4.4). In contrast, only 30% of the settled transhumant farmers altered the breed composition of their Zebu herd by introducing some N'Dama and crossbreds, to increase disease resistance. The fact that settled transhumant farmers do not systematically crossbreed their Zebu cattle with the N'Dama indicates that their Zebu breed can well adapt to the study area. In addition, Boutrais (2007) noted in Burkina Faso that settled transhumant farmers avoided crossbreeding their Zebu cattle with the smaller trypanotolerant cattle, except when they noticed that their cattle could not survive in a new environment. We found a contradiction with respect to farmers' stated intentions and their actual behavior: out of 41 local farmers

who expressed their will to raise N'Dama cattle in the future, more than half had already changed their breed for crossbreds at the time of our survey. Their stated intentions might have been biased through the collaboration of the researcher with the PROGEBE project, with farmers expecting to get some benefits if they displayed a preference for the breed PROGEBE is working on.

Farmers with larger herd sizes tend even more to change their endemic breed for the higher performing Zebu cattle. Breed performance becomes more important the more farmers rely on their livestock rather than on cropping as a source of livelihood. The percentage of non-N'Dama cattle was far higher in the study area at the time of our survey in 2013, than that reported in the International Livestock Research Institute (ILRI) baseline survey conducted in 2009 (ILRI, 2010); we found a proportion of up to 50% compared to the 17% estimate given by ILRI. Crossbreeding N'Dama and Zebu cattle is a general trend in West Africa. However, the extent to which the current N'Dama population is affected by crossbreeding in Mali as well as in West Africa as a whole is not known since no statistics regarding the current population of N'Dama exist. The shift away from the trypanotolerant N'Dama breed in southern Mali is consistent with the trends reported from south-western Nigeria for the trypanotolerant Muturu breed (Jabbar and Diedhiou, 2003) and northern Côte d'Ivoire for the N'Dama and Baoulé breed (Sokouri et al., 2009).

Farmers' ethnicity and cultural background had a significant effect on the ranking of cattle trait preferences (Table 2.3). However, both local Bambara farmers and settled Fulani transhumants had clear preferences for productive traits, such as a large body size, high fertility and high milk yield over adaptive traits such as disease resistance, which was ranked least important by Fulani settled transhumants (Section 2.4.3). On the contrary, Tano et al. (2003) discovered more than a decade ago that disease resistance was among the most important traits, while body size was among the traits ranked lowest in southern Burkina Faso, which might indicate a change in trait preferences over time in the region. This change in trait preference could also partly be explained by the lower prevalence of tsetse flies in the study area (Bocoum et al., 2012) and the widespread use of subsidized trypanocidal drugs (Grace et al., 2009). The decreased prevalence of tsetse flies is mainly due to the expansion of agriculture and use of pesticides, especially for cotton production (Thévenon and Belemsaga, 2005). The strongest decrease in trypanosomiasis prevalence is projected to take place in the semi-arid and sub-humid zones of West Africa, where the climate is forecast to become more

arid and the human population to increase, while trypanosomiasis pressure in the humid zone of central and western Africa is projected to be less affected (McDermott et al., 2006). Additionally, control of tsetse flies is a priority of the African states that implemented programs such as the Pan-African Tsetse and Trypanosomiasis Eradication Campaign (PATTEC) (Thévenon and Belemsaga, 2005). With disease resistance becoming less relevant for farmers in West Africa, there will be less incentive for them to raise N'Dama in the future. As pointed out by Clausen et al. (2010), although raising trypanotolerant cattle might be a sustainable trypanosomiasis management strategy, farmers' preference for Zebu and crossbreds, for reasons which are independent of animal health, suggests that the genetic erosion of the N'Dama breed will continue. This forecast is confirmed by the results of our research. The lower preference of farmers for the N'Dama breed compared to crossbreds implies that there are not many prospects to ensuring its maintenance by farmers in the study area. Farmers in West-Africa are, however, facing the development of widespread resistance against trypanocidal drugs, while efforts to promote rational drug use are facing many constraints (Clausen et al., 2010). This means that the N'Dama could still be a valuable cattle breed for controlling trypanosomiasis in the future, given the long-term economic costs of trypanocidal drug resistance.

It is obvious that there is a trade-off between the long-term objective, formulated at national or international level regarding biodiversity conservation and N'Dama genetic improvement, and the farmers' desire for short-term benefits, best achieved through crossbreeding even if the possible productivity increase might not be sustainable. This could be addressed by regulations and incentives for farmers to participate in a breeding program.

A major breeding program was set up for the N'Dama cattle at the Madina Diassa selection ranch (ONDY) and achieved encouraging results regarding the growth performance of the breed (own data not shown). Following the gradual cessation of external financing in the early '90s and the high maintenance costs of the selection ranch, it was decided that the nucleus herds be transposed in a village setting in order to start an open selection scheme. The reduced level of support and follow-up has led to a decrease in the interest of breeders and the gains obtained by the selection were quickly lost (Ministère de l'Elevage et de la Pêche, 2009; own data not shown). This experience illustrates the need for careful planning and long-term organization, as well as the involvement of farmers from the start and continuous national government commitment for a breeding program to have any impact on breed improvement.

The clear preference for crossbreds in our study stresses the need to design a breeding program, which does not only focus on N'Dama pure breeding, but includes crossbreeding as a breeding strategy (Leroy et al., 2016). This would additionally contribute to the conservation of N'Dama cattle through its use as crossbreeding partners for the Fulani Zebu (Valle Zárate, 1996). Possible ways to undertake this are proposed by Traoré et al. (2017).

5.5 Methodological approach

5.5.1 Sampling and data collection methods

A limitation of the sampling was that we used a purposive selection of the villages in our study area. Therefore, the results should be carefully interpreted. However, regarding the distribution of the cattle breeds, our sampling was representative for the study area, as revealed from our preliminary investigation, which involved collecting a list of the households that included information on the main breed kept (own data not shown). We considered a possible confounding effect between the farmer group and herd category, but still all herd categories were present in both farmer groups. As local farmers and settled transhumant farmers differ in their production objective (Chapter 2), comparison of herd economic performance and household food security between Zebu herds and the other herd categories should be conducted carefully.

In addition to the household survey, the visits of the herd, in the frame of the herd surveys allowed to crosscheck the breed and herd inventory given by the household head. This was particularly important given that the breed composition of the herd reported during the household interviews usually differed from that observed by the main author. This might explain the higher proportion of crossbreds and Fulani Zebu found in this study compared to the result of the ILRI baseline survey conducted in 2009 (ILRI, 2010).

Because of the length of the questionnaire and the inclusion of a herd survey, the use of different enumerators in this research was required. Uniformity might have been affected in the way the questions were asked and thus, the respondents' response, thereby creating a potential source of variation in the data.

5.5.2 Determination of farmer preferences

Ranking procedures were applied to assess farmers' production objectives, traits and breed preferences (Chapter 2). Rankings and ratings have often been used to measure farmers' preferences for livestock breeds and traits (Bebe et al., 2003; Ndumu et al., 2006). The ranking technique is argued to have a higher reliability and validity compared to rating (Russel and Gray, 1994). As stated by Markemann and Valle Zárate (2010), the ranking method is similar to a purchase decision in which one option is placed above the other options. The advantage of ranking over scoring is that farmers can more easily state if one item is better or worse, or more or less important, than another item, which facilitates the process of data collection. However, ranking does not indicate the strength of the preference of one item and items can only be interpreted in relation to each other (Abeyasekera, 2001; Russel and Gray, 1994). Farmers' stated preference, especially regarding the breed, might have been biased through the collaboration of the researcher with the PROGEBE project, which aims to conserve and improve the productivity of the N'Dama cattle.

5.5.3 Assessment of cattle performance traits

Regarding the assessment of performance traits at the herd level, information was mainly given by the household head, which was not always the one involved in the daily care of the herd. The progeny history of the selected cow was in some cases difficult to reconstitute due to a change in herder or in the family member assigned to take care of the herd. A limitation could have been that the productive and reproductive herd performance data were collected via a retrospective survey in which cattle keepers were asked to recall events over a one year time period. Lesnoff (2009) suggested to carefully interpret results of retrospective surveys given possible recall errors, but noted that biological data in the case of cattle was less biased compared to small ruminants because of their slower demographic turnover. Nonetheless, the productive performances of cattle reported in the current study are comparable with other findings from West Africa (Ba et al., 2011; Sokouri et al., 2009), thereby stressing the reliability of the findings.

5.5.4 Economic assessment of cattle production

The values of respective market and non-market benefits for the N'Dama, crossbred and mixed herds (Section 3.4.4.1) were in line with farmers' ranking of production objectives for

local farmers (Section 2.4.2), with considerable economic weight for insurance and financing benefits and draught power. However, the importance of cash revenue (50% of total benefit) from cattle sale in Zebu herd were not reflected in the production objective ranking of settled transhumant farmers in which the sale of cattle did not differ from draught power or manure. The reason for this inconsistency could not be clarified. An explanation could be that the production objectives saving and sale of cattle were not well understood and distinguished by all farmers.

The data necessary to assess the economic performances of the cattle herd were collected retrospectively for the previous 12 months before the interviews were conducted, so imprecisions could have occurred given that farmers did not keep a record of their expenses or revenues from selling cattle or milk.

5.5.5 Determination of food security

In this study, both the indicator of food security from the HDDS based on a 24 hour recall of the food consumed and the FCS based on a seven day food recall were used (Kennedy et al., 2010). The 24 hour and seven day recall were carried out with the household head's wife, since women were better aware of the food items consumed by the whole household. This also avoided taking up additional time and concentration of the household head, and, therefore, reduced the risk of getting an inaccurate answer. Furthermore, asking a male household head could lead to a measurement bias, given that his diet likely differs from that of other household members, and he might want to give the impression that he could provide well for his family. Over or under-measurements because of the incapacity to recall exactly what was eaten might also have led to important biases. Furthermore, a more in depth survey on food security should take into account individual consumption to capture the intra-household patterns of food consumption.

In comparison to measuring direct caloric intake, HDDS and FCS indicate nutritional quality and adequacy (Goshu et al., 2013; Torheim et al., 2004), as well as access and the economic capacity of households to have a diversified diet (Hoddinot and Yohannes, 2002). Our results indicated that FCS was a better indicator than HDDS when assessing the special contribution of livestock, since it takes into account consumption frequency and the relative nutritional value of different food groups, for which animal source food has the highest weight (World Food Programme, 2008). Thus, FCS is more sensitive to dietary quality such as the intake of

animal source foods compared to HDDS. Measuring FCS is, however, slightly more time demanding, due to its longer reference period and the integration of the consumption frequency, but it provides a more complete picture of consumption (Kennedy et al., 2010). The use of both indicators in our survey has been resource consuming. For the purpose of this study, the use of HDDS unnecessarily increased the time burden of both the interviewer and respondents.

Seasonality is of very high importance for diet diversity as it influences the availability of and access to food items. The 24 hour and seven day recall interviews took place only in the harvest season, during which own farm crop production and first income from selling crops are available. Thus, the results of the food security indicators were positively influenced by the time of data collection. This was a limitation in our study: the initial planned data collection during the period of food shortage was impossible given impracticable road conditions at the corresponding peak of the rainy season. Seasonal patterns of food insecurity were only captured for the mHFIAS, which was assessed for the past 30 days before the interviews, still in the harvest periods and retrospectively for the month of August considered as the peak of food shortage. Thus, mHFIAS was very useful for our study since it gave valuable complementary information.

5.6 General conclusions

Farmers' preferences for cattle traits and breeds were found to be diverse, reflecting their multiple production objectives, which were linked to their ethnicity and cultural background. Crossbreds were, in general, the favored breed group due to their combination of adaptive and productive traits. Based on the economic valuation of the N'Dama cattle, better resistance to disease did not confer it much advantage regarding veterinary costs compared to Fulani Zebu or the crossbred breed group. Gross margin and the benefit-cost ratio revealed higher profitability and efficiency for households keeping Fulani Zebu and crossbreds. When non-market benefits were included, economic performances between the breeds were similar, as shown by the similar net benefit per cattle. Fulani Zebu and the crossbreed were found to be the most favorable options for market-oriented local and settled transhumant farmers under the prevalent conditions of low tsetse challenge. Fulani Zebu and mixed herd ownership had the most compelling effects on households' diet diversity and the strongest impact on reducing household food insecurity. Therefore, the shift to crossbred and Zebu cattle could

contribute to improved household food security directly through higher milk yield and higher milk consumption and indirectly through higher revenues, increasing financial access to food.

N'Dama cattle remain a valuable breed for poor subsistence-oriented local farmers due to its hardiness. However, unless the national governments or the international community invests in the genetic improvement of the endemic breed, local farmers will follow their obvious economic interests and further replace the endemic N'Dama breed by, for example, Zebu and crossbred cattle. In light of our results, efforts that aim to promote the use of the endemic N'Dama cattle will need to consider farmer production objectives and trait preferences, as well as the production environment. Farmers should be provided with adequate information about the effects of indiscriminate crossbreeding, especially the possible loss of adaptive traits, and researchers should consider farmers' experience in crossbreeding in order to support them in taking advantage of all available animal genetic resources. If well organized, crossbreeding could be an opportunity for farmers to improve their livelihoods and thereby maintaining the locally adapted N'Dama breed. Further research is required in order to investigate possible ways of optimizing and organizing the ongoing process of crossbreeding between N'Dama and Fulani Zebu cattle, and this should include a more systematic crossbreeding and selection program in line with farmers' interests.

5.7 References

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6 GENERAL SUMMARY

In recent decades, there has been a rapid shift in livestock breeds used in developing countries due to global drivers, such as an increasing demand for livestock products and market-oriented production, as well as technological and environmental changes. Local breeds are increasingly being replaced by exotic breeds, leading to a loss of genetic resources. The introduction of more productive but less adapted exotic livestock breeds might offer opportunities. However, it may also pose threats to the livelihoods of poor farmers. In southern Mali, where cattle play an important role in the livelihoods of rural households, the endemic trypanotolerant N'Dama cattle, which had been the only breed present in this area for long time, are increasingly replaced and crossbred with the larger and more milk yielding trypano-susceptible Fulani Zebu. Thus, the N'Dama cattle face serious threats of genetic erosion, despite their adaptive attributes. A systematic comparison of the endemic N'Dama cattle, Fulani Zebu cattle and their crosses under the same farming conditions in western Africa is required to reveal whether farmers benefit from the introduction of Fulani Zebu cattle or are negatively affected by the replacement of N'Dama purebreds.

The overall objective of the study was, therefore, to evaluate and compare N'Dama cattle with Fulani Zebu and their crossbreds based on their performance and contribution to household economic benefits and food security, taking into account the production environment and farmer breeding strategies. Specific objectives were (i) to investigate the production objectives and trait and breed preferences of cattle keepers; (ii) to evaluate and compare the productive and economic performances of N'Dama cattle, Fulani Zebu cattle and their crossbreds in order to assess the comparative advantages of these breed groups for farmers; and (iii) to examine households' food security and coping strategies, with a particular emphasis on the contribution of different cattle breeds.

The study was carried out in the communes of Sibirila and Garalo, which are located in the Sikasso region of southern Mali, from October 2012 to April 2013. Both communes – Sibirila and Garalo – and four villages in each of the communes were purposively selected, based on the presence of N'Dama, Fulani Zebu and their crossbreds. A stratified random sampling based on cattle and breed ownership was applied for the selection of 258 households. The 160 households with a herd were grouped into four herd categories based on breed composition. The first three categories comprised of herds with more than 75% of N'Dama, Fulani Zebu or crossbred cattle, respectively. Herds with less than 75% cattle from a single breed were

designated as mixed herds, forming the fourth category. Forty-five households with only oxen and 53 without cattle represented two additional herd categories. Data collection methods encompassed household interviews, herd surveys and focus group discussions. The household questionnaires contained socio-economic data of the households, production objectives, trait and breed preferences of cattle keepers, inputs and outputs of cattle production, herd biological performances, and household food security indicators. The herd surveys were carried out for 120 households to assess individual cows' (n=770) performances using a cow progeny history survey and body condition scoring (BCS). Food security was assessed using a household dietary diversity score (HDDS), food consumption score (FCS), and modified household food insecurity access scale (mHFIAS). Gross margin, net benefit and cost benefit ratio were calculated for the assessment of economic performance and efficiency. Besides descriptive statistics, data were analysed using an exploded logit model, mixed linear models and non-parametric tests using the Statistical Analysis System (SAS).

Results showed that trait and breed preferences reflected the multiple production objectives of the farmers. Draught power and savings were the most important production objectives. Farmers reported a large body size as the most preferred trait, followed by fertility, draught ability and milk yield. N'Dama was valued for disease and drought tolerance and their good traction ability. Crossbreds were the favored breed group and were appreciated for milk yield and body size, similar to Fulani Zebu. Breed preferences were mainly explained by resistance to disease for N'Dama cattle and high market price for Fulani Zebu and crossbred cattle. Production objectives, trait and breed preferences were mainly influenced by farmers ethnicity and cultural background. Local farmers who kept mainly N'Dama put comparatively more emphasis on livestock functions linked to crop production such as draught power, savings and manure, whereas settled transhumant farmers with mainly Fulani Zebu cattle emphasized milk production and sale of cattle.

Results on cow individual performances showed a higher body condition for N'Dama compared to crossbred and Fulani Zebu cattle indicating the hardiness of the N'Dama breed. Age at first calving was lowest for N'Dama (3.47 years) compared to crossbred (3.63 years) and Fulani Zebu cows (3.61 years). Calving interval of cows was similar ($P>0.05$) between the breeds, with an overall mean of 15.6 months. Calving and offtake rates were higher for the Fulani Zebu and crossbred herds than for the N'Dama herds. Veterinary costs per head of Fulani Zebu, crossbreds and herds of mixed breed composition did not differ from N'Dama

herds, and therefore, the better disease resistance of N'Dama cattle had no effect on profitability. Gross margin and the benefit-cost ratio were highest in Fulani Zebu herds, followed by crossbred herds due to higher revenue generated from cattle and milk sale from these herds. The higher cash revenue for the sale of cattle in crossbred and Fulani Zebu herds was explained by the higher offtake rate in these two herd categories and a 25 and 60% higher selling price for crossbred and Fulani Zebu, respectively, than for N'Dama cattle. When non-market benefits were included, economic performances between the herd categories were similar as shown by the similar net benefit per cattle.

Cattle ownership and breed group were important determinants of all household food security indicators. Households keeping Fulani Zebu and mixed herds had the highest FCS, which was mainly explained by their more frequent milk consumption compared to the other breed groups. HDDS and FCS were positively correlated with diversity of food crops cultivated on farm and household wealth and negatively correlated with cotton cultivation. Generally cattle herd ownership was strongly associated with improved household diet diversity and reduced vulnerability to food insecurity. During the food shortage period, households raising Fulani Zebu were less food insecure as indicated by a significantly lower mHFIAS than those keeping N'Dama, crossbreds or mixed herds. In times of food shortage, selling livestock was the main coping strategy for households with a cattle herd, while households without a cattle herd relied mostly on borrowing cash.

The results of the present study showed that the ongoing replacement of native N'Dama cattle by Fulani Zebu cattle and their crosses is contributing to an improved household economic situation and food security. This trend is expected to continue as local farmers follow their economic interests, putting the N'Dama breed at a high risk of genetic dilution in southern Mali. This change in trait and breed preference can partly be explained by the decreased prevalence of tsetse flies in the study area and the widespread availability and use of trypanocidal drugs. It is obvious that there is a trade-off between the long-term goals, expressed at national or international level regarding biodiversity conservation and N'Dama genetic improvement, and the interest of farmers in short-term benefits, through, for example, the use of crossbreds and Fulani Zebu. Fulani Zebu and crossbred cattle are the most suitable options for market-oriented local and settled transhumant farmers, given their higher price and increased profitability. The N'Dama cattle remain a valuable breed for subsistence-oriented local farmers for whom non-market benefits from cattle such as saving play a considerable

role. Further research is required to investigate possible ways of optimizing and organizing the ongoing process of crossbreeding between the N'Dama and Fulani Zebu cattle, with a more systematic crossbreeding and selection program in line with the farmers' interest.

7 ZUSAMMENFASSUNG

In den letzten Jahrzehnten hat in den Entwicklungsländern eine schnelle Änderung bezüglich der verwendeten Nutztierrassen stattgefunden, welche durch globale Einflussfaktoren, wie z.B. die steigende Nachfrage nach Nahrungsmitteln tierischer Herkunft, die marktorientierte Produktion sowie technologischen und ökologischen Wandel begünstigt wurde. Einheimische Rassen werden zunehmend durch exotische Rassen ersetzt, was zu einem Verlust genetisch wertvoller Ressourcen führt. Die Einführung von exotischen Nutztierrassen mit höherer Leistung, die aber weniger an die lokalen Umweltbedingungen angepasst sind, könnte zwar Vorteile bieten, aber auch Gefahren für den Lebensunterhalt der armen Bauern bergen. Im Süden Malis, wo Rinder eine wichtige Rolle für den Lebensunterhalt von vielen ländlichen Haushalten spielen, werden die endemischen, trypanotoleranten N'Dama Rinder zunehmend durch die größeren trypanoanfälligen Fulani Zebu ersetzt oder mit ihnen gekreuzt. Damit besteht eine ernsthafte Bedrohung der genetischen Erosion für das N'Dama Rind, trotz seiner adaptiven Merkmale. Ein systematischer Vergleich der endemischen N'Dama Rinder, Fulani Zebu-Rinder und ihrer Kreuzungen unter den gleichen Haltungsbedingungen im westlichen Afrika ist notwendig, um zu zeigen, ob Tierhalter Vorteile von der Einführung der Fulani Zebu-Rinder ziehen oder Nachteile durch die Verdrängung der N'Dama- Rinder haben.

Das übergeordnete Ziel der Arbeit war daher, N'Dama, Fulani Zebu und deren Kreuzung zu bewerten und miteinander zu vergleichen, basierend auf ihren Leistungen, ihrem Beitrag zum Lebensunterhalt und zur Ernährungssicherung der ländlichen Haushalte unter Berücksichtigung der Produktionsumgebung und der Zuchtziele der Tierhalter. Spezifische Ziele waren (i) die Produktionsziele, Merkmals- und Rassepräferenzen der Viehzüchter zu untersuchen, (ii) die produktiven und ökonomischen Leistungen der N'Dama Rinder, Fulani Zebu-Rinder und ihrer Kreuzungen zu bewerten und zu vergleichen, um die komparativen Vorteile dieser Rassen für Bauern zu bewerten, (iii) die Ernährungssicherung der Haushalte und die dazu notwendigen Strategien zu erkunden mit besonderem Augenmerk auf den Beitrag der verschiedenen Rinderrassen.

Die Datenerhebung wurde von Oktober 2012 bis April 2013 in den Gemeinden Sibirila und Garalo in der Region Sikasso im Süden Malis durchgeführt. Beide Gemeinden – Sibirila und Garalo – und vier Dörfer in jeder der Gemeinden wurden, basierend auf dem Vorhandensein von N'Dama, Fulani Zebu und deren Kreuzung, ausgewählt. Eine stratifizierte Zufallsstichprobe, basierend auf Rinderbesitz und Rasse, wurde für die Auswahl von 258

Haushalten angewendet. Die 160 Haushalte mit Rindern wurden in vier Herden-Kategorien eingeteilt und basierend auf der Rassen-Zusammensetzung wurde wie folgt gruppiert: die ersten drei Kategorien bestehen aus Herden, die jeweils mehr als 75% Anteil an N'Dama, Fulani Zebu oder Kreuzungstieren haben. Herden mit weniger als 75% Anteil von einer Rasse wurden als gemischte Herden bezeichnet und bilden die vierte Kategorie. Zwei weitere Herden-Kategorien, die in die Untersuchungen miteinbezogen wurden, bestehen aus 45 Haushalten mit nur Ochsen und 53 Haushalten ohne Rinder.

Methoden der Datenerhebung umfassten Haushaltinterviews, eine Herdenerhebung und Fokusgruppen-Diskussionen. Die Haushaltsfragebögen enthielten sozio-ökonomische Haushaltsdaten, Produktionsziele, Tiermerkmals- und Rassepräferenzen der Viehzüchter, Inputs und Outputs der Rinderproduktion, Herdenleistungen und Indikatoren für die Ernährungssicherung der untersuchten Haushalte. Die Herdenerhebungen wurden mit 120 Haushalten auf Basis der Ermittlung der Abstammungsgeschichte „cow progeny history" und der Körperkondition (body condition scoring) ausgewählter Kühe durchgeführt, um Einzelkuhleistungen (n = 770) zu erfassen. Die Ernährungssicherheit von Haushalten wurde anhand eines Nahrungsmittelvielfalt-Scores (HDDS), eines Nahrungsmittelkonsum-Scores (FCS) und einer modifzierten „household food insecurity access scale" (mHFIAS) ermittelt. Der Bruttogewinn, der Reingewinn und das Kosten-Nutzen-Verhältnis wurden für die Beurteilung der wirtschaftlichen Leistung und Effizienz berechnet. Neben deskriptiven statistischen Methoden wurden die Daten mit einem exploded Logit-Model, einem gemischten linearen Model und nicht-parametrischen Tests mit Hilfe der Statistischen Analyse System (SAS) Software analysiert.

Die Ergebnisse zeigten, dass die Tiermerkmal- und Rassepräferenzen der Tierhalter die Vielfalt ihrer Produktionsziele widerspiegeln. Die Zugleistung der Tiere und Haltung der Tiere als Anlage waren die wichtigsten Produktionsziele. Die am meisten bevorzugte Eigenschaft war nach Meinung der Tierhalter die Körpergröße der Tiere, gefolgt von Fruchtbarkeit, Zugfähigkeit und Milchleistung. N'Dama Rinder wurden für ihre Toleranz gegen Krankheiten und Dürre und für ihre gute Zugleistung geschätzt. Kreuzungstiere waren die bevorzugte Rassegruppe und wurden, ähnlich wie Fulani Zebu, für ihren Milchertrag und ihre Körpergröße geschätzt. Die Bevorzugung von N'Dama Rindern wurde mit "Krankheitsresistenz", die Bevorzugung von Fulani Zebu Rindern und Kreuzungstieren wurde mit "hoher Marktpreis" begründet. Produktionsziele, Merkmals- und Rassepräferenzen

wurden hauptsächlich von der ethno-kulturellen Zugehörigkeit (einheimische Bambara Bauern und sesshaft gewordene Fulani Hirten) beeinflusst. Einheimische Bauern, die vor allem N'Dama Rinder halten, legten vergleichsweise mehr Wert auf Tierproduktionsziele, die mit Pflanzenbau verknüpft sind, während sesshaft gewordene Fulani Hirten mit ihren Fulani Zebu Rindern Milchproduktion und Tierverkauf vorziehen.

Ergebnisse zur individuellen Kuhleistung zeigten eine bessere Körperverfassung und eine niedrigere Abkalbe- und Verkaufsrate der N'Dama Rinder im Vergleich zu Fulani Zebu Rindern und ihrer Kreuzung. Das Alter bei der ersten Kalbung war bei N'Dama (3,5 Jahre) im Vergleich zu Kreuzungstieren (3,6 Jahren) und Fulani Zebu (3,6 Jahre) etwas geringer. Die Zwischenkalbezeit der Kühen war zwischen den Rassen ähnlich ($P>0,05$), mit einem Gesamtmittelwert von 15,6 Monaten. Die Abkalbe-und Verkaufsrate waren bei den Fulani Zebu- und Kreuzungstierherden höher als bei N'Dama Herden. Die Tierarztkosten pro Tier waren ähnlich ($P>0.05$) zwischen den Herden verschiedener Rassen, und somit hatte die bessere Krankheitsresistenz der N'Dama Rinder keine Auswirkung auf ihre Rentabilität. Der Bruttogewinn und das Kosten-Nutzen-Verhältnis waren am höchsten in der Zebuherde, gefolgt von der Kreuzungstierherde. Dies wurde durch höhere Einnahmen aus Tier- und Milchverkäufen aus diesen Beständen erklärt. Die höheren Einnahmen beim Viehverkauf aus Herden mit Kreuzungstieren und Fulani Zebu erklärten sich durch höhere Verkaufsraten und einen 25% bzw. 60% höheren Verkaufspreis bei Kreuzungs- bzw. Fulani Zebu-Tieren im Vergleich zu N'Dama-Tieren. Wenn nicht-marktbezogene Vorteile berücksichtigt wurden, ähneln sich die Wirtschaftsleistungen aller Herden- Kategorien, wie aus dem gleichwertigen Nettonutzen pro Tier hervorgeht.

Rinderbesitz und Herden-Kategorie waren wichtige Determinanten für alle Ernährungs-sicherheitsindikatoren der Haushalte. Haushalte, die Fulani Zebu und gemischte Herden halten, hatten die höchste FCS, was vor allem durch ihren häufigeren Milchkonsum erklärt werden konnte. HDDS und FCS waren positiv mit der Vielfalt der auf dem Betrieb angebauten Nahrungspflanzen und dem Vermögen der privaten Haushalte korreliert und negativ korreliert mit dem Baumwollanbau. In der Regel war der Besitz einer Rinderherde eng mit einer verbesserten Ernährungsvielfalt der Haushalte und einer reduzierten Anfälligkeit für Ernährungsunsicherheit verbunden. In Zeiten von Nahrungsknappheit waren Haushalte, die Fulani Zebu-Rinder halten, deutlich weniger von Nahrungsmittelunsicherheit betroffen, als die mit N'Dama-Rindern, Kreuzungstiere und gemischten Herden, was durch einen

niedrigeren mHFIAS-Wert gezeigt wurde. In Zeiten von Nahrungsmangel verkauften Haushalte, die Rinder besitzen, Tiere, um Lebensmitteln zu kaufen, wohingegen Haushalte ohne eine Rinderherde Geld leihen mussten.

Die Ergebnisse der Arbeit zeigen auch, dass die derzeitige Verdrängung der heimischen N'Dama Rinder durch Fulani Zebu Rinder und ihrer Kreuzungen zu einer verbesserten wirtschaftlichen Situation und Nahrungssicherung der Haushalte beitragen. Es ist anzunehmen, dass der beobachtete Trend sich fortsetzen wird, da er den wirtschaftlichen Interessen der Bauern entspricht. Diese Situation setzt jedoch die N'Dama Rasse unter ein hohes Risiko der genetischen Erosion im Süden Malis. Diese Änderung der Präferenzen bezüglich Tiermerkmalen und Rassen lässt sich teilweise mit dem Rückgang von Tsetse-Fliegen im Untersuchungsgebiet und der breiten Verfügbarkeit und Verwendung von Trypanociden erklären. Es gibt offensichtlich einen Zielkonflikt zwischen den langfristigen Zielen der Erhaltung der biologischen Vielfalt auf nationaler oder internationaler Ebene und der genetischen Verbesserung von N'Dama und dem Interesse der Landwirte an ökonomischen Gewinnen durch die Haltung von Kreuzungstieren und Fulani Zebu. Fulani Zebu und Kreuzungstiere sind aufgrund ihrer höheren Preise und höherer Profite die geeignetsten Optionen für marktorientierte, sesshaft gewordene Fulani Hirten. Das N'Dama Rind bleibt eine wertvolle Rasse für die subsistenzorientierten lokalen Bauern, für die nicht marktabhängigen Vorteile von Rindern, wie ihre Nutzung als finanzielle Anlage, eine erhebliche Rolle spielen. Weitere Forschung ist erforderlich, um den laufenden Prozess der Kreuzung zwischen den N'Dama und Fulani Zebu-Rindern zu optimieren durch eine systematischere Kreuzungszucht und Zuchtprogramme, die im Einklang mit den Interessen der Tierhalter stehen.

8 RÉSUMÉ

Au cours des dernières décennies, il est intervenu un changement rapide au niveau des races animales utilisées dans les pays en développement et ceci en raison de nouveaux déterminants mondiaux de changement, comme la demande croissante de produits d'origine animale, une production axée sur le marché, ainsi que des changements technologiques et environnementales. Les races locales sont de plus en plus remplacées par des races exotiques, conduisant à une perte de ressources génétiques. Or l'introduction de races exotiques plus productives mais moins adaptées pourrait certes constituer une opportunité mais aussi une menace pour les moyens de subsistance des paysans pauvres. Au sud du Mali, où le bétail joue un rôle important de subsistance et de bien-être pour de nombreux ménages, les bovins N'Dama, endémiques et trypanotolerant qui étaient les seuls bovins présents dans cette zone il y'a fort longtemps, sont de plus en plus remplacés ou croisés avec les bovins trypano-sensibles Zébu peul de plus grand gabarit. Aussi, malgré ses qualités d'adaptation, les bovins N'Dama sont l'objet de sérieuses menaces d'érosion génétique. Cette comparaison systématique des performances des bovins endémiques N'Dama, des bovins Zébus peuls et leurs croisements dans les mêmes conditions d'élevage en Afrique de l'Ouest vise à montrer si les agriculteurs bénéficient de l'introduction des zébus peuls ou s'ils sont au contraire affectés par le recul des bovins de race pure N'Dama.

L'objectif global de l'étude est donc d'évaluer et de comparer les bovins N'Dama, Zébu peul et leurs produits croisés en se basant sur leur contribution à l'économie des ménages et à la sécurité alimentaire, tout en prenant en compte l'environnement de production et les stratégies d'élevage des paysans. Les objectifs spécifiques de l'étude sont : (i) enquêter sur les objectifs de production, les préférences de caractère et de races des éleveurs, (ii) comparer et évaluer les performances économiques et zootechnique des bovins N'Dama, Zébu peul et métis afin d'identifier les avantages comparatifs de chacune de ces races pour les paysans. (iii) examiner les stratégies de sécurité alimentaire du ménage et les moyens d'y parvenir en mettant en exergue la contribution spécifique des différentes races de bovins.

L'étude a été réalisée d'octobre 2012 à avril 2013 dans les communes de Sibirila et de Garalo, situées dans la région de Sikasso dans le sud du Mali. Les deux communes – Sibirila et Garalo – et quatre villages dans chacune des communes ont été sélectionnés en accord avec la présence de N'Dama, Zébu peul et leurs croisements. Un échantillonnage aléatoire stratifié basé sur la possession de bovins et de races bovines a été appliquée à l'échantillon total des

258 ménages. Les 160 ménages détenant un troupeau ont été répartis en quatre catégories de troupeau tenant compte de sa composition raciale : les trois premières catégories composés des troupeaux avec plus de 75 % de N'Dama, de Zébu peul ou de bovins croisés. Les troupeaux avec moins de 75 % de bovins d'une même race ont été désignés comme des troupeaux mixtes, formant la quatrième catégorie. Les 45 ménages détenant seulement des bœufs de labour et les 53 ménages sans bétail ont constitué les deux catégories supplémentaires de troupeaux. Les méthodes de collecte de données comprenaient les entretiens avec les ménages, les enquêtes au niveau du troupeau et les discussions de groupes. Le questionnaire-ménage a servi à recueillir des données socio-économiques du ménage, les objectifs de production, les préférences de caractères et de races des éleveurs, les entrées et les sorties du troupeau pour l'évaluation des performances zootechniques, les indicateurs de sécurité alimentaire du ménage. Les enquêtes de troupeau ont concerné 120 ménages et elles ont été conduites de façon à évaluer la performance de chaque vache (n=770) en faisant l'historique de la descendance de la vache à travers la méthode dite «Cow progeny history», et son état d'embonpoint à travers le BCS (Body condition Scoring). La sécurité alimentaire a été évaluée à l'aide d'une note de diversité alimentaire du ménage (HDDS), une note de consommation alimentaire (FCS) et une note modifiée d'accès des ménages à l'insécurité alimentaire (mHFIAS). La marge brute, le bénéfice net et le rapport coût/bénéfice ont été calculés pour l'évaluation de la performance et de l'efficience économiques. A côtés de la statique descriptive, les données ont été analysées en utilisant un modèle dit « exploded logit model », les modèles linéaires mixtes et les tests non paramétriques en utilisant le logiciel de système d'analyse statistique (SAS).

Les résultats montrent que les raisons pour lesquelles les agriculteurs élèvent des bovins ainsi que leurs préférences pour des caractères et des races reflètent la diversité des objectifs que ces agriculteurs poursuivent. La traction animale et l'épargne ont été les objectifs de production les plus importants. Les agriculteurs ont classé la taille comme un trait préféré, suivi de la fécondité, l'aptitude à la traction animale et la production laitière. Les bovins N'Dama ont été appréciés pour leur tolérance aux maladies et à la sécheresse ainsi que leur bonne aptitude à la traction animale. Les bovins croisés ont été le groupe racial le plus prisé et ils étaient appréciés, tout comme les Zébus peuls, pour leur production laitière et leur gabarit. Les préférences de race ont donc reposé principalement sur la résistance contre les maladies pour les bovins de N'Dama et sur le « prix de marché élevé » pour les Zébus peuls et les croisés. Il a été noté que les objectifs de production et les préférences de caractères et de

races sont principalement influencés par l'appartenance ethnoculturelle du fermier (agriculteurs autochtones et éleveurs transhumants sédentarisés). Les agriculteurs autochtones mettent davantage l'accent sur les aptitudes en lien avec la production agricole, comme la force de traction, l'épargne et le fumier, alors que les transhumants sédentarisés détenteurs de troupeaux Zébu peul insistent plus sur la production laitière et sur la vente de bétail.

En guise de performances, il a été noté un meilleur état d'embonpoint chez la N'Dama comparée au Zébu peul et aux croisés, ce qui dénote de la capacité d'endurance en période de déficit alimentaire. Avec un âge au premier vêlage de 3.47 ans, les N'Dama sont plus précoces que les métisses (3.63 ans) et les Zébus peul (3.61 ans). L'intervalle entre vêlages était le même pour toutes les races avec une durée moyenne de 15.6 mois ($P>0.05$). De meilleurs taux de vêlage et de taux d'exploitation du troupeau ont été enregistrés dans les troupeaux Zébu peul et dans les troupeaux métis comparés aux troupeaux N'Dama. Le coût par tête des soins vétérinaires est sensiblement le même chez les tous les trois groupes raciaux, minimisant ainsi l'avantage attendu de la N'Dama à cause de sa résistance contre les maladies. La marge brute et le rapport coûts-bénéfice étaient plus élevés dans les troupeaux de Zébus peuls, suivis par les troupeaux de croisés à cause des revenus tirés de la vente de lait et d'animaux. Le revenu plus élevé tiré de la vente des animaux s'explique lui par non seulement un taux d'exploitation plus élevé mais aussi à cause des prix de vente d'animaux de 25 à 60% plus élevés que les prix offerts pour les bovins N'Dama. Lorsque les bénéfices non-monétaires sont inclus, les performances économiques entre les catégories de troupeau étaient semblables comme en témoigne le bénéfice net par bovin.

La possession de bétail et la catégorie de troupeau sont des déterminants importants de tous les indicateurs de sécurité alimentaire des ménages. Les ménages possédant un troupeau de Zébus peuls et d'un troupeau mixte avaient le FCS le plus élevé, ce qui pourrait s'expliquer par une consommation plus fréquente de lait. Les notes HDDS et FCS étaient positivement corrélées avec la diversité des plantes cultivées dans les champs et le degré d'aisance des ménages et négativement corrélées avec la pratique de la culture du coton. On a constaté de façon générale que la possession de troupeaux bovins était fortement associée avec une amélioration de diversité alimentaire au niveau du ménage et une réduction de la vulnérabilité du ménage à l'insécurité alimentaire. Au cours de la période de pénurie alimentaire, les ménages élevant des Zébus peuls étaient mieux lotis et avaient un mHFIAS significativement plus bas que ceux de ménages élevant des N'Dama, des croisés ou de troupeaux mixtes. En

période de disette la vente de bétail a été la principale stratégie d'adaptation pour les ménages disposant de bétail, alors que les ménages sans bétail devaient emprunter de l'argent.

Les résultats de cette étude montrent que le remplacement en cours du cheptel endémique N'Dama par les Zébus peuls et leurs croisés contribuent à améliorer la situation économique et la sécurité alimentaire des ménages. Aussi, cette tendance vers plus de métissage continuera et mettra la race N'Dama sous haut risque de dilution génétique dans le sud du Mali. Ce changement de préférence raciale peut en partie s'expliquer par la faible pressions des mouches tsé-tsé d'une part et par l'utilisation très répandue des produits trypanocides. Le Zébu peul et les métis sont plus appropriés pour les éleveurs intéressés par l'économie de marché alors que la N'Dama reste une race très valable pour les éleveurs plus intéressés par l'économie de subsistance pour lesquels les bénéfices non marchands sont essentiels. Le Zébu peul ou les bovins croisés constituent les options les plus favorables pour les éleveurs transhumants sédentarisés plus orientés vers le marché local à cause de prix plus rémunérés et de gain plus élevé; par contre, le bovin N'Dama reste une race précieuse pour les agriculteurs locaux pour lesquels les avantages non marchands de bétail jouent un rôle important. Il faudra poursuivre les recherches sur les voies et moyens d'optimiser et d'organiser le processus de croisement entre bovins N'Dama et Zébu peul à travers un programme plus raisonné de croisement et de sélection tenant compte de l'intérêt des paysans.

CURRICULUM VITAE

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EDUCATION

10/2011- 08/2017	PhD at the Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute), Department of Animal Breeding and Husbandry in the Tropics and Subtropics, in the PhD program on 'Agricultural Economics and Related Sciences' at the University of Hohenheim, Germany Topic: Contribution of cattle breeds to household livelihoods and food security in southern Mali
10/2007- 03/2010	Master studies in Agricultural Economics at the University of Hohenheim, Germany Master thesis: Contribution of endemic ruminants to the livelihoods of small farmers in The Gambia
09/2008 - 12/2008	Exchange semester at the University of Guelph (Canada)
10/2004 - 09/2007	Bachelor studies in Agricultural Sciences at the University of Hohenheim, Germany, specialisation in Agricultural Economics Bachelor thesis: Cost-benefit analysis of individual cows in dairy Farming
1996 - 2003	High School at the French School, Bamako, Mali
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PRACTICAL TRAINING / WORK EXPERIENCE

05/2015 - 07/2017	Research assistant at the Department of Animal Breeding and Husbandry in the Tropics and Subtropics at the University of Hohenheim, Stuttgart, Germany

10/2010 - 04/2011	Trainee at the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) in a development project for decentralised rural development in the regions Mayo Kebbi and Ouaddai Biltine, Chad
04/2009 - 08/2009	Master research in Mali and The Gambia with the International Livestock Research Institute (ILRI) as part of the Regional Project for Sustainable Management of Endemic Ruminant Livestock in West Africa; Bamako, Mali
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PUBLICATIONS

Publications on Peer reviewed journals

Traoré, S. A, Markemann, A., Reiber, C., Piepho, H. P., Valle Zárate, A. 2017. Production objectives, trait and breed preferences of farmers keeping N'Dama, Fulani Zebu and crossbred cattle and implications for breeding programs. Animal, 11, 687–695.

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SKILLS

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