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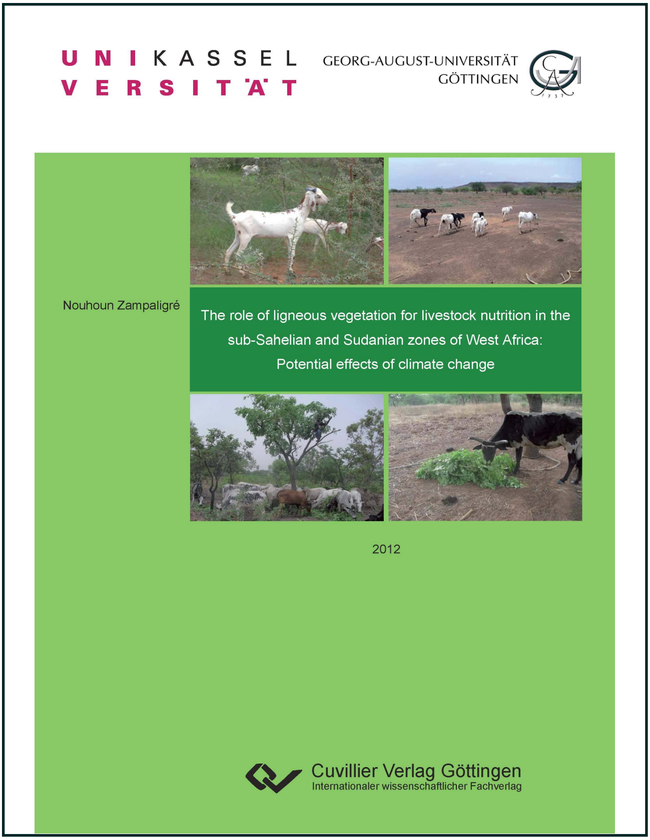
The role of ligneous vegetation for livestock nutrition in the sub-Sahelian and Sudanian zones of West Africa: Potential effects of climate change



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Chapter 1

General introduction, study objective and research hypotheses

1.1. Livestock farming system in West Africa: potential and constraints

In West African Sahelian countries, agriculture and livestock husbandry are important economic sectors given their multiple roles for food security, employment and their contribution to the Gross Domestic Product (GDP). Pure crop cultivation systems, mixed crop-livestock systems and pastoral livestock systems are the major forms of farming. The total number of domestic animals is estimated at about 60 million and 160 million cattle and small ruminants, respectively, which contribute about 20 to 30% of the agricultural GDP of the Sahelian countries (CILSS, 2010). Particularly in Burkina Faso, livestock keeping contributes about 15% to the national GDP and involve, in one way or the other, more than 90% of the rural population. The country's livestock population is estimated at 7.9, 7.5 and 11.3 million head of cattle, sheep and goats, respectively, whereby 70% of the cattle are managed by transhumant Fulani groups (MRA, 2005). The dominant livestock husbandry systems in the Sahelian and Sudanian zone of West Africa countries are transhumant pastoralism, and predominantly sedentary, sometimes also semi-transhumant agro-pastoralism. The latter is characterized by a more or less intensive integration of crop and livestock farming, and is mostly characterised by small size of the cattle and small ruminant herds (Blench, 2001). Transhumant pastoralism, on the other hand, is defined as “a system of animal production characterised by seasonal and cyclical migration of varying degrees between complementary ecological areas and supervised by few people, with most of the group remaining sedentary” (Blench, 2001). Transhumant pastoralism involves 70% to 90% of the cattle and 30% to 40% of the goats and sheep in the Sahelian zone, supplying about 65% and 40% of cattle and small ruminant meat in West Africa (OCDE/SWAC, 2009). The seasonal mobility of ruminant herds, main characteristic of mobile systems, is adapted to marginal, unbalanced and changeable environments such as the Sahelian zone (Standford, 1983). Micro-mobility as well as long-distance transhumance are ways of adapting to a harsh environment and the spatio-temporal variability of forage resources, and has since centuries allowed pastoralists and agro-pastoralists to use the complementary natural pastoral resources of the Sahelian and Sudanian zones (Thebaud and Batterbury, 2001, Adriansen and Nielsen, 2002, Brook, 2006; McGahey, 2011). Recent studies proved that pastoralism, for ecological, social and economic reasons seems to be adapted to arid and semi-arid regions of West Africa (Fratkin and Mearns, 2003; Hatfield and Davies, 2006; OECD/SWAC, 2008; Mortimore, 2010). Pastoralism and agro-pastoralism have allowed the local population groups to cope with recurrent droughts and high climate variability in the region, whereby agro-pastoralism is considered as adaptation strategy to climate variability and change (CILSS, 2009). However, the transhumant pastoralism formerly practiced in the Sahelian zone has been threatened by the severe droughts of the years 1973/74 and 1984 which caused changes in the pastoral management system due to changes in land use, vegetation changes and socio-economic transformation (Nori et al., 2008; Basset and Turner, 2007). Nowadays, the transhumant pastoralism is in transition to “semi-transhumance” or agro-pastoralism with the sedentarisation of former pastoralists, who now also rely on cereal cropping for household purposes. Pastoralist groups have moved from the Sahelian zone to settle in the Sudanian zone where water and forage resources are still abundant: pastoralists from Burkina Faso, Mali and Niger have been gradually settling down in northern Ghana, Benin and Ivory Coast since the severe droughts of the 1970s and 1980s (Tonah, 2003; Bassett and Turner, 2007). The increasing livestock densities in the Sudanian zones of West Africa, in addition to cropland expansion and agricultural intensification, increase the pressure on the yet relatively abundant natural resources – soil, water, and vegetation.

1.2. The role of ligneous fodder resources for ruminant husbandry in semi-arid and sub-humid West Africa

In the Sahelian and Sudanian zone of West Africa, primary fodder resources for ruminants are natural forages such grasses and dicotyledonous herbaceous species, ligneous plants and crop residues (Teferedegne, 2000). A ligneous fodder plant, so-called “browse”, comprises the tender shoots, twigs and leaves of shrubs and trees, and their fruits and pods (Devendra, 1996). Browse plants provide valuable fodder that, particularly in the dry season, supplements the senescent herbaceous vegetation and cereal residues of poor digestibility and low nutritive value. Numerous studies have addressed the value of browse for livestock nutrition, such as an increased metabolizable energy intake, nitrogen intake and feed use efficiency, and thus an improved reproductive and productive performance of the animals (Le Houerou, 1980a; Fall Touré et al., 1998; Abdulrazak et al., 2000; Sangaré et al., 2003; Bwire et al., 2004; Yayneshet et al., 2009). Browse availability is especially important for grazing livestock systems, where it enables survival of sheep, goats, cattle and camels during dry periods and drought years (Le Houerou, 1980b; Thomas and Sumberg, 1995; Devendra, 1996), and herders generally have a good knowledge on the occurrence, palatability and availability of browse (Bellefontaine et al., 2002; Gautier et al., 2005). Apart from direct grazing of browse plants and their organs, different techniques are practiced by herders to make browse material available to livestock. Pruning, which consists in “eliminating dead or small branches and the suckers that tend to weaken the tree”, is often practiced by herders (Teferedegne, 2000). This technique aims to obtain a maximum amount of forage and also has a positive effect on tree growth and leaf production if properly practiced (LEAD, 1999). Leaves and pods are also harvested by agro-pastoralists and serve as feed supplement for sedentary animals during the dry season (Sanon, 2005).

For the Sahelian zone of Burkina Faso, Sanon et al. (2007a) reported that browse represented 43 - 52%, 5 - 28% and 4 - 7% of the daily diet of grazing goats, sheep and cattle. The contribution of browse to the daily diet of small ruminants may be greater than of herbaceous forage in certain areas and during dry seasons: in Botswana goats spent 50% and 80% of their daily feeding time on browse fodder in the wet and the dry season (Ommple et al., 2004). The use of browse for livestock nutrition has also been promoted through the implementation of shrub- and tree-based fodder banks in agro-forestry and silvo-pastoral systems (Kessler and Breman, 1991; Ayuk, 1997). Those systems have several benefits: firstly, environmental improvement by increasing soil fertility and productivity; secondly, increased water infiltration and erosion control; and thirdly improvement of animal production through the provision of quality livestock feed (Le Houerou, 2006). The most promising multipurpose species used in these systems are *Gliricidia sepium* and *Leucena leucocephala* as exotic species*, Acacia senegal, Faidherbia albida, Prosopis africana, Pterocarpus erinaceus* and *Afzelia africana* as native adapted species (Dowela et al., 1997*).* The nutritive value of browse plants has also been widely investigated – while leaves with metabolizable energy (ME) content between 3 and 5 MJ ME kg^{-1} DM can ensure the maintenance of sheep but do not allow for production, maintenance and production of goats may be provided by a pure browse diet (Devendra, 1996; Table 1.1). However, the potential use of browse as ruminant feed is often limited by the presence of anti-nutritional factors that affect nutrient availability, palatability and intake of the respective plant or plant part (D'Mello, 1992; Balogun, et al., 1998; Aganga and Tshwenyane, 2003). Those factors are mostly non-protein amino acids (mimosine and indospecine), glucosides (cyanogens and saponins) and polyphenolic compounds such as tannins and lignin. In semi-arid and sub-humid West Africa, browse fodder is especially important as feed for livestock in dry season and drought periods, when grasses and herbages lack, both quantity and quality (Thomson et al., 1987). As indicated by Yayneshet et al. (2009), during the rainy season grass species contained crude protein levels close to the critical level suggested for maintenance, but in general, ruminants cannot satisfy their maintenance needs on dry grass alone over the whole dry season. In particular, they would suffer from mineral deficiency, but they also depend on browse to saturate their needs of protein, phosphorus, calcium and vitamin A (Le Houerou, 1980b). Although, browse nutrient contents and digestibility also decrease in the course of dry season, fresh or dry browse leaves available at that period of the year, have nutrient contents adequate to sustain smallholder livestock production systems (Yayneshet et al., 2009). Browse thus plays a very important role for livestock nutrition in semi-arid and sub-humid West Africa; it provides an ideal and necessary complement for the diets of goats, sheep and cattle especially during the long dry season and droughts periods (Le Houerou, 1980a). Many species are selected on pasture by ruminants according to their preference, palatability, occurrence, abundance and nutritive value (Ngwa et al., 2000). Among the most important livestock reared in West Africa, goats' intake consists to a very large part of browse due to their feed preferences for a very diverse diet. This was affirmed by the high number of different species goats consumed in preference trials (Ngwa et al., 2002). In the respective feeding trials, *Acacia senegal, A. nilotica, Dichrostachys cinerea* and *Pterocarpus lucens* showed to be high quality protein supplements (Rubanza et al. 2006). Sheep and cattle also consume browse, especially in the dry season when grass and herbage is scarce (Bwire et al., 2004; Sangaré et al., 2003). For both, *Guiera senegalensis* played a major role in preference and feeding trials. Additionally, *Acacia albida, A. tortilis, Dichrostachys cinerea* and *Ziziphus mauritania* induced high weight gains (Fall-Touré, 1997; Bwire et al., 2003; Yayneshet et al., 2008). Pods and fruits are especially valuable for supplement feeding, and leguminous browse is of particular importance for the diets. Concerning browse species above biomass production, of 16 Sahelian and Sudanian browse species such *Acacia senegal*, *A. dudgeoni, A. macrostachya, Afzelia africana, Daniellia oliveri, Ficus sycomorus* subsp. *Gnaphalocarpa, Pterocarpus erinaceus, Guiera senegalensis, Pterocarpus lucens, Balanites aegyptiaca Piliostigma thonningii, Anogeissus leiocarpa, Combretum glutinosum, C. micrantum, C. nigricans* and *Detarium microcarpum* above ground biomass production can be estimated by species-specific allometric equations using dendrometric parameters (Sanon et al., 2007b; Bognounou et al., 2008; Sawadogo et al., 2010) as well as a combination of allometric equations and satellite imagery approaches (Savadogo and Elfving, 2007). The existence of generalized or species-specific allometric equations for the prediction of tree biomass production is of increasing interest in the actual context of climate change for carbon sequestration studies but could also be used for determining edible foliage and twig biomass in livestock nutrition investigations. For Sub Saharan African forests, about 850 available allometric equations and 125 related references were reviewed by Henry et al. (2011) and incorporated into an open-access database on the Carboafrica website (www.carboafrica.net).

1.3. Anticipated climate change in West Africa

1.3.1. Consequences for farming systems in semi-arid and sub-humid zones

Climate projections for West Africa are consistent when it comes to predicting and forecasting temperature changes, but projections of future rainfall patterns and overall amounts are contrasting. According to IPCC (2007), the average rise in temperature between 1980/99 and 2008/99 is expected to be between 3°C and 4°C for the whole African continent with the highest increase in West Africa (+4°C). According to the vulnerability and adaptation analyses by MECV (2007), temperature projections based on the climate model of the Meteorological Research Institute (MRI) of the Japanese Meteorological Agency (JMA) indicated that in Burkina Faso average daily temperatures will increase by about 0.8°C in 2025 and 1.7°C in

2050 as compared to year 1990, whereby the increase may be doubled due to seasonal variation. At the same time, the average annual rainfall will be reduced by 3.4% in 2025 and by 7.3% in 2050, with very strong inter-annual and seasonal variability. Local farmers have also observed an increase in maximum daily temperatures and a decrease in rainfall over the last decade in the Sahelian region (Metz et al., 2009). Although there is still a fair amount of uncertainty in rainfall-related climate projections for West Africa (Brook, 2006; OCDE/SWAC, 2009), changes will occur and increasing climate variability will have negative impacts on cereal production, land use, water resources and food security (Mendelsohn, 2009). As far as the regional grazing-based livestock systems are concerned, the anticipated changes will very likely lead to a decreasing animal productivity and will threaten the provision of a wide range of livestock products (MRA, 2005; Nardone et al., 2010) due to an expected drastic reduction of pasture biomass production and of the possibilities for watering the major livestock species, namely cattle, sheep and goats (Seo and Mendelsohn, 2006). The grazing and rainfed mixed systems will be threatened most by the negative effects of climatic change (Nardone et al., 2010; Crane et al., 2011); nevertheless the integrated crop-livestock systems are presumably more resilient than the specialised pastoralist systems (Seo, 2010). In order to mitigate or reduce the increased vulnerability of their production systems and thus their livelihoods, crop and livestock farmers in the region respond to climate change and variability by various adaptation strategies (Nyong et al., 2007). Studies reported an adoption of a wide range of small-scale adaptation and coping strategies by local farmers to secure their farming activities and incomes (Barbier et al., 2010; Ouedraogo et al., 2010, Metz et al., 2009, 2011). At the national level, most of the Sahelian and Sudanian countries in West Africa have adopted national programmes to mitigate the negative impacts of climate change (Kandji et al., 2006). How effective these are in reaching the local crop and livestock farmers and sustaining their livelihoods remains to be investigated.

1.3.2. System vulnerability and adaptive capacity

There have been many attempts to define vulnerability in relation to climate change (Adger et al., 2005; Brooks et al., 2005; Barry and Wandel, 2006; Traerup, 2010) and each definition depends on the purpose of the study. According to the IPCC (2007), vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. It is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptation capacity (IPCC, 2001). Vulnerability has also been defined as ”the propensity of human and ecological systems to suffer harm and their ability to respond to stresses imposed as a result of climate change effects” (Adger et al., 2007). Adaptive capacity is the ability of a system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2007, p. 869). In sub-Sahara Africa, the Sahelian countries are considered to be more vulnerable than others because of the intrinsically high climate variability in the region and the low local adaptive capacity (Sarr, 2010).

1.3.3. Farmers' coping measures and adaptation strategies

In the literature on adaptation to climate change, the term 'coping' is sometimes used as a synonym for adaptation (Fankhauser et al., 1999). But the two concepts are differently used in many cases. Dinar et al. (2008) defined coping strategies as those that have evolved over time through people's long experience in dealing with the known and understood natural variation that they expect in seasons, combined with their specific responses to the season as it unfolds. The same author defined adaptation strategies as long term strategies that are needed for people to respond to a new set of evolving biophysical, social and economic conditions that they have not experienced before. This definition of adaptation is consistent with IPCC (2007) that defined adaptation as an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, in order to moderate harm or exploit beneficial opportunities. Adaptation can be anticipatory (i.e. proactive) or reactive (Frankhauser et al., 1999; IPCC, 2007). Anticipatory adaptation takes place before impacts of climate change have been actually observed, whereas reactive adaptation occurs after the impacts have been observed. Both anticipatory and reactive adaptations may further be differentiated as either public or private. While public adaptation is normally initiated, implemented or facilitated by governmental institutions, the private one is initiated and implemented by individuals, households, or communities.

1. 4. Study objective, research hypotheses, and thesis outline

Against the background of increasing climate variability and anticipated negative effects of climate change in the Sahelian and Sudanian zones of West Africa, this PhD research project aimed to investigate the importance of the ligneous vegetation for the nutrition of domestic ruminants in the semi-arid and sub-humid zones of Burkina Faso, and determine current and possible future impacts of climate change and variability on livestock grazing management as this provides the basis for livestock production.

Therefore, it departed from the following hypotheses:

1. The impacts of climate change on the agro-silvo-pastoral production systems of Burkina Faso can be studied along a transect representing a false timeline and ranging from the semi-arid sub-Sahelian zone (already more strongly affected by climate variability) to the more humid northern and southern Sudanian zones (most probably affected by increasing climate variability in the near future).
2. Browse fodder will play an important role for ruminant nutrition in these systems as climate variability increases and probabilities and patterns of precipitation change.
3. Although agro-pastoralist and pastoralists perceive the impacts of climate change on their cropping and livestock activities, their adaptation strategies are of very limited effectiveness.

To achieve the main objective, participatory rural appraisal tools including focus group discussions and household interviews (chapter 4) were combined with repeated herd monitoring of feeding behaviour (chapter 3) and itinerary tracking using global positioning and geographical information systems tools (chapter 2) across three agro-ecological zones of Burkina Faso (Figure 1.1). This allowed in chapter 2 an assessment of the possible impacts of climate change on ruminants' general grazing itineraries and specifically the selection of grazing areas, and in chapter 3 the determination of the probable consequences of climate change for the contribution of browse to ruminant nutrition and health care across the three agro-ecological zones. Chapter 4 evaluates the perception of pastoralists and agro-pastoralists on climate change and its possible impact on livestock management, as well as their respective adaptation and coping strategies. Results and insights gained in the previous chapters are discussed comprehensively in chapter 5, and implications with respect to projected climatic and environmental changes in the Sahelian and Sudanian region of Burkina Faso and neighbouring countries are discussed.

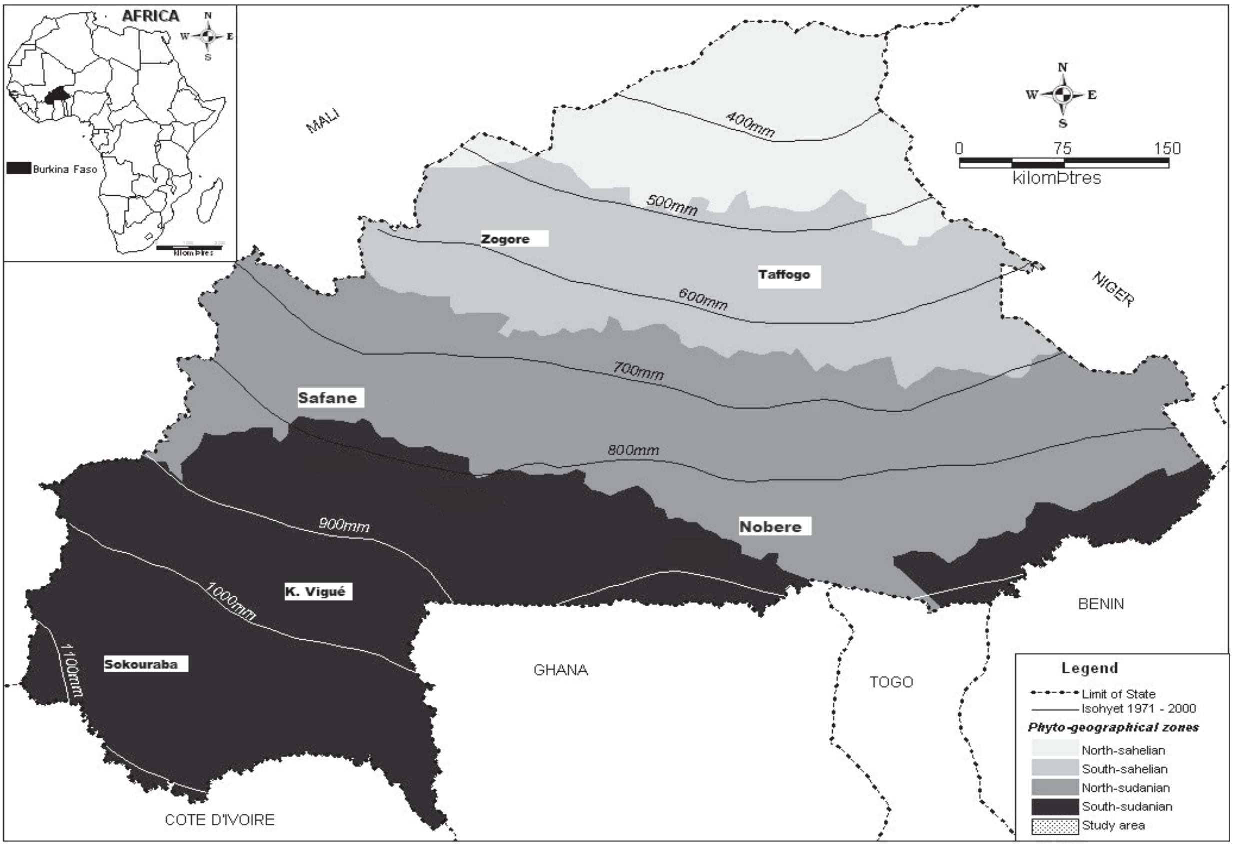

Figure 1.1: Agro ecological (phyto-geographical) zones of Burkina Faso with isohyets and location of the six study sites (Readapted April 2007 by CTIG/INERA/Burkina Faso after Fontes and Guinko 1995 and Direction of the National Meteorology).

Table 1.1: Feeding value of dry grass and browse during the dry season (Le Houerou, 1980b)

Feed	NE (MJ/kg DM)	Digestible Protein (g/kg DM)	P (g/kg DM)	Ca (g/kg DM)
Dry grass/ straw	2.6- 3.4	-	-	1.5- 3.0
Browse	1.7- 3.0	56- 300	1.5- 2.5	2.5- 20
Maintenance needs	3.0	50	1.3	2.5

Note: NE (Net energy), DM (dry Matter), P (Phosphorus), Ca Calcium).