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ENVIRONMENTAL IMPACTS OF LIVESTOCK HUSBANDRY: APPROACHES TO IMPROVING RANGELANDS IN NIGER

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ABSTRACT

In Niger, as in most Sahelian countries, livestock has an important socio-economic, cultural and food security role for the population. Ranked as the second socio-economic activity after agriculture, livestock also represents the second strongest export after mining. Livestock production in the Sahel is threatened by multiple factors and subsequently household livelihoods are at stake. This project summarizes available published studies on the environmental impacts of domestic animal husbandry and some approaches, either through management or through restoration, to improve rangelands in Niger. I found that livestock farming in Niger is characterized by a great diversity of domestic animals (species and breeds) and a great diversity of forage species (woody plants and grasses) with a scarcity of surface water. Animal management (livestock practices) differs according to the agro-climatic zones of the country. This study highlights the main effects or impacts of livestock on vegetation, soil and surface water. Some solutions are discussed such as restoration and land management to improve pasture areas and to sustain livestock production in the Sahelian countries where livestock is the main income source for smallholders.

Key words: Livestock, rangeland, impacts, restoration and management, Sahel.

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1. INTRODUCTION

Desertification and land degradation associated with unsustainable land uses are threatening arid and semi-arid regions worldwide (Yengoh et al. 2011). The Sahel refers to a region in Africa, between the Saharan domain in the north and the savannahs of the Sudanian domain in the south, characterized by arid to semi-arid climate and reduced vegetation. In the Sahel, livestock is the main renewable resource, which contributes to the foundations of the social values of rural Sahelians (Hiernaux & Le Houérou 2006) with a contribution of up to 69% of rural incomes in the zone (Permanent Interstate Committee for Drought Control in the Sahel [CILSS] 2010). Livestock farming in this region is often marked by widespread drought and the rapid growth of human and animal populations, resulting in an increase in the demand for animal products and, importantly, the widespread degradation of rangelands (Dicko et al. 2006).

Niger is a continental country located in the heart of the Sahel. Nigerien livestock husbandry is one of the pillars which the country must rely on to sustain its economy. Livestock husbandry is practiced by nearly 87% of the active population, either as a main or a secondary activity after agriculture (vegetable production), and contributes nearly 11% of the national gross domestic product and 35% of the agricultural gross domestic product (Ministry of Livestock 2014).

The livestock of Niger has grown dramatically in recent decades, from around 18 million heads in 1970 to nearly 47 million heads in 2017, which makes Niger a large country in terms of pastoral livestock farming (Ministry of Planning 2017; FAO 2018). With larger herds, pastures become poorer with each passing year and consequently, increased soil compaction, wind and water erosion and deforestation, all of which lead to land degradation (Humphreys 1991).

Despite the negative consequences of livestock husbandry practices on rangelands in Niger, so far there are no consistent analyses of the environmental impacts of pastoral livestock practices and the approaches used to improve these natural pastures. Such knowledge would help update information at the national level and guide policymakers (government) and other stakeholders (NGOs and breeders) to regulate farming practices and promote measures to manage and restore degraded rangelands.

This research project synthesizes the existing body of literature on the environmental impacts of livestock husbandry and identifies potential approaches to improve rangelands in Niger, to address the following research objectives:

- Assess the environmental impact of livestock husbandry practices on rangelands in Niger;
- Identify land management and land restoration practices to improve rangelands in Niger.

2. METHODOLOGY

To evaluate the environmental impact of livestock husbandry practices on rangelands and to identify practices to improve the management of rangelands in Niger, I have reviewed scientific and professional literature.

To conduct the literature review, I used search engines and online databases like Google, Google Scholar and Scopus, to access scientific documents (articles in scientific journals, books and reports) related to the topic. The search on these engines was based on the use of keywords or targeted searches of specific documents. I first searched for references related to farming practices on rangelands in Niger, and then looked at the approaches used to improve rangelands in Niger.

To broaden the search related to the project, I also reviewed the reference lists of the documents found. Articles and books from the UNU-LRT (United Nations University Land Restoration Training Programme) library in Reykjavik and at the library of the Soil Conservation Service of Iceland in Gunnarsholt were also used to widen the scope of the work.

3. ENVIRONMENT AND LIVESTOCK SYSTEMS IN NIGER

3.1 Physiography of Niger

Niger is a continental country located in the heart of the Sahel. Two-thirds of the country is desert. Niger covers 1,267,000 km^2 and is bordered on the north by Algeria and Libya, on the east by Chad, on the south by Nigeria and Benin, and on the west by Burkina Faso and Mali. The country is subdivided into eight regions (Fig. 1); Agadez, Diffa, Dosso, Maradi, Tahoua, Tillabéry, Zinder and Niamey (the capital city of Niger).

The arid and semi-arid tropical climate of Niger is characterized by:

- A short rainy season (June to September),
- A long dry season (October to May) that is subdivided into:
    - A hot dry season without rain (October and November),
    - A cold dry season (December to February),
    - A hot dry season (March and May).

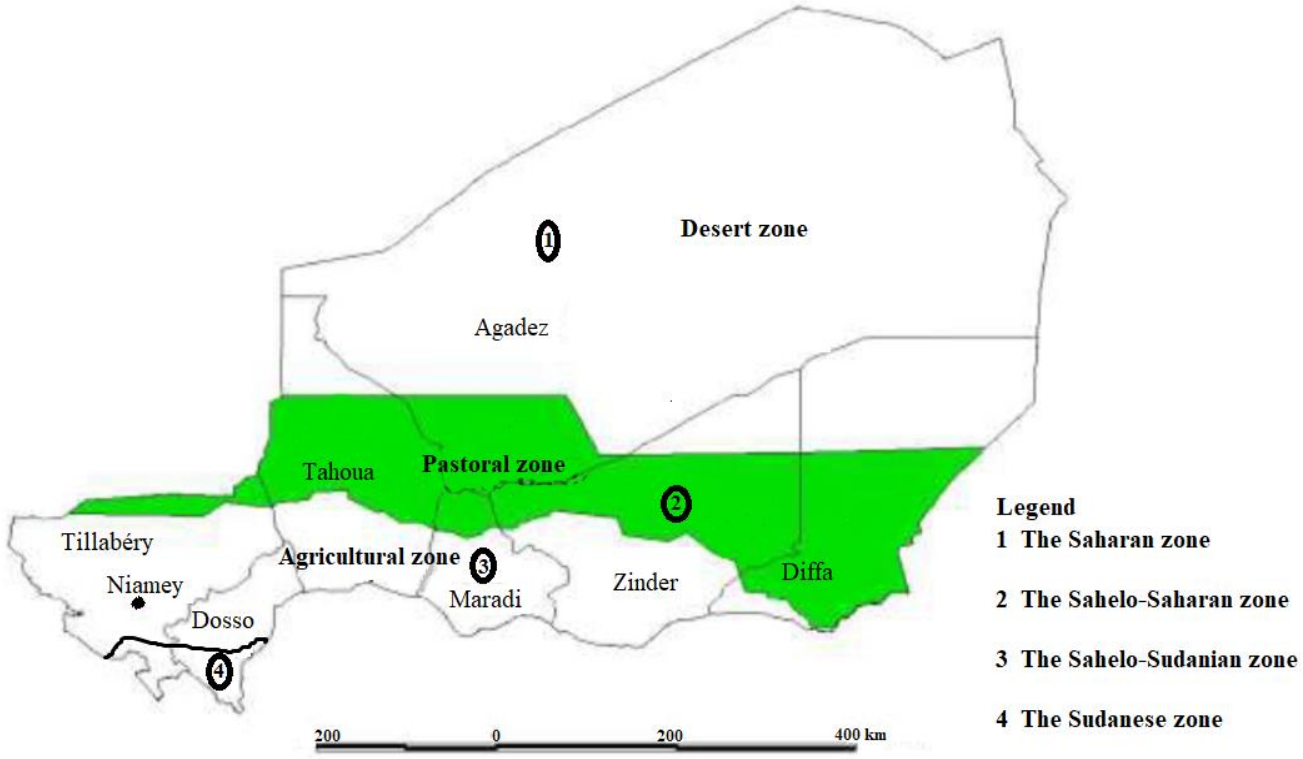

Figure 1. Agropastoral and climatic zoning, and regions of Niger. The green zone indicates the pastoral zone of Niger. (Map source: From Rhissa 2010).

The variation in the number of rainy days from north to south divides the country into four climatic zones (Fig. 1), each corresponding to a different agropastoral use:

- The Saharan zone (desert zone 1) with 65% of the country and less than 100 mm of rain per year. This is the domain of camels and goats that are rustic animals of Tuareg breeders;
- The Sahelo-Saharan zone (pastoral zone 2) with 12% of the national territory and annual rainfall between 100 and 300 mm. The climate is sub-desert and it is a pastoral area. Rainfall is sufficient for the development of most herbaceous plants but insufficient to complete the vegetative cycle of the country's main food crops (millet, sorghum, maize, groundnuts and rice). All domestic animal species are found in this zone, especially in winter, with the return of animals from the agricultural zone to the pastoral zone. In this area fodder is often exposed to devastating bush fires throughout the dry season;
- The Sahelo-Sudanian zone (agricultural zone 3) with 22% of the national territory and annual rainfall between 300 and 600 mm. It is the agricultural zone although there are many herds of all species. All domestic animal species are found in this area, particularly cattle, sheep and goats;
- The Sudanese zone (agricultural zone 4) covering 1% of the national territory, receives between 600 and 800 mm of rainfall annually. Camels are rare.

3.2 Soils and water of Niger

Niger is a large plateau with an average elevation of 350 m reaching up to 2,000 m in the Aïr massif in central Niger.

The soils of Niger differ between the different zones:

- In the Saharan zone, soils are poorly developed. In this zone, deficiencies in water and vegetation inhibit soil formation.
- In the Sahelo-Saharan zone, there are either poorly developed soils of aeolian contribution or red-brown soils with sandy dominance. They are very poor in organic matter.
- In the Sahelo-Sudanian zone, the soils are of the tropical ferruginous type, which are more developed soils than those in the Sahelo-Saharan zone.
- In the Sudanese zone, there are ferruginous and fersialitic soils. The soils are more developed than those in the Sahelo-Sudanian zone (Weynants 2005).

Apart from seasonal streams, Niger's main freshwater system consists of the main river (Niger), a smaller river (Komadougou yobe) and Lake Chad. The river Niger crosses the country in the southwest for 550 km. The Komadougou Yobe marks the border between Niger and Nigeria for 140 km. Lake Chad is shared by Niger, Nigeria, Cameroon and Chad. The scarcity of surface water leads the population to use ground water from wells and drilling (Dambo 2007).

3.3 Vegetation in Niger

According to Mahamane et al. (2009) and the Ministry of Livestock (2014), the vegetation of Niger is very diverse and varies from north to south in quantity and is as follows:

The Saharan zone (Saharo-Sindian zone) is marked by vegetation at the level of the lowlands located in the plains dominated by the grass *Panicum turgidum.* In dry valleys, vegetation is dominated by the grass *Cymbopogon schoenanthus*, while in the dunes, the herbaceous cover is dominated by *Cyperus conglomeratus* in association with *Aristida mutabilis, Tragus racemosus*, and *Cenchrus biflorus*. On the plateaus, the most common grasses are *Aristida hordacea, Aristida funiculata, Cenchrus ciliaris, Eragrostis pilosa* and *Schoenefeldia gracilis*. The rare woody species found in this area are *Acacia raddiana, Acacia ehrenbergiana, Cordia sinensis, Maerua crassifolia* and *Grewia tenax*.

The plant formations of the lower part (between 500 and 900 m of altitude) of the mountains of the Aïr include woody species *Maerua crassifolia, Leptadenia pyrotechnica, Calatropis procera, Balanites eagyptiaca, Salvadora persica, Acacia raddiana* and *Acacia ehrenbergiana*. The grasses encountered are *Stipagrostis* spp., *Aristida* spp. and *Eragrostis* spp. On the upper part (above 900 m), we find *Acacia raddiana, Acacia ehrenbergiana, Acacia laeta, Faidherbia albida, Boscia senegalensis, Ziziphus mauritania*. Poaceae are represented by *Aristida mutabilis, Cymbopogon schoenanthus, Tripogon multiflorus and Desmostachya bipinnata*.

The Sahelo-Saharan zone is characterized by woody species such as *Faidherbia albida, Sclerocarya birrea, Boscia senegalensis, Balanites aegyptiaca, Hyphaene thebaica, Acacia*

raddiana and *Salvadora persica* shrubs. The herbaceous cover is composed of *Cenchrus biflorus, Cenchrus prieurii, Brachiara villosa, Schoenefeldia gracilis, Panicum turgidum, Aristida mutabilis* and *Eragrostis tremula* and the plant cover is mainly composed of *Cenchrus biflorus, Cenchrus prieurii, Tragus racemosus, Dactyloctenium aegyptium,* and *Aristida adscensionis*.

The Sudano-Sahelian zone is composed of trees such as *Guiera senegalensis, Acacia raddiana, Acacia nilotica, Acacia senegal, Balanites aegyptiaca, Prosopis africana, Faidherbia albida, Hyphaene thebaica* and *Boscia senegalensis*. The herbaceous layer is rich in *Aristida adescensionis, Eragrostis tremula, Eragrostis pilosa, Brachiaria villosa, Cenchrus biflorus, Cenchrus prieurii, Dactyloctenium aegyptium, Schoenefeldia gracilis,* and *Brachiaria xantholeuca*.

The Sudanian zone is marked on the lateritic plateau by *Loudetia togoensis, Brachiaria xantholeuca, Digitaria gayana*. In the valleys we find *Andropogon gayanus* and *Pennisetum pedicellatum*. The woody vegetation is composed of *Butyrospermum parkii, Parkia biglobosa, Mitragyna inermis, Cola laurifolia* and *Afzelia africana.*

3.4 General information on Nigerien domestic livestock

Small ruminants (sheep and goats) represent around 66% of the national livestock (Ministry of Livestock 2014). Other animal species raised in Niger include cattle, camels, horses, asses and poultry. For each of these species, Niger has a diverse range of locally adapted breeds, and this diversity is part of the natural wealth of Niger (Ministry of Livestock 2014; Fig. 2). There are five breeds in the cattle herd: Azawak, Bororo, Kouri, Goudali and Djelli (Marichatou et al. 2005), and five breeds of sheep: the Oudah, Ara-ara, Bali-bali, Balami and Koundoum (Ari 1975). The goat breeds are the Sahel goat and the red goat (Mani et al. 2014), and camel breeds include Azaouak, Red from Gouré and Azarghah (Chaibou 2005).

In Niger, the four regions located in the southern band of the country (Fig. 1) account for 77% of the total number of national livestock: Zinder (25%), Tahoua (21%), Maradi (16%) and Tillabéry (15%). These areas are largely included in the pastoral zone, which is favourable to extensive breeding in contrast to the agricultural zone (further south), which is reserved for crops.

In Niger, the size of the herd determines the social status of the farmer. The herd confers prestige and notability to those who possess it (Musabyemariya 1997), so the bigger the flock, the more esteemed the breeder. Unlike agricultural products, livestock products are a source of income for farmers throughout the year (Musabyemariya 1997).

Figure 2. Livestock breeds of Niger for cattle (a: Djelli, b: Kouri, c: Goudali, d: Bororo, and e Azawak), sheep (f: Balami, g: Bali-bali, h: Ara-ara, i: Oudah, j: Koundoun), goats (k: Sahel goat, l: red goat), camel (m: Azarghah, n: Red from Gouré, o: Azawak). (Sources: Cattle and camel photos by Ministry of Livestock 2014; sheep and goat photos by A H. Yayé, 2017).

3.5 Livestock systems and modes of access to pasture in Niger

In general, there are three farming systems in Niger (Ministry of Livestock 2014), associated with the practice of extensive, semi-extensive and sedentary breeding.

3.5.1 The pastoral system

The pastoral system is dominant in the pastoral zone of Niger (Fig. 1), with an estimated area of 40 million hectares (Ministry of Livestock 2014). The main characteristics of this system are a very low livestock exploitation rate and the nearly constant mobility of herders and herds in search of water and pastures. Resources are exploited extensively without the use of zootechnical inputs, except in years with critical forage deficit. Transhumance is a widely practiced adaptation strategy in the Sahelian countries, with benefits of optimizing access to water and quality pastures for all year-round livestock production. In 2012, the proportion of transhumant livestock in Niger was estimated at more than 15.9% of the national livestock (Ministry of Livestock 2014). This system, based on extensive breeding, has been associated with overgrazing (in the pastoral system, the numbers per herd are higher than in the agricultural system) leading to scarcity and / or disappearance of food resources for livestock. The practice of pastoralism is for the human populations living in this region a way of life, allowing them to express their identity as pastoralists. The herd moves to exploit the rangelands and existing water points in the area. This mobility is intended to search for new pasture to cope with pronounced spatial and temporal variations in forage resources (Amadou 2009).

3.5.2 The agropastoral system

This system is like the sedentary production system (see below), characterized by a relatively low mobility of animals. The agropastoral system, however, remains based on extensive exploitation of forage resources, and the animals are supplemented with crop residues. This system is typical of the agricultural zone. The exploitation rate of livestock is higher than in the pastoral system.

3.5.3 The urban and peri-urban system

On the other extreme of the intensification gradient, the urban and peri-urban system is gaining importance with increasing urbanization. This system is based on a sedentary production system and is practiced around urban and peri-urban centres. This system introduces the concept of an improved and available diet at any time (stocking of feed and /or concentrated feed). It is subdivided into: 1) traditional sedentary village breeding, where animals consume the by-products of the harvests and the products of the gathering (pods of the leguminous trees and shrubs); and 2) improved urban and peri-urban livestock breeding, which uses by-products from milling, brewing, oil milling and ginning. The production costs of this system are relatively high since it uses a large amount of zootechnical inputs (agricultural and agro-industrial by-products) and veterinary inputs to support livestock production.

3.5.4 Modes of access to pasture

In the Sahel, in general, access to pasture (pastoral zone) and crop residues (agricultural zone) is either free, or allowed by contract where livestock owners negotiate with farmers to have animals graze on their post-harvest farms, or subject to taxation (Kiema et al. 2014). The advantage of keeping animals in the fields is that manure transfer is provided by the animals themselves (with little investment) because all excretions (faeces and urine) are deposited on the field while the animals are grazing.

In Niger, in addition to access to natural pastures and crop residues, access to grazing is conditioned by the presence of water (generally well water during the dry period, between October and May) and social links (family, ethnic or professional) that share farmers and landowners or wells (Hammel 1999). Some individuals, development partners and the government dig wells and charge a fee for their maintenance. In winter, animals are banned from using the agricultural zone, where most crops are grown, in order to avoid conflicts between farmers and livestock breeders. Therefore, large herds migrate to the pastoral zone until farmers release the crop fields. In case of drought and the subsequent shortage of forage, farmers can move in search of fodder and water to areas not affected by drought.

4. ENVIRONMENTAL IMPACTS OF LIVESTOCK

Livestock husbandry is in some cases considered a negative activity on the environment, as it contributes to the acceleration of deforestation and desertification due to increased need for pastures and pasture resources (Laouali et al. 2014). Grazing and repeated trampling of livestock can cause severe damage to vegetation cover, exposing large areas of soil and accelerating soil erosion (Dumont et al. 2001; Meaux et al. 2004).

Overgrazing is an excess of "grazing pressure" by animals (domestic or semi-domestic) that over-exploit the plant resources used to feed them (Coughenour & Singer 2000; Viramontes-Pereida & Descroix 2000; Mysterud 2006). Overgrazing prevents natural regeneration of the vegetation cover and causes soil erosion and is the most serious and common problem that affects arid and semi-arid soils. Although it has been argued that the ultimate causes of overgrazing in the Sahel could be found in economic pressures, greed, despair and sometimes ignorance, environmental conditions, like extreme temperatures, intense sun, strong winds, limited humidity and the low fertility of Sahelian soils limit the natural recovery of these areas (Bainbridge 2007).

Free grazing of herbivores can lead to overgrazing depending on the spatial distribution and the temporal availability of plant resources and their palatability. In contrast, grazing of animals under the guidance of man (i.e. herding) can prevent overgrazing if well managed and can also protect sensitive areas from grazing. However, herding in arid and semi-arid areas can accelerate the process of degradation of sensitive vegetation that struggles to regenerate because of the erratic precipitation patterns in these areas. Grazing on such sparse vegetation reduces the potential for plant replacement through seed production (Wang et al. 2018).

4.1 Effects of livestock grazing on vegetation

Several authors have recognized the protective role of plant cover against the damage caused by the hooves of animals on the ground (Taboada & Lavado 2007, McDowell et al. 2008). However, the degree of protection provided by vegetation depends on the quality and quantity of the vegetation (Climo & Richardson 1984).

The aboveground parts of plants represent at first a direct physical boundary between hooves and the soil (O'Connor 1956). In turn, belowground parts of plants increase soil shear strength and bearing capacity (Patto et al., 1978). Plants also protect the soil indirectly by decomposing plant residues that bind to the mineral component of the soil and other agents that give rise to water-stable aggregates that are more resistant to deformation (Taylor & Gaylen 1972; Patto et al. 1978).

The effects of herbivores on vegetation can result in defoliation, trampling, deposition of excrements on the ground or saliva on the aerial parts of plants (Lefebvre & Gallet 2018) (Fig. 3). The damage caused by herbivores through defoliation depends on the phenological stage or organs consumed by the animal on the one hand, and the species of herbivore on the other (Lefebvre & Gallet 2018). During grazing, the selection of plants by animals depends, according to Demment & Van Soest (1985), on the physical or chemical characteristics of plants, but the criteria for selection of plants vary depending on the herbivore species (Edouard et al. 2010). Selective herbivory generally favours the development and increase of plants not consumed by herbivores or those that tolerate herbivory, to the detriment of palatable, grazing-sensitive plants (Olofsson & Oksanen 2002; Lavours et al. (2001). Intense defoliation can lead to plant death (Hester et al. 2006). Also, selective defoliation of buds can stimulate the formation of new leaves and branches and hence increased evapotranspiration and soil nutrient uptake (Bationo & Somda 1994).

In the Sahel in general and in Niger in particular, the absence of the herbaceous carpet during the dry period leads the animals to use the foliage of ligneous trees (the shrubs directly by the animals and the trees with the help of the breeders). Shrubs accessible by animals are defoliated by intense grazing. Trees are pruned or cut down by breeders to provide foliage for animals (Escadafal & Hubert 2012). However, in the subhumid regions where the herbaceous carpet is more abundant than in the Sahel, intensive grazing weakens the competitiveness of grasses in favour of ligneous plants (Escadafal & Hubert 2012).

The domesticated animals physically affect the plants by cutting and tearing plant organs, uprooting (with the teeth) of young seedlings, breakage of branches and trampling of low plants. Defoliation reduces the photosynthetic activity of plants (Escadafal & Hubert 2012).

Deposition of saliva on plants by grazing animals can delay plant growth (Liu et al. 2012). The quantity and chemical composition of saliva varies between grazing species (Austin et al. 1989) and the size of the animal (Hofmann et al. 2008). The saliva of animals deposited on the aerial parts of the plants during their consumption can induce the production of plant defences (Lefebvre 2016; Lefebvre & Gallet 2018).

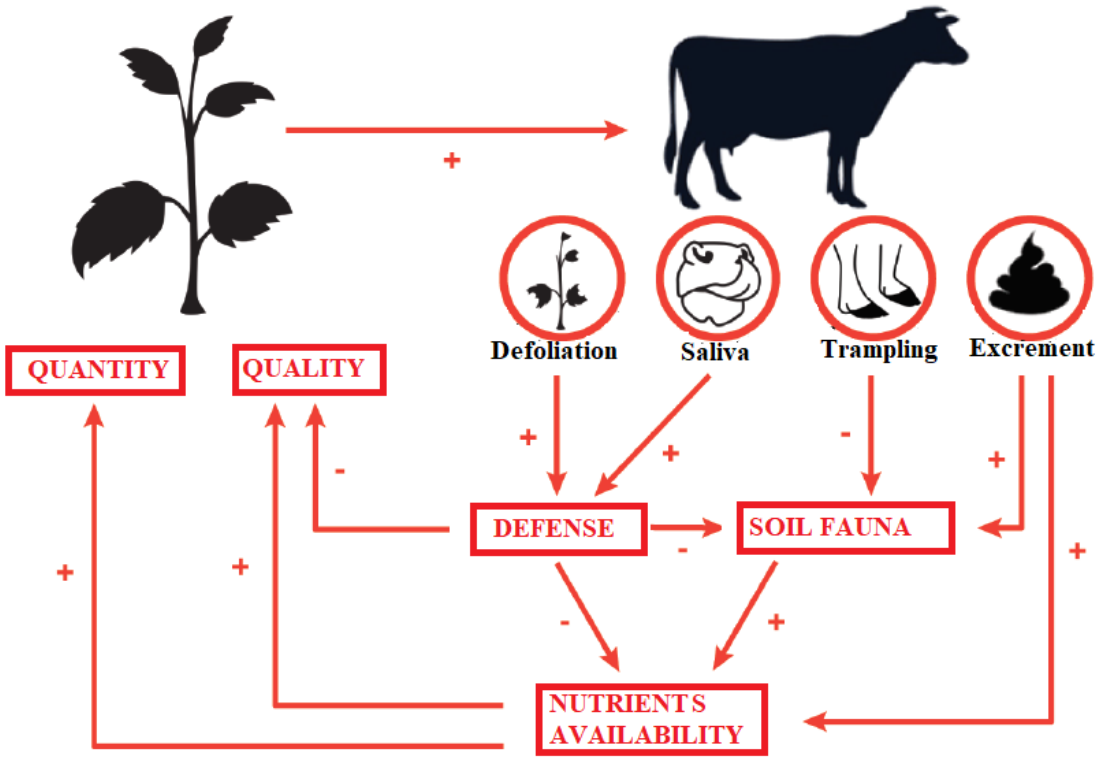

Figure 3. Conceptual diagram summarizing the processes by which herbivores can affect the quantity and quality of plants, and the different mechanisms of action involved. The sign "+" or "-" indicates whether the effect of one item on another is positive or negative. For clarity, only the main interactions and effects are represented. (Source: Lefebvre & Gallet 2018).

Trampling and track formation by grazing animals can cause loss of vegetation cover, also known as denudation (Verheij 2003). Denudation increases the vulnerability of soils to erosion (Goodall et al. 2009; see next section). Marteinsdóttir et al. (2017) have shown that sheep grazing in Iceland affects the structure of the plant community and can lead to denudation in the rangelands.

The deposition of urine and animal excrement can have positive effects for the soil and the plant. Faeces can accelerate nutrient cycling, increase plant growth, and the nutrient content of plant tissues (Bloor et al. 2012). Animal manuring is an important process for cycling of nutrients to maintain or improve soil fertility (Parker 1990). The nutrient enrichment of soil with excrement and urine leads to an increase in the availability of nutrients directly assimilated by plants (Stark et al. 2000). Barthelemy et al. (2018) showed that urea from urine of mammalian herbivores can be efficiently assimilated by the plant and the soil microbial bioma, and thus contributes to nitrogen cycling in ecosystems.

The deposition of excrement by herbivores can also facilitate the dispersal of seeds from the plant from which they originate and promote their germination (Milotic & Hoffmann 2016).

According to Clauss et al. (2002) and Bakker et al. (2004), the effect of herbivore droppings varies depending on species and especially the quantity and quality of the excrement. The spatial distribution of excreta is influenced by pasture management and animal behaviour (Bloor et al. 2012; Lefebvre & Gallet 2018).

However, deposits from faeces of herbivores can also have negative impacts on plants and soil, for example causing physical or chemical damage to the plant, retarding its growth or causing its death by suffocation or preventing access to light (Hester et al. 2006; Bloor et al. 2012). For Hoekstra et al. (2002) excreta can inhibit the germination process or limit root growth. Haynes et al. (2014) state that the urine of herbivores can cause "burns" in the plant roots.

4.2 Impacts of livestock grazing on soils and soil erosion

One of the direct impacts of livestock on the physical properties of soils is superficial soil compaction (Carrière 1996). Raghavan et al. (1990) defined soil compaction ‘‘as the compression of a mass of soil into a smaller volume’’ (p. 4).

The pressure exerted on the soil is dependent on the age and species of the grazing animals, vegetation cover and the structural forms (e.g. deformation) resulting from the stocking density, soil texture and moisture content (Bilotta et al. 2007). Soil compaction leads to the compression of soil pores that can carry water and air, leading to an increase in bulk density (Humphreys 1991), hindering root growth and causing oxygen deficiency. Soil compaction is more pronounced on clay or silty clay soils than on sandy soils, and wet soils are more sensitive than dry soils to animal trampling (Mitchell & Berry 2001; Nawaz et al. 2013; Warren et al. 1986). Warren et al. (1986) showed that sediment production increases significantly while the rate of infiltration also decreases significantly as a result of periodic and intensive trampling of animals.

In the Sahel where soils are dry and covered only by sparse vegetation, the risks of wind and water erosion are high. In general, soil erosion results from a combination of factors such as climate, livestock, and agriculture. However, Carrière (1996) highlights that “the intensity of the impact on soils is greater under the effects of agricultural activities compared to pastoral activities” (p. 36). Defoliation of trees and soil denudation exposures have been shown to cause physical and chemical degradation of the soil in the Sahel, particularly in Niger (Bationo & Somda 1994)

In turn, soil compaction can lead to a sharp decrease in the yield of plants (Lipiec et al. 2003; Unger & Kaspar 2010). In rangelands, the areas most affected by soil compaction occur near shelters, drinking troughs, rest areas and movement paths (Laouali et al. 2014).

4.3 Water pollution

Several authors have mentioned the negative impact of livestock on water quality and quantity (Noah et al. 2001; Herrero et al. 2009; Corson & Doreau 2013). Uncontrolled grazing can affect water quality due to erosion (loss of vegetation cover due to frequent grazing, trampling or grazing too close to the ground) and sediment transport of nutrients from urine and faeces released by animals into surface water (Noah et al. 2001; Hubbard et al. 2004). In Uganda,

Swidiq et al. (2014) found that the water in dams had high sediment loads due to water and wind erosion caused by overgrazing around dams.

In the Sahel, access to crop production is conditioned by the presence and location of surface water resources (permanent or semi-permanent pools) or underground water (wells and boreholes). According to Abdou et al. (2019), the wells (82.60%) and permanent ponds (10.10%) are the sources of water for animals during the long dry period (8 months).

These very insufficient watering places on the national territory (to which the animals have access) are polluted by the excrement and urine of the animals to the point where their water changes colour and smell (Yayé Abdou 2019 personal observation). Forage availability around these watering places is non-existent or in very bad condition because of the high animal densities which converge there every day, in particular during the dry season.

5. LAND MANAGEMENT AND LAND RESTORATION PRACTICES TO IMPROVE RANGELAND MANAGEMENT IN NIGER

Land management can be defined as a process of managing by policies the use of land resources to avoid land degradation. Changing management practices can thus alleviate some of the consequences of degradation (Eweg et al. 1998; Bestelmeyer et al. 2004). On the other hand, land restoration can be defined as a process of land rehabilitation through practices (for the benefit of humans and animals) that have been degraded by natural phenomena or human activities (Harris et al. 1996).

In the following section I discuss land management and land restoration practices that have been implemented in Niger to improve rangeland condition.

5.1 Land management

The population of Niger is highly dependent on natural resources (Moussa et al. 2016). The agricultural land that is permanently harvested or grazed represented 36% of the total area of Niger in 2015 (Perspective monde 2019). However, we are witnessing accelerated reduction in natural resources and a worsening of poverty in rural areas (Ambouta & Bouzou Moussa 2004). The proper management and restoration of the natural capital of the country would alleviate the suffering of the population, no doubt linked to the continued degradation of these resources.

In areas with marked seasonality, grazing intensity must be adapted to climatic conditions: in the dry period, recovery periods must be longer because of the limited potential for recovery of plants and their high sensitivity to overgrazing and erosion. The relationship between periods of presence and absence of grazing determines the yield and vigour of plants (FAO 2011).

In Niger, several practices such as better distribution of water points, installation of water collection structures and improvement of corridors for herds are used in the field to manage livestock distribution. Increased access to water points allows using previously unexploited areas. A more balanced distribution of herds around a limited number of wells greatly reduces

the over-exploitation of vegetation. Thus, the increase of wells in the pastoral zone and the development of animal corridors in agricultural zones would make it possible to reduce conflicts between pastoralists in the pastoral zone on the one hand and between farmers and pastoralists during transit between crop growing areas to pasture areas on the other hand (Baroin 2003). Still, according to Baroin (2003) these facilities and equipment must be well managed by management committees at the community level or privately, because for the author the lessons of the past have shown that leaving these facilities in the public domain only leads to deterioration of pastoral areas.

The protection of the environment and in particular grazing areas requires in some cases fencing off some areas for certain periods. Grouzis (1988) reports that at the end of an experiment during which animals did not have access to pasture areas (grazing exclusion), the recovery of the plant stand increased on these sites because grazing exclusion favoured the flowering and the fruiting of plants, increasing the chances of plant reproduction and establishment in the long term. Restricting access of animals to degraded rangelands for a certain time (resting or deferring) will promote the abundance and cover of plant species (Ousseina et al. 2013). In this sense, fencing off grazing animals can provide a simple and effective management tool because it enhances vegetation characteristics and soil properties (Ousseina et al. 2010, Tang et al. 2016). Al-Rowaily et al. (2015) showed that exclusion of livestock improved soil quality by increasing soil nutrient levels, and significantly increased the cover, density and species richness of plants. Exclusion also increased the abundance and richness of palatable species and hampered the encroachment of invasive species (Al-Rowaily et al. 2015).

Rampai (2017) points out that mismanagement of pastures would lead to their degradation and concludes in his study on the effect of grazing systems in Lesotho and Iceland that ‘‘Grazing management systems that include relatively long resting periods, like modified seasonal rotation, rest-rotation and deferred-rotation, might be more suitable for the mountainous terrains of both Lesotho and Iceland, by allowing some recovery time between grazing events’’ (p. 19). In Niger, these types of pasture management are found in national ranches, like the Sahelian experimental Toukounous station. Amiri et al. (2008) have shown that the inaccessibility of animals to pasture areas leads to a significant improvement in pasture condition (improved cover and plant density with a significant increase in Gramineae).

For Lhoste (2007) and D'Alexis (2015), the association of herbivore species in mixed grazing systems is necessary for good pasture management because it promotes a good composition of the forage species of the environment.

In the context of protecting and enhancing the forage resources and avoiding the burning of thousands of hectares of pastures by fire, firewalls are made. Thus, the hay recovered during the production of the fire creation strips makes it possible to constitute forage stocks to improve the feeding of the livestock during the lean season. (Moussa et al. 2015).

5.2 Land restoration

Restoring degraded lands is a multilevel process to improve the state of the land (Petursdottir et al. 2017). In the Sahel, as in Niger, several techniques for recovering degraded lands are used to recover as much water as possible after rain. This recovery will promote water infiltration and thus improve vegetation cover, and consequently improve soil quality. The main techniques used to restore or maintain soils in the Sahel according to the type of land are synthesized by Dorlöchter-Sulser & Nill (2012) (Table 1).

Table 1. The main soil conservation and restoration techniques in accordance with their topographical position, from uplands to slopes, pediments and valley bottoms in the Sahel.

Improvement of uplands	Improvement of slopes	Improvement of pediments	Improvement of valley bottoms
-Half-moons	-Manual trenches	-Stony cords	-Spreading thresholds
-Nardi trenches	-Filter dams	-Diguettes filtrantes	-Micro dams
-Benches	-Dune fixing	-Zaï	-Village irrigation schemes
-Firebreaks		-Supply of organic matter: manure and composting	
		-Mulching	
		-Natural regeneration assisted	

(Source: Adapted from Dorlöchter-Sulser & Nill 2012).

The most common restoration practices in Niger are usually simple erosion control techniques. These practices aim at restoring the productivity of the land, through maintaining soils and preventing further erosion (Roose et al. 1993; Ambouta & Bouzou Moussa 2004; Dan Lamso & Bouzou Moussa 2004). The involvement of local populations in the restoration of degraded lands has contributed to capacity building in the local communities and improving their living conditions (Mahamane et al. 2018). Local people carry out erosion control work manually with pickaxes, crowbars, shovels and rakes. The use of these tools does not easily allow the large-scale restoration of degraded lands in the Sahel in general and Niger in particular where soils are compact and hard to till (Dorlöchter-Sulser & Nill 2012).

It is important to note that the recovery of degraded lands is funded directly by international partners such as NGOs (Catholic Relief Services, World Vision, Millennium Challenge Corporation) or regional projects (Regional Project for Support to Pastoralism in the Sahel) through elaborate programmes. NGOs and projects are under the supervision of the Ministry of the Environment, Urban Sanitation and Sustainable Development and / or the Ministry of Agriculture and Livestock. These NGOs or projects allow the recruitment of young people (fight against unemployment) based on fixed-term contracts (one month to five years). The labour used for land restoration comes from local populations remunerated through cash for work or food for work. For example, creating 313 half-moons is remunerated at about US $ 225 per hectare, the uprooting of the invasive species *Sida cordifolia* at US $ 50 per hectare and the construction of firewalls at US $ 85 per kilometer achieved (Belgian Development Agency 2014). Dune fixation is US $ 222 per hectare treated (Dorlöchter-Sulser & Nill 2012).

5.2.1 Half-moons (semi-circular bunds)

Half-moons, i.e. semi-circular basins, are generally used for the land development from 0 to 3% of slope. The main objectives are to recover land for agro-sylvopastoral purposes, increase the availability of water for plants and reduce rainwater runoff and soil erosion and promote infiltration. Half-moons must be arranged perpendicular to the direction of flow of surface water and staggered to capture runoff and fine soil particles. Often only one, or sometimes several trees are planted at the foot of the dike inside the half-moon.

The dimensional characteristics of a half-moon are: diameter: 4 m, depth: 0.25 m, bead height: 0.30 m, distance along the line: 8 m, distance between lines: 4 m, slope of the structure: 1.5 - 2% and density: 313 half-moons per hectare (Dorlöchter-Sulser & Nill 2012).

5.2.2 Benches or bunds

A bench or bund is a contoured earth structure consisting of a berm downstream and an upstream basin in which plant species are planted. The benches are staggered perpendicular to the flow of surface water. They aim to capture runoff water and facilitate its circulation and infiltration over the entire treated area, increase the area harvested and re-vegetate the treated area.

The dimensional characteristics are: width: 15 m, length: 100 m staggered, spacing between 2 bundles: 6 m, spacing between 2 rows: 25 m, density per hectare: 3 to 6 units (Dorlöchter-Sulser & Nill 2012).

5.2.3 Zai

This technique is called "Zai" in Burkina Faso and "Tassa" in Niger. The dimensions of the cuvettes vary according to the nature of the soil (on average 20 to 30 cm in diameter and 10 to 15 cm deep) (Dorlöchter-Sulser & Nill 2012). They are wider on lateritic (porous) soil and smaller on clay soil. The spacing between the cuvettes is variable and there are between 12,000 and 15,000 cuvettes per hectare. During digging, the farmer accumulates downstream of the bowl the soil taken in the form of a bead intended to retain the runoff water. This often adds organic fertilization to the bottom of the cuvettes. The implementation of this method requires about 60 man / days of work per hectare.

5.2.4 Firewall tape construction

This is a preventive method in the fight against bush fires during the dry season, isolating the spaces from each other by large bands whose objective is to reduce or stop the progression of fire. These are strips 15 to 20 m wide cleared of vegetation and flammable materials. They are oriented perpendicular to the prevailing winds. The spacing between two firewalls is 300 m to 500 m depending on wind speed.

For a rapid and large-scale recovery of degraded lands, it is necessary to move from the traditional (manual) methods to strategies that allow large-scale implementation, such as mechanized methods. As well, natural recovery processes can be promoted to stimulate natural

revegetation, for example, the Hekluskogar project in Iceland (Aradottir and Halldorsson 2018) or the Humbo Assisted Natural Regeneration Project in Ethiopia (Clean Development Mechanism 2009). In many cases, these restoration activities may need to be re-implemented at sites to ensure their effectiveness. The restoration techniques for degraded lands could restore soil productivity by controlling runoff, restoring and stabilizing macropores, revitalizing the cultivated shallow horizon, suppressing toxicities due to pH below 5, and correcting the mineral deficiencies of the plants (Roose et al. 1993).

6. CONCLUSIONS

Livestock production can impact soil quality and plant communities in a number of ways. These impacts vary by animal species, space and time. However, good management of livestock grazing can reduce its environmental impacts. Many of the restoration methods and management strategies used in degraded lands in Niger are well known to the people and are implemented by the policies to restore these lands.

In order to achieve a balance between livestock and the environment (pasture areas), it is essential that the authorities focus on the restoration and sustainable management of degraded lands and rangelands, through erosion control works, by planting fodder plants, raising awareness, training and supporting populations and securing livestock farmers and their herds as well as grazing areas against armed bandits. This balance will improve the conditions of animals and human populations alike.

To cope with the very frequent forage deficit in the arid and semi-arid zones, it is essential to focus on the planting of fodder shrubs and trees (*Accacia raddiana, Accacia seyal, ziziphus mauritiana, Balanites aegyptia*) and the recovery of land invaded by invasive species, such as *Sida cordifolia* Linn, that are not palatable to livestock. Recovered areas and grazing areas should be sown in general with high quality, native herbaceous species.

Communicating the knowledge obtained in this project to local authorities and technical and financial partners could lead them to take an interest in and even act for the restoration and securing of natural resources. As well, this knowledge should be communicated to the various breeders' organizations so that they understand the environmental impact of livestock husbandry practices on rangelands and how to restore these degraded lands.

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