Matière
à débattre & décider

Livestock grazing systems and sustainable development in the Mediterranean and Tropical areas

Recent knowledge on their strenghts and weaknesses

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from a more sudden shock (e.g. the arrival of a predator) or a set of relatively continuous changes such as climate change or globalisation. The scale and time interval considered in the study of adaptations varies accordingly. The nature of the disturbances causing adaptation - climatic, environmental, technical, economic, political, social, etc. - also leads to diversity in the work. What is the extent of this adaptation? The three levels distinguished in the study of resilience (Darnhofer, 2014) can be used here: (i) the unit under consideration absorbs the disturbance and persists by remaining the same; (ii) the unit is slightly modified by the disturbance; (iii) the unit is radically transformed in reaction to the disturbance.

Another approach to research on adaptation in livestock farming is to distinguish between the significance given to the processes, properties or outcomes of adaptation (Gasselin *et al.*, 2020). Those focusing on processes will for example study the adaptation patterns of animals or farms, while those focusing on properties will analyse their response capacities, taking into account for example their resource allocation or their learning capacities (Chia and Marchesnay, 2008). For example, research on adaptation outcomes will examine the positive and negative effects of adaptation in relation to sustainable development.

This chapter aims at illustrating the extent of this work on the adaptation of grazing livestock systems. For this purpose, we have selected five sets of results from research conducted by UMR Selmet researchers over the past few years that deal with an original question, approach or object in relation to adaptation: diversity and adaptation of grazed plant cover to climate change, physiological levers mobilised by the animal, genetic diversity and adaptation of local animal genetic resources to their rearing environments, adaptive capacities of pastoral households and communities of livestock farmers, and adaptation trajectories of livestock farming in territories. Overall, the study provides the basis for reflection on adaptation in grazing livestock farming by highlighting the different levers and processes involved in adaptation and analysing its limits.

Adaptation in Mediterranean and Tropical pasture vegetation

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Mediterranean and tropical livestock systems rely to varying degrees on grazing vegetation as a food source. Vegetation dynamics are influenced by various factors such as biophysical conditions (including climatic hazards), livestock practices, changes in livestock numbers, the cultivation of grasslands, etc. It can adapt to changes through two processes:

- intraspecific adaptation: a single plant species can modify its functioning to adapt to changing conditions through morphological, physiological or phenological changes.
- interspecific adaptation: the botanical composition can be modified to allow the vegetation to adapt to change; this adaptation can be expressed simply by a modification of species abundances or by the appearance or disappearance of species.

These adaptations then have impacts on the characteristics of grazing vegetation, including grazing value (biomass, nutritive value). Understanding the adaptation of vegetation to global changes can help predict the trajectory of grazing value.

In the Sahel, the use of historical data helps to determine the adaptation of grazing vegetation to drought

Grazing in the Sahel is mainly found on the steppes and savannah vegetation. The Sahel has experienced periods of severe drought, in particular between the 1970s and 1990s, with significant reductions in rainfall over several consecutive years. Since then, there has been a general return of rainfall. Within the Pastoralism and Drylands research platform[1] (PPZS), numerous studies have been conducted over several decades to investigate the vegetation response, both the herbaceous stratum (Ndiaye *et al.*, 2015) and the woody stratum (Diouf *et al.*, 2002; Sarr *et al.*, 2013).

Change in Sahelian savannah communities following drought episodes

Recent studies combine both satellite data and historical botanical survey data in northern Senegal. Woody vegetation changes before, during and after the drought period are studied (Dendoncker *et al.*, 2020). This work was partly based on the use of historical vegetation databases, in particular the Flotrop database (Taugourdeau *et al.*, 2019) which contains more than 340,000 observations of plants between the 5th and the 25th parallel north for the African continent between 1920 and 2012 (figure 2.1). Data freely available on GBIF[2].

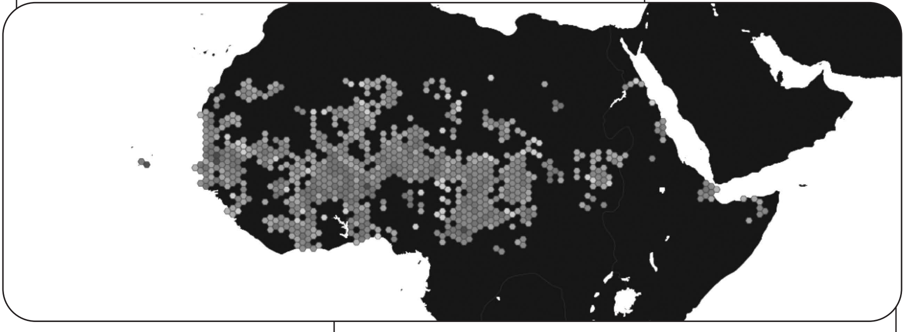
This study illustrates that tree density decreased between 1965 and 2008 but remained stable between 2008 and 2018 (around 10 trees per hectare). However, significant changes in species composition were noted, indicating an interspecific change in ligneous communities. Numerous species have decreased in abundance over this period. Only one species, *Acacia tortilis*, increased between both periods. The ligneous flora in the region is therefore less diverse and probably less resilient. Various factors are involved in this dynamic, such as grazing and human activities which restrict the development of new trees.

Study of intraspecific adaptation using herbariums

Historical data are also preserved in the form of herbarium samples. Herbariums can be used to study changes in the flora (interspecific adaptation) but can also be used to identify variations within species, in particular morphological characteristics such as leaf area from images of these samples. We measured leaf areas on typical Sahelian species from images available at the Recolnat[3]. For example, there is a relationship between the leaf area of *Zornia glochidiata* and the rainfall index in the Sahel (figure 2.2). For this annual species, the surface area was lower in dry years, showing a morphological adaptation to rainfall.

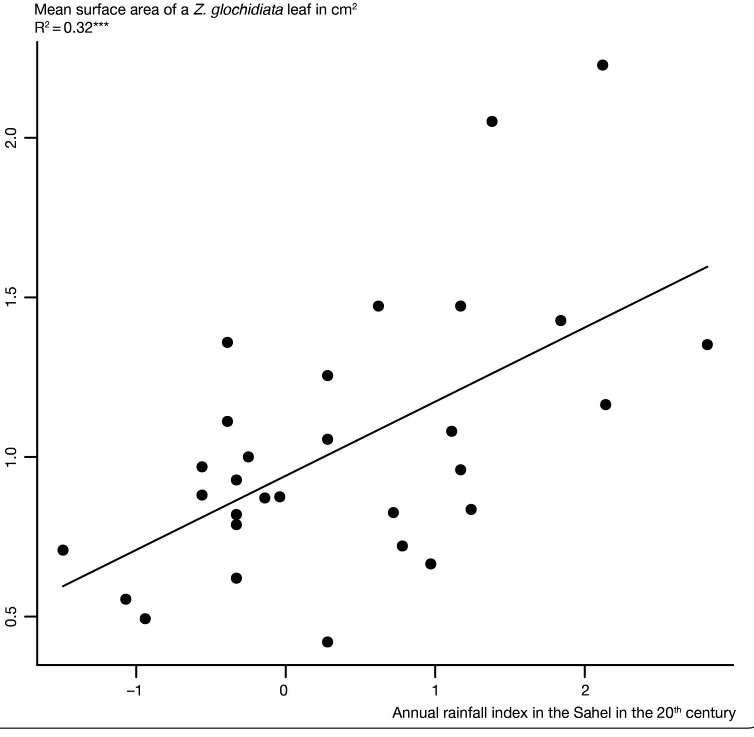
1. http://www.ppzs.org.
2. www.gbif.org/dataset/eb605c7a-a91c-4ab8-a588-85d0ccb2be9e.
3. www.recolnat.org/.

Figure 2.1. Distribution of Flotrop data (GIBF, 2019).



The intensity of the dots represents the data density of the online botanical surveys. The greater the intensity, the greater the density.

Figure 2.2. Relationship between the leaf area of Zornia glochidiata measured in the herbarium and the rainfall index in the Sahel.



It would be of interest to conduct similar work on variables other than surface area, notably chemical characteristics. However, these measurements are currently destructive. This creates a dilemma between data production and sample preservation. The development of indirect methods to avoid damaging the samples would be beneficial. Near infrared spectrometry analyses of herbariums are in progress to assess biochemical measurements indirectly (non-destructive method) (Svensk *et al.*, 2018).

Impact of livestock husbandry practices on vegetation adaptation and degradation of the steppes in the Maghreb

The north African steppes are located between the 400 mm/year rainfall isohyet to the North and 100 mm/year rainfall to the south and are covered with low, sparse vegetation. The symbolic grass *Stipa tenacissima* grows vegetatively on shallow drained soils. It accounted for 90% of the phytomass (5-10/t/year, with 20% green). Steppes covered in *Lygeum spartum* have a wider ecological range and are linked to sandy veils (260 ± 120 kg DM/ha/year). They replace *S. tenacissima* alongside low woody plants (*Artemisia*, *Salsola*, etc.). In areas of desertification where sandy veils reach 15 cm, *Stipagrostis pungens* develops (Hirche *et al.*, 2018). Shrubby steppes account for large areas, such as those with *Artissima herba-alba*, appreciated for its grazing value (Aïdoud *et al.*, 2006).

The North African steppes have been subject to a very ancient form of human exploitation through extensive sheep and goat rearing combined with shifting cereal cultivation (Aïdoud *et al.*, 2006). During the 20th century, this type of livestock farming underwent changes due to the evolution of demography, the expansion of crops in rangelands, the growth of livestock, the evolution of access to resources, persistent droughts, new livestock farming practices (e.g. use of concentrates and random mobility), the lifestyles of grazing communities (e.g. schooling), the economic context and rural policies (Bencherif, 2018; El Bilali *et al.*, 2020). Cultivation (mainly of cereals and arboriculture) and the silting up and subsequent desertification of the most intensively used areas of the steppes have led to a reduction of more than 25% of their surface area (Hirche *et al.*, 2018).

The impact of changing practices on steppe vegetation

Numerous factors have weakened steppe grazing vegetation, starting with more pronounced droughts, but above all anthropogenic factors: cultivation of rangelands, increase in livestock numbers, (Bencherif, 2018; El Bilali *et al.*, 2020; see also "Adaptation trajectories of livestock in the territories" in this section).

In the course of studies in areas with homogeneous soil and climate conditions, we noted a spatial heterogeneity of plant formations with *Stipa tenacissima*, *Lygeum spartum* and *Stipagrostis pungens*. In the same area, degradation is reflected in the disappearance of the *S. tenacissima* community and the appearance of the *L. spartum* community, with worsening degradation of this community which also disappears to make way for the *S. pungens* community. This is a regressive ecological succession characteristic of steppe grazing vegetation under severe constraints. In the study areas, each of these vegetation community was distributed differently in space, in the form of a patchwork. After identifying the grazing access rights of each herder in the 'terroir', we were able to establish relationships between the zoning of the different vegetation communities and their method of use. Consequently, agropastoralists who only had a grazing area of 0.25 to 0.5 ha/head of sheep and who lacked the means to migrate often had very deteriorated *S. pungens* pastures. Conversely, agropastoralists with multiple rangelands and engaging in transhumance generally kept pastures in good condition with *S. tenacissima* (Hammouda, 2019). The vegetation on their rangelands had rest periods. The land situation and dynamics of the rangelands may therefore lead to high-impact livestock farming practices, although they need to be identified (Daoudi, 2021).

Steppe regeneration, a method to prevent degradation?

Actions to regenerate the steppes have been undertaken since the 1960s, through the use of grazing fences and the establishment of aerial grazing (woody plants whose forage leaves do not fall to the ground) (Corriols, 1965; Gintzbuger *et al.*, 2000). Plant regeneration in the absence of grazing is proving satisfactory, though it is still linked to weather conditions. However, the results obtained after several years of grazing are disappointing, because farmers, realizing the high forage potential, impose intensive grazing over long periods of time, which weakens the vegetation (Louhaichi *et al.*, 2019).

In the framework of a research-action project in a steppe commune (rainfall of 250 mm/year), an assessment of the condition of the pastures was carried out in order to identify, jointly with the agropastoralists, the most degraded and fairly degraded rangelands. For the former, fodder bushes (*Atriplex* spp.) were planted with a 3-year grazing ban. As for the latter, they have been subject to 3-year fencing. Monitoring of these rangelands started in 2009 and ended in 2017 (grazing resumed in 2012). It involved 7 rangelands planted with *Atriplex* spp., 4 grazing fences and 3 controls.

The results (Table 2.1) are based on annual rainfall (in millimetres).

Table 2.1. Change in mean overall vegetation cover (OVC) in % on the different rangelands over time (Bouchareb *et al.*, 2020).

Years	2009	2010	2011	2012	2013	2015	2017
R (in mm)	390	425	337	245	277	221	202
C	35	42.2	38.6	38.41	33.4	34.11	33
PR	56	78.3	69.7	64	62.5	54.3	48
PL	27.1	58.4	57	54.8	62.8	65.3	61

R: annual rainfall. C: control rangeland.
PR: protected rangelands.
PL: rangeland planted with fodder shrubs.

Planted and fenced rangelands have benefited from the first rainy years. As of 2012, the decrease in the mean overall vegetation cover (OVC) of the protected areas can be explained by the drop in rainfall and the reintroduction of grazing. These factors do not affect the planted rangelands (PL), whose OVC is multiplied by 2.25, whereas these rangelands were initially the most deteriorated. *Atriplex* plants dampen the rainfall (which runs off less) and their denser bush structure alleviates the effect of grazing by limiting livestock grazing.

Species richness was expressed by the Shannon index calculated for rangeland and areas irrespective of the rangeland management (Table 2.2).

The index remains at a satisfactory level in the protected areas. The decline is evident in planted rangelands as the plantations grow. In the case of *Atriplex* plantations, biodiversity decreases initially, followed by a gradual return of local species in response to the improvement of stationary ecological conditions. This is confirmed in the lands subject to fodder plantations in the last year of monitoring, despite low rainfall. Protected environments, such as the rangelands that have been protected and the rangelands where fodder plantations have been carried out, manage to maintain a floral diversity linked in part to the “umbrella” aspect that the clumps generate, protecting all of the accompanying species (Slimani and Aïdoud, 2018).

Table 2.2. Changes in the Shannon index over time on the various rangelands.

Years	2009	2010	2011	2012	2013	2015	2017
R (in mm)	390	425	337	245	277	221	202
C	2.7	2.84	2.57	2.43	2.37	2.11	1.78
PR	3.21	3.13	3.03	2.72	3.24	2.81	2.92
PL	2.75	2.85	2.8	2.63	2.44	2.25	2.32

R: annual rainfall. C: control rangeland.
PR: protected rangelands.
PL: rangeland planted with fodder shrubs.

There is a clear correlation between cover and productivity, as well as rainfall (Table 2.3). The productivity of the reserves increases in the first few rainy years but cannot be maintained in drier years. The protected rangelands exhibit a significant increase in productivity in the third year after a three-year rainy cycle that enabled the annual and perennial species to be expressed at their maximum. This phenomenon of successive favourable years has often been analysed (Slimani and Aïdoud, 2018). *Atriplex* plants exhibit differing functional traits, which mitigate the rainfall effect, both up and down. They demonstrate an aptitude for mitigation, as even in recent dry years they remain the most productive, even though they have been heavily grazed.

A survey of farmers enabled us to note that, when grazing was resumed on the protected rangelands or those with fodder plantations, given the fodder supply, farmers increased their livestock (by 140%). We also noted that farmers with fodder plantations reduced their area planted with barley. This was not compensated for by the external purchase of barley, as they had reduced their concentrate intake.

Due to the high inter-annual rainfall variations in the Algerian steppes, livestock farmers seem to have developed strategies of intense exploitation of the resource when the year is suitable, considering that whatever their vegetation practices, the following years may be subject to drought and therefore to extremely low pastoral resources. This observation highlights the importance of dialogue with herders, so that they can recognise the vegetation of regenerated rangelands, notably through fodder plantations, as a resource that can partly withstand droughts if these rangelands have not been overgrazed the previous year. The participatory research work undertaken during the clearing and planting should have continued when the land was opened to grazing, but could not be carried out because the project was coming to an end. In the case of the younger generations, support should be considered. Such an approach would require work on the alliance rules and access to rangelands by mobilising the human and social sciences.

Table 2.3. Productivity of rangelands over time in kg/ha/yr.

Years	2009	2010	2011	2012	2013	2015	2017
R (in mm)	390	425	337	245	277	221	202
C	250	270	300	280	265	255	205
PR	313	790	1000	485	600	400	320
PL	221	390	460	615	605	575	450

R: annual rainfall. C: control rangeland.
PR: protected rangelands.
PL: rangeland planted with fodder shrubs

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Livestock grazing is a system that relies on the use of spontaneous vegetation as the main source of feed for livestock. This spontaneous vegetation is influenced by soil and climatic conditions and also by livestock practices. The adaptation of vegetation can be based both on changes in a species (intraspecific) and changes in plant communities (interspecific variation). These adaptations can only be observed in the long term and require studies based on multiple historical data. The main trend indicates an expansion of desertification areas by 10% per decade. Rehabilitation and fodder crops can stabilise this progression by means of co-construction work that take account of social dynamics and revive the logic of regulated collective grazing.