RISK ASSESSMENT OF LIVESTOCK FEED SUPPLY IN THE CONTEXT OF CLIMATE CHANGE, A CASE FROM NORTH AFRICA

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Abstract. The increase in livestock population over recent decades has been driven by demographic pressure and a consistent demand for red meats. However, this growth has negatively impacted the state of natural grazing lands. This issue is particularly concerning in the context of climate change, which ecologists have long highlighted. The balance between fodder supply and demand does not support a stable pastoral equilibrium or the grazing ecosystem. This study aims to assess the balance between forage supply in the Algerian Central Highlands region with the dietary needs of livestock using the zootechnical unit approach. The main findings of this analysis reveal a consistent growth in the demand for forage in this region, thereby highlighting the increasing deficit in forage resources and the growing dependency on artificial forage sources. Indeed, there is an increasing degradation of the natural environment, primarily to satisfy the dietary needs of the livestock. This situation is further exacerbated considering the future fodder requirements projected for livestock rearing to meet the meat consumption needs of future generations.
Keywords: *demographic pressure, Djelfa, fodder balance, food security, overgrazing, steppe*

Introduction

For a considerable period, concern about the feeding of livestock in the Algerian steppe has remained strong among both herders and public authorities. The number of herds continues to grow year after year, spurred on by ever-increasing population pressures for red meat. Indeed, the combined effect of population and income growth has significantly increased the demand for food products (Bedrani and Cheriet, 2012; Bouzid and Bedrani, 2018). In Algeria, fodder resources are largely provided by rangelands (fallow land, natural grasslands, steppe rangelands, forest rangelands, etc.) and cereal sub-products (cereal stubble, straw) (Abdelguerfi et al., 2008). Regarding

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pastoral production in steppe regions, several studies show a decline in productivity measured in fodder units "FU", an arbitrary unit that corresponds to the energy equivalent of one kg of standard barley (INRA, 2010).

Faced with this situation, and to better understand this problem, the establishment of a fodder balance which corresponds to the total quantity produced for each type of forage, with a coefficient assigned based on the nutritive value in forage unit FU per surface unit (hectare). This approach helps in the assessment of the balance between the supply of pastured fodder and the demand for feed for livestock in the Central Highlands is of paramount importance. Therefore, anticipating forage needs is becoming an imperative necessity to proactively meet the future demands of the livestock sector, thus satisfying the needs of the population, without compromising the degradation of the ecosystem of the natural environment of steppe pastures.

The steppe rangeland ecosystem is characterized by a semi-arid climate: very harsh with low rainfall, cold winters, and hot dry summers (Abbas et al., 2011; Benhizia et al., 2021). This ecosystem is currently facing various socio-economic and bioclimatic changes which are putting increasing pressure on the ecosystem and its various components.

Throughout the history of these events, the pressures induced by the factors mentioned persist continuously. According to the General Directorate of Forestry (DGF, 1999), in steppe areas, mechanized plowing unsuited to this fragile environment, significant overgrazing accentuated by persistent drought results in the herbaceous layer no longer being able to regenerate, and bare soils undergo continuous erosion, leading to environmental impoverishment and desertification. Indeed, inappropriate soil practices and counterproductive actions in the exploitation of rangeland resources contribute to exacerbating the situation, thus creating an enabling environment and favoring a dramatic manifestation of the effects of climate change.

According to the conclusions of the Ministry of Spatial Planning and Environment (MATE, 2008), the new system of exploitation of the resources of the steppe areas (soil and vegetation) is not aligned with the principles of sustainable development and generates a dynamic process of desertification that is exacerbated by climate change, while harming biodiversity. Similarly, experts argue that even though land use activity on steppe rangelands manifests itself in the form of "overgrazing", drought plays an accelerating role in the degradation of this ecosystem. According to Aidoud (1989), the degradation and desertification of steppe rangelands are directly attributable to overgrazing, the effects of which are most noticeable during periods of drought, and the episode that has marked the steppe in recent years seems to be among the most intense.

The drought, which is closely linked to the amount of rainfall, has led to a sharp decrease in rainfall levels throughout the country. Indeed, the Ministry of Environment and Renewable Energies is presenting a study on the impact of climate change on water resources. Carried out by the National Agency for Water Resources (ANRH), the study disclosed in 2009, that following the analysis of rainfall data series dating back to 1900, rainfall fell by 40% in the West of the country, 30% in the center, and 20% in the East (MEER and GIZ, 2019). Like the 17 African countries affected by water stress, Algeria is one of the poorest countries in terms of hydric potential (Nichane and Khelil, 2015). The major vulnerability of the country is observed in the areas of water and agriculture (Sahnoune et al., 2013).

According to a report by the Ministry of Foreign Affairs, Algeria is facing a series of considerable ecological challenges. Climate change, biodiversity degradation, and desertification pose serious threats to sustainable development (MEA, 2011). The

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Highlands, which cover about 9% of the national territory and lie between the Tellian and Saharan Atlases, are characterized by their vast plains and semi-arid climate, conducive to agro-pastoralism and low-yield cereal cultivation (MATE, 2003). However, the Highlands are suffering from the impacts of climate change, particularly drought, which is having direct effects on natural resources, which are increasingly limited and severely threatened. Although the Highlands cover about two-thirds of the country's Utilised Agricultural Area (UAA), this advantage is largely offset by arid conditions and lack of water resources, as pointed out (MATE, 2003). Indeed, the Ministry of Housing, Urban Planning and Urban Affairs stipulates: that Algeria is located in an area particularly vulnerable to climate change. According to the Intergovernmental Panel on Climate Change (IPCC or GIEC in French) projections, an increase of about 2 degrees in temperature, a decrease in precipitation as well as an intensification of extreme weather events are to be expected (MHUV, 2021).

As a result, climate change is a state of alarm not only for the environment but also for the production process of populations dependent on natural rangeland resources. Indeed, for small non-transhumant livestock farmers, the decrease in pastoral resources is accompanied by increased use of feed rations for livestock, which puts pressure on their budgets and, in the long term, leads to a decrease in the value of the herd and a progressive impoverishment. This counteracts the reduction of economic insecurity, a situation that is likely to worsen if action is not taken (MATE, 2008). This situation also impacts the quality of life of the inhabitants of these regions and generates increased vulnerability. According to a study by the National Agency for Spatial Planning and the United Nations Development Program (ANAT and UNDP, 2001), it is indicated that it is mainly the regions of the Highlands, where 17.6% of their municipalities have an unfavorable overall index, that are the most affected by poverty. The same study also highlights that the results converge to identify territories mainly located in mountainous or steppe areas, and to a lesser extent in the South, as those of extreme poverty. According to a more recent study, MEA (2019) argues that the regions hardest hit by multidimensional poverty are the South (27.6%), the Central Highlands (22.5%) and the Western Highlands (20%). In terms of residential distribution, deprivation is more pronounced in rural areas (24.4%) than in urban areas (14.1%).

As a result, the development of the Highlands and Steppe region is gradually being hampered by climate change, particularly drought, which is affecting in all directions and leading to a visible and widespread decrease in rangeland productivity, thus leading to direct stress on pastures. This reality can be observed in the context of natural population and livestock growth in the region, which conditions the food security of the population. In this context, issues related to livestock feed are becoming increasingly important, raising major concerns and requiring solutions to ensure an adequate supply of red meat. Algeria's National Climate Plan addresses this issue by stating that these changes are considered by the scientific community to be inevitable. In other words, global mitigation efforts and actions can only partially mitigate its effects. Therefore, the Algerian economy and society need to adapt to climate change to reduce its negative impacts (MEER and GIZ, 2019).

On the steppe, and according to the Ministry of Agriculture and Rural Development (MADR, 1996), it is obvious that a worrying degradation of rangelands is observed, clearly visible everywhere, accompanied by an increasing deterioration of their production potential. The causes of rangeland degradation are complex in time and space and associated with interactions between pastoralists, governance and policy, and environmental factors (Bedunah and Angerer, 2012). This degradation is the logical result

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of inappropriate practices such as plowing mechanized, overgrazing, sedentary lifestyle and disruption of transhumance (Bensouiah, 2004; Nedjimi and Homida, 2006; Hadeid, 2008, 2009; Daoudi et al., 2010; Nedjimi and Guit, 2012; Hadeid et al., 2015; Djeddaoui et al., 2017; Mallem et al., 2017; Boukerker et al., 2021; Habib et al., 2024), and climate change (Aidoud et al., 2011; Belhouadjeb et al., 2022; Boukerker et al., 2022), affecting biodiversity and productivity of species on rangeland grazing, which has an impact on livestock husbandry conditions. Indeed, a serious decrease in production on rangelands went from 120 FU to 150 FU/ha/year in 1978, to 30 FU on degraded rangelands, and 60 to 100 on palatable pastures (Nedjraoui, 2006). As a result of these events, an imbalance between forage production and livestock feed needs has occurred and is becoming increasingly important (Hirche et al., 2015). So, on steppe rangelands, we are no longer in the case of sustainable development (Hirche et al., 2011).

In Algeria, the prior assessment of the implications of climate change on the economy and society has become an increasingly important priority. This approach is part of the anticipation of the consequences and the adaptation of society to the likely impacts. In this perspective, an investigation into the challenges of livestock feed in the Algerian steppe, more precisely at the level of the Central Highlands, occupies a central place in this dynamic and offers elements of response to the concerns of livestock farmers and public authorities. Indeed, according to the National Institute of Agronomic Research of Algeria, sheep are distributed throughout the northern part of the country, with a more marked concentration in the steppe and the high semi-arid plains of cereals, representing 80% of the total population. There are also populations in the Sahara, which exploit the resources of oases and desert rangelands (INRAA, 2003). As for the goat herd, according to the same source, it is more concentrated, as in other Mediterranean countries, in difficult areas and disadvantaged regions throughout the country, including the steppe, mountainous regions, and oases.

This study aims to examine the balance between the growing demand and supply of different sources of fodder in a region threatened by the effects of climate change. This area is marked by demographic and livestock trends in an ever-increasing demand for foodstuffs and by a deterioration in the productive potential of biomass, as well as counter-productive acts on natural grazing land. The originality of our investigation lies in the lack of studies that clarify this issue in its various dimensions, as well as the ecological and socio-economic impacts of the current conditions of the rangelands and the likely implications of the amplification of the pressures already mentioned. Our investigation also aims to provide a better understanding of current and future food security issues, in particular livestock farming on the steppe and the conditions under which red meat is produced. From this perspective, and because the real dimensions of climate change on our well-being are still not well known, this paper also opens up many avenues of research, which are expected to provide operational responses to strengthen society's resilience in the face of human imperfections and changes in nature.

Materials and methods

Study area

The Central Highlands region geographically encompasses the Provinces of Djelfa, Laghouat, and M'sila, as shown in *Figure 1*. From an administrative point of view, a region is defined as an area comprising a whole that shares homogeneous natural and development characteristics in agro-sylvo-pastoral areas.

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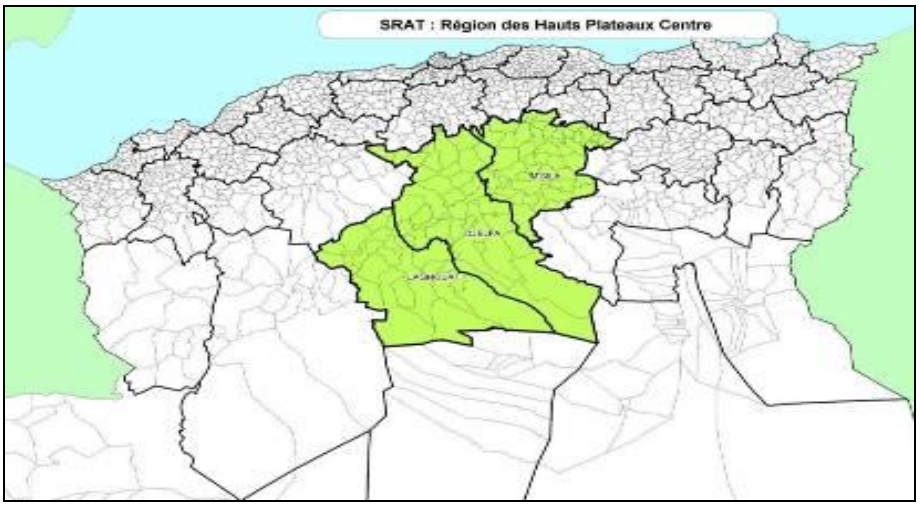

Figure 1. *The regional territory of Central Highlands in the national ensemble*

The three Provinces have a total of 107 municipalities and cover an area of 77,795 km², with a population of 2.7 million inhabitants in 2008, and an average density of 34.6 inhabitants/km², significantly higher than in the Saharan regions and significantly lower than in the coastal regions (MATE, 2008).

The Central Highlands region occupies 3.1% of Algeria's total land area and is home to 7.6% of the population, which has quadrupled since 1966. According to the National Land Use Planning Plan (SNAT, 2010), the Highlands as a whole (including West, Central, and East) represented 27.3% of the total population in 2008, compared to 26.5% in 1998. The population growth rates recorded for each of the areas, the West, the Centre, and the East, are higher than the national average (1.6%). They stand at 3.8% for the Centre, 1.95% for the West and 1.51% for the East. Thus, the sharp increase in the population of the Highlands, especially the Central Highlands, is a distinguishing feature of this territory. Assessing the future needs of this population is of major importance in anticipating the demands of this growth.

The Central Highlands region is defined as a region included in the land use planning and sustainable development program. It is described as a territory bringing together three neighboring Provinces and sharing similar or complementary physical characteristics as well as development orientations. Due to its pastoral vocation, an activity that plays a preponderant role in the regional economy and constitutes a considerable source of income for the local population (Benyounes et al., 2013; Senoussi et al., 2014; Zirmi-Zembri and Kadi, 2016; Ouali et al., 2023), we focus on the study of the balance between livestock and plant production (i.e. fodder) in this region.

It is important to note that the evolution of livestock numbers varies according to the bioclimatic levels and the different Provinces of the country (Meguellati-Kanoun et al., 2018). In the Central Highlands region, livestock production occupies a prominent position in the local economy. Indeed, the Central Highlands are the leaders in terms of sheep and goat production at the national level (see *Table 1*).

This table highlights the distribution of livestock numbers in the Provinces of the Central Highlands in 2019. It can be observed that Djelfa dominates in terms of sheep and goat heads, while Laghouat and M'sila have slightly lower figures. Beef and camel heads remain quantitatively less significant in the region as a whole. These data reflect

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the importance of livestock production in this region and highlight the specificities of each Province in terms of livestock. This performance is the result of local know-how as well as favorable biophysical conditions, which unfortunately undergo advanced and continuous deterioration.

Table 1. *Livestock production in the Central Highlands (HPC) in 2019*

Province	Sheep heads	Beef heads	Goat heads	Camel heads	Total
Djelfa (%)	3 456 000 (88.75%)	30 400 (0.78%)	406 000 (10.42%)	1 250 (0.03%)	3 893 650 (100%)
Laghouat (%)	1 985 150 (88.03%)	20 995 (0.93%)	245 150 (10.87%)	3 552 (0.15%)	2 254 847 (100%)
M'sila (%)	1 580 000 (90.73%)	35 000 (2.01%)	125 000 (7.17%)	1 360 (0.07%)	1 741 360 (100%)

Source: MADR (2019) and our calculations

Data collection

To analyze aspects of fodder resources in our study area, and their impacts in the context of climate change, we used production and superficies area statistics from the Ministry of Agriculture and Rural Development, over the period 1999-2019. From the High Commissariat for the Development of the Steppe, in particular, but not only, to take into account the productivity of steppe rangelands. And from the Ministry of Spatial Planning and Environment for demographic and land area data for Algeria's Central Highlands region, as well as from Djelfa Directorate of Budget Programming and Monitoring. All data and information are official sources, and we chose this material because it is in harmony with our study, and very useful for obtaining the expected results to cover the needs of our investigation, based on which, we calculated the demand, supply, and deficit of natural and artificial fodder resources, and we also estimated the demand to be forecast for the future.

Assessment of fodder supply and requirements for livestock

Assessing the feed requirements of sheep and goats in the study area is crucial for balancing rangeland production with the livestock's forage unit (FU) requirements. With this in mind, we have adopted the approach of the Sheep and Goat Zootechnical Unit (UZO) and Goats (UZC). The Zootechnical Unit is based on a simple standard for specifying the component of a herd. For example, the Ovine Zootechnical Unit (UZO) corresponds to a ewe followed consuming 400 FU. The Zootechnical Unit is very useful for calculating the herd's feed requirements and for determining the pastoral load on a given grazing area. This methodology is based on recent research by Kanoun (2016) and Yousfi et al. (2017) on the dietary coverage of small ruminants. It is natural for an animal herd of a species to consist of several age groups. To simplify the estimation of the herd's total feed requirements, the zootechnical unit of each species is used as a reference. This involves calculating the product of the animal population for each age group of the species, multiplied by a specific coefficient. The sum of these products provides the total number of zootechnical units for each species. The calculation process is defined by *Equations 1* and *2*:

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$$1\ UZO = 1ewes + 0.05\ ram + 0.02\ male(10 - 18\ months) + 0.02\ female(10 - 18months) + 0.7male(< 10months) + 0.2\ female(< 10months) \quad \text{(Eq.1)}$$

$$1\ UZC = 1goat + 0.05\ buck + 0.7\ male\ (6\ months) + 0.2\ female\ (6\ months) \quad \text{(Eq.2)}$$

To harmonize the calculation between UZO and UZC, we determined that the UZC is equivalent to the UZO weighted by a coefficient of (0.8). It should also be noted, that the UZO is set at a value of (400 FU year^{-1}) based on the standards established by the National Institute of Agricultural Research (INRA, 1978).

Regarding the calculation of the fodder supply, we relied on the guidelines of the Technical Institute of Livestock (ITELV, 1997), where cultivated fodder provides 1 500 FU ha^{-1} and grazed fallow land 350 FU ha^{-1}. As far as the rangelands of the steppe areas are concerned, their estimation is based on the study conducted by the High Commissariat for the Development of the Steppe and National Bureau of Studies for Rural Development (HCDS and BNEDER, 2010), based on research undertaken since the spring of 2001. The HCDS has shown that, on average, productivity of these rangelands is 72.53 FU ha^{-1}.

Predict the future production by analysis of the growth rate

For the analysis of the growth rate of zootechnical units, the forecasting process requires a time series of data over several years. In our case, this series is made up of Sheep Zootechnical Units (UZO) over 21 years, from 1999 to 2019. Forecasting inevitably requires the calculation of the average annual growth rate or (Tm). This rate, expressed as a percentage, over n years, is given by *Equation 3*:

$$T_m = \sqrt[n]{G_n/G_0} - 1 \quad \text{(Eq.3)}$$

where Gn final value; G0 is the initial value and n is the number of years.

Results and discussion

Growth in demand for forage units in the Central Highlands

Once the forage requirements in the Central Highlands are calculated using the formula mentioned above (*Eqs. 1* and *2*), as employed by Yousfi et al. (2017), we will obtain the volume required to support livestock during the period from 1999 to 2019. The results of this assessment are graphically shown in (*Fig. 2*).

Figure 2 highlights the continued net growth in demand for forage units (FU) from 1999 to 2019. This increase can be explained by the constant increase in livestock production, supported by demographic pressure still in search of red meat. According to Bedrani (1994), there are many reasons for this expansion of the herd. These include the maintenance of robust livestock growth in steppe areas, the growing and sustained demand for red meat, the high profitability of livestock farming in these areas due to the free availability of fodder, and the presence of cheap imported livestock feed over a long period. In addition, the attraction of capital to steppe areas due to sheep farming, coupled with the ability of this capital to diversify into non-agricultural activities, particularly industrial, has also contributed to this growth.

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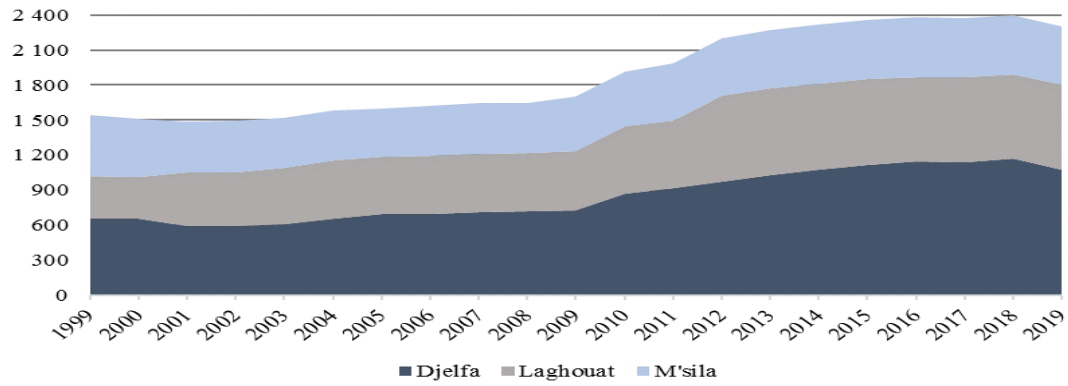

Figure 2. *Evolution of the feed requirement of sheep and goats in the Central Highlands 1999-2019 (in million FU)*

State support for herders, as mentioned earlier, seems to play a key role in this herd expansion. Indeed, pastoralists in the steppe have benefited from the supply of barley at relatively affordable prices. According to Bedrani (1993), during the period from 1970 to 1980, the policy of setting low prices for livestock feed, combined with a significant overvaluation of the dinar (DA currency unit of Algeria), encouraged pastoralists and agro-pastoralists in the steppe regions to greatly increase their livestock, thus leading to overloading of steppe lands. This policy has also led to a considerable increase in rangeland clearing. Indeed, with herds becoming substantial, herders needed more private space for their herds, and traditional plowing of rangelands became the means of choice to appropriate these spaces.

In addition, the consumption of red meat in Algeria is about 340 000 tons (10 kg inhabitant-1 year-1), the average coverage of national production is 300 000 tons of sheep and beef, the 40 000 tons deficit or 12% are imported in the form of frozen beef meat (Bessaoud et al., 2019). However, according to the National Economic and Social Council (CNES, 2015), and based on a study by the Office for National Statistics (ONS), red and white meat occupy the first position in the structure of household food expenditure (2011), with 21.7% well ahead of cereal products 17.5%, and fresh vegetables 13.4%. Red meat accounts for 13.3% of household expenditure, while dairy products and white meat account for 8.4% and 8.3% respectively (ONS, 2015). All knowing, overall household spending was estimated at 4 489, 5 billion DA in 2011, 71% of which was in urban areas (ONS, 2014).

Regarding the estimation of fodder supply in the Central Highlands, *Figure 3* provides an initial assessment of the fodder supply in the three Provinces of the Central Highlands. In 1999, according to our calculations based on the previously mentioned *Equations 1* and *2*, the supply amounted to 728 044 043 FU, increasing to 834 881 019 FU in 2019. This increase of 106 836 976 FU over the same period does not seem to be in line with the growth in demand due to the increase in the number of livestock heads. As a result, the situation is alarming for society's future food requirements. We not only need to preserve the natural ecosystem against current degradation factors, but we also need to enhance our resilience to climate change, which continues to impact land productivity with severe socioeconomic and ecological consequences.

In addition, the coverage rate of rangeland production (*Fig. 4*) decreased from 34% to 24.5%, as did the overall coverage, including fallow land and cultivated fodder, which fell from 47.2% to 36.3%. These declining trends threaten livestock activity and

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food security in terms of red meat. If the trend persists in this direction, small livestock farmers will most probably abandon livestock activity to avoid purchasing fodder at exorbitant prices. This issue is not only due to technical constraints that hinder optimal productivity but also requires more land to support production. Consequently, the area allocated to livestock farming is shrinking in favor of plant biomass production. Additionally, the productivity of off-pasture fodder is affected by climate change, necessitating more resilient forage varieties and increased irrigation.

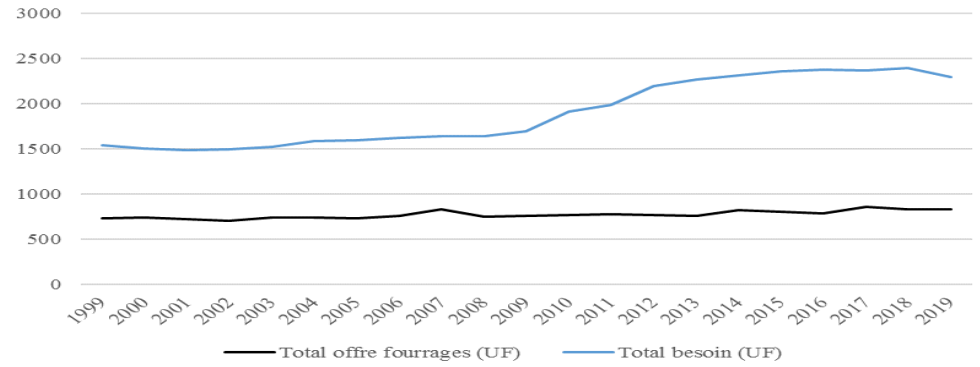

Figure 3. *Evolution of the supply and need for fodder in the Central Highlands from 1999-2019 (in million FU)*

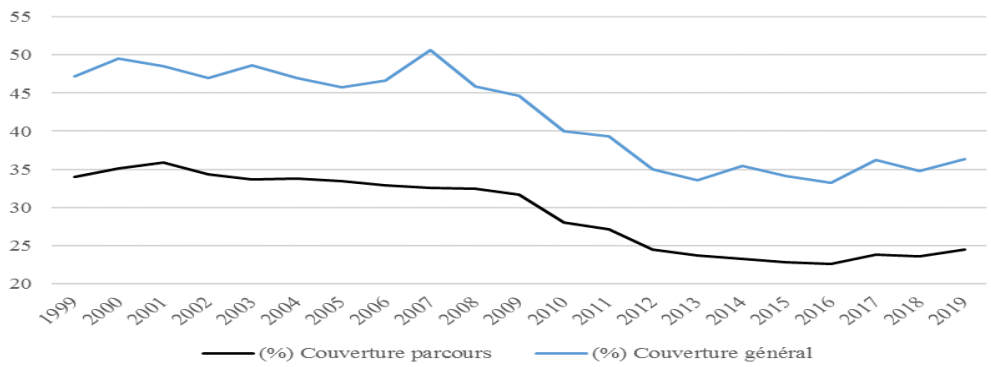

Figure 4. *Evolution of rangeland coverage in the Central Highlands from 1999-2019*

Estimation of the contribution of each type of fodder in the supply of the Djelfa region

Regarding the estimation of the contribution of each fodder type in the fodder supply, *Figure 5* illustrates the importance of each fodder type component and its contribution to the total supply. During the period 1998-2019, the values attributed to cultivated fodder gradually increased occupying an increasingly significant share. This observation leads us to the conclusion that pastoralists and agro-pastoralists are placing increasing importance on the adoption of fodder cultivation techniques. This is happening in a context where rangeland production is deteriorating and the number of livestock heads is increasing.

There is no doubt that the issue of livestock feed occupies a crucial place in the regional economy and this issue is becoming increasingly worrying. There was a time

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when the idea of using fodder produced locally by pastoralists was hardly considered in local communities, due to the abundance of fodder resources in the rangelands, local skills, and the limited number of livestock heads. Indeed, as described (Bourdieu, 1961), extensive agriculture, mainly focused on cereal crops, is combined with extensive livestock farming; this model is based on alternating between crops and bare fallows, allowing both the land to rest and to provide food for the herd. In this subsistence economy, the symbiosis between agriculture and livestock ensures that basic needs are met. However, as early as the 1960s, environmentalists pointed the finger at overgrazing.

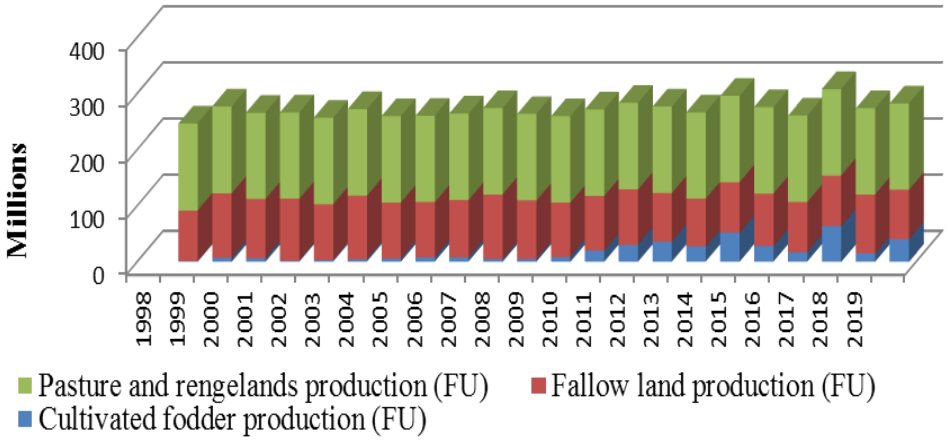

Figure 5. *The contribution of each type of fodder unit in the total supply in the Djelfa region 1998-2019 (in millions FU)*

To compensate for the lack of fodder, fodder crops have been introduced. However, these crops remain far from meeting not only the needs of existing livestock but are also largely dependent on erratic rainfall and drought damage (*Fig. 6*). During the period 1998-2019, fodder crops were overtaken by fallow, which can be partly explained by ancestral livestock farming practices in the region, as the region is pastoral where historically the use of cereals was hardly considered until after the end of transhumance, after which the resting of the land allowed more fodder. Forage crops are therefore emerging, as a valuable alternative to fill the gap, this type of crop is still far from covering a significant share of demand, because the choice of adopting it depends closely on the willingness of farmers and agro-pastoralists to adopt it, but under the necessity and on the basis of the market prices of animal feed, Farmers and agro-pastoralists will widely adopt this crop. The challenge is to multiply the popularization campaigns in this sense, and to prepare the plant material that is suitable for the soil, the animal and adapts perfectly to climate change.

Fodder production has fluctuated, with areas allocated to fallow land and fodder crops steadily increasing. This trend is driven by livestock feed needs, pushing agro-pastoralists to diversify their fodder sources. On the one hand, this reflects the risk taken by pastoralists who rely on good rainfall when choosing their fodder sources, and on the other hand, it highlights the dependence of pastoralists on climatic hazards (climate change).

As for the composition of artificial fodder in the Djelfa region, in 1998 the contribution of cultivated fodder to the total supply was almost negligible, at around 0.4%. However, this contribution has increased timidly year on year to reach 14.2% of total supply in 2019. Artificial forage consists mainly of two distinct sets: dry fodder

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and green fodder or silage. The first set includes various varieties of vicia, oat, lucerne, and harvested cereals. The second group consists of corn, sorghum, barley, oat, and rye, as well as clover and lucerne.

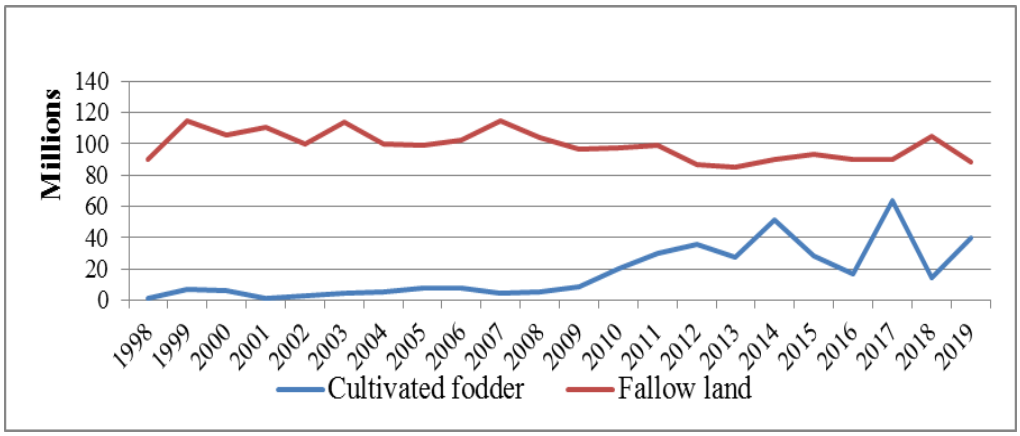

Figure 6. *Local supply from grazed fallow land and cultivated fodder in Djelfa region for the period 1998-2019 (in million FU)*

Figure 7 provides a visual representation of the areas allocated to the various components of the artificial forage. From 2010 onwards, the largest areas began to increase, mainly due to the conversion of cereals to dry fodder, as well as barley, oats, and rye to green or ensilage. The trend of dedicating land to cereal crops is not new in the region. However, the massive use of rangeland clearing and the increasing need for fodder have led to an expansion of the areas dedicated to fodder production. This has gradually led farmers to rely more on artificial fodder. Indeed, the combination of cereals, fallow land, and sheep allows us to manage climatic risk (Abbas and Abdelguerfi, 2005).

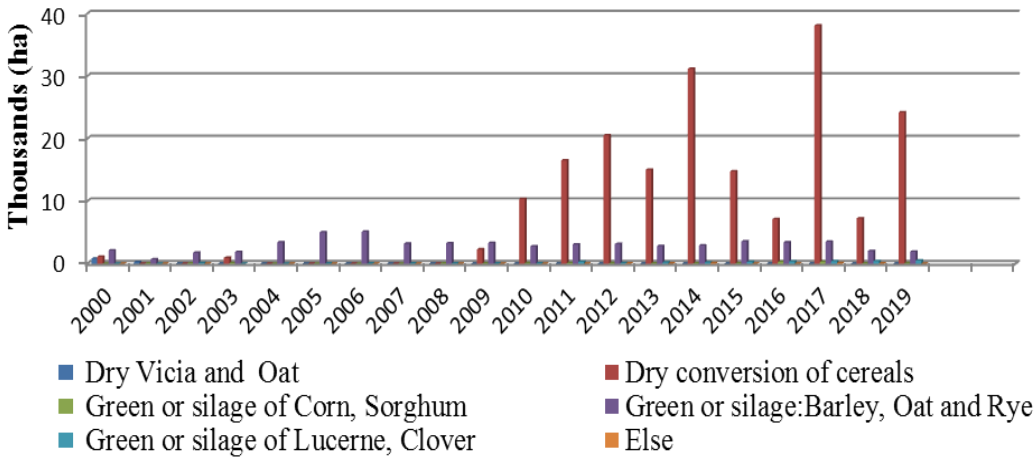

Figure 7. *Evolution of the areas in hectares of the different types of artificial fodder in dry and green produced 1998-2019 (in thousands ha)*

This has also contributed to the emergence of increasingly preponderant agro-pastoral practices, bringing about new changes, as described by Boukhobza (1982), the combination of livestock and agriculture by the most influential herders inevitably led

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to an "anarchic" growth in herd size, herd concentration, and a differentiated distribution of rangeland throughout the steppe.

About the fodder deficit in the region, it is clear that a lack of fodder resources is still a major concern for livestock farmers. Faced with this situation, the farmer is forced to remedy this deficit at all costs, either by resorting to the feed market or by using rangeland in a non-rational manner. This can lead to overgrazing, as demand far exceeds the supply of fodder. In addition, not only is the supply stagnating, but the needs are also becoming more and more important. In the last century, and response to a similar situation, sociologists note that modern livestock farming was introduced in Europe. The shepherds themselves grow the fodder they need (barley, oats, lucerne, sainfoin), maintain artificial or temporary meadows, and adopt fertilization techniques, mechanization, and irrigation techniques (Gilbert, 1989). This means that the conditions of vulnerability in terms of natural fodder have led to a mechanical effect in terms of the decision to opt for artificial fodder and the adoption of new techniques.

The analysis of fodder deficit in the Djelfa region

The analysis highlights an increasing trend in the deficit from one year to the next. This increase is certainly driven by an increase in livestock production and by the fact that the supply of fodder is stagnating. *Figure 8* provides a clearer visual representation of this situation.

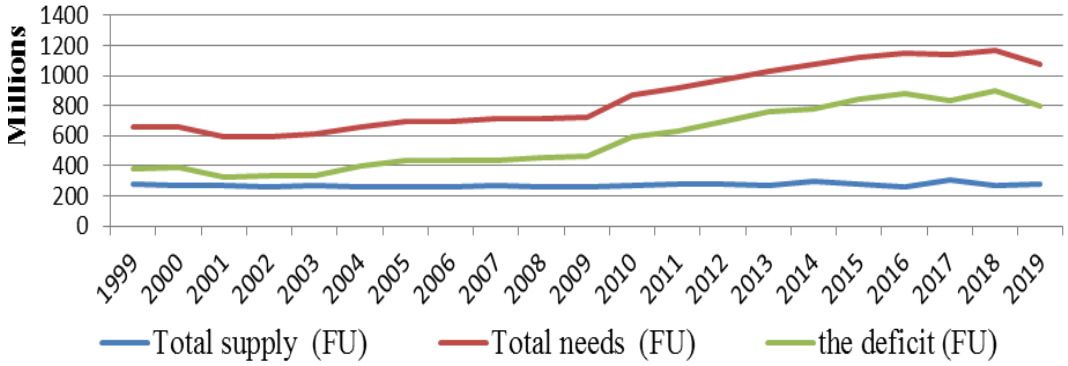

Figure 8. *Fodder deficit in the Djelfa region 1998-2019 (in millions FU)*

As for the contribution of rangelands to livestock feeding in the region, according to our calculations, only 23.6% of the feed requirements for sheep and goat farming were provided by pastures and rangelands in 1999. This situation deteriorated in 2019, with the share of rangelands declining to just 14.2% (*Fig. 9*). This finding largely corroborates the conclusions of specialists in this field, in particular those of Nedjraoui and Bedrani (2008), in 1998, rangelands suffered severe degradation, fodder production halved and livestock numbers increased tenfold to the rangeland's carrying capacity. Faced with this situation, according to Houmani (1998), livestock farming is increasingly dependent on concentrated feed in the livestock's diet, and the areas of high rainfall in the north represent one of the sources of making up for the deficit.

The decrease in rangeland feed by almost 10% over 20 years is bound to have an impact on the socio-economic conditions of the region. Indeed, as mentioned by Smail (1991), who explains according to a study by INRA (1983), the supply of fodder,

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whether from any source, is the main obstacle to increasing red meat production in Algeria. As a result, the cost of this meat has increased significantly, making it one of the most expensive in the world.

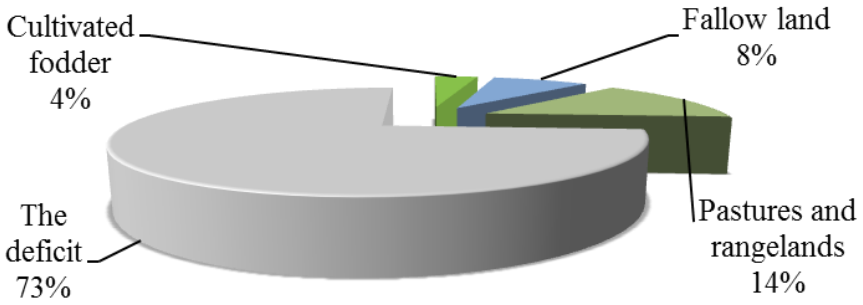

Figure 9. *The share of fodder types and the deficit in 2019 in the Province of Djelfa*

The analysis of future needs on fodder

After calculating the average growth rate over this period (*Eq. 3*), we obtained an estimated rate of 1.92% year^{-1} for the Central Highlands and 2.38% for Djelfa. The application of these growth rates will allow us to predict the future production of Sheep Zootechnical Units (UZO) for the coming years and consequently, to estimate the expected supply in the Central Highlands and the Province of Djelfa, over 11 years.

According to the calculation previously outlined, the forecast leads to an estimate of 3,491,366 Sheep Zootechnical Units (UZO) for the year 2030, with expected demand, according to our calculations, of 1,396,546,691 FU for the same year in the Province of Djelfa (*Fig. 10*). For all three Provinces of the Central Highlands, the forecast is 7,095,691 Sheep Zootechnical Units (UZO), requiring 2,838,276,259 FU for the year 2030.

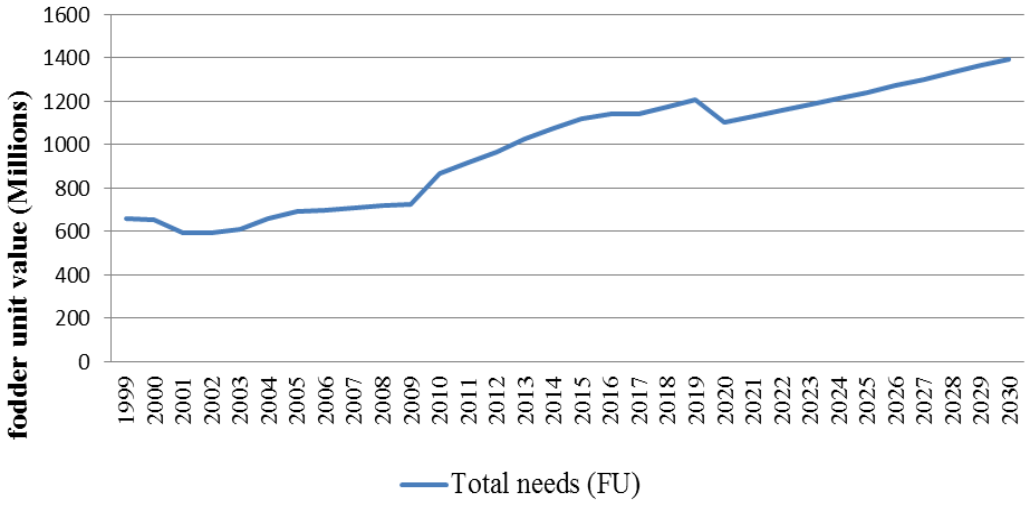

Figure 10. *Forecasts of fodder unit requirements in the Djelfa region for the period 2020-2030 (in millions FU)*

Our forecast estimates, based on calculations, show that by 2030, feed demand could reach around one and a half billion Forage Units (FU), compared to a demand of just

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over 1.2 billion FU in 2019. Only 26.1% of this demand is covered by various sources of fodder, of which 14.2% comes from rangelands. This increase of more than 15% in the demand for fodder will inevitably have considerable socio-economic and ecological consequences. Indeed, the productivity of rangeland above-ground biomass is very important, especially where livestock feed is essential to the main human activity (Kouba et al., 2024), especially since there is significant population growth.

Indeed, according to data from the Directorate of Budget Programming and Monitoring (DPSB, 2019), the Djelfa region had 1,090,578 inhabitants in 2019, recording a population growth of 36.71% compared to 1998, with a population of 797,706 inhabitants and an average annual growth rate of 3.2%. This demographic pressure is driving the increase in demand for red meat, creating an increasingly intense and continuous pressure on the natural resources of the rangelands. This has long been pointed out by scholars, such as Bedrani (1982), who has described how the growing demand for agricultural products is linked to population growth and rising cash incomes. Boukella (2008) adds a new parameter, which translates into increasing urbanization, and stipulates that the majority of Algerians are no longer made up of food producers but of buyers who must be well insured. In addition, Boukhobza (1989) points out the difficulties in creating a dynamic equilibrium relationship between the increase in wealth (food or not) and population growth, particularly in underdeveloped countries.

This situation leads to an increasingly unbalanced exploitation of natural rangelands, to maximize profits and increase herds. However, each individual finds himself in a system that pushes him to indefinitely increase the size of his herd in a world of limited resources, as evoked (Hardin, 1968). Thus, it triggers a phenomenon of the "tragedy of the commons", explained by Ostrom (2010) as the environmental degradation that is to be expected from the moment that several individuals use a limited resource in common.

Future challenges scenarios: analytical keys to build resilience

Given the current socio-economic and biophysical conditions likely to increase given ongoing climate change, directly affecting ecosystem services, in particular the production of biomass on rangelands, and to support our collective well-being in the context of sustainable development, we can anticipate some effects impacting not only economic and social development, but also the ecosystems and their modes of operation which are changing the vocation of people and territories, and on which we must focus to reduce their manifestations and prepare effective solutions one step ahead. The challenges imposed are the proposed result of provoking the active mind, based on the keys of analysis already mentioned.

We can anticipate the following likely scenarios: excessive and uncontrolled use of rangelands, clearing of rangelands to grow cereals needed to cover part of the demand for fodder, conflicts over the use of natural resources, intensification of artificial fodder production leading to overconsumption of water and intensive land use, a production of artificial fodder outside the region encouraged by increasing demand to the detriment of other agricultural products, a reintroduction of transhumance to areas not exploited until now (uncleared sub-Saharan areas and its unexploited aquifers), an import of livestock feed which will further burden the public treasury, and even an import of red meat to satisfy local needs and balance the market, attempts to substitute red meat with white meat, trials to replace red meat with aquaculture production requiring technological advances and training, and initiatives to change Algerians' eating habits.

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On the other hand, the production of artificial fodder will undoubtedly experience an increasing and favorable dynamic, the development of this sector is considered favorable given the opportunity displayed by the growing demand for the product, and as a corollary of this situation, the actors of the sector accumulating profits that allow them to extend the activity. Thus, it becomes more and more attractive and directs men and capital, which will require more land to increase production, and technical advances to increase productivity, which will generate more gain.

How can we judge the situation? It should be emphasized that the objective is not to dramatize the situation, but rather to understand and study it in its various dimensions. This includes an analysis that takes into account the diversity of its causes, whether socio-economic, historical, biophysical, climatic, or other. The goal is to achieve innovative solutions that not only meet our current needs but also anticipate those of future generations while preserving our ecosystems beyond the threshold of degradation.

The intervention of the public authorities through the HCDS has made a real difference in the areas of intervention. The missions of the HCDS have been assigned mainly to combat all forms of land degradation of steppe rangelands, to improve the conditions of livestock husbandry, watering and protection of herds against disasters, as well as to promote the socio-economic living conditions of rural families in steppe areas.

In the current context, the HCDS is considered a major hope for the development and preservation of the steppe area, in the face of the imbalances and alterations, both ecological and anthropogenic that these areas are experiencing. It plays a key role in combating desertification and rangeland degradation. In this regard, the HCDS has launched many initiatives to improve and conserve steppe rangelands, including deferred grazing, pastoral planting, and seeding. These techniques improve the productivity of degraded grazing land, from 30 FU ha-1 on degraded land to 500-600 FU ha-1, depending on the technique used (Samail, 1999; MATE, 2000; Aidoud et al., 2006; Amrani and Chehma, 2020; Houari et al., 2021; HCDS, 2022; Yerou et al., 2022).

However, much more needs to be implemented to encourage rangeland operators to adopt more rational use of rangeland ecosystems. This requires strengthening intervention methods in the field in collaboration with all actors concerned by this problem. It is important to support the implementation of the idea that pastoralists to be considered as essential partners in all development and preservation efforts while empowering them. In this regard, (Sahli and Amrani, 2019) point out that the mountains, steppe, oasis, and arid and semi-arid regions of the Maghreb represent vast geographical and demographic spaces. It is therefore essential to consider local communities and territories in these ecosystems as key actors in development and integral part of potential development solutions. This presupposes their mobilization and active participation.

Conclusion

The main objective of this study was to assess the situation of sheep and goat farming in the Central Highlands region, with a particular focus on fodder supply and food demand. To achieve this objective, the study sought to quantify the feed requirements of the herds using the approach of Sheep Zootechnical Units (UZO), as well as to estimate the supply of fodder from different data sources from the local authorities in charge.

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The methodology used to conduct this analysis was to use data collected over 21 years from 1999 to 2019, as well as average annual growth rate calculations. The analysis was based on zootechnical data, production figures, and forage consumption standards. The results were presented using graphs to illustrate the dynamics of feed requirements, forage supply, and growth rates.

The main results of this analysis reveal a continuous growth in the demand for fodder for sheep and goat farming in the Central Highlands region. This growth is fueled by increased livestock production, population pressure, and other socio-economic factors. However, the supply of fodder, especially from rangelands, is not able to meet this growing demand. Rangelands are undergoing significant degradation due to overexploitation and climate change reducing their production potential.

As a result, the analysis highlights the growing deficit of fodder resources and the increasing dependence on artificial fodder sources. The results also suggest that this situation could have major socio-economic and ecological impacts in the future, due to continued pressure on natural resources and population growth. Government intervention through initiatives such as the HCDS is highlighted as an essential strategy for the sustainable improvement of resource management and the preservation of ecosystems.

The wealth of lessons that can be drawn from this study highlights the fact that livestock growth is inevitable to meet the growing needs of society. However, this growth has unfortunately been accompanied by an excessive exploitation of the natural resources of the steppe rangelands leading to a deterioration of the regeneration and production potential of these areas. This deterioration is inevitably exacerbated by climate change, sometimes to irreversible stages of regeneration. Rising demand for food, fueled by demographic pressure, requires innovative solutions to address these complex challenges, through ecological, zootechnical, technological, and socio-economic approaches. In the context of climate change, scientists' concerns about the future of food, particularly about organic red meat from steppe rangelands, are amplified.

The vision of rural and sustainable development, in line with social and economic aspirations, while preserving the ecological balance of the natural steppe environment, is proving to be increasingly complex, even difficult to achieve. Constant warnings from ecologists about the advanced degradation of steppe range ecosystems caused by climate change reinforce this concern. Indeed, the transition to more sustainable and robust production systems requires immediate responses to current challenges, as well as profound and careful interventions that adapt to the current situation and anticipate future challenges.

Our resilience in the face of climate change, and that of future generations, depends foremost on the practices and decisions we make today. Given the alarming state of natural rangelands in the steppe and the findings of this work, it is crucial —and even a priority— to consider innovative production systems and farming methods that do not harm the natural ecosystem. To achieve this, scientific research must be directed towards providing decision-makers with a comprehensive toolbox that includes: functional assessments of natural ecosystems health; strategies for developing agropastoral practices that enhance fodder production to meet the future needs of livestock; and prepared scenarios based on current conditions and feasible options. Naturally, these elements extend beyond our own discipline; a truly multidisciplinary approach, which integrates diverse fields of knowledge, is essential. This synergy also

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involves all stakeholders in the red meat sector, especially breeders. Ultimately, our resilience hinges on expanding our knowledge and improving our capacity to listen and adapt.

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