



## Sheep Feeding Strategies in the Face of Declining Steppe Fodder Resources in Tebessa Region/Algeria

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**Abstract:** In Algeria, sheep farming in the steppe areas is the main source of income for the populations of these regions. The share of pasture in the daily food ration of sheep has become very low, less than 30%. As a result, breeders have diversified their feeding system strategies. Our questioning concerns the different strategies adopted by breeders and their efficiency to deal with the lack of fodder from natural steppe rangelands. To carry out our research, we used free interviews, with resource persons (extension worker, developer, etc.) and surveys/interviews with 100 breeders from two municipalities in the center of the province of Tébessa. We opted for a holistic and systemic approach to acquire and analyze our collected information. This result in three main feeding strategies adopted by 3 groups of herders: The 1<sup>st</sup> strategy exploited all the food resources available in the study environment, namely the exploitation of natural rangelands, pastures from cropland, fodder supplementation and concentrate supplementation (barley grains and wheat bran, etc.), the 2<sup>nd</sup> strategy used all the resources of the 1<sup>st</sup> except natural rangelands. The 3<sup>rd</sup> strategy consisted of grazing the free fodder supply from natural rangelands of different statuses and using the cheapest concentrated feeds (wheat bran). The use of supplementation in concentrate was essential, it was found in all strategies

**Key words:** Animal feed, breeder, sheep farming, steppe rangelands, strategy.

The Algerian steppe extends over 20 million hectares between isohyets 400 mm yr<sup>-1</sup> and 100 mm yr<sup>-1</sup>. It is essentially agropastoral with a sheep population of nearly 18 million head (HCDS, 2012).

In this territory sheep farming plays a major socio-economic role. It is the main source of income (80%) for the pastoral population of this region (HCDS, 2012) and the leading supplier of sheep meat in the country (Kanoun *et al.*, 2007). It contributes to more than 50% of national red meat production and 10 to 15% of agricultural GDP (Moula, 2018). Nevertheless, since the 1970s, soil erosion and the degradation of grazing vegetation in the grazed steppe ecosystem have become worrying (Le Houérou, 2005; Nedjraoui and

Bedrani, 2008). This situation is the result of the combined effects of recurrent droughts and increasing anthropogenic pressure, particularly through the cultivation of rangelands (Khaldi, 2014).

Grazing steppe areas are declining from 10 million hectares in 1985 to 8.7 million in 1995 (Bensouiah, 2003), while the sheep population has increased from 8 million nationally in (1970) to 27 million in 2014 (Kanoun *et al.*, 2015). Cultivated land has increased from 1.1 to 2.9 mha between 1970 and 1994. This dynamic contributed to increased animal pressure on rangelands (Bourbouze, 2000).

The degradation of the steppe, resulting from important transformations that are associated to changes related to social organization, the economy and ecosystems (Bourbouze, 2006),

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has led to significant changes in herd feeding in recent decades. Before the 1970s, the herd's diet was from natural vegetation taken from the rangelands which provided fodder for the animal's nutritional needs.

Currently, the fodder supply of the Algerian steppes is estimated 1.5 billion FU (corresponds to 15 million quintals of barley) (HCDS, 2012) can only cover 20% of the fodder needs of the existing sheep flock. Since the droughts of the 1970s, the state has given and then subsidized barley grain as a feed supplement, known as "concentrate", for herds.

Now, this supplementation (barley, wheat bran, wheat) is a common practice to compensate for the loss of fodder inputs (Senoussi *et al.*, 2014). Thus, breeding has become more and more dependent on exogenous inputs (BNEDER, 2014).

In addition to concentrates, livestock farmers also practice supplementation with fodder resources from crops that have developed in the rangelands (hay and straw, pasture with alfalfa, maize, regrowths of cereals etc.). Decreased contribution of natural rangelands in meeting out the nutritional needs of the livestock requires breeders to diversify their strategies for animal feeding.

Objective of our study is to identify the new feeding strategies adopted by breeders in the Algerian steppe zone. For this center of the province of Tébessa has been chosen which represents steppe rangelands of Algeria.

## Materials and Methods

The method adopted in our study was based on interviews with hundreds of breeders in two municipalities located in the centre of the province of Tébessa, (Chéria and Thlidjene) (Fig. 1), which is reputed for their ancestral pastoral

farming. The interview of the sheep farmers was through some pre-tested questionnaire. The breeding activity constitutes the sole source of income for the majority of the local

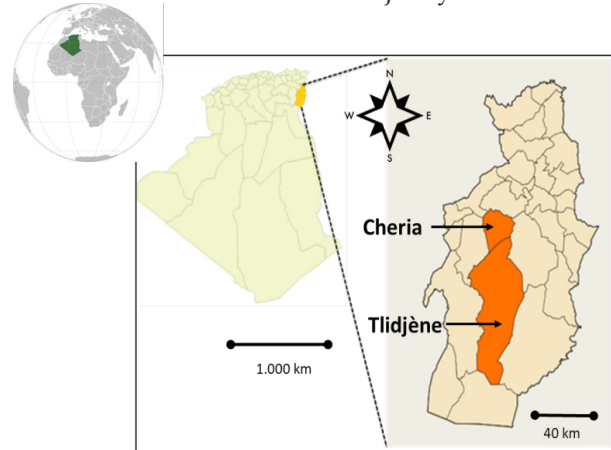


Fig. 1. Localization of Tébessa province and study area.

population, thus, justifying the importance of sheep and breeders numbers who live there.

Interviews were carried out in 2015 and 2016. The objective was to gather as much data as possible on the practices of sheep farming in general, and feeding practices in particular.

### Study area description

The province of Tébessa is part of the large regional group of highlands east. It is a border province with Tunisia located in the North East and is part of the huge steppe area of the country. Tébessa covers an area of 13 878 km<sup>2</sup> of which 31% is rangeland. It is characterized by a semi-arid continental climate with hot, dry summers and harsh cold winters. The rains are irregular too; this province has scanty rainfall with 100 to 350 mm per year with irregular spatial and temporal distribution (300 mm to 350 mm per year on average in the north, 200

Table 1. Variables selected for the analysis and their modalities

Variables	Number of modalities	Modalities
Pastures of natural steppe rangelands	5	Private natural rangeland (for private use), leased natural rangeland, improved leased rangeland, collective rangeland, winter transhumance free rangeland (Azzaba)
Pastures from cropland	7	Damaged barley, summer stubble, autumn cereal regrowth, fallow, barley grazing, alfalfa grazing, maize grazing
Fodder supplementation	3	Alfalfa hay, oat hay, straw
Concentrate supplementation	4	Barley grain, corn grain, wheat flour, wheat bran

mm to 300 in the centre and less 100 mm in the south).

The study area extends to 2092 km<sup>2</sup> with 91672 inhabitants; a density of 44 inhabitants km<sup>-2</sup>. The area of the rangelands is 88900 ha and represents 21% of the overall area of the rangeland of the province. The size of the sheep herd is estimated at 179900 head and constitutes 19% of the total of the province, while the number of breeders amounts to 1066 and occupies the first place in the province.

Our information and data collected were ordered in a general matrix (database: 100 breeders × 21 variables/107 modalities). For feeding strategies, we analysed 4 specific variables and their modalities (Table 1).

The information was processed by Multiple Factor Analysis (MFA) (Lebart *et al.*, 1984), followed by an Ascending Hierarchical Classification (AHC). The groups obtained were described by prioritizing the most contributing criteria using test values. The statistical analyses were carried out using the R software (R Core team, 2016) and the Factomine R package (Husson *et al.* 2009).

## Results and Discussion

All the breeders were interviewed (100 breeders) live in solid houses. This reflects the high level of sedentarization achieved in the pastoral environment. Agro-pastoralism was the main activity of pastoral populations. The average age of the respondents was 57 years, of which the youngest represented 26% (from 29 to 45 years), those of average age (between 46 and 60 years) are 25%, the oldest of which age range was between (61 and 70 years) represent 32%, and finally the category of old breeders (from 71 to 87 years) which represented 17% of the surveyed sample. 32% of the breeders visited were illiterate and have never attended school, these were the oldest people, 25% attended Koranic school, and rest (43%) the younger ones had different educational levels: primary, middle, secondary and even university. Agro-pastoralism was the main activity of pastoral populations. Our sample was made up of 94% agro-pastoralists and 6% breeders, the latter live on their land and practice breeding alone. The means of production was an important factor in ensuring production on a farm. 26% of respondents owned agricultural equipment, they were considered to be the most

financially comfortable. The average herd size was 103 ewes. 27% of the surveyed breeders had small herds with less than 50 heads, 30% have herds with numbers between 50 and 100 heads, 39% had medium-large herds of 100 to 300, and finally 4% had large herds with a number of more than 300 head.

Food resources: Four types of resources were used for livestock feeding in the study area.

### *Pastures of natural steppe rangelands*

Legally, the steppe natural rangelands were the property of the State, but their access was differentiated.

*Collective rangelands:* Legally, they were regulated in an ancestral way by tribes (arch). These rangelands were found with most breeders around their farms. They were mainly exploited from March to June if the year was good (rainfall year), or all year round except summer (period of stubble grazing).

*Private natural rangelands:* Legally, they belonged to the private domain of the State, but they were used according to local social rules. Herders and their families had exclusive inheritable right of using these lands because they were close to their habitats. Animals grazed there most of the year, all day long traveling less than 3 km day<sup>-1</sup>, except in summer.

*Natural leased rangelands:* Legally belonging to the private domain of the state. They were rented to the breeders either by owners being private users of the rangelands (who have monopolized collective rangeland) living in the village, or by the state where the High Commission for the Development of the Steppe (HCDS) ensured their protection from grazing and managed their exploitation by fixing the period and the animal load.

*Improved natural leased rangelands:* They were restored by the HCDS (deferred grazing for several years, planting of pastoral species, etc.) Their exploitation was authorized by the HCDS from November to December and in the spring when the fodder supply was greater at 150 FU ha<sup>-1</sup>. The animal load was 3 to 5 head ha<sup>-1</sup>.

*Winter transhumance free rangeland (Azzaba):* These were pre-Saharan rangelands located in the south of the steppe zone, where pastoralists and their herds moved in early winter and stayed, until spring (until April), to hunt for

food and to escape the harsh winter that steppe characterized with.

#### *Pastures from cropland*

The steppe agricultural lands were generally used to grow cereals, especially barley, where breeders feed their animals on this cereal during all its growth phases: on the regrowths in autumn (autumn cereal regrowths) at the beginning cycle of vegetation (barley grazing), bad growth due to lack of rain (damaged barley), and on stems after harvest (stubble).

*Damaged barley:* The barley land was cultivated from October to November and waited for the rains to come. In case of water deficit, breeders waited, still hoping for the arrival of rains until April which was the last chance for the growth of cereals, otherwise the crop goes wasted, and the herders are forced to release their animals to feed on these damaged cereals. The lands in damaged barley exploited, belong either to the breeder, or were rented from owners that could be from the same municipality or could belong to other municipalities of the province. Some herders were associated with other people on larger plots; they grew together and with whom they shared the harvest, stubble use and even the exploitation of the damaged cereal.

*Autumn cereal regrowths:* During the three months of summer, breeders feed their animals on the stubble of cereals grown on their lands, or rented other stubbles, especially when the number of sheep was high, sometimes even traveling kilometers to enable their animals to exploit the residues of cereals. During this period the animals grazed cereal straws and grains that have fallen during the harvest.

After consumption of all the grain stubble on the cultivation lands, the access to these lands, whether private or rented, became open for all the breeders of the neighborhood who brought their animals to feed on the regrowths of the cereals that appeared after the first autumn rains. These lands then became collective for all breeders before their ploughing, from September to November and sometimes even to December. But once plowed, access returns to be exclusive to the owners.

*Barley grazing:* It was a pasture for barley at the beginning cycle of vegetation, between

November and; March. Then the cereal was no longer used so that it can resum its growth and produce grain.

*Grazed fallow:* It was an important resource especially in spring in favorable rainfall years, and sometimes in late autumn and winter. The breeder used his own fallow land and if this was insufficient, he could rent others. The breeder could also use the neighboring fallow land that had not been cultivated. Some herders owned land in other municipalities, which they used to feed their animals.

Agro-pastoralists with boreholes and wells cultivated alfalfa or maize in irrigated form and gave it to their animals when still green.

#### *Fodder supplementation*

These were mainly alfalfa hay and oats. This fodder supplement was a backup food when there happened to be a shortage in spontaneous plants on both natural rangeland and fallow, as well as during inclement weather when animals remained in stabling. Breeders used oat hay or alfalfa hay, or both, depending on their availability, whereas they preferred alfalfa hay since it was richer and more appreciated by sheep, according to them. The quantity distributed is on average 0.8 kg head<sup>-1</sup> day<sup>-1</sup> when the animals were in stabling. Generally hay was bought from producers, vendors, or on the cattle market. Some breeders produced it themselves because they have water resources on their farms.

Straws were the least used by our surveyed; they are distributed in the lack of alfalfa or oat hay. The breeders who cultivate cereals collect the straws after the harvest, otherwise they were bought from the cereal growers in the region or from the food vendors or at the cattle market.

#### *Concentrate supplementation*

Since the contribution of natural rangelands in the herd feeding in the steppe was in continuous decline, the use of subsidized concentrated feeds became a necessity. The most used foods in our study area were: barley grain and corn grain, wheat bran and wheat flour.

*Barley grain* was the most important concentrate for breeders in the study area. It is used as supplementary food in case of lack

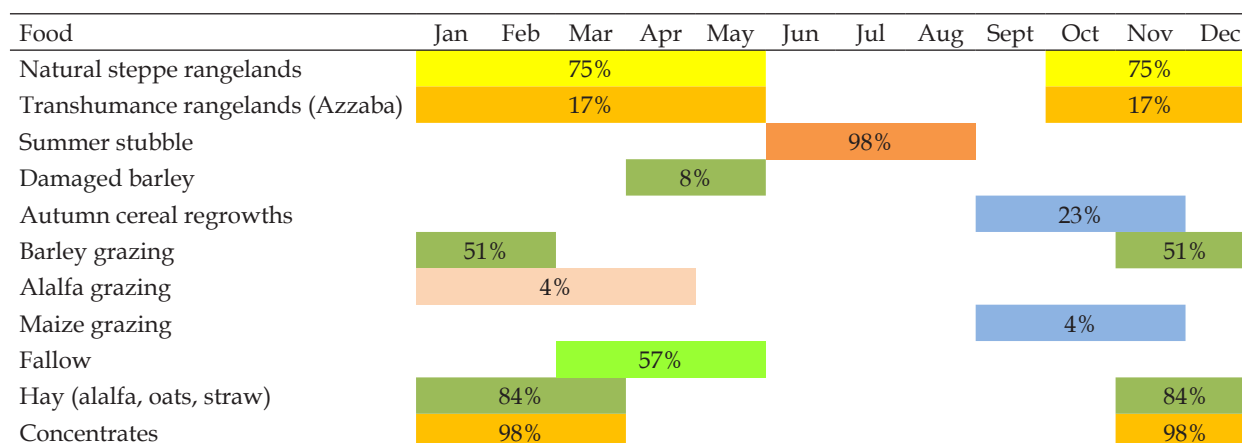


Fig. 2. Calendar of use of the different food resources exploited by the 100 breeders interviewed during a satisfactory rainfall year (percentage of breeders carrying out these practices).

of vegetation in a bad year; it was also the staple food for fattening lambs. The quantity distributed was on average 1 kg head<sup>-1</sup> day<sup>-1</sup> to 1.5 kg head<sup>-1</sup> day<sup>-1</sup>.

*Corn grain:* It was less used than barley by breeders because of its high price and not subsidized unlike that of barley. The quantity distributed was on average 1 kg head<sup>-1</sup> day<sup>-1</sup>.

*Wheat bran:* It was the cheapest concentrate. Usually it was mixed with barley grain or corn and distributed to the animals.

*Wheat flour:* This concentrate, by-product of low quality soft wheat, not used for human consumption, was sold to breeders at flourmills at high prices, although its use in animal feed was prohibited by the state. Wheat flour was mixed with barley grain or corn or both.

The distribution of these concentrates remains highly dependent on the climatic conditions of the region. If the year was good, they were used only in winter to fight against the cold and in bad weather when the animals did not go out to the natural pastures. If this was not the case and the natural vegetation

on the grazing lands was rare, they were used throughout the year.

*Feeding strategies:* Three groups of breeders adopting three different feeding strategies as shown in Table 2.

#### Group 1: Breeders using the most different resources

This group comprised 39 breeders (39% of the total surveyed number). The strategy to feed their herds was using all the sources of food available in their environment: Pastures of natural steppe rangelands, pastures from cropland, fodder supplementation, and concentrate supplementation (Table 2).

The breeders in this group used all types of rangelands to meet the food needs of their herds: The use of collective rangelands predominated with (90%) (Table 3). These rangelands were found in most of the breeders that we visited around their farms. In this group, those who did not have rangelands near their homes (33% of surveyed) and whose sheep numbers were between 50 and 800 head moved in transhumance to other lands

Table 2. The three feeding strategies and the corresponding typology of breeders (100 breeders surveyed)

Groups of breeders	Breeders number	Feeding strategies	Food resources used
1	39	Breeders using the most different resources	Pastures of natural steppe rangelands Pastures from cropland Fodder supplementation Concentrate supplementation
2	28	Breeder-farmers who do not use natural rangelands but fallow land	Pastures from cropland Fodder supplementation Concentrate supplementation
3	33	Breeding on free rangelands and with cheaper concentrate	Pastures of natural steppe rangelands Concentrate supplementation

Table 3. Use of available food resources in the three groups of breeders

Food resources	Quantity head <sup>-1</sup> day <sup>-1</sup> (kg)	Use percentage (%) per group		
		Group 1	Group 2	Group 3
Pasture of natural steppe rangeland				
Collective rangeland	-	90	14	73
transhumance rangeland	-	33	4	9
Private natural rangeland	-	13	4	12
Leased natural rangeland	-	3	4	9
Improved leased rangeland	-	3	0	3
Pastures from cropland				
Damaged barley	-	18	4	0
Summer stubble	-	100	100	94
Autumn cereal regrowths	-	8	57	12
Fallow	-	31	96	55
Barley grazing	-	46	54	55
Alfalfa grazing	-	5	7	0
Maize grazing	-	3	7	3
Fodder supplementation				
Alfalfa Hay	0.8	97	89	24
Oat Hay	0.8	74	61	15
Straw	0.8	44	57	45
Concentrate supplementation				
Barley grain	1-1.5	87	93	33
Corn grain	1	56	25	42
Wheat flour	1	18	39	52
Wheat bran	1	77	86	97

accompanying their animals to other pastoral areas qualified here as "winter transhumance free rangeland (Azzaba)". These breeders were forced to move periodically in transhumance (Azzaba) in search of natural vegetation to meet the food needs of their livestock, and allowed their animals to evolve in a mild climate even in winter. Among the breeders of this group, 13% exploited private natural rangelands. Leased natural rangelands were exploited by only 3% of the surveyed breeders.

This group of breeders often used damaged barley as pastures from cropland resource. It should be noted that the areas of total cultivated barley were important in this group of breeders, with an average of 21±18.52 ha (Table 4). These herders cultivated the maximum amount of barley enough to feed a large sheep herd with an average of 127±139 heads (Table 4).

The purpose of this culture was always animal feed. In this group 46% of breeders rented additional land to sow them in barley. *Alfalfa* hay was used almost by all group

1 breeders (97%) where about a quarter of them (23%) produced it on their farms. These were farmers with boreholes or wells, which represented 49% of the group (Table 4). Oat hay was less used than that of alfalfa. Of the 39 breeders in group 1, 29 breeders (74%) (Table 3) used it as a supplement for their sheep.

Concentrated feeds used by group 1 breeders, were 87% barley grain and 56% corn grain (Table 3). This one was the most expensive concentrate. It was used by breeders who were more financially comfortable.

#### *Group 2: Breeder-farmers who do not use natural rangelands but fallow land*

This group included 28 breeders (28% of surveyed breeders). Their strategy was to use three (3) food resources among the four (4) available in the study area: Pastures from cropland, fodder supplementation, and concentrate supplementation.

Our results showed that 96% of breeders of this group used fallows to feed animals (81 ± 66

head on average). This category of breeders did not have natural rangelands near their farms, and never moved. They were sedentary and graze on their own fallows, or those in the neighborhood or on rented fallows. They used the various products of their farms to cover the food needs of their livestock.

More than half of the breeders in this group (57%) used autumn cereal regrowths as pastures from cropland (Table 3). Alfalfa hay was used by 89% breeders of this group as fodder supplementation (Table 3) to supplement the ration of their sheep. Almost half of breeders in this group (46%) owned boreholes and wells, consequently, alfalfa hay was produced in 21% of the visited farms (Table 4). The supplementation in concentrate was provided by barley grain which was used by 93% of the surveyed in this group.

*Group 3: Breeding on free rangelands and with cheaper concentrate*

They were 33 breeders (33% of the total), with an average sheep number of  $92 \pm 72$  head. Their food strategy was based on the exploitation of two existing food resources in the area: Pastures of natural steppe rangelands and concentrate supplementation. These herders used the free pasture resource and the cheapest supplementation concentrates (wheat bran) for feeding their herds.

Large number of breeders in this group (73%) used collective rangelands because they had large pastoral areas around their farms. This was the reason why the transhumance rangelands (Azzaba) were less exploited (9%) (Table 3), except for three breeders, two of which had their farms being far from the rangelands, and having a good number of animals (100 and 217 heads). This led the first to travel a distance of 30 km and the second 140 km only just to feed their herds. The third breeder with 160 heads of sheep, moved at a distance of 25 km to the south of his town, and stayed for nearly 7 months (from October to May). Four breeders of group 3 (12%) had private natural rangelands which were exploited during three quarters of the year, excepted summer.

*Leased natural rangeland:* 3 breeders of class 3 (9%) rented natural rangelands: The first, rented each year a rangeland of 80 ha not far from his farm (about 5 km), from an owner

who lived in the village. He exploited it from October to June to feed his flock of 200 ewes. The second who owned 217 ewes rented each year from October to June, a rangeland located south of his municipality. The third breeder rented when the year was good (rainfall), a rangeland around his farm that he used during the spring season (March to May).

*Improved leased rangeland:* They exploited by only one breeder of this group (3%). He rented an improved state-owned rangeland during both winter and spring periods for its 60-sheep herd. Wheat bran was the most used (97%) in this group, wheat flour was used by 52% of Group 3 (Table 3).

The quantities of complementary feed (Fodder supplementation or Concentrate supplementation) distributed to the sheep were the same in the three groups of breeders (Table 3). The quantification of grazed vegetation was difficult therefore, it was not indicated in the table.

Our original results shed light on the feeding systems and strategies implemented by the herders in the study area through one hundred interviews with herders.

The characterization of the farms of the three groups (Table 4) showed that those of group 1 had a higher sheep population, one of the reasons justifying their exploitation of all the available food resources in their environment to meet the needs of their herd. Kanoun *et al.* (2007) pointed out that the feeding of herds in pastoral areas was often based on the combination of several food resources (rangelands, fallows, crop residues "stubble", green barley, concentrate supplementation etc.).

*Pasture of natural steppe rangelands* was an essential practice for breeders because it was the main resource in steppe areas (Bensouiah, 2003). In the study area, the majority in groups 1 and 3 used collective rangelands (Table 3) because most of them lived near large pastoral areas. According to Dutilly-Diane (2006), farms that use collective rangelands were located mainly in the neighborhood of these spaces. Those in group 2, use these spaces less for lack of rangelands around their farms. It had been demonstrated that farms that did not use rangelands, are far from them, and were relatively well endowed with land and practiced breeding and agriculture (Dutilly-Diane, 2006).

Table 4. Farms characteristics of the three breeder groups

Characteristics	Group of breeders		
	1	2	3
Number of Breeders	39	28	33
UAA (ha)			
Total	711	514	607
Average	18±18.30	18 ± 27	18 ±17.59
Barley-grown area (ha) on land (private + leased)			
Total	809	391	553
Average	21 ± 8.52	14 ±18.27	17 ± 18.19
Sheep number (heads)			
Total	4943	2280	3041
Average	127 ± 139	81 ± 66	92 ± 72
Breeders percentage			
Having boreholes or wells	49	46	48
Producing hay	28	25	21
Producing alfalfa hay	23	21	12
Barley grown on leased land	46	21	27

Despite the significant acceleration of the privatization process of collective lands in the Algerian steppe over the last thirty years (Daoudi *et al.*, 2015), a low rate of breeders among our interviewed have private natural rangeland (for private use): 13, 12, and 4% belonging respectively to groups "1", "3" and "2" (Table 3). Transhumance rangelands (Azzaba) were poorly frequented by breeders in all three groups. The practice of transhumance had become rare nowadays (Benchérif, 2011). This practice has undergone profound changes (Bensouiah, 1997) in terms of quality (with reference to the organization of its process) and quantity (with regard to the reduction in traveled distances, for instance). Leased natural rangelands were exploited by a small number of breeders from the three groups (Table 3). Improved leased rangelands where the impact of the pastoral plantation on the improvement of fodder production (from 30-50 FU ha<sup>-1</sup> to more than 600 FU ha<sup>-1</sup>) offered a real opportunity for herds (Brouri, 2011), they remained very weakly used by the 3 groups of breeders.

*Pastures from cropland:* The scarcity of pastoral resources in meeting the needs of the herd had led to a strong use of resources produced on the farm (Alary and El Mourid, 2007). These resources were used mainly by the two groups 1 and 2. Group 1 breeders who had higher sheep numbers, 127 heads on average, cultivate more barley area: 809 ha so that's 21

ha per individual (Table 4) hence the use of damaged barley (in a bad year) as cropland resources. In the dry year, the farmer preferred to offer these unharvested cereals to animals (Medouni *et al.*, 2004).

The area of cultivated barley (809 ha) was 12% larger than the area of UAA (711 ha) (Table 4); this was explained by the fact that a significant percentage (46%) of group 1 breeders leased land in other places to sow them in barley. The practice of cereal crops on the rangelands allowed the breeders in favorable rainfall conditions, to construct a stock of food in several forms: barley grain, stubble, and straw (Kanoun *et al.*, 2007).

Apart from renting, some farmers grew barley in association with other people. The associates of the agro-pastoralists in the cereal farming were essentially close family/or friends that dwelled in the city (Daoudi *et al.*, 2013). Group 2, on the other hand, used cereal regrowths as a cropland resource because, in addition to their land, these breeders could access neighboring croplands that became collective after consuming all the stubble. Pasture fallow, essentially used in herd's food (Abbas and Abdelguerfi, 2005), was used by breeders of group 2 to feed their animals, this appears clearly through the area of the UAA (514 ha) that was not fully cultivated, knowing that the total area of barley grown is 391 ha (Table 4), which means that part of the UAA was left fallow to feed the herds.



Pasture fallow, typical of arid and semi-arid farming zones, offered forage resources that were sometimes of paramount importance (Bourbouze and Donadieu, 1987). The use of stubble was practiced by almost all breeders in the three surveyed groups (Table 3). The straws and stubble of cereals were very important food resources used by breeders during the summer, when other forage and/or pastoral resources were rare or even unexistent. (Abdelguerfi *et al.*, 2008).

*Fodder supplementation:* Group 1 and 2 breeders mainly used alfalfa hay as fodder supplement because many of them were endowed with water resources (49% of group 1 and 46% of group 2) that allowed them to produce alfalfa on their farms (23% and 21% respectively for group 1 and 2).

*Concentrate supplementation:* In Algeria, as in other neighboring countries (like Tunisia and Morocco), the low contribution of rangelands in the sheep's diet had led to an abundant use of concentrated feeds, in particular barley and bran (Ben Salem, 2011; Jemaa *et al.*, 2016). The breeders in the three groups used concentrate supplementation, which has become the main source of livestock nutrition regardless of the state of the rangelands. One of the main objectives of the government after Independence was the re-establishment of the sheep herd by the introduction of subsidized livestock feed in the steppe (Bensouiah, 2003) since the droughts of the 1970s.

It should be noted that breeders in groups "1" and "2" used barley grain more than wheat bran to supplement the feed, while those in group "3" used the wheat bran which costs less (Table 3) and wheat flour which, according to our breeders interviewed, increased milk production in lactating ewes which allowed good growth of lambs.

According to the declarations of the breeders interviewed, large quantities of barley were bought from the sellers because of the inaccessibility of barley subsidized for procedural difficulties and/or for lack of certificate of vaccination of the herd (Daoudi *et al.*, 2013).

Our analysis showed that beyond the diversity of strategies developed, the mode of feeding was highly dependent on the means available to the breeders. Breeders who had

the most means can diversify their food resources using all available resources. Even if our investigation was not focused on the economic aspects including those relating to the cost price, it is obvious that the economic logic of the respondents is driven by the need to control the expenses related to the feeding of the livestock. In fact, supplementing the feed for livestock required the use of purchased feed, often at a high price in the face of the pressure that existed on subsidized feed. In this logic, the respondents who had the most potential were those who had large areas of cereal cultivated and could buy the most expensive concentrates (corn grain) (Group 1).

Those who had the least means use the least expensive resources, namely the natural rangelands and the cheapest concentrated foods (wheat bran) (Group 3). The price of corn grain (3500 DA<sup>-1</sup> quintal) cost more than twice as much as the price of wheat bran (1500 DA<sup>-1</sup> quintal), (1DA= 0,0074 \$)

Even if the natural rangelands were still frequented by breeders, the place represented by food from steppe rangelands in the total food ration of the herds had fallen sharply in comparison with the pastoral production system before the 1970s. We give the example of the breeders of Group 2 who frequent the rangelands the least.

On the economic level, we noted that the financial expenses of the breeders of group 1 for feeding their animals were numerous, namely the expenses of transhumance trips (rental of trucks to transport livestock); expenses to cultivate barley on large areas of their land and rented land (land rental costs); expenses to produce hay in their farms and expense for the purchase at high prices of unsubsidized feed concentrates such as barley grain (3000 DA<sup>-1</sup> quintal) and corn grain (3500 DA<sup>-1</sup> quintal). In group 2, breeders spent less to feed their animals, they used their own fallows or those of the neighborhood to graze their sheep; they used the various products of their farms to cover food needs, and distributed barley grain (3000 DA<sup>-1</sup> quintal) as a concentrated feed.

Financial expenses for feeding animals belonging to group 3 breeders were the lowest. In this group, breeders mainly relied to feed their animals on the free use of natural rangelands and the purchase of the cheapest concentrates: wheat bran (1500 DA<sup>-1</sup> quintal).

It is inferred from data that the feeding strategy adopted by the first group was the most expensive, that of the second group was less expensive, and that of the third group was the cheapest. The latter could be the most profitable only in a rainy year when natural vegetation became abundant on the steppe rangelands and therefore provided abundant free fodder to the animals, thus ensuring that all their nutritional needs are covered, and saved breeders the expense of buying supplementary feed.

Our results made it possible to take stock of the difficult situation experienced by breeders to feed their animals. They have developed a diversification of feeding strategies to be able to compensate for the inability of natural rangelands to cover the food needs of their livestock.

This is an exploratory study to highlight the different strategic feeding systems with their elements according to their organization and interactions. Consequently, it could not give technical and economic details, or a precise level on ration values according to trends and seasons. We could nevertheless have a clear perception of the supposed aptitudes of breeders to cope with the forage deficit of natural rangelands. Further studies were needed to obtain higher levels of precision.

However, we could suggest some solutions. The fodder deficit of natural rangelands in the steppe zone could be solved through 1) actions for the rehabilitation and restoration of natural rangelands 2) sensitization of pastoral communities and future generations (through the child) on the importance of steppe heritage, and educate them to respect their environment by preserving its natural resources 3) rational use of natural rangelands (make the breeders responsible for the use of the rangelands) 4) the application of laws governing steppe rangelands through regulations that ensure the sustainability of natural resources and the guarantee of pastoral activity in the steppe.

## Conclusion

Since rangelands contribute in low proportion to animal feed, the feeding of sheep flocks in the steppe zone has become the main concern of breeders. They are still trying to find the best solutions to feed their flocks and save their herds in the face of multiple constraints that

can have several origins (climatic: because of the drought, fodder: Due to the degradation of the natural rangelands, economic: considering the high cost of concentrated feed and the difficulty of access to subsidized concentrates). Confronted by this situation, breeders have developed a diversification of feeding strategies to cope with the fodder deficit of natural rangelands. These are three feeding strategies to compensate the fodder deficit in their steppe environment.

It is therefore necessary to give serious thought to the future of steppe rangelands and sheep farming. Even if many other resources have been found, the natural vegetation of the rangelands will remain indispensable. It is therefore necessary to look for more efficient and sustainable alternatives to improve fodder availability in rangelands.

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