ABSTRACT
Weather hazards and changing climatic regimes combined with socio-cultural changes are forcing farmers living in Algerian steppe territories to find new strategies to maintain their business, particularly in terms of animal feeding sources. Animal's nutritional needs in the past used to be met mainly by grazing lands which nowadays cover less than 40% of feeding sources. This study aimed to determine the status of livestock system practices used by breeders in Algerian steppe territories and presents a novel method in identifying intensive systems. Data were obtained from 90 farms through a survey in the province of Tebessa. The farms were divided by their characteristics with a discriminant analysis by zone to know the characteristics of each region. Moreover, a discriminant analysis was performed to select the variables that best differentiated the farms characterised by a different percentage of feed purchased (PFP), which was taken as an index of intensive management. A stepwise regression analysis was also conducted to get predictors variables that mainly influence the percentage of feed purchased and characterise the intensive livestock farms in this area. As a result, livestock systems in steppe territories are up to changing to more intensive forms. These trends appear as solutions for farmers to improve their productivity in the face of various problems. Nevertheless, not to worsen the situation of livestock farming with the orientation towards the intensive system, it is important for farmers to be informed about international policies for practising intensive livestock farming.

HIGHLIGHTS
• The current state of livestock production and practices was identified in the steppe areas.
• The percentage of purchased feed had greater effects in determining the nature of the livestock systems and identifying intensive systems.
• The use of modelling techniques in the identification of livestock intensification could be successfully used in the differentiation of livestock systems.

Introduction
Nowadays the livestock farmers in the steppe of Algeria have undergone profound changes. The steppes of North Africa, located between the isohyets of 100 and 400 mm, cover more than 63 million hectares of scattered low vegetation (Aïdoud et al. 2006). The Algerian steppe represents almost half of this territory (32 million hectares), i.e. nearly 14% of the country’s surface area (MADR 2018) and represents a territory essentially characterised by pastoral activities (Nefzaouï 2004).

The breeding of small ruminants, especially sheep, is the first choice of income-generating resources for the region’s breeders (Yabrir et al. 2015) and contributes up to 50% of the total Gross Domestic Product (GDP). This Kindle of livestock farming is concentrated mainly in the steppe territories where numerous changes have been recorded and which have generated a context of growing uncertainty responsible for the accelerated transformation of the sheep productions in the steppe. Thus, pastoralism has given rise to agropastoralism and even to more intensive forms of agriculture-livestock farming (Kanoun 2016).

In Algeria, the steppe has been recently impacted by a significant population expansion, which has
triplled from 4 million in 1977 to 12 million in 2010 (ONS 2011), and by an important growth in livestock numbers, increasing from 18 million in 2009 (Yabrir et al. 2015; Gaci et al. 2021) and more than 28 million in 2017 (Hadbaoui 2020), as well as in fodder cereal production (Benchefir 2018).

The evolution of socio-economic, demographic, political and climatic conditions in the Algerian steppe over the past decades has led to profound changes in livestock rearing practices (Gaci et al. 2021). The environment of sheep breeders has not been exempted from these different changes (Kanoun 2016). Even when climate change has received great attention during the last decade for its impacts on the human ecosystem and the economy (Sgharhi and Hammami 2016), it is still vulnerable with few solutions and extreme droughts have an impact on the productivity of the community, structure and modulating the responses and resistance of the steppe (Ma et al. 2020).

Population growth, cultivation to the detriment of the rangelands, socio-cultural developments and changes, as well as the intensification of climatic hazards, especially droughts are the main upheavals that have occurred in the steppe. As a result, the steppe rangelands are undergoing increasingly severe degradation, forcing stock-breeders to find new animal feed sources for their herds to replace the flagrant lack of natural pastoral resources in the livestock ranges (Benchefir 2018). Consequently, animal feeding demand has more than tripled in the last 50 years, increasingly shifting the livestock sector towards intensive production systems (Davis and D’Odorico 2015), which have been established as a key method of food production in the world (Cronin 2014).

Although the transformation of the livestock sector in the steppe territories has already taken place for decennia, there is currently a deficit of information on the most important characteristics of livestock farming in Algeria, and more particularly in Tebessa, which is counted among its biggest pastoral areas. We are therefore interested in understanding the characteristics and distribution of different types of livestock systems that have proved to be resilient to climatic, social and economic changes up to now. To understand this and to determine whether there is a transformation to intensive livestock production, a comprehensive and holistic approach is needed.

In this paper, we explore the possibility of using the percentage of purchased feed-in determining the nature of livestock systems and identifying intensive systems as a novel method to identify the different livestock production systems adopted by steppe farms in Tebessa in the different bioclimatic stages.

Materials and methods

Study sites

The survey was conducted in different districts of Tebessa province, being for the most part under an arid climate. Its agricultural potential is estimated to be 1,269,358 ha, of which 20% is used land, with 312,315 ha, and only 5% is irrigated. The studied region was chosen for its important agro-pastoral resources since it includes all the steppe zones and constitutes an asset for the biogeography diversity of livestock systems, including mixed crop-livestock and pastoral production systems. The province of Tebessa contains four different bioclimatic stages: superior semi-arid, semi-arid, sub-arid and arid. The upper semi-arid is very small and covers only part of the territory, limited to a few reliefs. The semi-arid (rainfall of 300–400 mm/year) represents the cold and fresh sub-layers and covers the whole northern part of the province. The sub-arid region has a rainfall of 200–300 mm, while the arid or mild Sahara (rainfall below 200 mm/year) begins and extends beyond the Saharan Atlas.

Due to its natural pastoral vocation, the province has an interesting animal production according to the statistics of the year 2017 with 920,000 heads of sheep (DSA Tebessa 2017).

Experimental design, data collection

This study is an observational study involving 90 livestock farms, who agreed to collaborate in the study. They were selected randomly and were evenly distributed in the four main bioclimatic stages represented in the study area. The collection of reliable data in pastoral territory, including different kinds of farms, is a challenging task because data collection and structuring must be consistent and allow for database processing and statistical analysis. For this reason, a detailed questionnaire was designed and delivered to each farm in 2019. The questionnaire was filled in during a face to face survey between farmers and trained personnel. The questionnaire included the profiles of the farmers, the size and composition of the livestock herds, livestock management, feeding and housing, and more particularly the nature of the feed used (nature of fodder, fattening practices, the practices of mobility, the use of concentrates, water availability, and characteristics of the livestock building). Our work was conducted without using clinical trials or animals.

To describe each farm characteristics, we used the variables reported in Table 1, including mainly...
bioclimatic stage, size, the main source of feed, application of the transhumance, etc.

**Statistical analysis**

To analyse the intensification profile of livestock production, farms were assessed on the basis of common indicators that are considered as the pillars of intensifications such as animal density expressed as livestock unit (LSU) per hectare (LSU/ha), the use of concentrates as the feed source, availability of water, and the percentage of feed purchased, categorised in four levels (0–25%; 26–50%, 51–75% and 76–100%) that we considered as the main parameter to attribute a level of intensification to a farm.

Spearman rank correlation was calculated among the predictor’s variables and the target ones (PFP and zones).

Factorial discriminant analyses (FDA) was performed to select the main variables (qualitative/quantitative) which can better discriminate the farms according to the four classes of PFP and zones. The procedure determines which of the predictor traits have more discriminant power than the other. Unlike the ANOVA model, factorial discriminant analysis cannot be expressed by a mathematical equation. It is a multivariate technique that analyses a response variable as a function of latent ones (components). The canonical discriminant function coefficients are calculated which are used to estimate the new data coordinates in the system of axes represented by the new latent components. In addition, classification functions are calculated to estimate a posteriori probability of the data being assigned to one of the classes of the discriminant predictor. Correlations among the original variables and main factors were calculated, as well as the loadings (projections) of the 90 farms.

| Table 1. Descriptive of the variables used in the statistical analysis. |
|---------------------------------------------------------------|
| **Quantitative/qualitative variable** | **Abbreviation** | **Code** | **Characteristics** | **Mean ± sd** | **Number of breeders** |
|---------------------------------------------------------------|
| PREDICTORS                                                     |                   |         |                   |               |                          |
| - Classification variables                                     |                   |         |                   |               |                          |
| Original activity                                              | Origi. Act        | 0       | Farmer–Breeder     |               | 27                      |
|                                                               | Breeder           | 1       | Breeder           |               | 63                      |
| Age of breeder                                                | Age               | 1       | Young: 0–35 year   | 52 ± 13       | 8                       |
|                                                               |                   | 2       | Medium: 36–50 year |               | 37                      |
|                                                               |                   | 3       | Old: >50 y        |               | 45                      |
| Superficies                                                   | Supf              | 1       | Small (under 10 ha)|               | 47                      |
|                                                               |                   | 2       | Medium (11–20 ha)  |               | 33                      |
|                                                               |                   | 3       | Large (over 21 ha) |               | 10                      |
| Importance of sheep breeding                                   |                   | 1       | Mainly            |               | 70                      |
|                                                               |                   | 0       | Secondary         |               | 20                      |
| Water source                                                  | H2o Sour.         | 0       | Purchased        |               | 30                      |
|                                                               |                   | 1       | Owner             |               | 60                      |
| Transhumance                                                  | Transhum          | 0       | No               |               | 74                      |
|                                                               |                   | 1       | Yes              |               | 16                      |
| Fattening                                                     | Fat               | 0       | No               |               | 40                      |
|                                                               |                   | 1       | Yes              |               | 50                      |
| Type of feed                                                  |                   | 0       | Cereal           |               | 22                      |
|                                                               |                   | 1       | Mixed            |               | 68                      |
| Feed sources                                                  | FS1               | 1       | Concentrates      |               | 59                      |
|                                                               | FS2               | 2       | Cultivated forages|               | 13                      |
|                                                               | FS3               | 3       | Cultivated forages with concentrates | 11 |
|                                                               | FS4               | 4       | Pastures         |               | 7                       |
| Quality of courses                                            | QC1               | 1       | Good            |               | 18                      |
|                                                               | QC2               | 2       | Medium           |               | 61                      |
|                                                               | QC3               | 3       | Poor             |               | 11                      |
| - Continuous variables                                        |                   |         |                   |               |                          |
| LSU/ha                                                        |                   |         |                   | 9.76 ± 24.51 |                          |
| LSU/ha ovine (%)                                              | LSU-OV            |         |                   | 70 ± 30       |                          |
| LSU/ha caprine (%)                                            | LSU-CP            |         |                   | 5 ± 5         |                          |
| LSU/ha bovine (%)                                             | LSU-BV            |         |                   | 10 ± 13       |                          |
| LSU/ha chicken (%)                                            | LSU-CHK           |         |                   | 12 ± 32       |                          |
| LSU/ha camelid (%)                                            | LSU-CM            |         |                   | 2 ± 10        |                          |
| TARGET VARIABLES                                              |                   |         |                   |               |                          |
| Zone                                                          |                   |         |                   |               |                          |
|                                                               | 1                 | Semi-arid superior |               | 20                      |
|                                                               | 2                 | Semi-arid     |               | 22                      |
|                                                               | 3                 | Sub-arid      |               | 24                      |
|                                                               | 4                 | Arid/ Saharan area |               | 24                      |
| Percentage of feed purchased or rented                        | PFP               | 0       | 0–25%           | 57 ± 30       | 17                      |
|                                                               | 1                 | 25–50%       |               | 26                      |
|                                                               | 2                 | 50–75%       |               | 17                      |
|                                                               | 3                 | 75–100%      |               | 30                      |
|                                                               | 4                 |                |               |                          |

LSU: animal density expressed as livestock unit.
A stepwise regression analysis was applied to the full set of data to select the variables that are more correlated with PFP (considered as continuous dependent variable). The relative importance of the selected predictors were assessed using partial $R^2$ and global $R^2$, F-statistic, and the level of significance. $p$ values <.05 were considered significant. All the statistical analyses were performed using SAS and XLSTAT 2017 (SAS Inc., Cary, NC).

**Results**

**Descriptive analysis (general farm characteristics)**

The general characteristics of the farms obtained from the quantitative and qualitative variables were collected (Table 1). The 90-farm surveyed were distributed over the 4 zones in the region of Tebessa of which 63 are breeders and 27 are farmer breeders; the latter integrated animal farming with different cultivations. Among the surveyed farms 10 extended for a surface area of more than 21 hectares, 33 between 11 and 20 hectares, and the remaining 47 for less than 10 hectares.

Sheep farming was considered as the primary activity by 70 farmers, whereas the remaining 20 did not breed sheep or raise sheep as a secondary source of income. As regards the water availability, that is a crucial factor for farming systems in this region, 60 farms owned their water sources, whereas the remaining 30 chose between 25% and 50%, 17 bought up to 25% of feed and the rest purchased feed between 50% and 75% of their total needs. Among feed sources used, 59 farms relied on concentrates, 11 on cultivated fodder, 13 on both cultivated fodder and concentrates and only 7 on pasture. Regarding rangelands quality, 61 respondents stated to have average quality rangelands, 11 had very poor rangelands and 18 declared to have good quality rangelands.

**Correlation analysis**

Spearman rank correlation coefficient describes the most significant variables correlated with PFP and the zones, as reported in Table 2. The PFP has a strong positive correlation with the use of concentrates (feed source 1), the importance of sheep farming, LSU/ha, the original activity (main activity) and LSU-CHK, whereas it shows a negative correlation with the use of feed sources 2 and 3 (cultivate fodders and mixed sources), the density of goats (LSU-CP) and cattle (LSU-BV) and water sources.

Concerning the zones, transhumance was negatively correlated with the upper semi-arid and semi-arid region.

**Table 2.** Spearman rank correlation coefficients between target variables percentage of feed purchased (PFP) and zone versus predictor.

|                    | PFP   | Zone 1 | Zone 2 | Zone 3 | Zone 4 |
|--------------------|-------|--------|--------|--------|--------|
| Age                | -0.12 | 0.04   | -0.01  | -0.15  | 0.13   |
| Orig. Act          | 0.38*** | -0.23* | 0.09    | 0.07   | 0.07   |
| importance of sheep breeding | 0.45*** | 0.03    | -0.01  | -0.10  | 0.08   |
| H2O sour.          | -0.24* | 0.09    | 0.18    | -0.11  | -0.16  |
| supf1              | 0.10  | 0.03    | -0.03   | -0.13  | -0.12  |
| supf2              | -0.15 | 0.04    | 0.10    | 0.17   | -0.30** |
| supf3              | 0.07  | -0.10   | -0.12   | -0.05  | 0.27*** |
| LSU/ha             | 0.42*** | 0.02    | -0.18   | 0.11   | 0.05   |
| LSU-OV             | -0.21 | 0.07    | 0.09    | -0.10  | -0.05  |
| LSU-CP             | -0.26* | -0.14   | 0.04    | -0.06  | 0.16   |
| LSU-BV             | -0.22* | -0.01   | 0.05    | -0.08  | 0.04   |
| LSU-CHK            | 0.37  | 0.01    | -0.08   | 0.19   | -0.12  |
| LSU-CM             | -0.08 | -0.10   | -0.11   | -0.11  | 0.31*** |
| FS1                | 0.61*** | -0.01   | -0.08   | 0.12   | -0.04  |
| FS2                | -0.37*** | -0.04   | 0.10    | -0.15  | 0.08   |
| FS3                | -0.39*** | 0.08    | 0.06    | -0.18  | 0.04   |
| FS4                | -0.12 | -0.06   | -0.07   | 0.20   | -0.08  |
| QC1                | 0.08  | -0.07   | -0.09   | 0.14   | 0.01   |
| QC2                | -0.002 | -0.03   | 0.12    | -0.01  | -0.07  |
| QC3                | -0.10 | 0.13    | -0.05   | -0.15  | 0.08   |
| Type of feed       | 0.16  | 0.12    | -0.22*  | -0.01  | 0.11   |
| Transhum           | 0.02  | -0.25*  | -0.26*  | -0.02  | 0.51*** |
| Fat                | -0.005 | -0.05   | 0.01    | 0.07   | -0.03  |

Values in bold are significant for *: $p<0.01$; **: $p<0.001$; ***: $p<0.0001$. Predictors abbreviation for PFP: percentage of feed purchased; Orig. Act: original activity; H2o Sour: water sources; Supf: superficies; LSU/ha: animal density per hectare; LSU-OV: LSU Ovin; LSU-CP: LSU caprin; LSU-BV: LSU Bovin; LSU-CHK: LSU chicken; LSU-CM: LSU camelin; FS1: concentrates, FS2: concentrates + cultivated forages, FS3: cultivated forages, FS4: pasture; QC1: good quality of courses, QC2 medium quality of courses, QC3 poor quality of courses; transhum: transhumance; fat: fattening.
arid areas (zones 1 and 2) but was positively correlated to the arid area (zone 4). The upper semi-arid area was also negatively correlated with the breeding activity as the only income of the farm, whereas the semi-arid zone was negatively correlated with the use of mixed feed. The arid zone was positively correlated with the density of camels and the large farm surface, whereas it is negatively correlated with the medium size farm surface.

**Discriminate analysis among zones**

To know the characteristics of farms in each region, a discriminate analysis was carried out. The two main factors (F1 and F2) accounted for 85.5% of the total variability, which explained the high percentage of accuracy of our results (Figure 1). The transhumance traits were explained by the high contribution on the F1 axis with 0.646 and on the F2 axis with −0.510, which explains the nature of the systems that fall in this dial of the graph (right-bottom); the herders in this area are characterised by transhumance, camels (LSU-CM) and goats breeding (LSU-CP) with a contribution of 0.352 and 0.370 on the F1 axis, respectively. Moreover, most of the farms of this area used surfaces over 21 hectares (supf-3); these parameters are related to each other and characterise this zone with a typical transhumance breeding system. Between the third and fourth dials the F2 axis is negatively correlated with pure breeding activity and PFP, especially for goats in zone 4 and for chickens in zone 3.

On the other hand, on the opposite dial (left-up), we can note two parameters ‘H2O source’ with a contribution on the F2 axis = 0.360 and on F1 = −0.434; the herders in this area have their water source with an average size of land (supf-2 from 11 to 20 hectares). We can notice that the quality of the rangelands in this area is medium. This area has a similarity with area represented in the first dial (upright), which is characterised by ‘LSU-OV’ with a contribution on the F2 axis = 0.267. Based on the above-mentioned parameters, it can be concluded that this area is mostly typical for sheep farming and allows the cultivation of forages.

The third dial (left bottom) has two parameters with a good contribution: ‘LSU-CHK’ with a contribution on the F1 axis = −0.269 and the pastures ‘source of feed4’ with a contribution on the F2 axis = −0.293: this is the intensive area with a high density of chickens ‘LSU-CHK’ feeding on concentrates (FS1), but it hosts also pastoralists who use rangelands for their flocks (FS4).

The projection of the 90 farms on the factor level (F1, F2) of the discriminant analysis (DA) (Figure 2) identified the four zones with their characterisations. Whereas zones 1 and 2 slightly overlap for farm characteristics, zones 3 and 4 were well separated from the others according to F1 and F2 axes. Zones 1 and 2 are characterised by the use of cultivated fodder with concentrates; the farmers have their water, raise mainly sheep, and do not practice transhumance. The sub-arid zone (3) was characterised by a pure intensive farm, where the value of LSU-CHK per hectare is high and the type of feed more used concentrates, and by mixed livestock farming, where farmers use state land for grazing and fatten flocks of lambs. In the dry Sahara zone (zone 4), livestock keepers practice transhumance; they have large areas of land, and breed especially camels (LSU-CM) and some goats (LSU-CP).

**Discriminate analysis among a percentage of feed purchased**

Discriminant analysis was applied to select the variables that best differentiated between the four classes of PFP. Figure 3 shows the correlation between the original variables and the new calculated factorial
levels (F1, F2) of the DA. In the right-bottom dial (PFP 4) we find the highest concentration of LSU/ha when raising chickens (LSU-CHK), which describes an intensive farm system made of pure breeders (Origin act) purchasing more than 75% of the feed used. The lowest level of PFP (up to 25%), in the first dial (right upper), is correlated with the importance of sheep farming and in these farms the purchased feed is mainly represented by concentrates (FS1). In the second dial (left upper, PFP 26–50%) the concentration of (LSU-OV) is correlated with the use of pasture (FS4) and private water (H2O source). In the remaining dial (left bottom), farmers cultivate fodders (FS2) and use mixed feed (FS3).

This projection (Figure 4) combines the highest possible variability and resumes 91.9 of the variability. Figure 4 shows that farms belonging to the four levels of PFP are well separated from each other along with the F1 and F2 axes.

**Stepwise regression analyses**

The stepwise regression analysis (Table 3) showed that feed source 1 (concentrates), original activity, LSU-CHK and importance of sheep breeding were the most discriminating variables among all farm characteristics in predicting farm PCP. Their respective partial $R^2$ were 0.353, 0.1133, 0.052, and 0.057.

The first factor that is evaluated by the model is feed source 1 (concentrates) which is best related to our equation and explains the 35% of the variation in the system, for the dependent variable ‘y’, the amount of feed purchased. The variables underlined in the present study occurred to be the most important and informative and could be used to characterise the breeding systems as more or less intensive.

**Discussion**

The use of the face-to-face, open-ended survey allows us to acquire original information where it is difficult
to make multiple visits to pastoral areas. This methodology allowed us to highlight the current farming systems used by farmers in the Algerian steppe territories, while identifying the different types of strategies used. According to Bourbouze et al. (2009), the Algerian steppe livestock farming has changed completely in recent decades, unlike in other pastoral countries, such as Mongolia, where most livestock farmers have remained nomadic despite the changes that have taken place (Gardelle and Ruhlmann 2009). Also, in Morocco and Tunisia, the tribal framework and the customary organisation still allow for local pastoral management, despite many conflicts and abuses regarding access to resources (Bencherif 2018).

Our results characterised the farming systems in four zones with different bioclimatic stages in steppe territories, on the basis of many criteria, mainly the percentage of feed purchased, the original activities, animal densities (LSU), the type of breeding systems, intensity of production and the importance of sheep breeding. In the upper semi-arid and semi-arid zones, an extensive form of sheep farming using cultivated fodder with concentrates is done; farmers have their water, do not practice transhumance, have an average size of land with a high density of sheep. The sub-arid zone is mainly based on breeding poultry with a high density (LSU-CHK), using concentrates as a feeding strategy, but some traders fatten flocks of lambs and have access to stubble. In the dry Sahara zone, farmers have large areas of land, breed, mainly camel and goats and are transhumant livestock keepers. While all the region of the steppe in the Maghreb was in the last years of pastoral type and livestock breeding was mostly extensive (Bourbouze 2006; Jemaa et al. 2016). A general change like what we are reporting can be found throughout the Maghreb and in steppe areas such as Algeria (Kanoun et al. 2015). The findings confirm our hypothesis according to which farmers are introducing new practices outside pastoral and traditional activity, and they are changing their strategies moving towards intensification. This study has shown that the application of multivariate discriminant analysis could successfully distinguish between degrees of intensification on farms. According to the correlation

Table 3. Summary of stepwise regression of percentage of feed purchased (PFP); partial and global $R^2$ of the model were reported along with F statistic, $P$, estimated regression coefficient and standard error.

| Step | Variable                           | Partial $R^2$ | Global $R^2$ | $F$   | $P$   | Estimated regression coefficient | Standard error |
|------|------------------------------------|--------------|--------------|-------|-------|-------------------------------|---------------|
| 1    | Feed_source1                        | 0.35         | 0.35         | 47.54 | <.0001 | 0.27                          | 0.05          |
| 2    | Orig_Act                            | 0.11         | 0.47         | 18.26 | <.0001 | 0.16                          | 0.05          |
| 3    | LSU-CHK                            | 0.05         | 0.52         | 9.15  | .003  | 0.20                          | 0.07          |
| 4    | Importance_of_sheep_breeding       | 0.06         | 0.58         | 11.31 | .001  | 0.20                          | 0.05          |
| 5    | $H_2O\_Source$                      | 0.03         | 0.61         | 7.41  | .008  | -0.12                         | 0.04          |
| 6    | Sup3                                | 0.03         | 0.64         | 6.2   | .015  | 0.14                          | 0.07          |
| 7    | LSU-CP                              | 0.01         | 0.65         | 2.12  | .150  | -0.88                         | 0.44          |
| 8    | Quality_courses1                    | 0.01         | 0.66         | 2.89  | .093  | 0.09                          | 0.06          |

Figure 4. (a) Projections of the observations (90 farms) on the factorial system axes: data were grouped according to four percentage of feed rented (PFR) classes: 1: < 25%; 2: 26–50%; 3: 51–75%; 4 > 75%. (b) Centroids of the four groups on the factorial system axes.
coefficients, the percentage of PFP that characterised
the intensive systems was mainly related to the use of
concentrates (35%), the specialisation in breeding
(11%), density in poultry breeding (5%), sheep farming
as the main source of income (5%) and property of
water sources (3%). The use of concentrates has
become indispensable, as already reported by
Nefzaoui (2004).

The fact that the possession of water is negatively
related to PFP means that less clean water is available,
so more water is purchased. The water used for ani-
mal feed production in the livestock farms are high as
reported by Chapagain and Hoekstra (2004) who
pointed out that the production of chicken meat, pork
and beef requires an average of 3.9, 4.9 and 5.5 cubic
metres of water, respectively. The fact that they did
not use purchased feed for goat and the negative sig-
nificance of LSU-CP is related to farmer practices
based on natural pasture.

The significant progress in animal production has
been made in terms of breeding, feeding and man-
agement of livestock in different production systems
to increase the level and efficiency of animal produc-
tion (Webb and Casey 2010). In Algeria, livestock far-
ners with cultivated land seem to be more resilient to
changes than pastoral livestock farmers, who are more
vulnerable (Makhloufi et al. 2014). We notice that the
development of irrigated areas from 5527 hectares in
the year 2000 to 28,129 hectares in the year 2017,
which means a development of 09.01% in comparison
with the farming areas. According to DSA (2017), the
production of livestock in Tebessa is increasing
(broilers from 69.000 in 2005 to 5.184.584 in 2015)
and the intensification results when farmers specialise
in the production of a single commodity (FAO 2009).

This work allows us to estimate that most farmers
use purchased feed for the needs of their herds and
concentrates constitute more than 50% of the dry
matter ingested by the animals. The rest of the intake
corresponds to cultivated fodder and concentrates
with cultivated fodder and grazing. The use of concen-
trated feeds allows farmers to limit the impact of
drought, but on the other hand, it binds them to the
availability of feed supply and variations in the price
of raw materials, particularly barley. Changes in agri-
cultural land use make production systems more com-
plex. The territories must keep pastoral areas, which
are still essential for agro-pastoral livestock farming,
while dealing with the increasing use of crops. On the
one hand, livestock manure from ruminant systems
can be a valuable source of nutrients for smallholder
crops. On the other hand, in more industrial systems,
or where there are large concentrations of animals,
they can pollute water sources (Steinfeld 2006). More-
over, ruminant systems in developing countries
can be considered relatively resource-use inefficient.
Because of the high yield gaps in most of these pro-
duction systems, increasing the efficiency of the live-
stock sector through sustainable intensification
practices present a real opportunity where research
and development can contribute to providing more
sustainable solutions (Herrero et al. 2013).

Mapping out these different systems can help poli-
cymakers and agricultural and land-use planners to
visualise and develop strategies targeted towards
addressing the underlying constraints (Notenbaert
et al. 2009).

The spatial distribution of production systems
defined by Seré and Steinfeld (1996) and mapped by
Kruska et al. (2003) will evolve by 2030 (Notenbaert
et al. 2009). It would be relevant to explore ways to
valorise current pastures and to consider other forage
resources in order to decrease the dependence on
purchased concentrates. According to Steinfeld et al.
(2013), modelling rangeland production is essential to
assess changes at large temporal and spatial scales
(Oomen et al. 2016), and guide management decisions
on state-managed land.

The use of modelling techniques in which some
measure of livestock intensification is taken as a
dependent variable and modelled using several
explanatory variables could be successfully used in
breeding systems differentiation. The general aims of
identifying breeding systems and intensive livestock
farming is to maintain breeding diversity and keep
safe steppe territories. Furthermore, biodiversity is
indirectly affected by concentrate feed requirements
and the resulting intensification and expansion of crop
agriculture. Finding the balances between increased
food production and the preservation of the world’s
natural resources remain a major challenge
(FAO 2018).

**Conclusion**

While developed countries tend to find solutions and
make different policies for the effects of the intensive
livestock breeding system on environment and ecosys-
tems. We find that, at the same time, the breeder in
steppe territories threatened with desertification every
year tends to intensively raise his livestock and leave
the old practices in using the natural pastoral system.
This study showed that livestock systems in steppe
territories are changing to a more intensive form,
most farmers use purchased feed for the needs of their herds and concentrates constitute more than 50% of the dry matter ingested by the animals. The percentage of feed purchased had higher effects to determine the nature of breeding systems and identifying the intensive systems within different species in different farms. The proposed method can be readily used in practice. However, the present information on the breeding systems differentiation in steppe territories and the modalities of intensification could be complemented with other characterisation using the density of nitrate in the soil. This could aid field assessment, management of farmers with different populations, where the goal is to obtain mixed breeding systems with pure control to environment resources for hygienic production and breeding improvement strategies.

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Ethical approval

This article does not contain any studies with human or animal subjects.

Discloser statement

The authors declare no conflicts of interest exist in the submission of this manuscript.

Data availability statement

The data that support the findings of this study are available from the corresponding author, [author initials], upon reasonable request.

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