Livestock Pressure Distribution in Relation to Land Use and Aridity in Tunisia

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1. Abstract

Widespread overgrazing and chronic forage deficits characterize extensive pastoralism in Tunisia. These shortfalls could be greatly reduced with an improved distribution of livestock pressure among the various land uses of the country's agricultural lands. Data obtained from the National Forest and Pastoral Inventory (1995) and the 1993/94 Agricultural Compaign Survey were examined at the level of the 21 Tunisian administrative districts. A regression analysis using total livestock pressure as a dependent variable was performed for all agricultural land uses in relation to the zonal aridity of each district. The newly developed area-weighted aridity index served as a covariate of production potential among administrative entities. Results showed that rangelands offered the highest correlation (r = -O.91), between livestock density and aridity (P < 0.01), followed by olive plantations (r = -0.62), and arboricultural lands in general (r = -0.48). Contrastingly, positive correlations were found between animal density and aridity in forests (r = 0.80) and croplands in general (r = 0.52). These relationships are explained by the scarcity of forests and tillable lands in addition to greater accumulation of livestock in dry areas. Similarly, dry legume crops and annual forage crops also presented positive correlations for the same regression. Their correlation coefficients were of 0.75 and 0.74 respectively. Reversing the trend of the latter correlations constitutes the basis for providing more forage to livestock. Improved integration of livestock needs into various agricultural land uses may also be achieved by reconsidering the distribution of fallow-lands, perennial forage crops and irrigated lands. Indeed, these uses presented no significant (P > 0.10) correlation between livestock pressure and the covariate of aridity. Specific livestock foraging systems were identified for districts within major geographical regions based on major land uses and their availability to livestock.

2. Introduction

In Tunisia, 16% of the total agricultural production is provided by its domestic livestock [17]. Most of this livestock is raised under extensive grazing conditions in flocks of 10-40 sheep [10], or their equivalent in goats in the South or cattle in the North. These small herds provide up to 60% of the income of rural populations [18]. However, this economic activity has caused various problems of widespread overgrazing, chronic forage deficits, and low animal productivity resulting in the deterioration of extensive grazing land [3]. Paradoxically, more animals are stocked on the land in an effort to offset the reduction in gain due to declining rangeland condition. This vicious cycle is essentially maintained by the natural increase of animal numbers through reproduction, thezaurizing, and government subsidies in periods of severe droughts and feed shortages. Under such conditions, livestock husbandry can grow and prosper without significant investment [4]. Fortunately, the growth rate of livestock numbers seems to be stabilizing these last few years due to a gradual shift towards intensive livestock production systems on one hand, and the reduction in grazing land surface areas on the other hand. Indeed, rangelands have been shrinking at an approximate rate of 30,000 hectares/year during the last three decades [14]. Most of the estimated subtracted lands were converted into dry farming in an effort to secure self-sufficiency in food production for humans. It is therefore, obvious that deteriorating rangelands, alone, can no longer satisfy the livestock forage needs.

Furthermore, the resorption of persistent forage deficits throughout the country cannot be achieved without the integration of livestock forage needs into other agricultural land uses. This integration is *de facto* taking place since livestock grazing is common in woodlands, olive plantations, and croplands after harvest. However, no information is presently available on how important this integration is, apart from the widely shared belief that woodlands and rangelands bear most of the grazing burden.

Therefore, the purpose of this study was to evaluate the livestock pressure distribution on each of the country's major agricultural land uses / covers, using aridity as a covariate of production potential. We also aimed at identifying specific livestock foraging systems according to geographical location, land use and availability in terms of surface area/unit of animal. Moreover, this study was conducted at the level of the administrative districts of Tunisia in order to help regional planners take advantage of its results and recommendations for improved sustainable management of both resources: domestic livestock and agricultural land.

3. Materials and Methods

Relevant data for each of the 21 administrative districts of Tunisia were gathered from two official sources of information. The first source represented by the National Forest and Range Inventory (NFRI) provided species livestock numbers, as well as forest and rangeland surface areas [5]. The surface areas of the remaining agricultural land uses were obtained from the Direction Générale de la Planification, du Développement et des Investissements Agricoles [6], which represented our second source of information. All livestock numbers were converted into standard livestock units (SLU) of 250 kg body weight, using the following approximation: 1 SLU = 1 cattle head = 5 sheep = 6 goats = 0.75 camel = 1.5 equines [12].

Departing from the hypothesis that all livestock forage needs must be integrated into the various agricultural land uses and covers, we postulated that animal pressure could be evaluated by livestock density levels. Hence, for each district, standardized livestock numbers were first divided by the surface area of each land use/cover type. The obtained livestock density (SLU/ha) for a given land use/cover was then regressed against a North-South gradient of aridity ranging from 1 (wet) to 10 (dry) (Figure 1). This aridity zone index was previously elaborated using long-term pluviothermic data and weighted against the area of each district and its phytomorphic units. It serves as a covariate of production potential between administrative districts [3]. The same procedure using aridity as an independent variable was earlier reported in studies investigating range/livestock production systems in Kenya [13] and Tunisia [3], as well as in predicting cereal crop production in Russia [8].

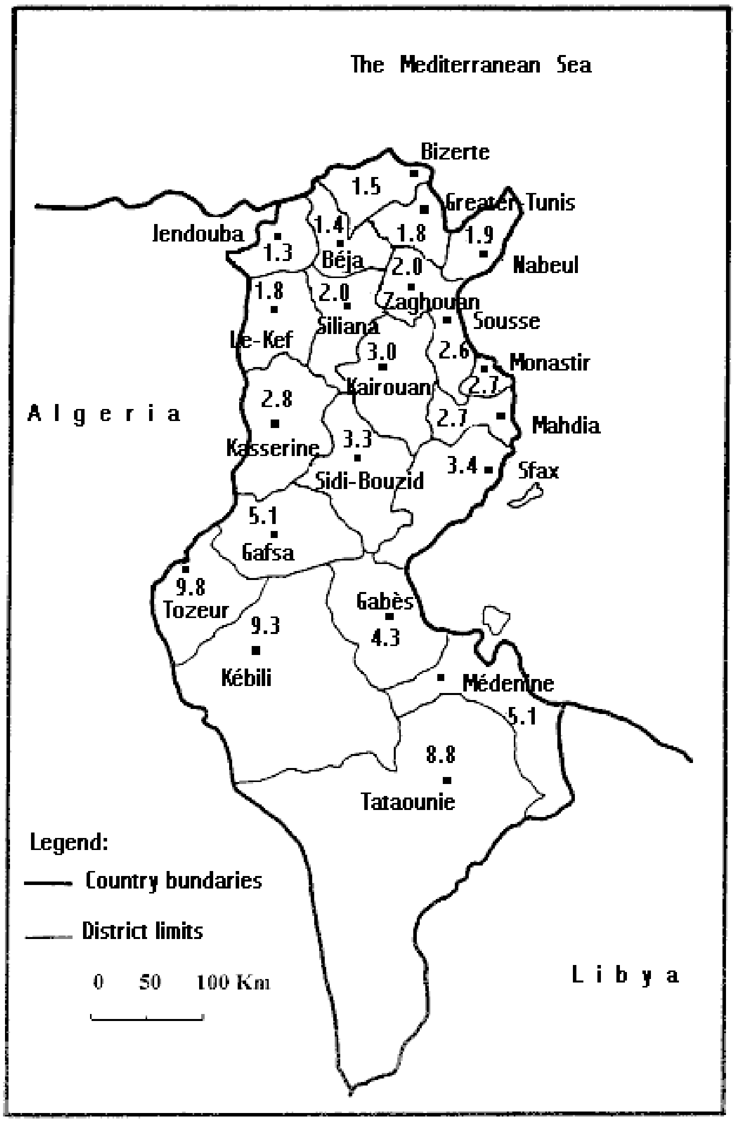

Figure 1. Map of the 21 Tunesian Administrative Districts with their Area Weighted Aridity Index, where 1=wet and 10=dry.

Regression models using actual or log-transformed values of both independent and dependent variables were considered significant only if they met the 0.05 probability criterion level, and that their correlation coefficient was superior to 0.30 in absolute value [7]. Levels of livestock integration into various land uses and covers were ranked and compared after examination of their corresponding correlation coefficient absolute value. Foraging systems were identified according to the availability of the major agricultural land uses/covers in terms of surface area/animal unit (ha/SLU). This parameter is the reciprocal of livestock density (SLU/ha). Districts with similar livestock foraging systems were grouped together.

4. Results and Discussion

The typical pastoral space covered with natural vegetation constituted 52.5% of the total agricultural lands in Tunisia. This space comprises the woodlands (forests and maquis) with 8.0% and the rangelands with 44.5% (Table 1). Complementary seasonal grazing is further provided to livestock by cultivated lands, particularly cereal croplands, arboricultural plantations, and fallow-lands. Together, these uses make up more than 88% of the country's total cultivated lands. Thus, traditional pastoralism associated with extensively grazed areas, whether covered with natural vegetation or cultivated, affects more than 94% of the country's total agricultural lands. Contrastingly, forage croplands which constitute an unavoidable basis to promote intensive livestock husbandry, amount to only 3.1% of all agricultural lands and 6.5% of total cultivated surface areas (Table 1). In the United States, the latter proportion varies between 10 to 24% depending on the source providing land utilization statistics [2].

Table 1. Agricultural land use/cover in Tunisia

Land Resource	Surface area (1,000 ha)	Percent of agricultural land	Percent of cultivated land
Total agricultural land	10,569	100.0	-
Woodlands[1]	843	8.0	-
Rangelands[1]	4,706	44.5	-
Cultivated lands[2]	5,020	47.5	100.0
Cereal croplands	1,480	14.0	29.5

[1] Source DGF, 1995
[2] Source DGPDIA, 1995

Similarly, the proportion of irrigated lands is also low, due to limited water resources. It amounts to only 3.3% of total agricultural lands compared to a worldwide average of 14% [9]. In fact, irrigated lands can contribute to the adjustment of forage deficits through crop rotations and multiple cropping. Small proportions of land are equally reserved to dry legume crops and vegetable crops with respectively 1.0 and 1.5% of all agricultural lands (Table 1). In addition, their production is mainly oriented towards human consumption, not livestock feeding.

Consequently, the shift form extensive to intensive livestock husbandry, driven by greater human populations and the advent of urbanism [3], has not been followed by greater forage production as indicated by the proportion of forage producing lands. Persistent dominance of traditional pastoralism is further corroborated by significant ($P < 0.05$) correlations between total livestock density and the index of aridity for four major land uses providing extensive grazing. Indeed, rangelands, woodlands, cereal croplands and arboricultural lands constitute more than 85% of Tunisian agricultural lands (Table 1). Taken separately, each of these land uses showed either a negative or a positive correlation. Negative correlations were exhibited when uniformized livestock populations were divided by the surface area of rangelands ($r = -0.911$) or arboricultural lands ($r = -0.477$) within a given district (Figure 2). Positive correlations were obtained when the same procedure was applied to woodlands ($r = 0.803$) and cereal croplands ($r = 0.518$) (Figure 3). Nevertheless, a ranking of the absolute value of these correlation coefficients seems to confirm the widely shared belief that most of the grazing pressure is inflicted to rangelands, followed by woodlands. In addition to these two naturally covered lands, traditional olive plantations, representing more than 75% of all arboricultural orchards (Table 1), offered the third highest correlation coefficient in absolute value: ($Y = 9.328 - 12.758 \log X$, $r = -616$, $P < 0.05$). By contrast, the weakest correlation coefficients are provided by modern land uses, which greatly expanded during the last few decades in an effort to achieve self-sufficiency in food production for human populations. They pertain to croplands and arboricultural lands, especially orchards other than olive plantations. Hence, the regional distribution of these modern land uses expansion was not harmoniously conjugated with that of domestic livestock, resulting in greater pressure on rangelands, woodlands, and olive plantations. These findings are in agreement with those of .[11] and [15] stating that human dominated land uses can result in a degradation of natural ecosystems and limit the development of natural resources such as domestic livestock on a sustained basis compared to natural land cover patterns.

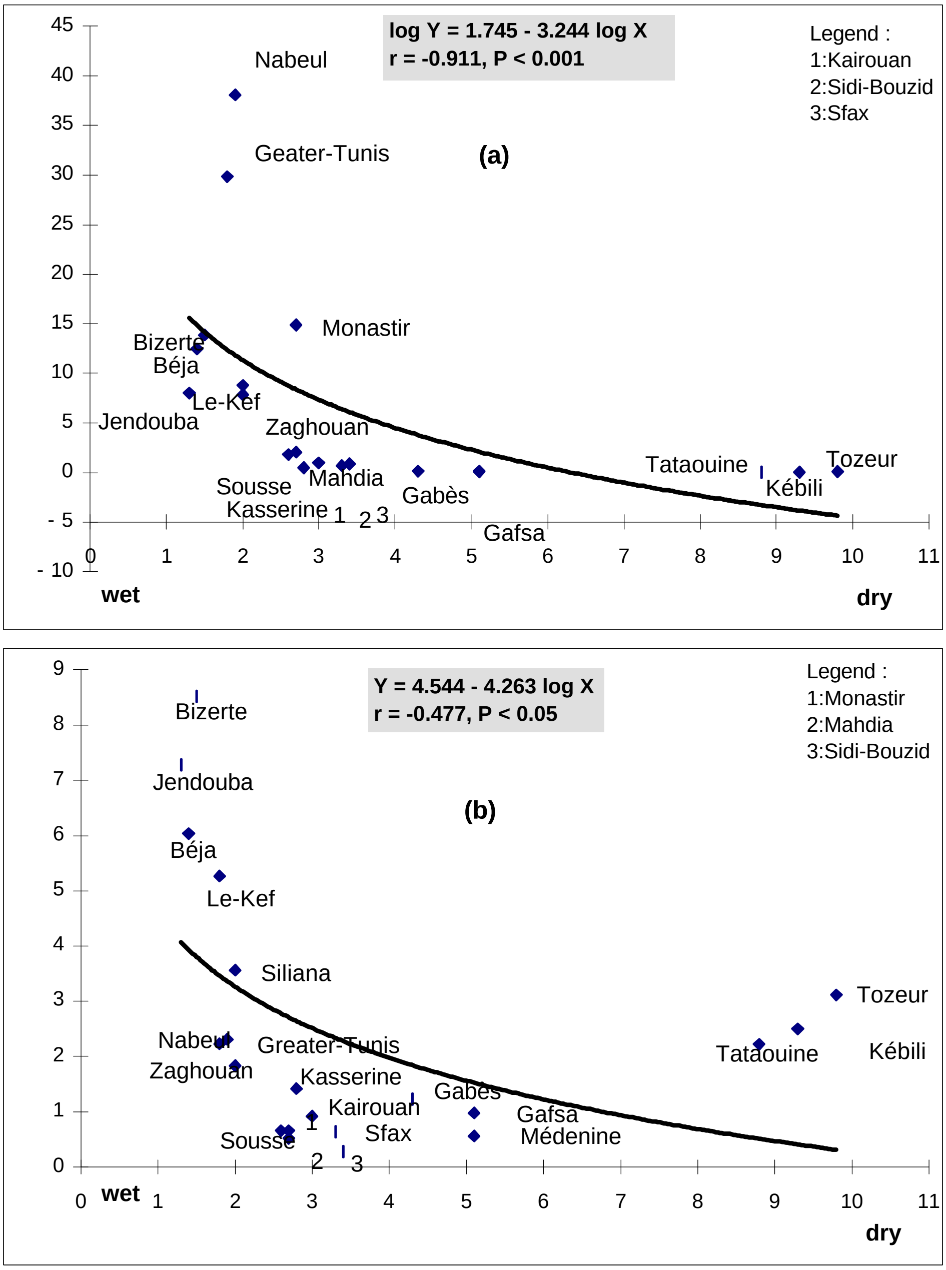

Figure 2. **Total livestock density showing negative correlation with aridity, based on the sole use of either rangelands (a) or arboricultural lands (b).**

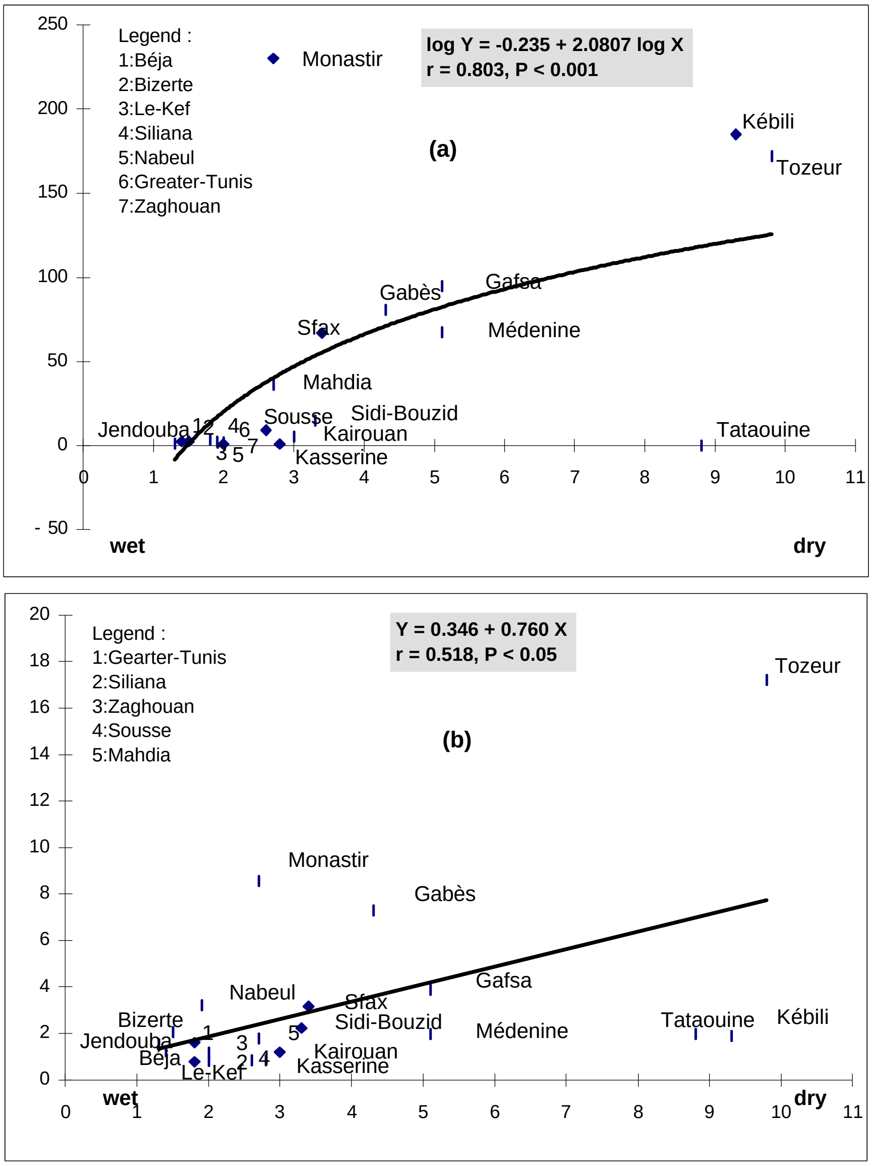

Figure 3. **Total lifestock density showing positive correlation with aridity, based on the sole use of either woodlands (a) or cereal croplands (b)**

Negative correlations with rangelands, arboricultural lands (Figure 2), and particularly with olive plantations represent a natural response to aridity. In other terms, as aridity increases, the potential for forage production decreases and so does the carrying capacity of the land [3] and [13]. Nonetheless, positive correlations recorded for woodlands and croplands (Figure 3) are artefacts caused by the scarcity of both forests and tillable lands under increasing xericity. This is in addition to greater livestock accumulation in drier areas, particularly in the Center and South of the country [5]. Other positive correlations were also found for minor land uses such as forage crops, dry legume crops and vegetable crops (Table 2). These equally artefactual correlations must be reversed in order to maintain the necessary equilibrium between sustainable land use and developing livestock husbandry. Except for afforestation which may be difficult to achieve in dry areas, forage production could well expand in fallow-lands which showed no significant ($P > 0.10$) correlation with aridity. Idling land for a full year is a no longer tolerable practice especially in a country with limited land resources and expanding demography. Moreover, dry and hot summer months would unavoidably cause the evaporation of fallow-land conserved moisture[16]. Additionally, soil surface crusts which often develop in fallow-lands were found to cause severe erosion problems, in addition to reduced soil microbial activity [1].

Table 2. Total livestock density in relation to aridity, based on separate minor land use availability to livestock

Land use	Regression model	Correlation coefficient (r)	Coefficient of determination (R^2)	Probability
Forage crops	Log Y = 0.565 + 0.156 X	0.598	0.357	P < 0.01
Annual	Log Y = 0.541 +2.289 log X	0.736	0.542	P < 0.01
Perennial	N.S.[1]	-	-	P > 0.10
Dry legume crops	Y = 206.951 + 128.889 X	0.747	0.557	P < 0.01
Vegetable crops	Y = 11.155 + 5.380 X	0.462	0.213	P < 0.05

Idling land still affects about one million hectares in Tunisia, representing approximately one fifth of all tillable lands (Table 1). Abolition of this unjustified and widely used practice throughout the country may greatly reduce the tremendous forage deficit, and improve animal productivity. If only half of fallow-lands were sown with forage species the proportion of forage croplands would jump from 3.1 to about 9.0% of total agricultural lands. This would concomitantly reduce the overgrazing suffered by rangelands, woodlands, and olive plantations.

Table 3. Identified Foraging systems in different Tunisian districts based on the integration of livestock pressure into the major agricultural land uses

Foraging system ranked by land use Livestock pressure (ha/SLU)	Land availibility (ha/SLU)	District	Aridity zone index	Region
1.Croplands / Forests /Arboriculture/Range 0.49 - 1.27 / 0.32 - 1.05 / 0.12 - 0.55 / 0.03 - 0.13	1.11 to 2.95	Béja, Bizerte, Greater-Tunis Jendouba, Le-Kef, Siliana Zaghouan	1.3 to 2.0	North
2. Forests /Arboriculture/Croplands/Range 0.47 / 0.43 / 0.31 / 0.03	1.24	Nabeul	1.9	North
3. Arboriculture/ Croplands / Range / Forests 1.52 - 1.92 / 0.12 - 1.19 / 0.07 - 0.54 / 0.00 - 0.11	3.00 1.71 3.36	Mahdia Monastir Sousse	2.6 2.7 2.7	Center
4. Range /Forests / Croplands/ Arboriculture 2.12 / 1.35 / 1.19 / 0.70	5.36	Kasserine	2.8	Center
5. Arboriculture/ Range / Croplands / Forests 1.09 - 3.57 / 1.00 - 1.43 / 0.32 - 0.83 / 0.02 - 0.19	3.11 3.51 5.09	Kairouan Sidi-Bouzid Sfax	3.0 3.3 3.4	Center
6. Range/Arboriculture/ Croplands / Forests 6.67 - 11.11 / 0.32 - 1.02 / 0.06 - 0.26 / 0.00 - 0.01	7.62 9.62 11.49	Gabès Gafsa Tozeur	4.3 5.1 9.8	South
7. Range/ Croplands / Arboriculture/Forests 16.67 / 0.51 - 0.53 / 0.40 - 0.45 / 0.00	17.60 17.63	Kébili Tataouine	9.3 8.8	South

Specific livestock foraging systems were also identified for various districts within major geographical locations (Table 3). These systems are based on the major land uses/covers and their availability to livestock in terms of surface area/unit of livestock. The relatively wet northern districts rely primarily on crops residues, followed by woodlands, in feeding their livestock, except for Nabeul, which is the only northern district where most of the grazing pressure is supported by forests. Nabeul is also characterized by its well-developed intensive arboriculture compared to other districts. Foraging systems in Central districts are essentially dependent on dry arboricultural lands, except for Kasserine, which has greater range and forest resources (Table 3). For southern districts however, extensive grazing in rangelands is the most predominant livestock production system. The effect of aridity in reducing land productivity, regardless of its agricultural use, is clearly demonstrated in Table 3. Indeed, land availability/unit of animal increases from a low of approximately 1 to 3 ha/SLU in the North, to a high of about 8 to 18 ha/SLU in the South, with an intermediate level of about 3 to 6 ha/SLU in central districts of Tunisia. These results are in agreement with those reported elsewhere [3, 13]. The national averages in Table 3, in addition to those represented by the regression lines in Figures 2 and 3 provide guidelines illustrating livestock pressure distribution in Tunisia according to major land uses/covers. These national averages must be improved by greater forage production in order to eradicate overgrazing and forage deficits. Further research work relative to the determination of foraging calendars for the major land uses/covers used by livestock is needed. This would yield valuable information for assessing the length of the grazing season for each land use type within major geographical regions.

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