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Evolution and transformation dynamics of rangeland in Moroccan north Atlasic plains and plateaux: Rhamna's case

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Abstract. Rhamna region is an agro-pastoral zone characterized by an arid climate. It is part of pastoral ecosystems classified as moderately degraded in Morocco. The objective of this research is to determine the dynamics of this ecosystem over time by integrating the effects of climate change. The dynamics of land-use change was apprehended by a study of multi-date remote sensing of satellite images (1987 and 2017). The diachronic study of land use in Rhamna shows a clear regression of pastoral areas in favor of cultivated land and often gives way to completely bare land. Critical regression of vegetation cover is mainly due to increasing pressure. But climate change has aggravated the situation in recent decades. Long-term analysis of climate data shows that one year out of two is considered agronomically dry. Other environmental degradation factors stem from current changes in pastoral society. Indeed, the last sequence of dry years has led to a massive use of concentrate feeds. Cereal cultivation, although not a new phenomenon in the region, has reached alarming proportions.

Keywords. Rhamna – Pastoral area – Degradation – Climate change – Vegetation cover.

Dynamique d'évolution et de transformation des parcours dans les plaines et plateaux atlasiques du Nord marocain : le cas de Rhamna

Résumé. *Rhamna est une zone agro-pastorale caractérisée par un climat aride. Elle fait partie des écosystèmes pastoraux classés comme moyennement dégradés au Maroc. L'objectif de cette recherche est de déterminer la dynamique de cet écosystème au fil du temps en intégrant les effets du changement climatique. La dynamique du changement d'occupation du sol a été appréhendée par une étude de télédétection multi-date d'images satellitaires (1987 et 2017). L'étude diachronique de l'utilisation des terres à Rhamna montre une nette régression des zones pastorales en faveur des terres cultivées et cède souvent la place à des terres complètement nues. La régression critique du couvert végétal est principalement due à la pression croissante. L'anthropisation est établie depuis longtemps, mais le changement climatique semble avoir aggravé la situation au cours des dernières décennies. L'analyse de long terme des données climatiques montre qu'une année sur deux est considérée comme sèche sur le plan agronomique. D'autres facteurs de dégradation de l'environnement découlent des changements actuels dans la société pastorale. En effet, la dernière séquence d'années sèches a conduit à une utilisation massive d'aliments concentrés. La culture de céréales, bien que n'étant pas un phénomène nouveau dans la région, a atteint des proportions alarmantes.*

Mots-clés. *Rhamna – Zone pastorale – Dégradation – Changement climatique – Couvert végétal.*

I – Introduction

In Morocco, rangelands are the scene of a negative and continuous ecological imbalance with an inexorable degradation resulting from overgrazing, clearing and cultivation (Berkat and Hammoudi. 1989, El Koudrim *et al*., 2003, El Koudrim *et al.,* 2014). This resulted in low production and declining forage quality.

Rhamna is an agro-pastoral zone characterized by an arid climate. It is part of pastoral ecosystems classified as moderately degraded to degraded (Berkat *et al*., 1992). But currently, these range-

lands are in an increased degradation that places them rather among the most degraded ecosystems. Unfortunately, much information is lacking concerning this degradation and the resilience capacity of rangelands.

Currently, there is a growing interest in understanding the interaction of climate change and agricultural production and this is driving a significant amount of research (Aydinalp and Cresser, 2008). Moreover, there is still limited research regarding the impacts of climate change on livestock production (IPCC, 2014).

The objective of this research is to determine the dynamics of the Rhamna ecosystem over time by integrating the effects of climate change on land-use change and grazing evolution.

II – Materials and methods

Rhamna is part of the greater Marrakech-Safi region. Its area is over 550.000 ha, with a population of 350.000 inhabitants, 60% rural. The climate is arid with an average rainfall of 250-300 mm. Rhamna is classified as an agro-pastoral system.

The study of meteorological drought plays a key role in any program to combat the effects of climate change on agriculture (Rojas-Downing *et al*., 2017, Dong *et al*., 2011). Therefore, in a long-term strategy program, decisions should be based primarily on the analysis of meteorological variables and agricultural production. Climatic data used in this study was retrieved from the meteorological station of Benguerir. The data is verified, sorted and added into database. The analysis of climatic variability is carried out by the study of long climatic series (30 years).

The potential indicators used in the climate study are aimed at establishing a comprehensive system of long-term climate change. However, taking into account the specificity of the study area, a limited number of indicators can be proposed. For this work, we used the Precipitation Standardized Index (Mckee, 1993). In fact, several indices are developed to characterize drought, the most used are Standardized Precipitation Index (SPI) (Mckee, 1993). Our objective is to characterize agronomic drought, so we used SPI for 3 months (Barakat and Handoufe, 1998).

Vegetation is a major environmental parameter that, through its physical and floristic structure, can be used for the environmental identification and characterization of the agro-ecological zones (Berkat *et al*., 1992). The study focuses on environmental stratification and vegetation characterization and land-use comparisons between 1988 and 2017 in the Rhamna region using remote sensing. Two free Landsat images downloaded from USGS (US Geological Survey, http://glovis.usgs.gov/) were processed and analyzed using GIS software. Several algorithms have been applied to highlight the land use and its evolution between the two dates. The identification of land cover layers for 2017 was done by a supervised classification based on field data.

III – Results and discussion

1. Climatic study

In Rhamna agro-pastoral zone, drought contributes in soil cover reduction and lands deterioration and consequently in increasing soil vulnerability to erosion.

The results show that the annual precipitation average is about 230 mm/year. The minimum is 99.4 mm recorded during 2000/2001 and the maximum is 396.4 mm during 1996/1997.

We can also note, alike the majority of arid zones (Benzarti *et al*., 2001), a wide distribution of annual precipitations (Fig. 1) with 34% of coefficient of variation. However, the trend remained stable.

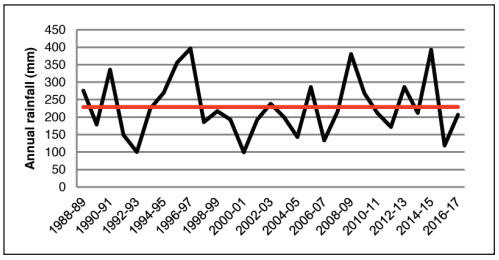

Fig. 1. Variability of annual rainfall and linear trend.

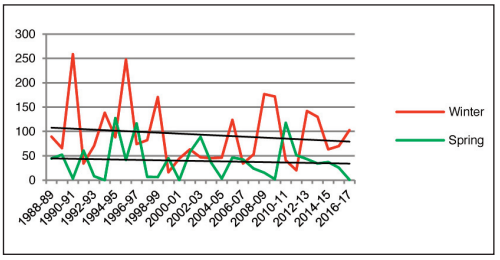

Fig. 2. Seasonal precipitations trend.

For the annual plants, spring is also a very critical period. A water deficit during this period, which corresponds to the end of a vegetative stage, would have consequently a reduction of the growth and a decrease in forage biomass. Indeed, a linear relation was established between rainfall, in particular the effective rain, and herbaceous biomass (Grouzis and Albergel, 1989).

For cereals, spring is the period of grain filling stage, so water deficit in this period would have a very significant reduction in cereal production. Definitely, cereal cultivation in this region is not justified on the agronomic and economic perspective.

Regarding the Standarized Precipitation Index (SPI), results show that during the last decades, half of years were dry (Fig. 3). Furthermore, the value of the drought index proves that 1992/1993 and 2015/2016 are the driest years during this period.

The monthly comparison of rainfall between dry years and the average of the series shows that the decrease in the rainfall occurs in the middle of the growing season and worsens in January, February and March. Similarly, there is a very significant reduction in precipitation in September (Fig. 4). It is therefore clear that the rainfall deficit during the years of drought will have a negative impact on soil cover.

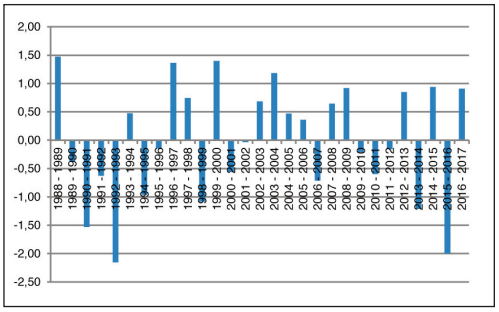

Fig. 3. Variability of SPI index in Benguerir station.

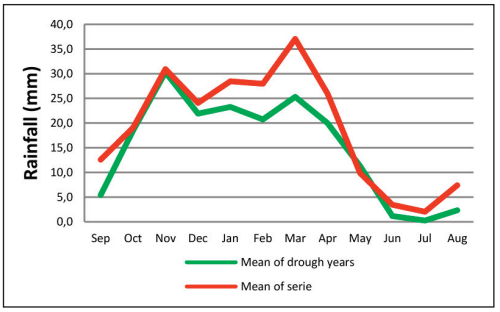

Fig. 4. Monthly rainfall in drought years and mean of the series.

2. Rangeland dynamic changes

For the assessment of change between 1988 and 2017, the study was based on the main land use strata, namely: forest, shrubs, rangeland, cropland, and bare soil and uncultivated areas.

Results obtained from satellite image processing, ranging from lean data to exogenous data, highlighted changes in the major classes of land cover. It is noted that the evolution of the environment is generally regressive. As a result, rangeland was decreased by 26%, shrubs by 17% and forest by 5%. On the other hand, crop land was increased by 20% and bare soil and uncultivated areas by 30% (Fig. 5).

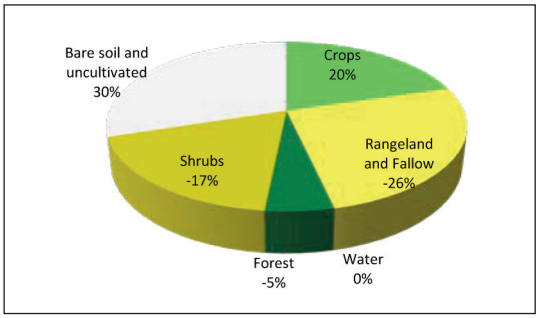

Fig. 5. Soil cover changes between 1988 and 2017.

These different changes in land use can be explained by simple shifts from one stratum to another. Indeed, rangeland, forest and scrub are recovered as cropland and bare soil and uncultivated areas. Nevertheless, the analysis of the matrix of changes shows that the contribution to change can occur simultaneously from several strata (Table 1).

Table 1. Matrix of changes in soil cover between 1988 and 2017

Land use class (2017)		Land use class (1988)						
		Crops	Rangeland and fallow	Water	Forest	Scrub and shrubs	Bare soil and uncultivated	Total
Crops	ha	10,811	90,115	3	13,033	5,882	5,230	125,076
	%	39	26	0	38	6	13	23
Rangeland and fallow	ha	11,041	139,212	0	2,076	59,030	6,251	217,611
	%	40	40	0	6	57	16	39
Water	ha	0	3	1,391	19	0	0	1,413
	%	0	0	88	0	0	0	0
Forest	ha	1,289	5,358	9	2,051	79	833	9,620
	%	5	2	1	6	0	2	2
Scrub and shrubs	ha	104	8,485	1	4,511	109	1,802	15,012
	%	0	3	0	13	0	4	3
Bare soil and uncultivated	ha	4,257	101,064	179	12,836	39,014	26,125	183,475
	%	15	29	11	37	37	65	33
Total (2008)	ha	27,502	344,239	1,582	34,527	104,115	40,242	552,207

Thus, the main changes observed in land cover between 1988 and 2017 are summarized as follows:

- Forest: the spaces assigned to this level are distributed among all the other strata. Thus, only 6% of the area in this class remained stable, while 38% was converted to cropland, 13% to shrubs, 6% to rangeland and 37% completely disappeared, leaving room for bare soil.
- Scrubs: Less than 1% of the area of this stratum remained unchanged. The remains were severely degraded to rangeland (57%) or disappeared completely by clearing (37%) or by cultivation (6%).
- Rangeland: this class has retained 40% of its area. Most of it disappeared to give bare soil (29%) and cropland (26%). Only 5% regenerated by reforestation and planting;
- Cropland: In general, this area has increased by 20% and 39%. The increase of these areas is due to the loss of rangeland (40%) and forest 5%. We also note that 15% was recovered from the bare soil.

– Bare soil and uncultivated: This class represents most of the area of Rhamna. It represents respectively 7% and 33% of this space in 1987 and 2017. These spaces have increased by 30% between these two dates. Most of it remained unchanged (65%), 16% comes from rangelands and 13% from cultivated land.

IV – Conclusion

The critical regression of the vegetation cover is due first to the growing pressure over the resources that has been in place for a long time, but climate change has worsened the situation in recent decades. The analysis of the current state of vegetation and environment shows a general tendency towards degradation.

In fact, the long-term analysis of climate data shows that one year out of two is considered agronomically dry. We would therefore find it difficult to support the hypothesis of a cyclical drought to explain the advanced level of degradation of the pastoral environment and which is rather the final stage of a long-standing process in which drought occurs only as a catalyst element.

Other factors of environmental degradation derive from the current changes in pastoral society. Indeed, the last sequence of dry years has led to massive use of concentrate feeds. Cereal growing, without being a new phenomenon in the region, has taken alarming proportions.

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