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Rangeland rehabilitation using rainwater harvesting and rosemary (*Rosmarinus officinalis* L.) transplantation in the Southeast of Morocco

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Abstract. Common grazing lands in the south east of Morocco have provided for centuries forage for livestock, but they are now highly degraded essentially due to the continuous high grazing pressure. The Moroccan government and IFAD implemented in this area an integrated project since 2008. One of the goals of this project was to demonstrate promising rehabilitation methods of rangeland. Assoul, an arid region located in the southeast of Morocco, was one of the communes in which these actions were set. Accordingly, we tried in 2012 to rehabilitate 10 ha of a degraded rangeland using micro-catchment water harvesting in contour ridges lines combined to small trapezoidal bund to establish rosemary seedlings. Over four years, results showed that mortality was of $20\% \pm 11.6$. Rosemary production estimated in the fourth year after the transplantation is of 429 g DM/plant (density 1333 plants/ha). This transplantation permitted also the regeneration of local vegetation. Thus, the Shannon-Weaver diversity index increased from 2.6 in 2013 to 4.3 in 2015. In addition, the rangeland production was improved from 51.3 ± 37.8 kg DM in 2012 to 82.9 ± 53.6 kg DM in 2015. Plant density and cover increased significantly compared to the baseline situation.

Keywords. Steppe – Degradation – Rehabilitation – Rainwater-harvesting – *Rosmarinus officinalis* – Transplantation.

La réhabilitation des parcours en utilisant la collecte des eaux de pluie et la transplantation du romarin (*Rosmarinus officinalis* L.) dans le sud-est du Maroc (Assoul)

Résumé. Les parcours collectifs dans le sud-est du Maroc ont assuré pendant des siècles l'alimentation du bétail, mais ils sont aujourd'hui en état de dégradation avancée principalement en raison du surpâturage. Le gouvernement marocain et le FIDA ont mis en œuvre un projet intégré en 2008 dans cette région. L'un des objectifs assignés à ce projet était de démontrer les bonnes pratiques de la réhabilitation des parcours. Assoul, situé dans le sud-est du Maroc, est l'une des communes arides choisies pour mener ces actions. Ainsi, nous avons essayé depuis 2012 de réhabiliter 15 ha d'un parcours dégradé en utilisant les techniques de collecte des eaux de pluie. La technique utilisée combine des cuvettes en trapèze installées sur des contours qui suivent les courbes de niveau pour réussir l'établissement des plantules de romarin. Après quatre ans, les résultats ont montré que la mortalité a été de $20\% \pm 11,6$. La production du romarin estimée dans la quatrième année est de 429 g de MS/plante (densité 1333 plants/ha). Cette transplantation a permis aussi le retour de la végétation autochtone. Ainsi, l'indice de diversité de Shannon-Weaver a augmenté de 2,6 en 2013 à 4,3 en 2015. En outre, la production des pâturages a été améliorée de $51,3 \pm 37,8$ kg MS en 2012 à $82,9 \pm 53,6$ kg MS en 2015. La densité et le recouvrement de la végétation ont augmenté significativement par rapport à la situation de référence.

Mots-clés. Steppe – Dégradation – Réhabilitation – Collecte des eaux de pluie – *Rosmarinus officinalis* – Transplantation.

I – Introduction

In Morocco, rangelands are overgrazed and are subject to impoverishment of their vegetation cover and plant diversity. In this regard, approximately 8.3 million ha of rangelands are heavily degraded (MADR, 2003). The estimated annual cost of rangeland degradation stands at 133.6

million MAD (Dahan *et al.*, 2012). This degradation is located in several regions of Morocco between them the Pre-Sahara.

In this context, the Regional Office of Agricultural Development of Tafilalet (ORMVA-TF) with the International Fund for Agricultural Development (IFAD) implemented a Rural Development Project in the Mountain Zones of Errachidia Province (PDRME) in 2008. The main objective of the project was to provide support to poor and vulnerable populations, in order to increase their income and improve the level of their livelihood. Among the component of this project was the demonstration of good practices for rangeland rehabilitation. National Institute for Agricultural Research (NIAR) was responsible to accomplish these actions.

One of the practices concerned the rehabilitation of Assoul rangeland by using rainwater harvesting techniques in combination with rosemary (*Rosmarinus officinalis* L.) transplantation. The main goal of this action was to conserve biodiversity and to improve forage production. In this paper are the main results of this successful action.

II – Material and methods

Study Area. The study was conducted from 2012-2015 (from March 2012) in Agouray village that belongs to Assoul rural community. It is located in the southeast of Morocco at 1690 m a. s. l. (34°51'08.4"N and 08°15'05.3"E). Soils are skeletal, with loamy-sand texture and poor in organic matter. Long-term climatic data (1989–2015) revealed that the Mediterranean climate of this region is arid-type with cold dry winters and hot dry summers. The region receives an average of 188 mm of rain per year (SD= 104 mm; n = 32). Average annual temperature is about 16.4 °C with a minimum of 7.65 °C in January and a maximum of 27.5 °C in July.

Plant material and plantation. The rosemary seedlings (*Rosmarinus officinalis* L.). were raised in 25 cm plastic bags. Nearly one month before the transplantation, seedlings were stressed in the perimeter of plantation under natural solar radiation (open nursery). Seedlings were transplanted at the age of six months, the height was about 25 cm.

Prior to planting rosemary in trapezoidal bunds, contour ridges lines were traced and distance between lines was defined based on the slope. The ration of catchment to cultivated area (C: CA) was four to seven meters. Seedlings were planted inside trapezoidal bunds combined with natural gravel mulch (diameter 2 to 5 cm) beside the contour lines. Irrigation of 5 L/plant has been assured immediately at the establishment of the plants.

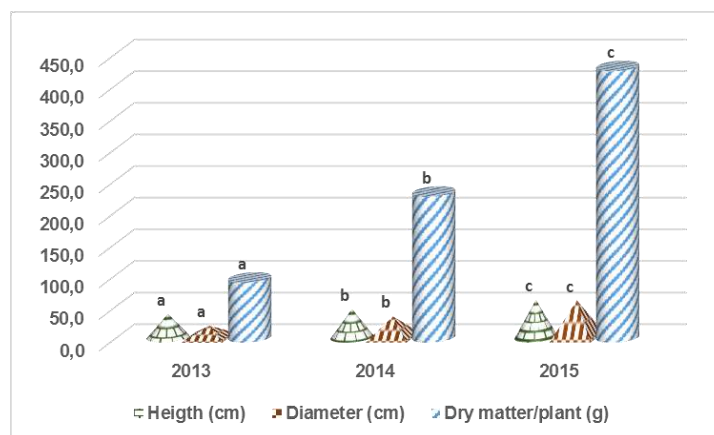
Data collection. Plant mortality rate was calculated during the first summer period and at the last time point of measurement. Then, height, diameter and dry matter were measured for each rosemary plant every year after the establishment. Dry matter was measured according the reference unit method. To study rangeland vegetation, the experimental site was divided into three parts. First, vegetation was inventoried along the site. Then, phytosociological surveys were made within plots of 16 m² (obtained from the minimum area). Hence, 10 records (quadrat) were taken along the diagonal (four quadrats in the median part) every year at the peak of plant's growth. We adopted The Braun-Blanquet system (Braun-Blanquet, 1932) to estimate cover-abundance. Additionally, the plant cover was measured by using the line point intercept method. Density was also counted in the quadrat and dry matter production was estimated indirectly by harvesting some quadrats and estimating others. Harvested biomass was dried (70 °C, 48 h) and weighed. The quantitative approach involved also the calculation of some species diversity indices such as Shannon-Weaver's diversity index H'; Simpson's dominance index D and Pielou's evenness E (Hubalek, 2000).

Statistical analysis. Statistical analysis were performed using Microsoft Excel and SPSS software (18 version). The experimental data of rosemary mortality, growth and production were submitted to analysis of variance. Differences between treatments were compared using the Student-Newman-Keuls (SNK) test at P≥0.05. A Student's t-test was done to assess whether

the diversity indices were statistically different from each other. The phytosociological abundance/dominance scores for vegetation were converted into cover percentages before doing an ANOVA between years.

III – Result and discussion

Rosemary transplantation. Mortality rate of rosemary plants was only of $20\% \pm 11.6$ four years after their establishment even under unfavourable climatic conditions. In fact, the average annual rainfall from 2012 to 2014 was about 130 mm highly lower compared to the mean annual precipitation of 180 mm. The height, diameter and dry matter production of rosemary plants have significantly increased since their establishment in 2012 (Fig. 1). As a consequence, the dry matter production of rosemary was about 457 Kg DM/ha (calculated for a density of 1333/ha) in 2015.



Values in columns followed by different letters for the same parameter are statistically significant according to SNK test.

Fig. 1. Growth dynamics and average dry matter per rosemary plant in the Agouray.

Richness and diversity of Agouray site. The study of floral composition revealed the presence of 69 species. They were divided into 56 genera belonging to 21 botanical families. Five families (Fabaceae, Poaceae, Caryophyllaceae, Cistaceae and Lamiaceae) represented the 40% of the total flora. It seems that the diversity was improved by the rehabilitation action, since 40% of these species appeared after the intervention. The species belongs to five different life forms (Raunkiaer, 1934), the most common were: therophytes and hemicryptophytes. The existence of chamaephytes and some nanophanerophytes in the site are of great importance, indicating that this steppe remains resilient, and could be improved. The Shannon- Weaver diversity index for the whole site was increased significantly from 2.6 to 4.3 (Table 1). First, this higher index indicates that vegetation is diversified and not dominated by a specified species. Indeed, this was also indicated by the very low value of Simpson's dominance index. The increase of diversity index values indicates the positive effect of the rehabilitation action. Finally, the high value of Pielou's Evenness indicates similarity or equitability in species relative abundance of this community (no dominant species). This diversity confers resilience and stability within this steppe (Tilman *et al.*, 1998). As a result, resting and rehabilitation actions increased significantly diversity indices.

Table 1. Floristic diversity for the studied vegetation

	2013	2014	2015	Significance ¹
Shannon-Weaver's Index H'	2.6	3.5	4.3	**
Species Evenness E (Pielou's E evenness)	0.8	0.9	0.9	**
Simpson's dominance index D	0.2	0.1	0.05	*

¹ ns: not significant; * P < 0.05 significant; P < 0.01 highly significant

Cover density and production. The intervention generated as well a positive impact on the global vegetation cover. This cover estimated from the Braun-Blanquet method (sub-estimated) increased from 2.1% in 2013 to 8.6% in 2015. On the other hand, the cover estimated according to the line point intercept method revealed that vegetation cover was about 19%, dominated essentially by ephemeral (14%) while perennials remained very low 5%. The density of natural vegetation quadrupled in three years (from 21857 to 52375 per hectare). In addition, some palatable species increased relatively in number like *Artemisia herba-alba* asso. (2018/ha in 2013 to 2938/ha in 2015) and *Thymus satureioides* Cosson. (2875/ha in 2013 to 3125/ha in 2015). The total average production of the entire site, although modest, was variable according to the precipitation received every year. The rangeland production was improved from 51.3 ± 37.8 kg DM in 2012 to 82.9 ± 53.6 kg DM in 2015 assuring forage of better nutritive value.

IV – Conclusion

The purpose of this study was to demonstrate good practices for degraded rangeland rehabilitation through simple action such as water harvesting techniques accompanied by rosemary transplantation. Although the natural environment constraints (recurrent droughts, aridity, poor soil, low plant cover, stoniness, etc.), this intervention generated a positive impact in terms of the success of the rosemary transplantation, the increase of rangeland floral diversity, vegetation cover, density of vegetation and pastoral production. Therefore, the local population was highly satisfied. After the presentation of the results of the action, they claimed to pursue the extension of this action.

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