Environmental and Agronomic Benefits of Aromatic and Medicinal Plant Strips for Rainfed Almond Orchards in Semiarid Slopes (SE, Spain)

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Abstract: In the Mediterranean zone semi-natural vegetation and diverse mountain-cropping systems have been converted into monocultures with low tree densities, leaving the soil unprotected. Soil loss and runoff over a three-year period were monitored in hillside erosion plots (35% slope and 144 m^2 in area) with almond (*Prunus amygdalus*) trees under three soil-management systems: no-tillage with sage (*Salvia lavandulifolia* L.) strips 3 m wide (NTSS); no-tillage with rosemary (*Rosmarinus officinalis* L.) strips (NTRS), and no-tillage with thyme (*Thymus baeticus* L.) strips (NTTS) in south-eastern Spain. Also, the nut yield from almond trees, and the biomass and essential oils from aromatic-shrub strips were measured. According to our findings, the NTTS, NTRS and NTSS reduced erosion with respect to the common local conventional tillage by 95, 94, and 77%, and the runoff by 85, 84, and 60%, respectively. In comparative terms among the plant strips, thyme and rosemary reduced soil loss by 78 and 73%, and runoff by 61 and 63%, respectively, with respect to sage. Significant differences (*P<0.01*) were found for both soil erosion and runoff values in sage and rosemary strips respect to thyme strip. The mean nut yield from NTSS, NTRS, and NTTS during the study period was 546.4, 658.8, and 829.6 kg ha^{-1}, and the essential oil yield from sage, rosemary, and thyme was 5.0, 5.1, and 7.1 l ha^{-1}, respectively. The nut yield from almond orchards without plant strips in the study zone is about 1,075 kg ha^{-1}, therefore, the production was reduced by plant strips probably due to the water competition. However, the thyme strips controlled the erosion and agricultural runoff and thus had a beneficial effect on the environment as well as a less negative impact on almond yields. In addition, the essential oils from herbs can offset the loss of profits from almond trees for farmers. Thus, this paper highlights the beneficial impact of cultivated plant strips in hilly areas by the association the soil- and water-conservation measures with production in traditional almond orchards.

Keywords: Almond orchards, aromatic-medicinal plants (AMP), agriculture runoff, mountainous agriculture, soil-management systems, mediterranean.

INTRODUCTION

Runoff and soil erosion is widespread and adversely affects virtually all natural and human managed ecosystems especially in agricultural lands [1]. The Mediterranean area is one in which climate, geomorphological changes and the impact of human activities have resulted in progressive degradation, ending sometimes in desertification [2]. Concretely in Spain, more than 22 million ha (43.8% of the land) is affected by erosion rates higher than 12 t ha^{-1} yr^{-1}, exceeding the tolareble limit of soil formation, which is 2-12 t ha^{-1} yr^{-1} [3]. In 2006, 12.6% of the land was affected by erosion rates higher that 50 t ha^{-1} yr^{-1} and 34.1% of 10-50% t ha^{-1} yr^{-1} [4]. Permanent rainfed crops such as almonds (*Prunus amygdalus*), cover vast areas of the Mediterranean landscape, and these crops have expanded rapidly into marginal soils of the hillslopes of south-eastern Spain [5]. Almond trees are widely spaced and the soil in between is kept bare to reduce competition with weeds for the scarce rainfall. In particular, the cultivation of almond is feasible primarily in the Spanish Mediterranean area in rainfed orchards (92%) [6], with some 661,920 ha of almond orchards soon to exceed a production of 204,500 t [7]. Hence, the large areas of bare soil among the trees are vulnerable to produce runoff and erosion. However, it has been demonstrated that soil redistribution by human agricultural activity such as tillage can be an even more severe cause of degradation as a result of the conversion of shrublands into almond or olive orchards with widely spaced trees and little plant cover. Unfortunately, the expansion of tree crops has not been accompanied by soil-conservation measures [8]. In semiarid regions, torrential rains are the major causes of soil degradation, especially in mountainous areas. In particular, for South-eastern Spain (Sierra Nevada Mountains), strong efforts have been made to curb cropland erosion, primarily by reducing runoff [9-12]. An appropriate measure for runoff and soil erosion control on Mediterranean slopes involves the use of plant covers, which have been shown to improve the soil quality [13, 14].

The aromatic and medicinal plants (AMP) have wide applications as fresh, frozen, or dry, as well as transformed into oils, extracts, and essences, primarily for the food, pharmaceutical, and cosmetic industries [15, 16]. A great proportion of AMP comes from wild plants, while more marketable species such as mint, lemon balm, lavender, and chamomile are cultivated [17, 18]. In this sense, the cultivated area of AMP in Spain is about 7,000 ha, of which some of 4,000 ha are especially devoted to lavender production. The organic production area, on the increase, is cur-

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rently about 2,300 ha, of which 1,700 ha is located in Andalusia (southern Spain). Thus, the maintenance and cultivation of AMP constitute one of the major economic activities for local farmers in mountainous areas [19, 20].

Intermittent plant strips including aromatic species can break-up the trajectory of the agricultural runoff, decreasing the erosive effect and increasing infiltration [9, 20, 21]. As rainfall is a limiting factor for rainfed crops in a semi-arid environment, it is critical to capture a maximum of rainfall while allowing a minimum of runoff. The diversification of existing cropping patterns coupled with suitable agro-environmental practices in soil management can provide sustainable agricultural systems that optimize production and maintain high environmental quality.

In the present study, we applied three different soil-management systems for almond orchards in steeply sloping areas of Lanjarón (Granada, SE Spain): no-tillage with sage (*Salvia lavandulifolia* L.) strips 3 m wide (NTSS); rosemary (*Rosmarinus officinalis* L.) strips (NTRS) and thyme (*Thymus baeticus* L.) strips (NTTS). We determined and compared the effects of these AMP strips on soil erosion and surface runoff, and we measured the nut and biomass yield from almond trees and plant strips, respectively. The aim was to identify the proper soil-management system for almond under the conditions studied and its influence in their yield.

MATERIALS AND METHODOLOGY

Site Description and Treatments

The field experiment was carried out in Lanjarón (SE Spain) (UTM coordinates X = 456,718.70; Y = 4,084,471.85) and at of 580 m a.s.l. (Fig. **1**). The soils of the zone, Typical Xerorthent [22], had a loamy-soil texture, with 52% sand, 32% silt and 16% clay, 1.03% organic matter, 0.09% N, 14.6 mg kg^{-1} P, and 45 mg kg^{-1} assimilable K.

The experiment plot was part of a hilly rainfed almond orchard (*Prunus amygdalus* Basch cv. Desmayo Largueta) with trees spaced 6 x 6 m. Three erosion plots (24 m x 6 m) were located on a hillside (35% slope). An erosion plot consisted of a galvanized enclosure, drawer collector, and sediment and runoff collectors (Fig. **2a**). Each erosion plot contained 3 almond trees with different treatments: one plot with no-tillage and four 3-m-wide strips of sage (*Salvia lavandulifolia* L. sub specie Oxyodon) (NTSS), a second plot with strips of rosemary (*Rosmarinus officinalis* L.) (NTRS), and finally a third plot with strips of thyme (*Thymus baeticus* L. *Boiss. exlacaita*) (NTTS) (Table **1**). Each strip, planted across the slope, was 3 m x 6 m so that the plot was 50% covered (Fig. **2b**). These AMP strips were intended to trap eroded soil and reduce the runoff down the slope.

Measurements

During the monitoring period, soil loss and runoff from plots were collected and measured after each rainfall that amounted to 28 erosive events. Three 1-liter aliquots were taken from different depths while the content of the tanks was being stirred. The sub-samples were immediately taken to the laboratory, oven dried at 105º C and weighed to determine the suspended sediment concentration.

At the end of each season the mature almonds were harvested from the trees. The biomass of the strips was also measured by clipping approximately the 50% of the above-ground biomass. Also, plant material from sage, rosemary, and thyme were taken for determination of essential-oil contents [23].

The rainfall data were collected from a local meteorological station (<100 m from the plots). For each rainfall

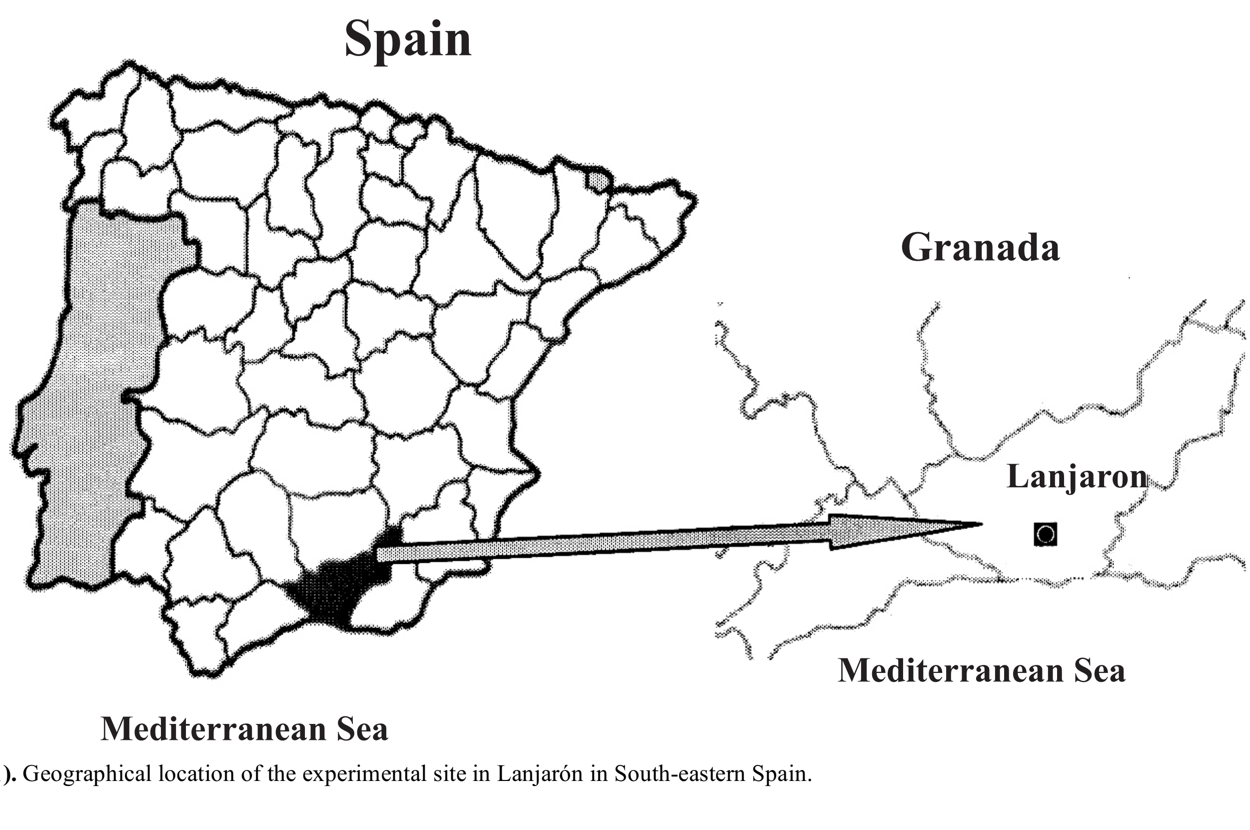

Fig. (1). Geographical location of the experimental site in Lanjarón in South-eastern Spain.

Table 1. Seasonal Field Management for each Studied Plant Strip (Weed Treatment and Harvest Period)

Treatment	Autum[a]	Winter	Spring[b]	Summer[c]
Thyme strips (NTTS)	None	Weed control between strips with Glyphosate herbicide (1 Kg ha^{-1})	Harvest of 50% of thyme biomass in April	None
Rosemary strips (NTRS)	None	Weed control between strips with Glyphosate herbicide (1 Kg ha^{-1})	Harvest of 50% of rosemary biomass in May	None
Sage strips (NTSS)	None	Weed control between strips with Glyphosate herbicide (1 Kg ha^{-1})	None	Harvest of 50% of sage biomass in September

[a]Planting strips at the middle of December with planting grid for thyme, rosemary and sage of 0.5 x 0.5 m, 1.0 x 1.0 m, and 1.0 x 1.0 m, respectively, leaving one year for fully plant development before starting the experiment.
[b]Fertilizer NPK by broadcasting in spring.
[c]Nut harvest from almond trees at early of September.

event, the average intensity and maximum intensity at 30 min (I_{30}) were calculated.

By analysis of variance, the means of different effects of treatments were compared, and differences between individual means were tested using Tukey Honestly Significant Difference (HDS) analysis at P<0.01.

RESULTS AND DISCUSSION

Rainfall Characteristics and Soil-Erosion and Runoff Response

The total rainfall depth for the first, second, and third year was 378, 384, and 313 mm, respectively. During the monitoring period 28 rainfall events were recorded in the study area, these ranging from 12.1 to 100.6 mm (Table **2**). The strong contrasts in quantity and intensity (within and between years) of torrential rains were characterized by the discharge of great amounts of water in short periods of time. The rainfall intensities (I_{30}) for storms were from 1.2 to 22.9 mm h^{-1} for the three-study period. This variability is particularly to Mediterranean basin, which is subjected to strong spatial temporal oscillations in weather [24, 25], especially in rainfall erosivity.

Fig. (**3**) shows the results for the analysis of the variance by Tukey HDS analysis concerning the effect of the soil-management systems on the average soil erosion and runoff. In the thyme and rosemary strips, values for soil erosion differed significantly (P<0.01) from those of the sage strips. Similarly for the runoff response the NTTS and NTRS differed statistically from the NTSS in the experimental area. The lowest soil-erosion and runoff rates, ranging from 0.40 to 0.70 Mg ha^{-1} yr^{-1} and from 23.4 to 30.4 mm yr^{-1}, respectively, over the entire study period, were measured under the NTTS. In the NTRS, erosion ranged from 0.30 to 1.30 Mg ha^{-1} yr^{-1} and runoff from 9.5 to 48.3 mm yr^{-1} while in the NTSS, erosion ranged from 1.1 to 4.0 Mg ha^{-1} yr^{-1} and runoff from 56.3 to 96.0 mm yr^{-1}. Throughout the entire experimental period, the NTSS reached the highest soil-erosion and

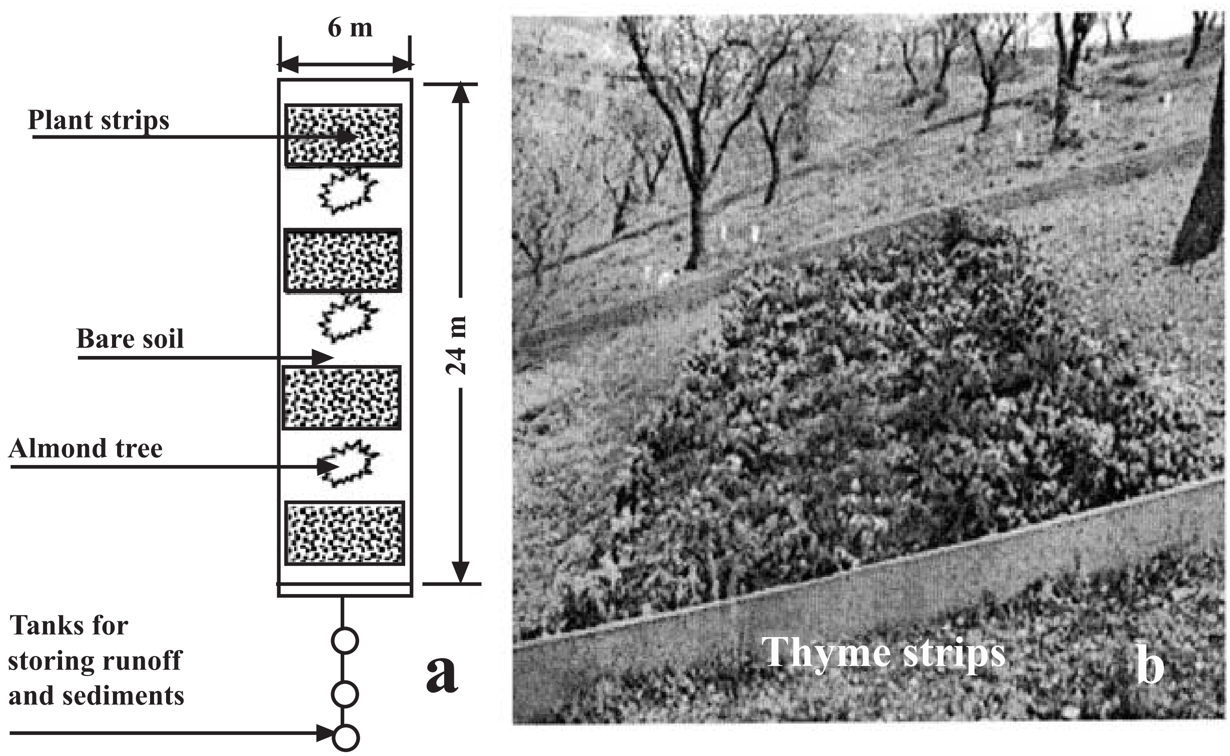

Fig. (2). Erosion plots used for the study and distribution of the almond trees and aromatic and medicinal plant strips inside the plot (**a**) in Lanjarón (SE Spain). Thyme strips of 3 m width running across the slope in the closed erosion plot (**b**).

Table 2. Main Statistical Characteristics for Rainfall and Intesity I_{30} for the Three Studied Years in Lanjarón (SE Spain)

Statically Parameters	First Year		Second Year		Third Year	
	Rainfall (mm)	Intensity I_{30} (mm h^{-1})	Rainfall (mm)	Intensity I_{30} (mm h^{-1})	Rainfall (mm)	Intensity I_{30} (mm h^{-1})
Average	42.0	9.8	29.0	12.3	52.2	9.1
S.D.	26.8	5.8	12.6	5.5	19.8	1.6
Maximum	100.6	19.0	51.2	22.9	66.5	11.2
Minimum	12.7	1.2	12.1	6.2	17.7	7.4
N	9	9	13	13	6	6

runoff rates. Thus, the high variability of rainfall amount and intensity from one year to another during the study period resulted in a broad range of soil-loss and runoff values.

In the study area at hillslope level with 35% incline with traditional conventional tillage in almond orchards (unpublished data) higher rates for erosion and runoff (11.8 Mg ha^{-1} yr^{-1} and 184.3 mm yr^{-1}, respectively) were found than those in the present study. In a mature almond orchard with conventional tillage, van Wesemael *et al.* [26], under even more extreme conditions than ours, estimated higher erosion rates

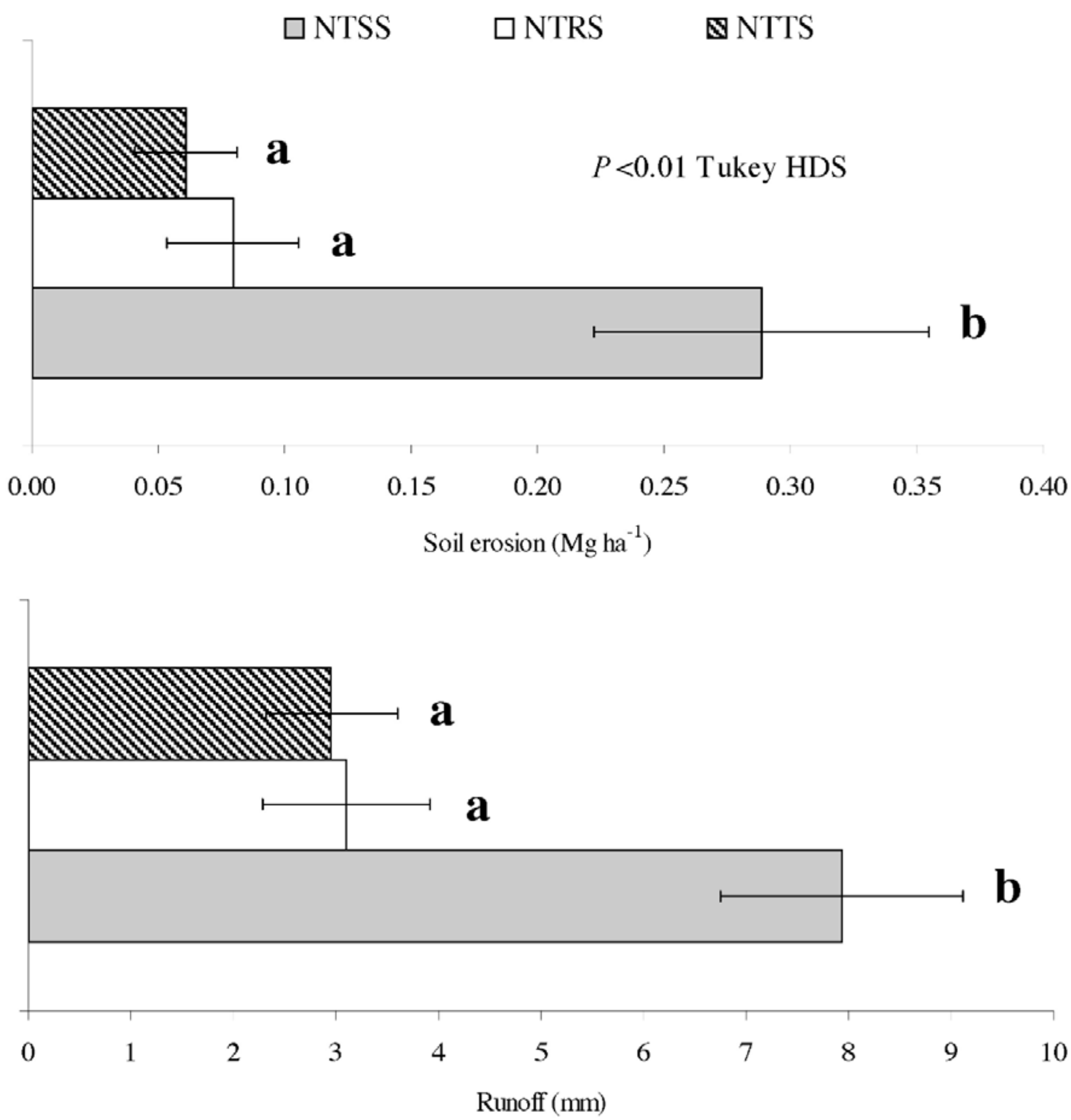

Fig. (3). Mean soil erosion and runoff for each treatment in Lanjarón (SE Spain). Horizontal bars represent the standard error (SE) and different letters in columns are significantly different by Tukey HDS analysis (*P<0.01*).

(26.6 Mg ha^{-1} yr^{-1}). In addition, for conventional tillage in the study zone in olive orchards with 30% slope Francia *et al.* [10] found for soil erosion and runoff rates of 10.4 Mg ha^{-1} yr^{-1} and 15.2 mm yr^{-1}, respectively. This difference especially for the runoff is probably due to the denser canopy of olive tree, which intercepts part of the rainfall before reaching the soil surface (by stemflow and leaf-drip), diminishing soil-surface sealing by direct raindrop impact.

According to our findings, the effectiveness the NTTS and NTRS treatments in reducing the soil loss was 78 and 73%, and runoff 61 and 63%, respectively, with respect to NTST. And in comparative terms between the AMP strips and the common soil-management systems without plant strips, the NTTS, NTRS and NTSS treatments reduced soil loss with respect to the conventional tillage by 95, 94, and 77%, and for the runoff by 85, 84, and 60%, respectively.

These results imply that the biomass of plant-cover strips across the slope significantly reduced erosion by cutting down surface runoff and buffering the rainfall impact on the ground surface. The intercepted rainfall, diverted to leaf drip or stemflow reaching the soil surface with lower kinetic energy than did the non-intercepted rainfall. Martínez *et al.* [9] pointed out that the plant morphology seemed to be an important factor because thyme knitted to the soil surface, forming a carpet of fine leaves and stems that restrained runoff and therefore soil sediments. Meanwhile, the sage plants, growing with a more open habit, allowed rainfall to penetrate more easily and restrained runoff and soil sediments to a lesser degree. In this sense, the plant biomass, living or dead, of shrub-cover strips between rows of almond trees, according to the results of the present experiment protected and reduced soil erosion and runoff, encouraging water infiltration and the water-storage capacity of the soil. In addition, the soil organic carbon (SOC) and plant nutrients under AMP covers increased as was pointed out by Durán *et al.* [14], which boost the soil organic matter and consequently the soil quality.

Thus, the soil degradation was reduced by planting AMP (thyme, rosemary and sage) strips, decreasing the soil-erosion risk on steep slopes with rainfed almond orchards. In this environment, the plant strips helped to harvest water rainfall by reducing the runoff across the hillslope that constitute a major advantage in conservation soil and water.

Almond and Essential Oil Yield

Fig. (**4a**) shows the average yield of almond trees for each treatment, being the lowest for NTSS treatment (546.4 kg ha^{-1}), and the highest for NTTS (829.6 kg ha^{-1}). However,

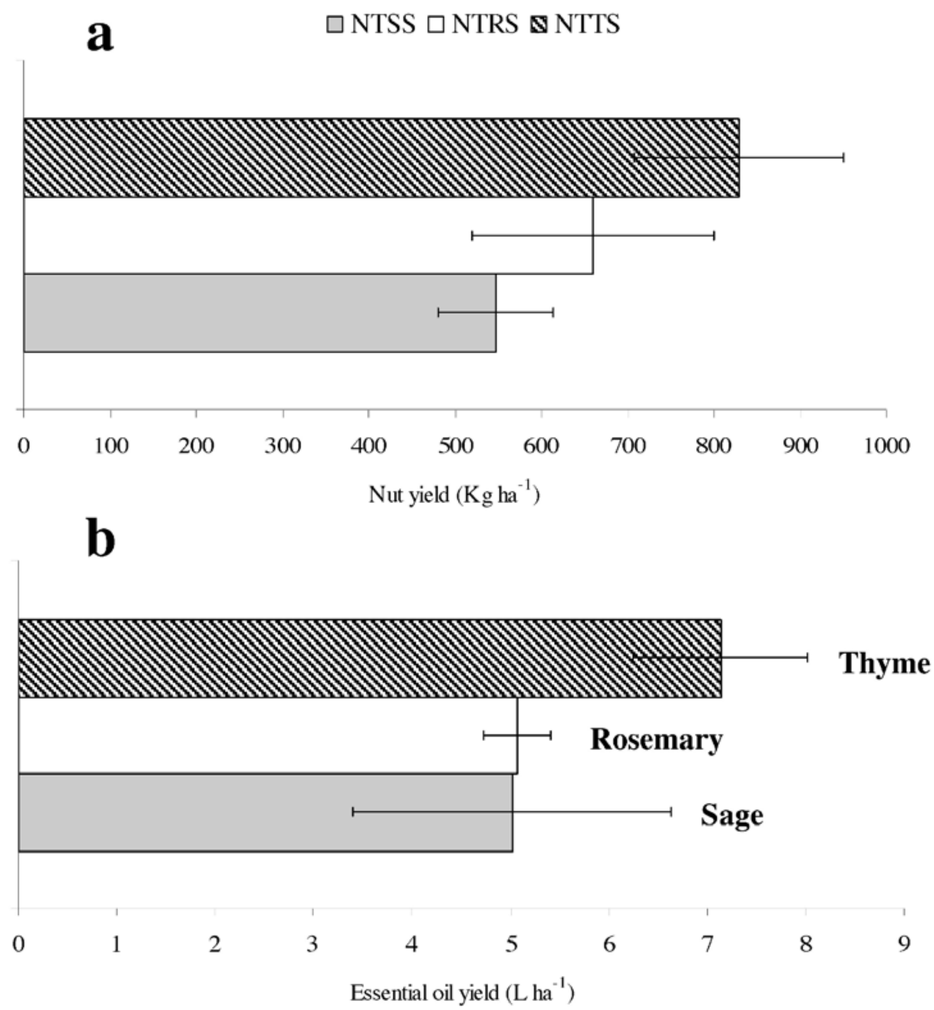

Fig. (4). Mean nut (**a**) and essential oil (**b**) yield from each treatment for the three-year study period in Lanjarón (SE Spain). Horizontal bars represent the standard error (SE).

yield oscillated throughout the study period, being higher yields not coincided with the greatest amounts of rainfall. The average nut yield per tree from NTSS, NTRS, and NTTS treatments were 2.2, 2.6 and 3.3 kg, respectively. In this context, in the study area under traditional soil-management systems without plant strips the average almond yield per tree is about 4.3 kg (~ 1,075 kg ha^{-1}), which is close to other Spanish Mediterranean producer regions under similar rainfed conditions of 5.4 kg $tree^{-1}$ [27]. Thus, the negative impact on yield of almond trees on hillslopes by cultivating plant strips of thyme, rosemary, and sage in relation to traditional conventional tillage was 23, 40, and 49%, respectively.

The worst yield per hectare was harvested under sage strips and the best among the shrub strips in thyme, which decreased the yield by 245.4 kg ha^{-1} with respect to average yield under traditional conventional tillage in the experimental site.

The average dry matter yield from fresh-biomass yield (by applying a rational harvest of 50% of biomass) for the study period from sage, thyme, and rosemary plants were 418, 374, and 230 kg ha^{-1}, respectively (Fig. **5**). As was expected since each shrub has a different height and shape (thyme being lower than open medium-sized rosemary and sage plants), the fresh biomass and dry matter yields differ and varied during the study period especially with sage.

On the other hand, the average yield in essential oils from sage (1.20% v/w), rosemary (2.20% v/w) and thyme (1.90% v/w) were 5.0 ± 2.8, 5.1 ± 0.6, and 7.1 ± 1.5 l ha^{-1}, respectively (Fig. **4b**). These yields are recorded by taking into account that from one hectare of almond trees only the 50% is cultivated with shrub strips 3 m wide-- that is, about 16 strips running across the hillslope. As these plants are perennial plants and grow year round, they compete unsuitably with the almond orchard for water in rainfed conditions. Therefore, the main drawback is the water availability between the shrub strips and almond tree, provoking lower almond yields, with respect to orchards without plant strips.

Spain is the largest producer of herbs in the EC with 14,906 ha of cultivated area [28], however the great majority of these materials being collected from wild resources. The demand for the aromatic and medicinal plants is increasing, and therefore, it will be advantageous to promote the cultivation of these plants instead of wild harvest, which can degrade marginal mountainous areas [12, 29]. The strip cultivation of AMP under rainfed conditions in semi-arid slopes could provide an economic income for farmers, being the demand of essential oil of AMP (sage, rosemary and thyme). In this sense, the cultivation both almond trees and AMP could be an initiative to develop a good practice for the sustainable agriculture. Thus, diversification of existing mountain-farming systems, by developing suitable agro-friendly measures could satisfy the needs of the modern agriculture while responding to the growing demand for maintaining, protecting, and recovering the environment.

CONCLUSION

The integration of cultivated plant strips on farmland improves the existing systems, by fomenting complex biological interactions and controlling erosion. In this thyme was the most beneficial plant to use in the strips between rows of almond trees in hilly areas, providing an effective system for trapping agricultural runoff as well as reducing soil erosion, thereby avoiding the soil degradation. In our study, the effectiveness of thyme and rosemary strips in reducing the soil loss respect to the sage strips was 78 and 73%, and runoff 61 and 63%, respectively. And in comparative terms the thyme, rosemary and sage strips with respect to the conventional tillage reduced soil loss by 95, 94, and

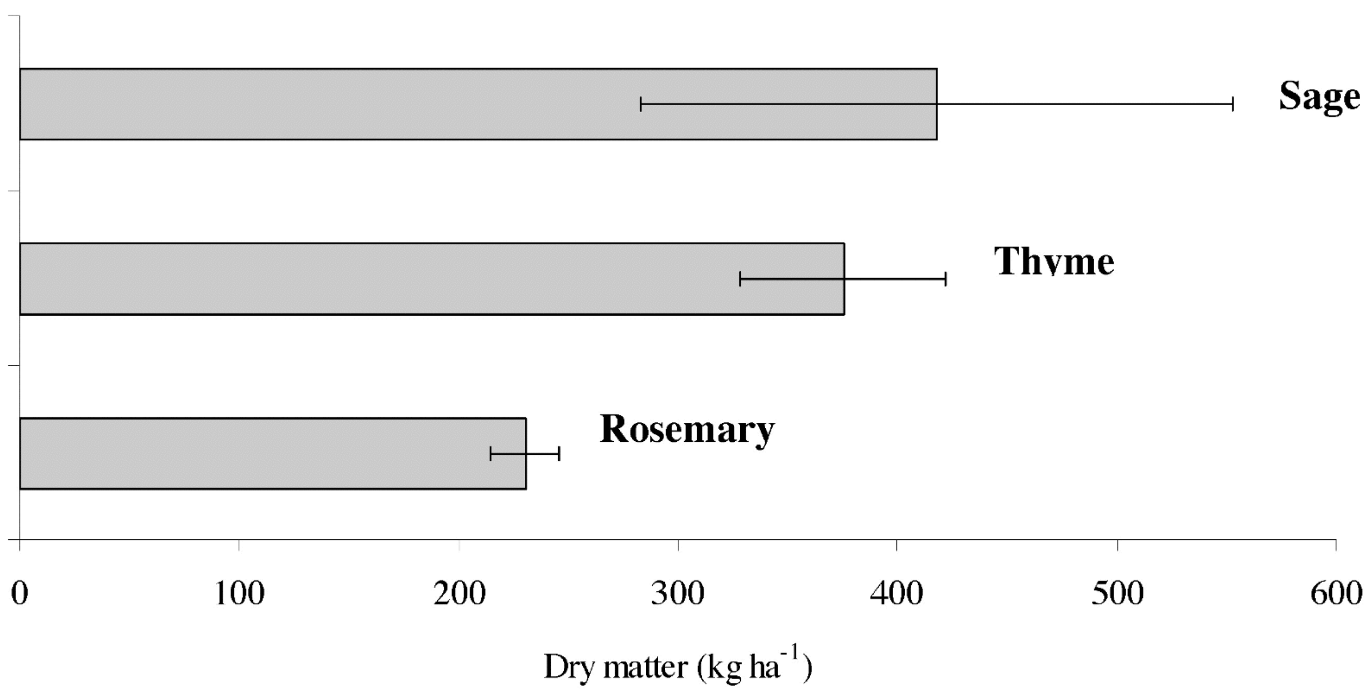

Fig. (5). Dry matter yield from AMP strips for the three-years monitoring period in Lanjarón (SE Spain). Horizontal bars represent the standard error (SE) (n = 3).

77%, and for the runoff by 85, 84, and 60%, respectively. In addition, the AMP strips led to the loss in the almond harvest, a loss that could be offset by the economic value of essential oils. Thus, yield losses can be offset not only over the short by the benefits of harvesting the plant strips but also over the long term by preserving soil and water quality. Diversification and sustainability in production are the two main goals in agriculture that can be achieved in almond orchards by planting aromatic species by compromising the environmental and agronomic interests.

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REFERENCES

[1] Arshad MA, Martin S. Identifying critical limits for soil quality indicators in agro-ecosystems. Agric Ecosyst Environ 2002; 88: 153-160.

[2] López BF, Romero MA. Génesis y consecuencia erosivas de las lluvias de alta intensidad en la región mediterránea. Cuadernos de Investigación Geográfica 1993; 18: 7-28.

[3] Rojo L. Plan Nacional de Restauración Hidrológico-Forestal y Control de la Erosión, Tomo I. Memoria; Tomo II. Mapas. ICONA, Madrid. 1990.

[4] DGB-MMA. Dirección General para la Biodiversidad, Ministerio de Medio Ambiente. http://www.mma.es/portal/secciones/calidad_contaminacion/indicadores_ambientales/perfil_ambiental_2005/pdf/perfilamb iental_2005_suelo.pdf. [1 April 2008].

[5] Faulkner H, Alexander R, Wilson BR. Changes to the dispersive characteristics of soils along an evolutionary slope sequence in the Vera badlands, southeast Spain: implications for site stabilisation. Catena 2003; 50: 243-254.

[6] Franco JA, Abrisqueta JM, Hernandez A, Moreno F. Water balance in a young almond orchard under drip irrigation with water of low quality. Agric Wat Manag 2000; 43: 75-98.

[7] FAOSTAT [homepage on the internet] Available from: http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567. [updated 2008, 3 March].

[8] Oñate JJ, Peco B. Policy impact on desertification: stakeholders' perceptions in southeast Spain. Land Use Policy 2005; 22: 103-114.

[9] Martínez RA, Durán ZVH, Francia JR. Soil erosion and runoff response to plant-cover strips on semi-arid slopes (SE Spain). Land Degr Dev 2006; 17: 1-11.

[10] Francia JR, Durán ZVH, Martínez RA. Environmental impact from mountainous olive orchards under different soil-management systems (SE Spain). Sci Tot Environ 2006; 358: 46-60.

[11] Durán ZVH, Francia JR, Martínez RA. Impact of vegetative cover on runoff and soil erosion at hillslope scale in Lanjaron, Spain. Environmentalist 2004; 24: 39-48.

[12] Durán ZVH, Rodríguez CRP, Francia JR, Cárceles RB, Martínez RA, Galindo PP. Harvest intensity of aromatic shrubs *vs* soil erosion: An equilibrium for sustainable agriculture (SE Spain). Catena 2008; 73: 107-116.

[13] Aranda V, Oyonarte C. Effect of vegetation with different evolution degree on soil organic matter in a semi-arid environment (Cabo de Gata-Níjar Natural Park, SE Spain). J Arid Environ 2005; 62: 631-647.

[14] Durán ZVH, Francia JR, Rodríguez CRP, Martínez RA, Cárceles RB. Soil-erosion and runoff prevention by plant covers in a mountainous areas (SE Spain): implications for sustainable agriculture. Environmentalist 2006; 26: 309-319.

[15] Miguel G, Simões M, Figueiredo AC, Barroso JG, Pedro LG, Carvalho L. Composition and antioxidant activities of the essential oils of *Thymus caespititius*, *Thymus camphoratus* and *Thymus mastichina*. Food Chem 2004; 86: 183-188.

[16] Bogers RJ, Craker LE, Lange D. Medicinal and aromatic plants. Springer, The Netherlands. 2006; pp 309.

[17] Lawrence BM. A review of the world production of essential oils. Perfumer Flavorist 1985; 10: 1-16.

[18] Bown D. New Encyclopedia of Herbs and Their Uses. Dorling Kindersley Ltd., London, England, 2006; pp 424.

[19] Blanco E, Morales R, Pellin R. Harvesting and trade of thymus in Spain. TRAFFIC Europe (Ed), Medicinal plant trade in Europe: conservation and supply. Proceedings of 1-st International Symposium on the Conservation of Medicinal Plants in Trade, Brussels, Belgium, 1998.

[20] Lange D. Europe's medicinal and aromatic plants: their use, trade and conservation, TRAFFIC International, Cambridge, UK, 1998.

[21] Le Bissonnais Y, Lecomte V, Cerdan O. Grass strip effects on runoff and soil loss. Agronomie 2004; 24: 129-136.

[22] Soil Survey Staff. Soil Taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Surveys, Agric. Handbook N 436, USDA-US, 1999; pp. 869.

[23] MSC. Determinación de aceites esenciales en drogas vegetales, in: Ministerio de Sanidad y Consumo (Ed), Métodos de farmacognesia, Real Farmacopea Española, Madrid, Spain; 1997; 125-126.

[24] Aronica G, Ferro V. Rainfall erosivity over the Calabrian region. Hydrol Sci J 1997; 42: 35-48.

[25] Renschler CS, Mannaerts C, Diekkruger B. Evaluating spatial and temporal variability in soil erosion risk-rainfall erosivity and soil loss ratios in Andalusia, Spain. Catena 1999; 34: 209-225.

[26] van Wesemael B, Rambaud X, Poesen J, Muligan M, Cammeraat E, Stevens A. Spatial patterns of land degradation and their impacts on the water balance of rainfed treecrops: A case study in South East Spain. Geoderma 2006; 133: 43-56.

[27] Valverde M, Madrid R, García AL. Effect of irrigation regime, type of fertilization, and culture year on the physical properties of almond (cv. Guara). J Food Eng 2006; 76: 584-593.

[28] More PE. Producción de plantas aromáticas y medicinales. Revista Horticultura-Ornamentales 2008; 46-47.

[29] More PE, Colom GA. Distribución comercial de plantas aromáticas y medicinales en Cataluña. Prod Protec Veg 2002; 17: 43-66.

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