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Long-term Impact of Cultivation on Soil Properties in the hilly olive orchards of NW-Syria.

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In NW-Syria, recent agricultural history shows that olive cultivation has expanded rapidly into marginal areas, including fragile mountain lands. Traditional land-husbandry practices have not kept pace with the intensification and expansion of olive production into steeper areas. As a result, tillage and water erosion results in declining soil fertility, which becomes a serious challenge to agricultural productivity and economic growth. The main objective of this study was to evaluate the long term impact of land use on land degradation in hilly olive orchards. To get a realistic idea about the long-term impact of cultivation (range 50-70 years), soil profiles and their properties under reference forest were compared with profiles under adjacent olive orchards. Deforestation and subsequent cultivation resulted in a severe decline in soil quality i.e.: average decline in soil depth of 31%, a significant difference for aggregate stability and soil bulk density, and a severe worsening of chemical soil fertility properties. A decrease of -62% for total soil organic matter, -62% for total N, -48% for total P and -58% for total extractable K were measured. Location at the slope also played a major role. The highest level of soil degradation was found on the steepest section of the catena, where the loss in SOM and the increase in bulk density were significantly higher than on the flat section at the top of the slope. The results indicate that present land management in the olive groves is very unsustainable. This highlights the need for alternative management practices in order to rehabilitate the degraded land, achieve sustainable olive production and eventually securing livelihoods.

Dans le nord-ouest de la Syrie, l'expansion rapide de la production d'olives dans les régions montagneuses marginales a abouti à de sérieux problèmes d'érosion, causant une profonde diminution de la fertilité des sols. Cette recherche a comme but principal l'évaluation de l'impact de la mise en culture sur la dégradation de la terre dans le cas de vergers d'olives vallonnés. Pour atteindre cet objectif, les profils et caractéristiques de sol de forêts naturelles ont été comparés avec les profils de vergers d'olives limitrophes. Les résultats montrent que les vergers sont associés à une forte diminution de la qualité du sol (une diminution de 31% de la profondeur du sol et une détérioration significative des caractéristiques physiques et chimiques) et que la dégradation est la plus forte sur la partie la plus raide de la pente. La gestion actuelle n'est pas durable et le besoin d'introduire des pratiques alternatives est urgent.

1 Introduction

In mountainous areas of the Mediterranean zone, fruit trees (like olives, almonds, grapes) are a major livelihood option; but they are often associated with strongly degrading management practices i.e. up-and down ploughing, frequent ploughing, limited soil cover percentage, etc (Tubeileh *et al.*, 2003). In the north-western part of Syria olive trees are the major source of

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income for small-scale farmers. Recent agricultural history shows that olive cultivation has expanded rapidly into marginal areas, including fragile mountain lands with marls or chalky limestone. Traditional land-husbandry practices have not kept pace with the intensification and expansion of olive production into steeper areas. As a result, water erosion and tillage erosion have a severe negative impact on the present soil status in hilly olive orchards, which becomes a serious constraint to agricultural productivity and economic growth. Symptoms of land degradation, such as surfacing white soils and subsoil (rock) outcrops are evident everywhere. The main objective of this study was to evaluate the long term impact of land use on land degradation in hilly olive orchards. More specifically, the aim is to come to grips with the net impact of land use and to zoom in on the effect of slope catena position on the land degradation rate.

2 Materials and Methods

The research area is located in northwest of Syria, i.e. Afrin district. The mountains and gently undulating hillslopes are mainly covered by olive orchards (84% of total agricultural land). The area has a Mediterranean-type climate. The annual rainfall ranges from 400 to 650 mm, which falls mainly from November till April. The coldest month is January with an average temperature of 7°C and the hottest months are July and August with an average of 27°C. The annual evaporation is approximately 1200-1600 mm. 14% of the total area is covered by forest.

To get a realistic idea about the long-term impact of cultivation (range 40-70 years), soil profiles and their properties under reference forests were compared with profiles under adjacent olive orchards. Land under natural forest can be considered as relatively undisturbed, or at least undisturbed for the last 100 years. So from a land use impact point of view, soil under forest can serve as a reference to compare with land that has been under cultivation for a certain number of years (Lemenih *et al.*, 2005; Islam & Weil, 2000).

Since fields of local farmers are used, the selection of 12 suitable research sites was an important part of the study. This selection was based on visual field observations and informal interviews with farmers concerning history of land- use and management, and present land management. The age of the olive orchards included in the study ranged between 40 and 70 years old. Subsequently, in each research site a selection of suitable contour lines was made that were used for the forest-orchard comparison. In order to assess the net impact of long term cultivation, 12 forest-orchard contour lines were selected positioned on a rectilinear very steep (30-50%) part of the slope. The effect of topography was determined by making a comparison between 3 different slope positions on a catena i.e. flat or almost flat (0-2%), moderately steep (10-30%) and very steep (30-50%), using 4 research catenas. All soils in this study were categorized as Calcaric Cambisols or Calcaric Luvisols.

Along each selected contour line, 2 soil profiles (forest/orchard) were assessed in detail in order to evaluate the changes of soil profile properties (soil depth), soil physical (bulk density, aggregate stability) and soil chemical properties (soil organic matter, available and total phosphorus, total Kjeldahl nitrogen and extractable potassium). To deal with irregularities in soil depth within the field, 6 to 8 soil augerings along the contour were used as extra soil depth measurements. Concentrations of chemical properties were expressed as (k)g nutrient per square meter soil surface in order to take the stoniness in the profile and differences in soil depth between forest and orchard into account. Also the data from bulk density of the fine earth (BD_{fe}) obtained from the lab analyses, was converted in data of total bulk density (BD_{tot}) (=fine earth + rock fragments). ANOVA was performed on each profile and soil property to test whether the changes were statistically significant. Mean values were compared using least significant differences (LSD) at 5% and 10% significance.

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3 Results

The overall long-term response of the soil to deforestation and subsequent long term cultivation resulted in a significant deterioration in almost all soil quality attributes.

Severe soil losses under olive orchards caused a decline in soil depth of 31%, ranging from a mean soil depth under forests of 38 cm to 26 cm under olive orchards. It is important to note that this decline is a conservative figure, as the real difference is probably much higher due to up-ploughing of parent material in olive orchards (especially in the sites with soft marl as parent material). A significant deterioration in physical soil properties could be established i.e. bulk density and aggregate stability differed significantly due to land use impact. Topsoil bulk density increased, going from an average of 1275 kg/m^3 under natural forests to 1343 kg/m^3 under orchards. The average % water stable aggregates > 0.5 mm was twice as high in the topsoil under natural forest (76 %) compared to the cultivated soils (36 %). The MWD (mean weight diameter) decreased significantly due to land use going from a mean MWD of 4.2 under forests to 3.1 under olive orchards. The strong decline in soil fertility could also be concluded from the severe worsening of soil chemical properties i.e. -62% for total soil organic matter, -62% for total N, -48% for total P and -58% for total extractable K (averages). Focussing on the division of the organic matter content per m^2 according to the different horizons, it showed that in the forest soil profiles only 4 % of total OM per m^2 (or per soil profile) could be attributed to the mulch layer.

Topography also played a major role. The highest degree of soil degradation was found on the steepest section of the catena. On the flat slope part, no significant difference between forest and orchard could be obtained for soil depth, bulk density, SOM and all included nutrients. On the moderately steep to steep and on the very steep slope parts respectively almost all and all of these parameters show significant differences for the comparison forest-orchard. Remarkably, a similar degree in aggregate breakdown can be found for all three slope positions. Significant differences (ANOVA) between all three slope positions could only be found for SOM and bulk density. The average loss in SOM is 10x higher on the steep (i.e. average loss of 20 kg/m^2) compared to the flat slope part (i.e. loss of 2 kg/m^2). Bulk density showed an average increase of 18 kg/m^3 on the flat slope part, while this was 110 kg/m^3 on the steep part.

4 Discussion and conclusions

The main causes of the observed decline in soil depth, soil fertility and structure under olive orchards are to be found in (1) the lack of a (natural) vegetation cover, (2) the implemented tillage operations, and (3) in a minor role, the lack of applying sufficient manure or fertilizer. The fact that no significant differences in SOM and nutrient content could be found between forest and orchard on the flat part of the slope, while a significant difference in soil aggregation could be assessed (similar to the steeper slope parts and indicating a similar tillage intensity), might be an indication of the minor role of nutrient mining in the land degradation processes. The results concerning slope position indicate that slope gradient is a major controlling factor for water erosion and tillage erosion, accelerating severely with growing gradient the impact rate of land use.

Soil organic matter is a key attribute of soil quality, because of its impacts on the physical, chemical and biological properties of the soil (Franzluebbers, 2002a). Many studies discuss the impact of tillage on the soil organic matter content (Hernanz *et al.*, 2002; Caracava *et al.*, 2002; Arshad *et al.*, 1999). The strong decline in SOM established in this study can be attributed to several aspects of land use impact i.e. soil inversion and pulverization by continuous ploughing accelerates decomposition of organic matter; tillage also acts as a soil redistributing process per se (‘tillage erosion’) causing truncated soil profiles by removal of fertile upper soil in the upper parts of fields; lack of natural vegetation cover causes a strong acceleration in water erosion whereby the particle-size selective processes of raindrop and overland flow erosion transport especially the fine-grained fraction containing most of the SOM while the coarser grains are left behind (Morgan, 1996); pruning and harvesting activities combined with the lack of applying sufficient manure or fertilizer create a net transport of SOM from the field.

Increased nitrification (one of the decomposition processes of SOM) goes sharply together with a strong increase in N leaching losses and an acceleration in cation leaching (like K) (Bormann & Likens, 1970). Most phosphorus is strongly adhering to soil particles and is therefore easily transported downslope by tillage and water erosion, nitrogen is transported both in soluble form and absorbed on soil particles

The frequent tillage passes and the magnitude of the observed differences in SOM have important implications for the structural stability of the soil. SOM increases the soil's resistance to erosion because it produces compounds that bind soil particles and reduce their susceptibility to detachment by raindrop or surface runoff. Thus, the decline in SOM, decreases soil aggregation, thereby reducing infiltration and increasing runoff and erosion (Franzluebbers, 2002b; Hernanz *et al.*, 2002). Poorer aggregation, losses in organic matter content and compaction by agricultural operations, probably accounts for the obtained higher bulk density under cultivation in comparison with the natural forest. This overall increase in soil's susceptibility to water erosion and the impact of tillage erosion as a soil redistribution process per se, explain the considerable decline in soil depth.

The overall results indicate that present land management in the olive groves is not sustainable. This highlights the need for alternative practices in order to rehabilitate the degraded land, achieve sustainable olive production and therefore secure livelihoods.

References

Arshad, M.A., Franzluebbbers, A.J. & Azooz, R.H. (1999). Components of surface soil structure under conventional and no-tillage in northwestern Canada. Soil & Tillage Research 53: 41-47

Bormann, F. & Likens, G. (1970). Nutrient cycles of an ecosystem. Scientific American 223(4): 92-110.

Caravaca, F., Masciandaro, G. & Ceccanti, B. (2002). Land use in relation to soil chemical and biochemical properties in a semiarid Mediterranean environment. Soil & Tillage Research 68: 23-30.

Franzluebbers, A.J. (2002a). Soil organic matter stratification ratio as an indicator of soil quality. Soil & Tillage Research 66: 95-106.

Franzluebbers, A.J. (2002b). Water infiltration and soil structure related to organic matter and its stratification with depth. Soil & Tillage Research 66: 197-205.

Hernanz, J., Lopez, R., Navarette, L. & Sanchez-Giron, V. (2002). Long-term effects of tillage systems and rotations on soil structural stability and organic carbon stratification in semiarid central Spain. Soil & Tillage Research 66: 129-141.

Islam, K. & Weil, R. (2000). Land use effects on soil quality in a tropical forest ecosystem of Bangladesh. Agric. Ecosyst. Environ. 79: 9-16.

Lemenih, M., Karltun, E. & Olsson, M. (2005). Assessing soil chemical and physical property responses to deforestation and subsequent cultivation in smallholders farming system in Ethiopia. Agriculture, Ecosystems and Environment 105:373-386.

Morgan, R. (1996). Soil erosion and conservation. Second Edition. Cranfield University. p 198

Tubeileh, A., Bruggeman, A. & Turkelboom, F. (2004). Growing Olives and Other Tree Species in Marginal Dry Environments. Internatiional Center for Agricultural Research in the Dry Areas (ICARDA), Aleppo, Syria. p 106