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LAND MANAGEMENT STRATEGIES TO SUSTAIN PRODUCTIVITY OF OLIVE GROVES ON STEEP SLOPES IN NORTHWESTERN SYRIA

Z. Masri[1], H. El-Naeb[3] , M. Zöbisch[2], A.Bruggeman[1], F. Turkelboom[1]

[1]International Center for Agricultural Research in the Dry Areas (ICARDA), P.O.Box 5466, Aleppo, Syria.

[2]Asian Institute of Technology (AIT), P.O.Box 4, Klong Luang, Pathumthani 12120, Thailand.

[3] The General Commission for Scientific and Agricultural Research - (GCSAR). Olive Research Section. P.O. Box. 57, Idleb, Syria

Abstract

In the northern hills of Syria, land degradation is a serious problem, particularly on vulnerable agricultural land. The traditional olive production land-husbandry practices have not kept pace with the intensification and expansion of into steeper areas. As a result, soil erosion is widespread due to intensive clear-tillage and the near absence of soil-conservation measures. Olive farmers seem well-aware about the risks of severe land degradation, but few farmers seem to find a suitable solution for this issue. Therefore, an on-farm research was conducted from 1997 to 2003 in two olive orchards in Yakhour village to develop, test and refine options for better land management that have the potential to stabilize and increase the productivity of olive groves in steepland.

Two packages of soil and water conservation measures: An 'agronomic package' designed to increase vegetation soil cover (by vetch intercropping), reduce soil disturbance (by minimizing tillage), and enhance soil structure (by incorporation of manure, and enhancing short-term chemical soil fertility (by application of mineral nitrogen, phosphorus and potassium). A second 'structural package' was based on designing and building earthen, semi-lunar shaped water-harvesting terraces, combined with the measures of the first package. Emphasis was placed on those soil and land-management practices that reduce soil erosion and help restore soil fertility.

The applied soil and water conservation measures increased soil fertility status, soil organic carbon content and soil structural stability and reduced soil and nutrient losses. The improved soil parameters were associated with a marked increase in olive productivity of 25 - 75%. Farmers evaluated the packages and some of the measures are now being practiced by farmers

Keywords: Olive orchards, Steepland, Water erosion, Soil conservation, Tillage, Syria.

1. INTRODUCTION

Cereal predominates, with barley in the drier areas and wheat in less dry areas. Cultivation of olives in this region can be traced back 5,500 years (Olive Bureau 2000). The olive is well adapted to the Mediterranean environment. It is a hardy tree which can grow on poor, shallow soils and will survive periods of low rainfall (Olive Bureau Statistics 2001).

Since ancient times, the northwestern part of Syria has been a major olive-growing area with olives and olive oil being fundamental elements in Syrian cooking. The oil is of high nutritional value, containing natural antioxidants that make it retain its fragrance and taste over long periods. The area planted with olives has increased substantially in recent decades and now totals 71 million ha of olive trees (51 million of which are fruit bearing) with a total production of 866 thousands tonnes in 2002 (Olive Bureau statistics 2000).

For Syrian agriculture in the west and northwest, olive trees are the major source of agricultural income for small-scale farmers. Land degradation in the area is caused by a combination of natural and social-economic reasons:

Olive production in the northwest of Syria has expanded as it an easy to manage cash crop, as it demands little labour, and as external labour is available during harvest.

Government policies in the early 1960's have encouraged farmers to grow olives, which resulted in an expansion of olive orchards in marginal lands.

Mechanization in olive production started during the 1970s. For safety reasons, the practice of tractors ploughing downhill has become the norm, particularly on the steeper slopes where a top-heavy tractor is less surefooted than the traditional mule. This change in land management has several consequences:

- Tillage is a major factor causing losses of soil organic matter (SOM) (Rasmussen and Collins, 1991). The process of repeatedly inverting and pulverizing soil exposes SOM to aeration and thus mineralization (Cannell and Hawes, 1994). While the impact of tillage leads to reduced biological and biochemical activity, the main factor is associated with aggregate destruction (Doran et al, 1998). In cultivated soils, a decline in SOM invariably leads to a decrease in soil porosity, an increase in bulk density (Tisdall and Oades, 1983), a decrease in surface infiltration, and subsequently an increase in runoff and erosion.
- Tillage-induced soil erosion (tillage erosion) causes a net downslope movement of soil material. .Although tillage erosion was recognized in the early 1940's, only within the past decade has the process been identified as a significant process in altering geomorphic features on the landscape (Lewis and Nyamulinda, 1996). The impact of tillage erosion can be observed by truncation of soil profiles in upper part of fields and at convex areas, while accumulation of soil occurs at bottom of fields and at concave landforms.
- The furrows created by up-and-down tillage are very conducive to stimulate water-induced soil erosion. As a result, rill and gully erosion is commonly observed during the rainy season.
- Mechanisation resulted in a reduced need for mules that traditionally were used for ploughing. As a consequence, there is now less requirement for animal fodder, such as barley, lentil and vetch.

Mechanised tillage had therefore radically increased the rate of land degradation. While tillage is seen as necessary to conserve soil moisture, to control weeds and to avoid grazing by sheep and goat, the key question is how to minimize the harmful effects of tillage while maintaining the beneficial effects.

The development of reduced or conservation tillage over the past few decades has demonstrated that tillage does not necessarily result in reduction of soil organic matter (SOM) or physical properties (Zibilske et al 2002; Franzluebbers 2002). In many instances, reduced tillage using appropriate land management resulted in an increase of soil carbon, thus contributing to soil stability and to carbon sequestration (Curtin et al 2000; Whitbread et al 2002). It is becoming increasingly recognized that, particularly in dryland agro-ecosystems, the increasing levels of SOM is critical as it impinges on each of soil physical, chemical, and biological processes.

Only recently, farmers on the steeper hillsides have become conscious of their increasingly unstable and declining yields. However, as orchards were already established, they could not install traditional terraces – which are established in other regions. Farmers generally realize the extent of soil erosion, but claim that the investments needed to conserve the soil are too costly. It became clear that land degradation could only be stopped by conservation systems that would enhance olive productivity in a cost-effective way.

The objectives of this study are twofold:

1. To find in association with farmers simple soil conservation measures which improving olive productivity in a feasible way under the present agro-ecological and socio-economic conditions.
2. To investigate the impact of land management packages on soil fertility, soil structural stability, water erosion and nutrient losses.

The study was run at farmer orchards at two experimental sites.

2. MATERIAL AND METHODS

2.1. Study area

The study commenced in 1997 at Yakhour village ($E\ 36^{o}\ 51^{/}\ 42^{//}$, $N\ 36^{o}\ 70^{/}\ 42^{//}$), which is located in the northwest of Syria, approximately 125 km northwest of Aleppo (Figure 1). The area is characterized by steep hillsides. The slopes tend to level out at the foot slopes due to the accumulation of gravelly slopewash and talus deposition. The altitude ranges between 500-700 m asl. The dominant soil order of the hillslopes is Entisols and the main soilscape units are Lithic Xerorthents and Xerorchrept (Louis Berger International 1982). The former are mainly medium to fine textured, mostly shallow soils of low and medium organic matter content occupying the hillsides. The latter soil type are well to moderately drained, very shallow, light grey to dark greyish brown, moderately fine textured, and occupying the narrow summits and the upper slopes.

The area has a Mediterranean type climate and receives an annual rainfall of 400-650 mm distributed between September to May. The mean annual temperature is 17^{o}C. The soil temperature regime is thermic and the moisture regime is xeric. The annual evaporation is approximately 1200-1600 mm.

The original vegetative cover of conifers and oaks has been subjected to strong anthropogenic changes, including clearing of the native since the beginning of the 19 century (De-Pauw 2001). Farmers have replaced native forest mainly with olive groves, as well as almond and walnut.

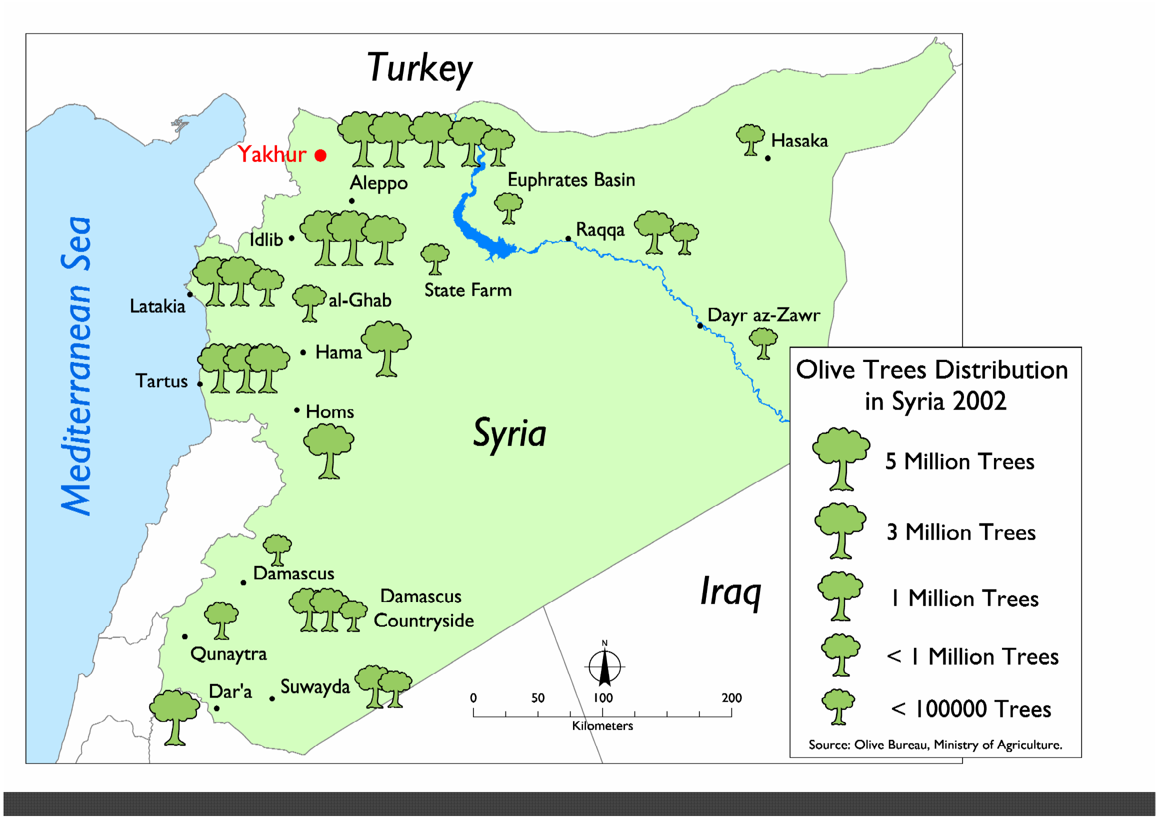

Figure 1. Olive trees distribution in Syria (Olive Bureau statistics, 2002) and location of Yakhour village in Northwest Syria.

2.2. The experimental sites and design

During farmer meetings, some alternative land management packages suited to the farmers' circumstances and their priorities were identified. Two village farmers, deliberately chosen because they were not the village's acknowledged top growers, each agreed to set aside an entire orchard for the experiments. The controlled on-farm experiments were designed and controlled by researchers, but the management was conducted by a local farmer.

Each field was mapped intensively in 2001 and individual trees ere identified. Each orchard was divided into three sections, with 75 trees in each of the two research treatments and 50 trees as control (farmer's management).

1. In the first orchard, 3 different 'agronomic packages' were tested:
    - "Vetch package": Vetch intercropping used as green manure (with an annual production of around 4 ton vetch biomass/ha), 2 tillage passes, and mineral fertilizer application.
    - "Manure package": Biennial incorporation of 4 ton/ha of fresh and contaminated sheep manure, 1 to 2 tillage passes, and mineral fertilizers application.
    - "Farmer package": None of the above treatments.

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2. In the second orchard, 3 different 'combined agronomic and terrace packages' were tested: This included the first package, combined with earthen, semi-lunar shaped water-harvesting terraces for each tree.

Ploughing was done by mule and faddan. Mineral fertilizer application was 400 kg/ha Ammonium Nitrate, 200 kg/ha TSP and 220 kg/ha Potassium Sulfate. More details of the management practices and a description of the structural (terrace) and agronomic packages at the two sites are described in Annex 1.

The slopes in the two experimental sites ranged between 25-45 %. In general, the soils are less than 30 cm thick, and at the upper slopes the limestone bedrock is found within 20 cm of the surface. The soils are light grey to dark greyish brown; moderately, fine textured, and contain a few angular limestone fragments (which occupy approximately 10% of the solum).

Topographic surveys were conducted during May 2002 and August 2003 on a 10 m grid within the catchment area of the two experimental sites. For site No. 1, the catchment for each Gerlach troughs was delineated and the catchment area was calculated by using SWAT 2000 of ArcView.

2.3. Field sampling and laboratory analysis:

In April 2002, the topsoil (0-20 cm) was sampled in all the main plots (i.e. packages) in the upper, middle, and lower zones of each plot. Three soil samples from each zones were combined into one sample. Samples were then sub-divided in two batches:

The first batch was dried in the shade solely to lose excess moisture and was sieved through various mesh sizes (10, 5, 4, 2, 1, 0.5, and 0.1 mm) with minimum vibration for adequate fragment separation with minimal abrasion (Braunack et al 1991) to determine dry aggregate size distribution (using a Retsch 3D series - Sieve Shaker; Kemper and Rosenau 1986). Geometric mean diameter (GMD) index was calculated to characterize soil fragment mass-size distribution (Klute, 1986). This parameter describes the actual aggregate size in log-normal distribution. Following dry sieving, three samples of 50 g of dry aggregates were taken proportionally to the total weight distributed on the different sieves. Samples were moistened slowly by micro-cracking on filter paper, which were placed on small dishes. After 30 minutes, wet-sieving was carried out for 2 minutes. Sieves of 2.0, 1.0, 0.5 and 0.20-mm mesh were used. Sieves were oscillated (amplitude 10 cm) 100 times, removed from the container and dry weight of the water-stable aggregates retained on a 0.5-mm sieve was determined to provide an assessment of macro-aggregation. The test was replicated three times for each soil sample.

The second batch of soil samples was passed through a 2-mm sieve for the determination of water stable aggregates, hydraulic conductivity, and other soil physical and chemical measurements. Three replicates of 50 grams of soil for each soil sample were wet-sieved to provide the percentage of water stable aggregates, or micro-aggregation (Rengasamy et al 1984). Five replicates of each soil sample (each 500 grams) were placed in plastic cylinders (80 mm diameter and 120 mm height) for determination of hydraulic conductivity, based on Klute (1986). The sieved soil was also used for determination of soil organic carbon (Anderson and Ingram, 1996), available Phosphorus (Olsen-Bicarbonate method), total Kjeldahl Nitrogen, inorganic Calcium Carbonate ($CaCO_3$) or Calcium Carbonate equivalent (CCE), and extractable Potassium (K) by the Ammonium Acetate Exchangeable test (Page, 1982). The pH and electrical conductivity (pH_w, and EC_w) were determined from a 1:1 (soil: water) suspension (Page, 1982).

Water runoff, soil and nutrient loss was collected by "Gerlach Troughs" from unbounded plots. They consisted of a 2 m wide collecting gutter, dug into the soil surface and connected to five splitters. One of the splitters was extended to a 1 m^3 collecting container. The site homogeneity was a main reason to construct the unbounded Gerlach troughs, i.e., no chance for minor depressions or rills which may affect the water flows was feasible.

The advantage of the unbounded plots is that cultivation and other farm operations could be conducted easily. Washed sediments and water runoff were collected and measured on daily records of accumulating rainfall erosive events Runoff and soil loss was assed as follows: Runoff water and suspended soil particles were stirred vigorously (to avoid the settling of large soil particles) and samples were collected in one or half-liter plastic flasks. Chemical and physical analyses were conducted to assess the nutrient loss, suspended fractions, and the runoff water quality.

Figure 2: The Gerlach Troughs in the plots of research site No.1. Each package was measured by two Gerlach troughs.

3. RESULTS

3.1. Impact of the packages on chemical properties of topsoil

After six years of conducting the experiments (2002), inputs of soil organic matter into the soil in the manure packages of the terraced and agronomic sites reached 27.3 ton ha^{-1}

and 13.4 ton ha^{-1} respectively While these inputs ranged from 3.5- 6.5 ton ha^{-1} for vetch packages at the two experimental sites (Table 1).

Measurements made during the spring of 2002 indicated that the manure and vetch packages induced changes in soil organic matter (SOM) (Table 1). The percentage of soil organic matter in the top 25 cm increased significantly by manure treatment (+ 28 to 59 %), followed by the vetch intercropped fields (+ 9 to 14%), compared farmer package (Table 1).

The highly built soil organic matter in the terraced treatment (+59%) compared with the agronomic treatment (+28%) after 6-years of running the experiment is likely relate to banning tillage, vegetation growth and biomass accumulation, and manure amendments. The increases in soil organic carbon may explain the changes of soil bulk density at both packages.

Values of extractable potassium, available phosphorus, organic nitrogen (Table 1) increased greatly as a result of the manure package and to a lesser extent by the vetch package, while the changes in the soil pH were small, since these changes are almost tardy.

Table 1: Soil chemical properties for the two studied sites with different packages (2002 sampling).

Location	Packages	Inputs of biomass	SOM	pH	E.C.(1:1)	$CaCO_3$	Olsen-P	Kjeld-N	NH4-N	NO3-N	Extr.K
		tons/ha	%	1:1	dS/m	%	- - - - - - - - - - - - - mg/kg				- - - - - - - - - - - - - -
Agronomic packages	Farmer	-	2.90	8.33	0.26	50.8	15.0	1289	6.8	14.3	82
	Vetch	6.5	3.32 (+14%)	8.17	0.39	50.8	18.9	1476	9.6	28.3	116
	Manure	13.4	3.70 (+28%)	8.20	0.87	50.7	69.0	1688	12.0	20.9	1082
Terraces with agronomic packages	Farmer	-	2.75	8.40	0.25	50.8	20.8	1237	4.8	14.5	79
	Vetch	3.5	2.99 (+9%)	8.17	0.37	50.7	35.7	1427	8.8	33.9	179
	Manure	27.3	4.38 (+59%)	8.23	0.49	50.53	95.3	2139	13.0	19.2	917
LSD (P= 0.01) for sites			0.48	0.14	0.21	0.11	14.1	243	2.3	11.4	234
LSD (P= 0.01) for treatment x site			0.39	0.12	0.16	0.09	11.5	198	1.8	19.4	191
C.V (%) =			0.68	0.20	0.29	0.15	19.9	.343	3.3	16.2	391
LSD (P= 0.01) for sites			11.2	1.30	35.7	0.20	25.4	4.2	19.5	40.3	45.2

3.2. Impact of the packages on physical properties of topsoil

The trends of water stable aggregate size were consistent with the previous results: 47.8 and 42.7% for manure and vetch packages at site 2, and 39.8 and 40.3 at site 1. At both sites, the water stable aggregate size at the farmer packages were only 37.5% (Table 2).

Sieved micro-aggregate size distribution generally agreed with the macro-aggregation, with the greatest values for the manure package, followed by the vetch and farmer packages. The smallest values for laboratory-measured hydraulic conductivity were observed with soil from the farmer packages at both sites (Table 2).

Table 2: Soil physical parameters of the topsoil (25cm) for the different packages (2002 sampling).

Location	Treatment	Soil organic matter (SOM) %	Soil bulk density g/cm[3]	GMD[1]	Inputs of carbon Tons/ha	Macro-aggregation[2]	Micro-aggregation[3]	Hydraulic Conductivity cm/h
Agronomic package	Zero	2.90	1.39	0.85	-	37.5	25.8	17.7
	Vetch	3.32 (+14%)	1.35	1.10	6.5	40.3	27.0	24.3
	Manure	3.70 (+28%)	1.34	1.20	13.4	39.8	26.2	22.1
Terraces with agronomic package	Zero	2.75	1.37	1.19	-	37.5	25.3	18.1
	Vetch	2.99 (+9%)	1.34	1.29	3.5	42.7	27.9	25.6
	Manure	4.38 (+59%)	1.29	1.33	27.3	47.8	32.9	35.2
LSD (P= 0.01) for treatments		0.48	0.04	0.11		5.4	3.2	7.65
LSD (P= 0.01) for sites		0.39	0.033	0.09		4.4	2.6	6.24
LSD (P= 0.01) for treatment x site		0.68	0.57	0.15		7.6	4.6	10.82
C.V (%) =		11.2	1.6	7.20		10.3	9.1	25.0

[1] Geometric mean diameter (= an index of dry aggregates distribution after sieving).

[2] Water stable aggregates retained on 0.5-mm sieve for the dry aggregate fractions.

[3] Water stable aggregates retained on 0.5-mm sieve for the disturbed soil samples < 2.0 mm.

3.3. Impact of the packages on runoff and soil erosion

During the years 2003 and 2004, the farmer package at site No.1 (unterraced site) caused the highest amounts of runoff water (2,909 m^3/ha/annum) and soil sediment (58 ton/ha/annum). These quantities were reduced with manure application (1,653 m^3 runoff/ha and 33 ton soil/ha), and were the lowest with the vetch intercropping treatment (1,238 m^3 runoff/ha and 14 ton soil/ha) (Table 3).

Table 3. Averages of water runoff and sediment yield of the sub-catchment of the different packages during the 2001- 2004 rainy seasons.

		Treatments					
		Farmer (control)		Vetch		Manure	
	Erosive	Water	soil	Water	soil	Water	soil
Season	events[1]	$m^3\ ha^{-1}$	$t\ ha^{-1}$	$m^3\ ha^{-1}$	$t\ ha^{-1}$	$m^3\ ha^{-1}$	$t\ ha^{-1}$
2001- 2002	18	1248.9	81	415.5	1.3	543.1	2.3
2002- 2003	35	2693.3	15.1	969.1	4.7	1297.2	6.5
2003- 2004	29	2908.9	58.3	1237.7	14.1	1652.5	32.7
Averages	27	2283.7	51.5	874.1	6.7	3	14

[1] daily records based on accumulating rainfall erosive events

The nutrient and organic matter contents of the sludge and suspended materials eroded from the different packages at the unterraced site during 2002 and 2003 were analysed (Table 4). The soil organic matter content of the eroded material in the farmer packages was the highest (3.48 and 3.28%) versus 2.9% as compared to the *in situ* soil (Tables 1 and 4). SOM of the eroded soil of the manure and vetch packages ranged between 3.2-3.6%, compared with 3.3-3.7% of the in-situ soil. The loss of organic nitrogen followed the same trend as the organic matter losses. The values of the other nutrients in the sediment, such as available phosphorus and extractable potassium were not different from the initial soil values. The dissolved nutrient quantities collected in the harvesting water tanks is quite low (Table 5).

The manure package lost was 854 kg ha^{-1} of soil organic matter and 37 kg ha^{-1} of organic nitrogen. The lowest total nutrient loss was from the vetch intercropping treatment (Table 6).

The texture of the detached soil is comparable with that of the initial soil textures (Table 7). Slight changes were depicted for the clay fractions. Clay fraction of the sediment the manure package slightly declined compared with the in-situ soil, while it was the opposite for the farmer and vetch packages.

Table 4. Nutrient and organic matter contents of the eroded soil in the un-terraced site during 2002 and 2003 seasons.

Packages	Season	SOM %	Norg	Pav mg/kg	Kextr
Manure	2002	2.40	1360	47.7	172.8
	2003	2.61	1132	17.7	123.3
Vetch	2002	2.20	1451	55.6	181.9
	2003	2.61	1280	22.4	130.9
Farmer	2002	3.28	1700	44.2	146.9
	2003	3.48	1664	16.7	138.8

Table 5: Mean values of dissolved nutrients, cations, anions, pH_w, and EC in the runoff water, for two runoff events in March and May, 2002.

Package	Month	pHw	E.C	K^+	Na^+	Ca^+	Mg^+	Cl^-	SO_4^{--}	HCO3	CO3	NH4+	NO3-
		%	dS/m	- Mg/l -									
Manure	March	8.2	0.3	0.8	6.8	57.3	19.5	63.5	39.5	122	12.0	1.0	2.6
	May	7.8	0.5	7.3	180	50.4	4.0	71.7	146.6	107	6.0	1.1	11.9
Vetch	March	8.1	0.3	1.5	6.8	59.9	11.3	64.8	27.2	110	15.0	1.4	2.9
	May	8.0	0.3	2.6	2.2	52.5	5.1	28.7	38.8	132	6.0	0.9	1.9
Farmer	March	8.1	0.3	0.8	9.5	57.3	22.4	64.2	23.9	146	12.0	1.0	2.4
	May	8.0	0.3	2.7	2.2	50.4	9.2	30.2	50.3	113	6.0	0.6	5.0

Table 6. Comparative quantities of organic matter, organic and mineral nitrogen discharged as a result of soil sediment and runoff water for the different packages (during 2002 and 2003 seasons).

Treatments	Year	Soil sediments		Runoff water
		Organic matter	Organic nitrogen	Mineral nitrogen
		- - - - - - - - - - - - - - kg/ ha^{-1} - - - - - - - - - - - - - - -		
Manure	2002	156	8.4	4.4
	2003	854	37.0	-
Vetch	2002	103.	6.8	4.2
	2003	368	18.0	-
Farmer	2002	495	25.7	9.7
	2003	2029	97.0	-

Table 7: Soil texture of the original soil and the eroded soil for the different packages during 2002-2003 seasons.

Particles	Clay	Silt	Very fine sand	Fine sand	Medium and coarse sand	Total sand
Fraction sizes (mm)	< 0.002	0.002- 0.05	0.05- 0.1	0.1- 0.200	0.200 - 2.0	0.05- 2.0
Packages	- - - - - - - - - - - - - - - - - *In situ* soil (%) -					
Manure	34.6	39.6	7.5	8.9	9.5	25.8
Vetch	35.0	40.0	7.6	8.7	8.7	24.9
Farmer	35.6	39.5	7.3	8.7	8.9	24.9
	- - - - - - - - - - - - - - - - - -Eroded soil (%) - - - - - - - - - - - - - - - - - - -					
Manure	32.1	46.3	7.9	4.6	9.0	21.6
Vetch	42.5	37.7	3.8	3.4	12.5	19.8
Farmer	45.0	38.0	3.4	3.1	10.4	17.0

3.3. Impact of the packages on olive yield

The olive trees in the unterraced vetch package site had the highest average olive productivity for 2000 and 2002 (24-30 kg/tree), followed by manure package (19-24 kg/tree) the farmer package (11-13 kg/tree) (Fig. 3). The olives from the manure and vetch package were also larger in size and matured earlier than those from the farmer package.

The olive trees at terraced site with manure and vetch packages had a yield varying between 20-25 kg/tree during 2000 and 2002. During 1998 harvest (x years after start of the experiment), there were only little differences (probably not significant?) between the packages. The olive productivity of the farmer package field remained stable around 15 kg/tree (Fig. 4).

Improved soil quality reflected in better quality of the olive fruits from the manure and vetch packages. Olive fruits were larger in size and were earlier maturing than those from the farmer package (Figure 5).

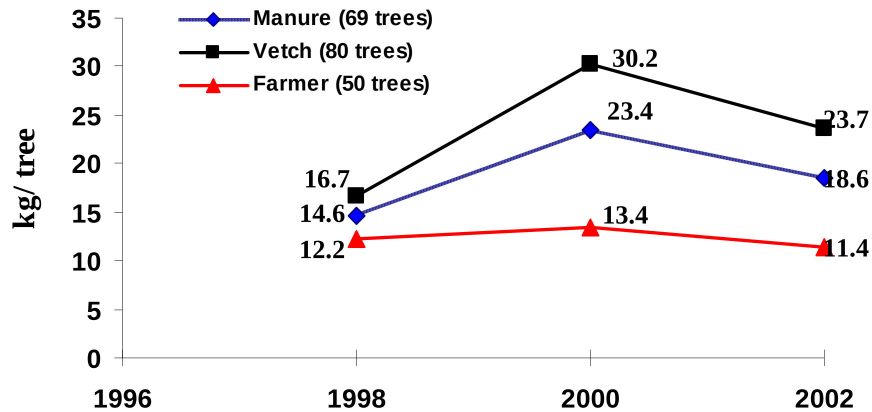

Figure 3. Average olive fruit production per tree for the three packages at the unterraced site for the fruit bearing seasons of 1998, 2000, and 2002.

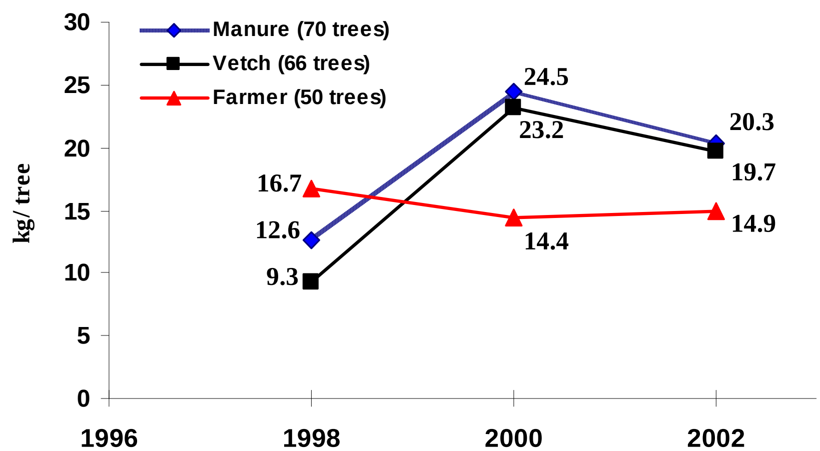

Figure 4. Average olive fruit production per tree for the three treatments in the terraced site for the fruit bearing seasons during 1998, 2000 and 2002

Figure 5. Olive fruits harvested in November 2004 from the farmer, vetch and manure packages. The olives from the manure and vetch packages were larger in size and were earlier maturing than those from the farmer package.

4. CONCLUSIONS & DISCUSSION

The farmer package (from the time the olives were planted in the 1920s) resulted in reduced soil quality, and thus lowered the productivity of the olive trees. After 5 years, the applied soil and water conservation packages have led to a marked improvement of olive productivity (+ 25 - 75%) compared to the farmer package. This yield increase is caused by a combination of factors.

The biennial application of sheep manure with a rate of 30 kg/tree (or 4.5 ton ha^{-1}) and an annual average of 4 ton ha^{-1} of green manuring of vetch biomass incorporated with the soil (combined with the other treatments) enhanced SOM. The increase in soil organic matter (SOM) content helped to lower the soil pH slightly. In the alkaline conditions (pH > 8) prevailing on these slopes, some nutrients such as phosphorus will become more readily available. The GMD, macro-aggregation, micro-aggregation, hydraulic conductivity indices correlated well with the changes in management practices. The improved soil parameters and enhanced soil cover, resulted in a decline of soil erosion and runoff. Though the vetch was grown for only a limited period (November- April) the increased vegetative cover and the established root system led to a significant reduction of overland flow, erosion and nutrient losses.

Tillage is a main driver for land degradation in the Yakhour village, causing erosion to be omni-present. Reduction of soil tillage to two passes, in association with the planting of vetch and possibly two applications of sheep manure (after harvesting and perhaps at the end of spring) will certainly lead to improved soil organic matter levels.

Some may consider the changes small and slow. However, they have certainly improved olive productivity. The farmers' current land management options will not succeed in protecting the land on hillsides and will certainly lead to reduced olive productivity. Improving olive productivity will increase the income of the farmers and subsequently will sustain both livelihoods, the land and the environment.

As a follow-up, a village meeting was organized in December 2003 to evaluate the trails and to list all other possible options for sustainable land management in steep olive orchards. A few of these options were selected by interested farmers for testing on their farms. They include: vetch intercropping and conservation tillage (reduced tillage or two passes/year, minimum tillage or one pass/year, no tillage), and natural vegetation strips. These measures are now tested by farmers, and monitored by SCLM staff of ICARDA.

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Annex 1: Work-sheet for the agronomic and terrace packages applied in the experimental sites in Yakhour, northwestern Syria.

	Site 2 - Terraced			**Site 1 – Un-terraced**		
	Farmer Package	**Manure package**	**Vetch package**	**Farmer package**	**Manure package**	**Vetch package**
Soil tillage (by mule across the slope)	Autumn-after harvesting, winter and spring	No tillage; earthen, semi-lunar shaped water-harvesting bunds on lower side each tree	Autumn and spring across entire field; no dams or embankments round trees	Autumn, winter and spring	Autumn and spring only between trees	Autumn and spring across entire field
Cover crop	None	None	Vetch intercropping, ploughed during April **	None	None	Vetch intercropping, ploughed during April
Fertilizer/ manure	None	Fertilizers *under canopy. Manure every 2 years on entire area	Fertilizer on entire area. No manure	None	Fertilizers *under canopy. Manure every 2 years on entire area	Fertilizer under tree canopy; no manure
Weed control	Soil tillage only	Herbicide when needed on basin area	No control; weeds grazed	Soil tillage only	Herbicide on untilled area as needed	Soil tillage only
Pest control	None	Insect traps (May/June); spray as needed	Insect traps (May/June); spray as needed	None	Insect traps (May/June); spray as needed	Insect traps (May/June); spray as needed
Pruning	Hard annual pruning	Light spring; summer cut unproductive branches	Light spring; summer cut unproductive branches	Hard annual pruning	Light spring; summer cut unproductive branches	Light spring; summer cut unproductive branches
Harvesting	By hand; no sticks; ground collection	Hand; no sticks; nets under trees	Hand; no sticks; nets under trees	By hand; no sticks; ground collection	Hand; no sticks; nets under trees	Hand; no sticks; nets under trees

* Fertilizer application per tree, before the vegetative growth, according to Olive Bureau recommendation:

Mineral (annual): - Ammonium nitrate 33%- 1-2 kg/tree applied at two rates in November and February
- Triple super phosphate 46%, and 1 kg/tree applied in November
- Potassium sulfate 50%, and 1 kg/tree applied in November

Organic (biennial**):** **-** Sheep manure (30 kg/tree)

** Local variety intercropped with olives and incorporated in soil as green manure and 10 kg of P2O5/ 1000m2 were applied to vetch before planting.