Strategies to sustain productivity of olive groves on steep slopes in the northwest of the Syrian Arab Republic

ABSTRACT

In the marginal Mediterranean areas of the northwest of the Syrian Arab Republic, land degradation is a serious problem, particularly on vulnerable agricultural land. The traditional land-husbandry practices have not kept pace with the intensification and expansion of olive production into steeper areas. In these areas, soil erosion by water and tillage is widespread, especially where the soil is left bare as result of intensive clear-tillage and where no land-conservation measures are applied. These conditions are prevalent in the northwestern hills of the Syrian Arab Republic.

In 1997, a small research project was started in Yakhour, a typical olive-producing village in the area. The aim was to develop, test and refine options for better land management that have the potential to stabilize and increase the productivity of the olive groves. The research followed a farmer-participatory approach that involved a large part of the community for selection of options and conducting controlled on-farm experiments with farmer consultation. Socio-economic studies and a survey of the land-users' perceptions of land degradation and constraints for the adoption of land-conservation measures confirmed that the land users were aware of the serious degradation of their agricultural land. Rainfall simulation studies revealed the high erodibility of the soils in the area.

In association with the farmers, two different comprehensive packages of soil- and water-conservation measures were designed for the olive groves. One was an "agronomic package" designed to increase vegetation soil cover (by vetch intercropping), reduce soil disturbance (by minimizing tillage), and enhance soil structure (by incorporating organic materials) and 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 bunds. This package was applied in addition to the first package. Emphasis was placed on those soil- and land-management practices that reduce soil erosion and help restore soil fertility.

After five years, the conservation measures had led to a marked improvement in the soil in terms of fertility, organic carbon content, and structure stability, while soil

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and nutrient losses had been reduced. The improved soil parameters were associated with a marked increase in olive productivity of 25–75 percent. As a result of the close cooperation with the villagers, the suitability of the measures to reduce soil erosion was successful and vetch intercropping has expanded in the village.

INTRODUCTION

Agriculture in West Asia has evolved over 10 000 years in the area known as the Fertile Crescent (White, 1970; Watson, 1974). This agriculture has been based on cool-season winter rainfall (Cooper *et al*., 1987). 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 that can grow on poor, shallow soils and will survive periods of low rainfall (Olive Bureau, 2001).

Since ancient times, the northwest part of the Syrian Arab Republic 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. For Syrian agriculture, in the west and northwest, olive trees are the major source of income for small-scale farmers. The area planted with olives has increased substantially in recent decades and now totals 71 million ha of olive trees (51 million ha of which are fruit bearing) with a total production of 866 000 tonnes in 2002 (Olive Bureau, 2000).

Olive production in the northwest of the Syrian Arab Republic has created many opportunities for local farmers, including the provision of an easy-to-manage cash crop, labour availability during harvest, and a tree that is tolerant to both drought and severe conditions. The main causes of land degradation in the area are a combination of natural, social and financial inputs. One important reason is that olive production has reduced the area and number of intensive traditional crops, so many farmers have started growing olives. Other factors leading to land degradation include the introduction of government policies that have encouraged olive production on marginal lands and the increase in demand (by farmers) for cash crops.

Mechanization in olive production commenced in the 1970s. One important outcome was the reduced need for animals (particularly mules) that had traditionally been used for ploughing. As a consequence, there is now less requirement for animal fodder, e.g. barley, lentil and vetch stubble. Since the advent of mechanization, the practice of tractors ploughing downhill has become the norm (for safety reasons), particularly on the steeper slopes where a top-heavy tractor is less surefooted than the traditional mule. This has radically increased land degradation, reducing soil depths from 1 m to 25 cm in places. Although tillage is still seen as necessary for conserving soil moisture and controlling weeds, the issue is to minimize any harmful effects of tillage while maintaining the beneficial effects.

The development of reduced or conservation tillage over the past few decades has demonstrated that soil organic matter (SOM) need not be reduced or physical properties degraded despite tillage (Zibilske, Bradford and Smart, 2002; Franzluebbers, 2002). Indeed, in many instances, reduced tillage has been shown to increase soil carbon, thus contributing to soil stability and to carbon sequestration (Curtin *et al*., 2000). Within reduced-tillage systems, the manipulation of cropping systems using appropriate land management can also enhance SOM (Whitbread, Blair and Lefroy, 2002) and, thus, improve soil quality, resilience and sustainability. It is becoming increasingly recognized that, particularly in dryland agro-ecosystems, increasing the level of SOM is critical as it impinges on the physical, chemical, and biological processes of the soil. In cultivated soils, a decline in SOM invariably leads to a decrease in soil porosity and related parameters and an increase in bulk density (Tisdall and Oades, 1983). Under rainfed conditions, a decline in SOM leads to decreases in surface infiltration and, through the profile, hydraulic conductivity, with subsequent increased runoff and erosion.

Tillage continues to be a major factor causing SOM loss (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, Elliott and Paustian, 1998). Only recently, have farmers on the steeper hillsides become conscious of their increasingly unstable and declining yields. They failed to identify degradation as a real problem, hence, they did not implement traditional terracing and other conservation techniques already established in other regions. Farmers did realize the extent of erosion, but claimed that the investments needed to conserve the soil were too costly. It became clear that land degradation could only be stopped by conservation systems that would not only be seen to enhance olive productivity but also increase income for the farmers.

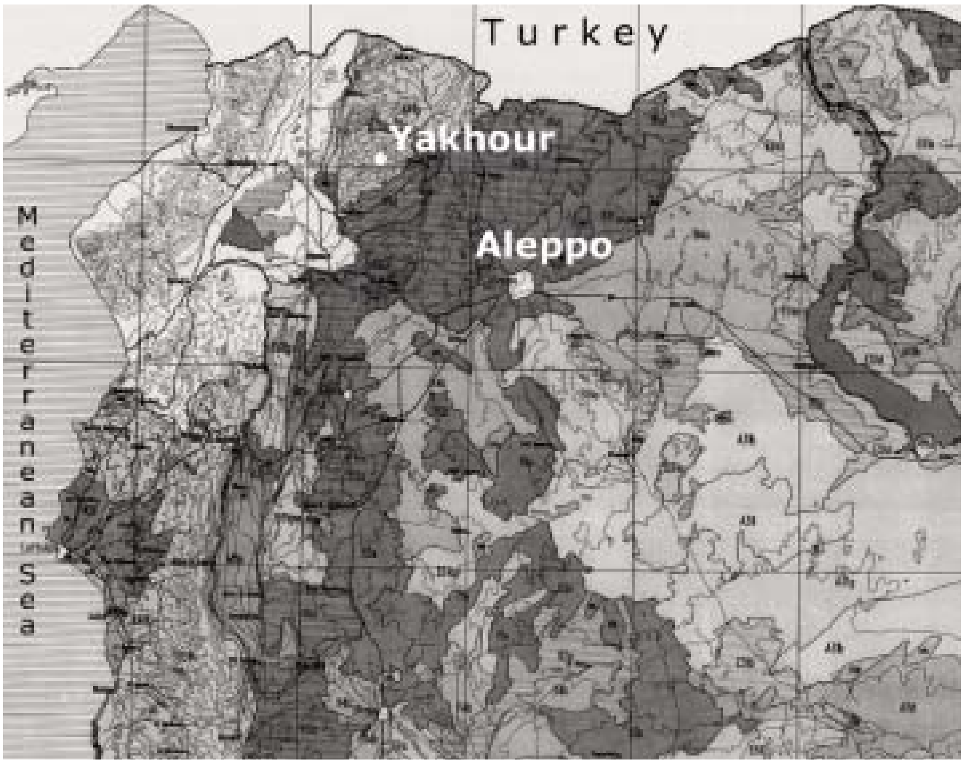
The objectives of this study are twofold: (i) evaluate (in association with farmers) different land-management options for protecting the hillsides in order to improve agricultural productivity, livelihoods and agro-ecosystems; and (ii) investigate the effect of applying these packages of land-management systems on soil fertility, soil structural stability, soil-water erosion, and soil and nutrient loss by water erosion.

MATERIALS AND METHODS

Study site

The study commenced in 1997, in the village of Yakhour in the northwest of the Syrian Arab Republic, close to Turkey, and about 125 km by car northwest of Aleppo (Figure 1). The area is typified by steep hillsides with flat divides and deeply incised

FIGURE 1
A portion of the FAO soil map of the northwest of the Syrian Arab Republic, showing the location of Yakhour village



valleys. The valleys are generally narrow, and in some sections, they are canyon-shaped. The topography tends to level out at the footslopes because of the accumulation of gravelly slopewash and talus deposits.

Climate and topography

The area has a Mediterranean-type climate, the altitude is about 500–700 m above sea level, and it receives an annual rainfall of 400–650 mm, concentrated between September and June. The mean annual temperature is 17 °C. The soil temperature regime is thermic and the moisture is xeric. The annual evaporation is about 1 200–1 600 mm.

Soils and vegetative cover

Entisols constitute the dominant soil order of the hillslopes, and the main soilscape units are lithic xerorothents and xerorochrept (Louis Berger International, 1982). The former are mainly medium-to fine-textured, mostly shallow soils of low and medium organic matter content, and the latter are well- to moderately drained, very shallow, light grey to dark greyish-brown, moderately fine-textured soils occupying the narrow summits and the upper slopes. The slopes in the two experimental sites range between 25 and 45 percent. In general, the soils are less than 30 cm thick, light grey to dark greyish-brown, and moderately fine-textured. The soils contain a few angular limestone fragments, which occupy approximately 10 percent of the solum. The limestone bedrock is found within 20 cm of the surface on the upper slopes.

The vegetative cover has been subjected to strong anthropogenic changes, including clearing of the native forest from about 1910 (De-Pauw, 2001). In the ensuing period, farmers have replaced native forest with olive groves, as well as almond, walnut and different forestry plantations.

Exploratory research

Socio-economic surveys in the olive-growing area of the northwest of the Syrian Arab Republic indicated that environmental concerns, such as soil erosion, were of low priority to the farmers. Their immediate interest was to secure and increase olive production with regular backstopping from the local team from the International Center for Agricultural Research in the Dry Areas (ICARDA).

Project design

Two farmers, deliberately chosen because they were not the acknowledged top growers in the village, each agreed to set aside an entire field for the experiments. Each field was divided into three sections, with 75 trees in each of the two research treatments and 50 trees in the farmer's own area. Each field was mapped intensively in 2001 and individual trees identified.

The details of the site management and the description of the structural and agronomic applied treatments in the different treatments (detailed in (Table 1), are summarized here:

- ➢ Site 1: Earthen semi-lunar waterharvesting bunds (akin to terraces) on a steep slope (40–45 percent). The main treatments were:
  - Treatment 1: terrace-like, no-tillage but with mineral and organic nutrient amendments through biannual sheep manure and annual fertilizer application,
  - Treatment 2: minimum tillage by Faddan (animal traction), two passes per year before planting and after harvesting the vetch,
  - Farmer practices: normal tillage by Faddan, 4–6 passes per year without any nutrient amendment;
- ➢ Site 2: Unterraced with moderate slope (24 percent). The main treatments were:
  - Treatment 1: two tillage passes with nutrient amendment through biannual manure and annual fertilizer application,

TABLE 1
Olive management comparisons by the ICARDA and Syrian Olive Bureau, Yakhour, the Syrian Arab Republic

	Site 1 - Terraced			Site 2 - Unterraced		
	Farmer Practice	**Treatment 1**	**Treatment 2**	**Farmer Practice**	**Treatment 1**	**Treatment 2**
Soil tillage (by mule across the slope)	Autumn, winter and spring	No tillage; small dam 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 outside tree canopy; harrowed in April **	None	None	Vetch; ploughed in at spring tillage (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

Notes:
* Fertilizer application per tree, before the vegetative growth, according to Olive Bureau recommendation: mineral (annual): ammonium nitrate 33 percent – 1–2 kg of nitrogen at two rates in November and February, triple super phosphate 46 percent, and 1 kg of P_2O_5, potassium sulphate 50 percent – 1 kg of K_2SO_4; organic (biannual): sheep manure (30 kg/tree)
** Local variety, planted in November and harvested in April; 10 kg P_2O_5/1 000m^2 were applied to vetch before planting.

- Treatment 2: two tillage passes with nutrient amendment through a forage legume (vetch) with annual fertilizer application,
- Farmer practices: conventional tillage (4–6 ploughs) without any nutrient amendment.

Field sampling and laboratory analysis

All main plots (treatment) were sampled (0–20 cm) in April 2002 in the upper, middle, and lower parts of the plot in order to characterize the sites. Three combined soil samples were taken from each area of the plots, along the contour. Samples were then subdivided in two batches. The samples of the first batch were dried in the shade solely to lose excess moisture, but care was taken not to dry out the soil excessively. The first batch of soil samples 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 to determine dry-aggregate size distribution using a Retsch 3D series sieve shaker (Kemper and Rosenau, 1986). The results were calculated by geometric mean diameter (GMD) – the antilog of the sieve size at 50-percent passing.

Subsequently, proportional amounts of the dry-sieved aggregates were taken for wet-sieving, thus providing an index of macroaggregation. Fifty grams of soil sample were moistened slowly on filter paper placed on small dishes. After 30 minutes, the wet sieving process was conducted for 2 minutes with the sieves being shaken 100 times. The sieves were then removed from the tank and the aggregates taken from each sieve to measure the dry weight. Each test used four sieves of 2, 1, 0.5 and 0.2-mm mesh. The test was replicated three times for each soil sample.

Plate 1
The layout of the Gerlach troughs in the plots of the research site. Two Gerlach troughs, consisting of 2 m of collecting gutters, were dug into the soil at the bottom of slope position in each of the manure, vetch, and farmer-practice treatments

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 g of soil for each soil sample were wet sieved to provide the percentage of water stable aggregates, or microaggregation. Five replicates of each soil sample (each 500 g) were placed in plastic cylinders (80 mm in diameter and 120 mm tall) for determination of hydraulic conductivity, based on Klute (1986). The sieved soil was also used for determination of soil organic carbon (Walkley and Black, 1934), available phosphorus (Olsen-Bicarbonate method), total Kjeldahl nitrogen, inorganic calcium carbonate ($CaCO_3$) or calcium carbonate equivalent (CCE), and extractable potassium by the ammonium acetate exchangeable test (Ryan, Estefan and Rashid, 2001). The pH and electrical conductivity (pH_w, and EC_w) were determined from a 1:1 (soil–water) suspension.

Water runoff, soil and nutrient loss were determined in simple unbounded plots, commonly referred to as “Gerlach troughs” (after their inventor). They consisted of a 2-m collecting gutter, dug into the soil surface and connected to five splitters likely to interfere to some extent with the flow conditions so there is a possibility of sediment being deposited within the system. One of them was extended to a 1-m^3 collecting container on the downstream side. The site homogeneity reduced the chance occurrence of minor depressions or rills and justified the sophistication in the construction of the gutters and containers, cost and construction, and reduced the number of replications to two unbounded plots for each treatment (Plate 1).

The unbounded plots were constructed in proper settings so that it was still possible to apply cultivation and other farm operations. Frequency of recording was based on accumulated rainfall erosive events in daily records that were aggregated into yearly totals. Respective samples were collected in one-litre or half-litre plastic flasks, being a mixture of water and suspended soil particles taken after stirring the mixture vigorously to avoid the settling of large soil particles and to keep the materials in suspension for estimating runoff and soil loss. Chemical and physical analyses were conducted to assess the nutrient loss, sludge and suspension texture and the runoff water quality.

Topographic survey

Topographic surveys were conducted in May 2002 and August 2003 on a 10-m grid within the catchment area of the two experimental sites. For Site 2, where the Gerlach troughs were mounted, the catchment was delineated and the slope length for two replicates of collecting gutters in each treatment was calculated and aligned with a 1-m sectional length (using SWAT 2000 for ArcView).

RESULTS

Measurements made in spring 2002 indicated that the application of sheep manure, incorporation of green manure (vetch intercropping) and chemical fertilization induced

TABLE 2
Average of soil physical parameters measured for different treatments in 2002

Location	Treatment	GMD[1]	Organic matter	Macro-aggregation[2]	Micro-aggregation[3]	Hydraulic conductivity
				(%)		(cm/h)
Site 1	Farmer	1.19	2.75	37.5	25.3	18.1
	Vetch	1.29	2.99	42.7	27.9	25.6
	Manure	1.33	4.38	47.8	32.9	35.2
Site 2	Farmer	0.85	2.90	37.5	25.8	17.7
	Vetch	1.10	3.32	40.3	27.0	24.3
	Manure	1.20	3.70	39.8	26.2	22.1
P (treatment)=		0.001	< 0.001	0.071	0.059	0.031
L.S.D. (treatments) =		0.11	0.48	5.4	3.2	7.65
L.S.D. (site) =		0.09	0.39	4.4	2.6	6.24
L.S.D. (treatments * site) =		0.15	0.68	7.6	4.6	10.82
C.V. (%) =		7.20	11.2	10.3	9.1	25.0

[1] Geometric mean diameter.
[2] Water-stable aggregate retained on 2-mm sieve.
[3] Water-stable aggregate retained on 0.2-mm sieve.

changes in SOM, and that these differences varied with imposed treatments (Tables 2 and 3).

In terms of the largest, water-stable aggregate size, sieved from the samples, the trends were consistent for the two sites and treatments. i.e. 47.8 and 42.7 percent with manure application and vetch in Site 1, and 39.8 and 40.3 in Site 2, and at each site reducing to 37.5 percent with farmer practice (Table 2).

Sieved microaggregate-size distribution generally agreed with the macroaggregation, with the greatest values for manure then vetch or green manure and the least being the farmer practices.

The lowest values for laboratory-measured hydraulic conductivity were observed with soil from the farmer practices in both sites, with the green manure treatments and sheep manure treatment in Site 2, together with the sheep manure treatment in the terrace site providing the greatest conductivities (Table 2).

Chemical analyses of the soil from the various treatments paralleled differences observed for the increases in SOM and related indices of soil structural and hydraulic properties (Table 3). Values of extractable potassium, available phosphorus, organic nitrogen and SOM increased greatly as a result of sheep manuring and less with vetch intercropping. The pattern for SOM content was similar for both sites being greatest in the sheep manure treatment (Table 3). With the sheep manure application in the terraced site, the increase was marginal (4.38 percent), and (3.73 percent) in the second site, and this remained the least in the farmer practice (2.75 and 2.9 percent) in both sites. The increase in SOM with the vetch intercropping in Site 2 was high (3.32 percent), but increased slightly in Site 1 (2.99 percent). Of concern were the changes in soil pH (Table 3), particularly the increased alkalinity in the manure and vetch intercropping treatments at both sites.

Measurements of water runoff and sediment yield (on the unterraced site) were calculated for four rainy seasons (2002–04). Data derived from accumulating rainfall erosive events during the whole rainy season (principally in 2003 and 2004) showed enormous water erosion (2 909 m^3/ha) combined with 58.3 tonnes/ha of sediment movement (loss) in the farmer treatment (Table 4). These quantities were reduced (to 1 653 m^3/ha and 1 297 tonnes/ha) with manure application and were the least with the vetch intercropping treatment (1 238 m^3/ha and 969 tonnes/ha). Moreover, analysis

TABLE 3

Average of soil chemical properties for the two sites with different treatments during 2002

Location	Treatment		pH (1:1)	E.C.(1:1) (dS/m)	O.M. (%)	$CaCO_3$ (%)	Olsen-P (ppm)	Kjeld-N (ppm)	NH_4-N (ppm)	NO_3-N (ppm)	Extr. K (ppm)
Site 1	Farmer	Upper part	8.4	0.26	2.88	50.8	17.7	1 297	4.9	14.2	77.1
		Middle part	8.5	0.24	2.77	50.8	24.9	1 241	5.2	15.4	89.1
		Lower part	8.3	0.26	2.59	50.8	19.9	1 174	4.4	13.9	71.4
	Vetch	Upper part	8.1	0.47	3.69	50.5	59.2	1 780	8.9	48.2	239.8
		Middle part	8.2	0.31	2.70	50.8	39.4	1 299	7.8	25.3	181.0
		Lower part	8.2	0.33	2.59	50.8	20.6	1 202	9.7	28.1	115.9
	Terraces or manure	Upper part	8.2	0.52	4.54	50.5	107.2	2 189	10.8	21.1	771.6
		Middle part	8.2	0.37	4.04	50.5	95.8	1 968	11.0	8.0	661.6
		Lower part	8.3	0.59	4.54	50.5	83.0	2 259	17.1	28.5	1 323.2
Site 2	Farmer	Upper part	8.2	0.29	2.59	50.8	11.1	1 145	6.0	15.8	55.9
		Middle part	8.3	0.27	2.98	50.8	17.2	1 376	8.5	13.9	102.0
		Lower part	8.5	0.21	3.12	50.8	16.7	1 346	5.8	13.2	89.1
	Vetch	Upper part	8.2	0.37	3.02	50.8	14.0	1 310	8.2	17.9	77.1
		Middle part	8.3	0.25	3.30	50.8	16.7	1 451	10.8	25.7	115.9
		Lower part	8.0	0.56	3.65	50.8	26.0	1 640	9.8	41.4	154.8
	Manure	Upper part	8.2	0.55	4.15	50.8	68.1	1 883	9.9	15.0	752.6
		Middle part	8.3	1.12	3.30	50.8	61.6	1 494	12.0	17.1	1 253.7
		Lower part	8.1	0.93	3.65	50.5	77.4	1 686	14.0	33.6	1 106.5
Site 1	Farmer		8.40	0.25	2.75	50.77	20.8	1 237	4.8	14.5	79
	Vetch		8.17	0.37	2.99	50.69	35.7	1 427	8.8	33.9	179
	Manure		8.23	0.49	4.38	50.53	95.3	2 139	13.0	19.2	917
Site 2	Farmer		8.33	0.26	2.90	50.77	15.0	1 289	6.8	14.3	82
	Vetch		8.17	0.39	3.32	50.77	18.9	1 476	9.6	28.3	116
	Manure		8.20	0.87	3.70	50.69	69.0	1 688	12.0	20.9	1 082
P (treatment) =			0.027	0.020	< 0.001	0.20	< 0.001	< 0.001	< 0.001	0.025	< 0.001
L.S.D. (treatments) =			0.14	0.21	0.48	0.11	14.1	243	2.3	11.4	234
L.S.D. (site) =			0.12	0.16	0.39	0.09	11.5	198	1.8	19.4	191
L.S.D. (treatments * site) =			0.20	0.29	0.68	0.15	19.9	0.343	3.3	16.2	391
C.V. (%) =			1.30	35.7	11.2	0.20	25.4	4.2	19.5	40.3	45.2

of the nutrient and organic matter contents of the sludge and suspended materials harvested with the different treatments in the unterraced site during 2002 and 2003 demonstrated the extent of nutrient loss with farmer practices (Table 5).

Discharged nutrient and organic matter of the sludge and suspended materials harvested with different treatments in the unterraced site during 2002 and 2003 are presented in Table 5. The SOM content of the detached materials in the farmer-practice treatments represents an increase (3.48 and 3.28 percent) versus 2.9 percent as assessed in the main soil (Tables 2 and 5). Values of organic matter in the discharge were less in the sheep manuring and vetch intercropping treatments which ranged between 3.2 and 3.6 percent compared with 3.3–3.7 percent of the treatment soil. It would appear that the discharge of organic nitrogen had the same trend as the organic matter redistribution.

TABLE 4

Water runoff and sediment yield per hectare of the subcatchment with different treatments during the 2000–04 rainy seasons

		Treatment					
		Farmer (control)		Vetch		Manure	
Season	Erosive events[1]	Water (m³/ha)	Soil (tonnes/ha)	Water (m³/ha)	Soil (tonnes/ha)	Water (m³/ha)	Soil (tonnes/ha)
2000–01	5	507.8	11.9	37.9	0.2	166.7	3.1
2001–02	18	1 248.9	81	415.5	1.3	543.1	2.3
2002–03	35	2 693.3	15.1	969.1	4.7	1 297.2	6.5
2003–04	292[2]	2 908.9	58.3	1 237.7	14.1	1 652.5	32.7

[1] Daily records based on accumulating rainfall erosive events.

[2] Up to date (25 April 2004).

TABLE 5

Nutrient and organic matter of the discharged materials harvested with different treatments in the unterraced site during 2002 and 2003 seasons

		O.M.	$CaCO_3$	Kjel-N	Olsen-P	Extr. K
Treatments	Season	(%)			(ppm)	
Manure	2002	2.40	53.9	1 360	47.7	172.8
	2003	2.61	53.6	1 132	17.7	123.3
Vetch	2002	2.20	53.9	1 451	55.6	181.9
	2003	2.61	53.1	1 280	22.4	130.9
Farmer	2002	3.28	54.1	1 700	44.2	146.9
	2003	3.48	53.1	1 664	16.7	138.8

TABLE 6

Mean values of dissolved nutrients, cations, anions, pH_w, and EC in the runoff water, retained in the harvesting tanks for two runoff events in March and May 2002 for the different treatments

		pHw	E.C. (1:1)	K^+	Na^+	Ca^+	Mg^+	Cl^-	SO_4^{--}	HCO_3^-	CO_3^-	NH_4-N	NO_3-N
Treat.			(%)				(dS/m)					(ppm)	
Manure	Mar.	8.2	0.3	0.8	6.8	57.3	19.5	63.5	39.5	122.0	12.0	1.0	2.6
	May	7.8	0.5	7.3	180	50.4	4.0	71.7	146.6	106.8	6.0	1.1	11.9
Vetch	Mar.	8.1	0.3	1.5	6.8	59.9	11.3	64.8	27.2	109.8	15.0	1.4	2.9
	May	8.0	0.3	2.6	2.2	52.5	5.1	28.7	38.8	132.0	6.0	0.9	1.9
Farmer	Mar.	8.1	0.3	0.8	9.5	57.3	22.4	64.2	23.9	146.4	12.0	1.0	2.4
	May	8.0	0.3	2.7	2.2	50.4	9.2	30.2	50.3	112.9	6.0	0.6	5.0

The values of the other nutrients in the discharge such as available phosphorus and extractable potassium were not different from the initial soil values.

The dissolved nutrient quantities retained in the harvesting water tanks is evidently low (Table 6). However, these values as a proportion of the eroded soil cannot be explained in terms of the amounts of nutrient amendments added to the soil (Table 7), especially those removed from the farmer practices, being 2 029 kg/ha and 97 kg/ha of organic matter and organic nitrogen, respectively.

The total amount of nutrients removed from the sheep-manure treatment was 854 kg/ha of organic matter and 37 kg/ha of organic nitrogen. The lowest total nutrient loss was from the vetch intercropping treatment (Table 6).

TABLE 7

Comparative quantities of organic matter, organic and mineral nitrogen discharged as a result of soil losses and overland flows for different treatments during 2002 and 2003 seasons

Treatments		Soil discharge		Water discharge
		Organic matter	Organic nitrogen	Mineral nitrogen
			(kg/ha)	
Manure	2002	156.0	8.4	4.4
	2003	854.0	37.0	-
Vetch	2002	103.0	6.8	4.2
	2003	368.0	18.0	-
Farmer	2002	495.0	25.7	9.7
	2003	2 029.0	97.0	-

TABLE 8
Averages of soil texture for different treatments above the runoff gutters, with averages texture of sludge and suspended retained in the harvesting tanks

Particles	Clay	Silt	Very fine sand	Fine sand	Medium and coarse sand	Total sand
Fraction seizes	< 0.002 mm	0.002–0.05 mm	0.05–0.1 mm	0.1–0.200 mm	0.200–2.0 mm	0.05–2.0 mm
Treatments	**Catchment 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
Sludge and suspension (%)						
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

FIGURE 2
Average production per tree of olive fruits for three different treatments in the unterraced site in three olive-bearing seasons, 1998–2002

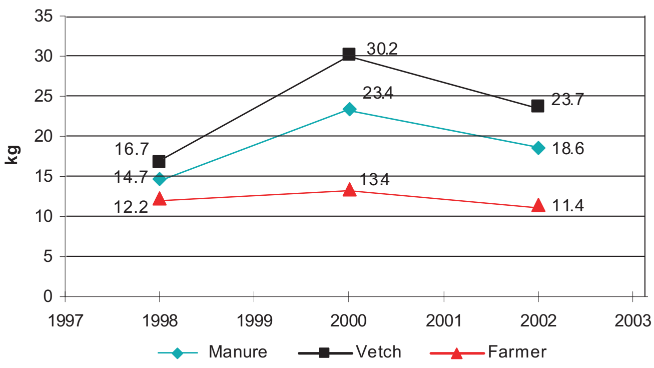


Plate 2
Olives harvested in November 2004 from the farmer, vetch and manure treatments. The olives from the manure and vetch treatments were larger in size and were earlier maturing than those from the farmer treatment

The texture of the detached soil is comparable with that of the initial soil textures determined (Table 8). Slight changes were depicted for the clay fractions and the lowest percentage existed with the manure application (32.1 percent), and a higher percentage reported with farmer practices (45 percent) while the detached clay of the vetch practices matched each of the sheep-manuring and farmer practices (42.5 percent).

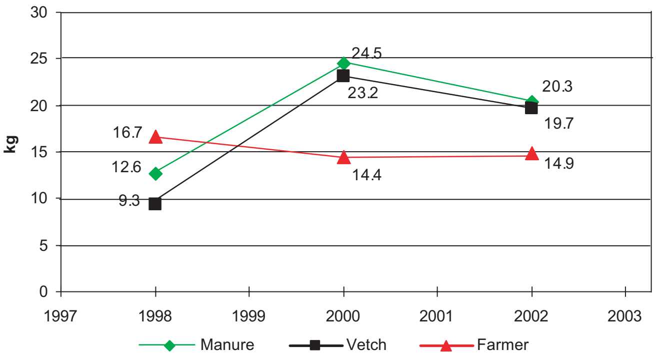
Increased olive productivity was the most pronounced output of the tested treatments. Marginal increases in olive production were reported in 2000 (Figures 2 and 3). In the vetch and sheep-manure treatments of the unterraced site, the increases ranged from 60 to 80 percent relative to the farmer practices in the unterraced site. However, the same treatments in the terraced site were 80–95 percent more than the farmer practices. In the terraced site, the increase in olive production exceeded 110–150 percent with the manure and vetch application. In 2002, the yield declined relative to 2000, but comparing the yield in the vetch intercropping and sheep-manure treatments in the unterraced site, the increases were still 27–42 percent more than the farmer practices. In the terraced site, the increases were 60–90 percent in the manure and vetch treatments. Olive quality was markedly better in the manure and vetch treatments with both having fruits that were larger in size and earlier maturing (Plate 2).

DISCUSSION

The GMD, macroaggregation and microaggregation indices correlated well with the changes in management practices, as tested in the Yakhour olive orchards and demonstrated improved soil physical conditions.

It was clear that the continuous farmer practices (from the time the olives were planted in the 1920s) had reduced soil quality, and thus diminished agricultural sustainability. The biennial application of sheep manure at a rate of 30 kg/tree (or 4.5 tonnes/ha) and an annual average of 4 tonnes/ha of green manuring of vetch biomass incorporated with the soil enhanced SOM.

FIGURE 3
Average production per tree of olive fruits for different treatments in the terraced site in three olive-bearing seasons, 1998–2002



The measured improvements in hydraulic conductivity, associated with growing legumes and with manure, leads to less runoff after the onset of autumn rains and better water-use efficiency as a result of improved water movement in the rootzone. Although the vetch was grown for only a limited period (November–April), the increased vegetative cover and established root system led to reduced overland flows and reduced quantities of soil and nutrient loss.

The increase in soil organic manure content helped to lower the soil pH slightly. In the alkaline conditions (pH > 8) prevailing on these slopes, organic derivatives and other locked-up nutrients such as phosphorus will become more readily available to boost yield if the pH can be lowered in the long-term, even by as little as half of a point.

The improved soil chemical and physical properties have been shown to induce positive changes in soil quality, as tested in the current range if management practices. 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 agricultural productivity. Improving olive productivity will increase the income of the farmers and, subsequently, will sustain livelihoods, the land and the environment.

Reduced cultivation in the new-style olive plantations is seen as a positive step in better land management. Tillage is seen as a main driver for land degradation in the Yakhour village, causing erosion to be omnipresent.

The reduction of soil tillage to two passes, in association with the planting of vetch and perhaps two applications of sheep manure (after harvesting and perhaps at the end of spring), will certainly lead to improved SOM levels.

The experimental treatments in this study are to be continued with new growers being encouraged to test the treatments under a wide range of management scenarios. Planning is underway to quantify soil loss, the soil being collected in natural vegetation strips (NVSs). More research is planned to evaluate the impact of traditional ploughing on sloping land, using mules that work along the contour.

By the beginning of 2004, another stage of farmer-participatory research on soil and water management with olive growers in the Yakhour area had already commenced. In this, both farmers and scientists are investigating, evaluating, and assessing the potential for adoption of the following technologies: NVSs, vetch intercropping, terracing, minimum tillage, and minimum pruning. This participatory research aims to improve the long-term sustainability of the soil and improve the productivity of olive production in the northwest of the Syrian Arab Republic.

CONCLUSIONS

As a result of the close cooperation and consultation with the villagers in the selected region, the suitability of introduced land-husbandry practices to reduce soil erosion and increase olive productivity has, apparently, been successful. In particular, the increase in vetch intercropping in the village can be cited as a success criterion. The trial of introduced management systems has indicated that legumes, sheep manure and chemical fertilization are potentially viable management options not only economically but also in terms of farmer acceptance and uptake as an alternative to farmer practices. Additionally, it has been demonstrated that the new practices have a positive effect on soil physical parameters and agricultural sustainability.

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