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# Intercropping with native perennial plants protects soil of arable fields in semi-arid lands

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ABSTRACT

Surface run-off and erosion are the major contributors to soil degradation worldwide. These processes are especially severe in regions with sparse vegetation cover. A 2-year experiment was set up along an aridity gradient in Al-Khalil, Palestine, to quantify soil loss and water loss from arable fields and to test for the mitigating effect of native perennial filter strips in arable fields. Three useful native plant species were chosen as intercrops: *Majorana syriaca*, *Salvia fruticosa* and *Salvia hierosolymitana*. The water and soil losses were experimentally measured in all the treatments. The results showed that considerable amounts of water (223–288 $m^3$) and soil (3.2–5.6 ton $ha^{-1}$) are lost from the fields. However, both total run-off and erosion were strongly reduced when the annual crop was intercropped with strips of native perennial plants (NPPs). The filter strips reduced the run-off by 34–89% and soil loss by 45–94%. This effect was more pronounced at the drier part of the studied sites and during the drier season. Our study implies that using filter strips of NPPs is a beneficial strategy for reducing run-off and soil erosion in the semi-arid regions of east Mediterranean.



## 1. Introduction

Soil degradation is a natural biophysical process. However, human activities involving alteration of land cover and disturbance of soil structure by agriculture promote soil degradation (Lal, 2001). About 80% of the world's agricultural land suffers from moderate to severe erosion, and worldwide about 12 million hectares of arable land are abandoned or destroyed annually as a result of non-sustainable farming practices (Ritchie, 2003). The global average value of soil erosion is estimated to be 10.2 ton $ha^{-1}$ $year^{-1}$, of which 60% is induced by human activities.

Soil erosion is the principal threat to agricultural sustainability, especially in the arid and semi-arid regions, due to reduction of top soil depth and loss of essential plant nutrients (Chappell et al., 1999; El-Swaify, 2001; Lal, 1998; Tengberg et al., 1997). Furthermore, soil erosion is predicted to increase in the future as a result of greater variability in monthly precipitation and increased frequency of large storms as predicted by global climatic change scenarios (Zhang and Nearing, 2005). In addition, soil erosion may increase due to the decrease in the vegetative cover, which is predicted to occur due to higher temperatures (O'Neal et al., 2005). However, new crop managements that aim to cope with the effects of climate change may in future enhance soil erosion stronger than predicted from the direct influence of the climate change alone (O'Neal et al., 2005). Therefore, climate change and its effects on land-use strategies need to be considered while developing future strategies for sustainable water and land use.

The key factor affecting run-off generation and erosion is the structure and density of the vegetation cover (Adekalu et al., 2006; Barton et al., 2004; Seeger, 2007). Other factors such as soil content of organic matter, aggregate stability and infiltration capacity are also important but their effect is highly variable in space and time (Adekalu et al., 2006; Barton et al., 2004; Rhoton et al., 2002; Seeger, 2007; Wischmeier and Mannering, 1969). Adding vegetation cover by mulching or intercropping was found to reduce run-off and soil loss (Adekalu et al., 2006; Ali et al., 2007; Barton et al., 2004; Dunj'o et al., 2004; Gafur et al., 2003; Jankauskas and Jankauskiene, 2003; Neave and Rayburg, 2007; Sharaiha and Ziadat, 2007). The vegetation cover reduces erosion mainly in two ways: the canopy and litter that intercept rainfall provide

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direct mechanical protection to the soil surface and incorporation of organic matter, in particular, causes an indirect improvement of the soil physical and chemical properties (Dunj'o et al., 2004).

In the arid and semi-arid regions, rain-fed agricultural fields remain bare of vegetation for a long period of the year including the first rain events. During this period, the physical condition of the soil makes it prone to both wind and water erosion. Therefore, successful techniques to prevent or reduce run-off and erosion in arid–semi-arid region must enlarge the area of permanent vegetation cover. Only such a permanent vegetation cover will efficiently act as a sediment trap during the early and often strong rainfall events. Moreover, as the semi-arid and arid areas are more sensitive to the expected global climatic change (O'Neal et al., 2005), it is necessary to develop land-use strategies that may mitigate run-off and erosion and allow a sustainable land use, even under changing climatic conditions for such regions.

To date, the cropping systems that have been suggested and/or tested as mitigation strategies are mulch, rotation and intercropping of annual crops with various tillage combinations (Adekalu et al., 2006; Ali et al., 2007; Altieri, 2002; Barton et al., 2004; Gilley et al., 1997; Lal, 1995; Laloy and Bielders, 2010; Sharaiha and Ziadat, 2007; Vandermeer et al., 1998). The intercropping of annual crops was effective in controlling run-off but has some disadvantages; it failed to maintain crop yields in some cases (Kinama et al., 2007), and it does not provide protection to rain-fed agricultural soils in the arid and semi-arid regions where the fields stay bare of vegetation especially when the first rainfall events occur. However, the use of perennial plants as intercrops may protect soil during this period. Dunj'o et al. (2004) found that natural vegetation of perennial herbs and shrubs in the arid–semi-arid regions was effective in reducing run-off and erosion compared to annual cropping. Jankauskas and Jankauskiene (2003) found that perennial grass cover as a soil conservation measure was more effective than crop rotation. This effect is partial because the natural perennial ground cover prevents overland flow and formation of rills and gullies (Dunj'o et al., 2004). However, as introduction of the natural perennial vegetation into a crop system is usually not an option for farmers (loss of productive area), the cultivation of useful native perennial plants (NPPs) as intercrops in annual crop fields may be a possible management strategy that overcomes the problem. The useful native plants compensate the loss of the productive area by marketing these plants as new crops, and as natives, these plants are adapted to survive during the drought season of the year, often maintaining above-ground parts or producing above-ground shoots prior to the beginning of the rainy season (thereby protecting the soil surface). The quantitative information on the efficiency of planting useful NPPs as intercrops as means to control soil erosion in the semi-arid–arid regions is scanty and the present study attempts to contribute to fill the gap. As plant species vary considerably in their morphology, growth period and canopy density, they may contribute differently to the reduction of run-off and erosion. Therefore, it will be necessary to test several species in order to identify any species-specific effects.

The present study aims to contribute to quantify erosion and run-off in the semi-arid–arid regions and to test whether intercropping with useful NPPs has the potential to protect soil and to reduce unproductive water loss under the present and future climate conditions. Specifically, this study attempts to examine the following hypotheses:

(1) Intercropping with NPPs will reduce water and soil loss.
(2) The efficiency of intercropping with useful NPPs in mitigating run-off and erosion is consistent under different amounts of precipitation.
(3) The efficiency of intercropping with useful NPPs in reducing run-off and erosion is not species specific.

## 2. Methods

### 2.1. Selection of the study area

The hilly slopes of the West Bank, Palestine, were selected as the suitable area to examine our hypotheses. The rain-fed agricultural fields form 87% of the total cultivated land in the Palestinian territories (Isaac et al., 2007). The Palestinian Ministry of Agriculture (2011) reported that 20.6% of the lands in the West Bank are at high risk of erosion and 42.6% of the lands face moderate erosion risk due to slopes. The area has a Mediterranean climate characterised by long, hot, dry summers and short, cool, rainy winters, with often intense rainfall events (ARIJ, 1995). Studies on regional climate changes predict a gradual rise of mean annual temperature of 3–5 °C and a 10–30% decrease of annual precipitation during the years 2070–2100 (Alpert et al., 2006, 2008).

The study was conducted in vegetable fields at Al-Khalil district in the southern part of the West Bank (Fig. 1). This district is located between 100 m and 1011 m a.s.l. The monthly average temperature ranges from 7.5 °C in winter to 22 °C in summer. The climate of the district is mostly semi-arid to Mediterranean (250–600 mm) with the wettest parts in the north and an increasing aridity toward the south (Negev desert) and the east (Jordan Valley). Most precipitation is received between December and February (ARIJ, 1995). Rainfall of high intensities occurs particularly early in the season when vegetation cover is still low or absent. The distribution of rainfall events over the season is highly variable. The dry period of the year can be 7 months (April–October).

In order to test the influence of changes in climatic conditions on our proposed mitigation strategy, we conducted our experiments at two sites differing in mean annual precipitation (Fig. 1):

- Al-Dhahriya: This site is located 15 km to the south of Al-Khalil city, (31° 26′ 46.2″ N, 34° 58′ 18.3″ E), receives a mean annual precipitation of 425 mm and is situated at 610 m above sea level. Four arable field blocks were chosen at this site for our experiment. The minimum distance between adjacent blocks was 50 m.
- Halhul: This site consists of three field blocks: H1 (situated at 31° 35′ 41.3″ N, 35° 06′ 06.2″ E), H2 (situated at 31° 35′ 18.1″ N, 35° 05′ 08.9″ E) and H3 (situated at 31° 34′ 07.2″ N, 35° 06′ 12.0″ E), receives a mean annual precipitation of 590 mm and is located between 910 m a.s.l. and 960 m a.s.l. Compared with the Al-Dhahriya site, the distances between the chosen experimental fields at the Halhul site were larger due to the local conditions. However, the distances between fields at each site were always shorter than that between sites.

The selected fields for our experiments share comparable features. They were located on moderate slopes with inclination between 8% and 10%. The soil of the investigation sites is classified as brown Terra Rossa (Land research Center, 2002). All sites have been used for the rain-fed production of annual vegetables and field crops for decades (traditional agriculture). The basic physical and chemical characteristics of the soils at the experimental fields were measured and show similarities enough to allow comparison (Table 1).

### 2.2. Selection of NPP species

In order to test whether or not the results obtained are species