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Effects of cultivation on chemical and biochemical properties of dryland soils from southern Tunisia

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ABSTRACT

The progressive degradation of cultivated drylands has been mainly ascribed to adoption of intensive soil use, namely repeated soil cultivation with external inputs and disturbances. Consequently, soil managements in equilibrium with environmental and social constrains are required to conserve and improve the soil fertility. We evaluated the impact of soil cultivation and management on chemical and biochemical properties of dryland soils from the Tunisian Jeffara Plain. This study considered three sites (Chenini Nahel, Matmata Nouvelle, and Menzel Habib), with both non-cultivated and cultivated soils. These latter were subjected to different soil management: organic fertilization and irrigation by submersion, chemical fertilization and drip irrigation, no fertilization and sporadic watering. The results showed that the addition of organic matter as compost or manure combined with irrigation may favor pH reduction, with consequently higher enzymatic activity and organic matter storage. The latter occurred because of the encapsulation of organic particles into collars made of re-precipitated gypsum and calcite. In cases where chemical fertilization and drip irrigation were applied, the organic matter stabilization occurred only at the surface; at depth we observed a reduction of organics due to microbially-mediated mineralization processes. When neither organic amendment nor water was supplied, no substantial difference occurred between cultivated and non-cultivated soils. We concluded that, in drylands, agricultural managements providing the use of water and organic amendments is the way to increase soil organic matter storage and improve physical, chemical and biological properties so to enhance the soil fertility.

1. Introduction

With respect to world land surface (148.94 million km^2), the current distribution of drylands includes 13.6% as semi-arid environments, 15.7% as arid environments, and 5.6% as hyper-arid environments (Thomas, 2011). This means that about 52 million km^2 are drylands – about one third of the global land surface. These areas are diffused in all the continents except Antarctica (Thomas, 2011), and are mostly made of Aridisols and Entisols (FAO, 2002). Most drylands are too dry for agriculture (Creswell and Martin, 1998). However, some arid lands have been cultivated for a long time, while others have been cultivated only in recent decades because of the population increase many countries have experienced (Creswell and Martin, 1998). The cultivation of these lands has been accomplished via dryland farming or thanks to irrigation where groundwater can be easily or economically extracted.

In many places, because of the even warmer climatic conditions and higher vulnerability of the drylands due to wind erosion and excess cultivation, a progressive soil degradation has occurred. Degradation of cultivated dryland soils has been ascribed to two factors, both far from the environmental equilibrium (Lal, 2000): (i) changes of land use, and (ii) adoption of intensive soil management represented by repeated soil cultivation with external inputs and disturbances. Thus, it is necessary to find or develop techniques for appropriate management and protection of soil fertility worldwide, especially given global climate change. This issue is even more important for the management of dryland soils in a way that can ensure soil conservation and stabilization of the agricultural production in the mid-to-long term (Creswell and Martin, 1998). To reach this goal, we have to increase knowledge of

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the relationships between soil management and chemical and biochemical properties on dryland soils.

It is known that soil microbial activity is related to ecosystem stability and fertility, and that soil fertility is a great problem in drylands. Few researches have investigated the impact of management on the biochemical properties of dryland soils. Most of these studies have dealt with soil physico-chemical properties (e.g., Ben Moussa-Machraoui et al., 2010; Jordan et al., 2010), or have taken into account the biochemical properties of the soil surface only (e.g., Pascual et al., 1999; Armas et al., 2007). To better understand soil–plant interactions and for a successful soil conservation under dry climates, a good knowledge of the chemical and biochemical properties of a considerable soil thickness (at least that of the *solum*) is required.

The main aim of this work was to test the hypothesis if a certain agricultural management in arid environments may improve soil fertility and foster soil evolution. To achieve this goal, we assessed the impact of cultivation on physico-chemical and biochemical properties of pre-desert soils with respect to non-cultivated soils. The cultivated soils were subjected to different management: (i) organic fertilization and irrigation by submersion, (ii) chemical fertilization and drip irrigation, and (iii) no fertilization and sporadic watering.

2. Material and methods

2.1. Site description, climatic features and soil uses

The region selected for this study was located in the Tunisian Djeffara Plain, which spans from the low plains located south of the Gafsa Mountains to the Sahara boundary in Southern Tunisia. Three sites were selected as they featured both non-cultivated and cultivated soils: Chenini Nahel, Matmata Nouvelle, and Menzel Habib (Fig. 1). Geomorphologic, physiographic and climatic details are given in the Supplementary file.

2.1.1. Chenini Nahel

The oasis of Chenini Nahel, located along the coast of the Gulf of Gabès, is one of the few coastal oases in the Mediterranean. The climate is arid Mediterranean with a mean annual precipitation of 185 mm, a mean annual air temperature of 22.5 °C and an Aridity Index of 0.12, corresponding to a land with an arid type of dryness (UNEP, 1997).

As a non-cultivated soil we selected one densely covered by cane [*Phragmites australis* (Cav.) Trin. ex Steud] and tamarisk (*Tamarix* sp.) that has not been cultivated at least during the last 30 years; no specific information was available on the previous use except that this soil has never been used for vegetable crops. For the cultivated soil we chose one at about 40 m apart that had been cultivated for 9 years with henna (*Lawsonia inermis* L.) and that had been previously devoted to vegetables for an unknown period. The henna crop was watered by submersion and the soil received about 10 Mg ha^{-1} y^{-1} compost derived from dry wastes of different vegetal and animal sources that are often mixed with manure.

2.1.2. Matmata Nouvelle

The site of Matmata Nouvelle is at about 7 km (north-west) from the city of Matmata Nouvelle. The climate is arid Mediterranean with a mean annual precipitation of 175 mm, a mean annual air temperature of 19.8 °C, and an Aridity Index of 0.09, corresponding to a land with an arid type of dryness (UNEP, 1997).

As a non-cultivated soil we chose one with about 80% barren surface and about 20% of plant cover dominated by Gymnocarpos (*Gymnocarpos decandrus* Forssk.) and field wormwood (*Artemisia*

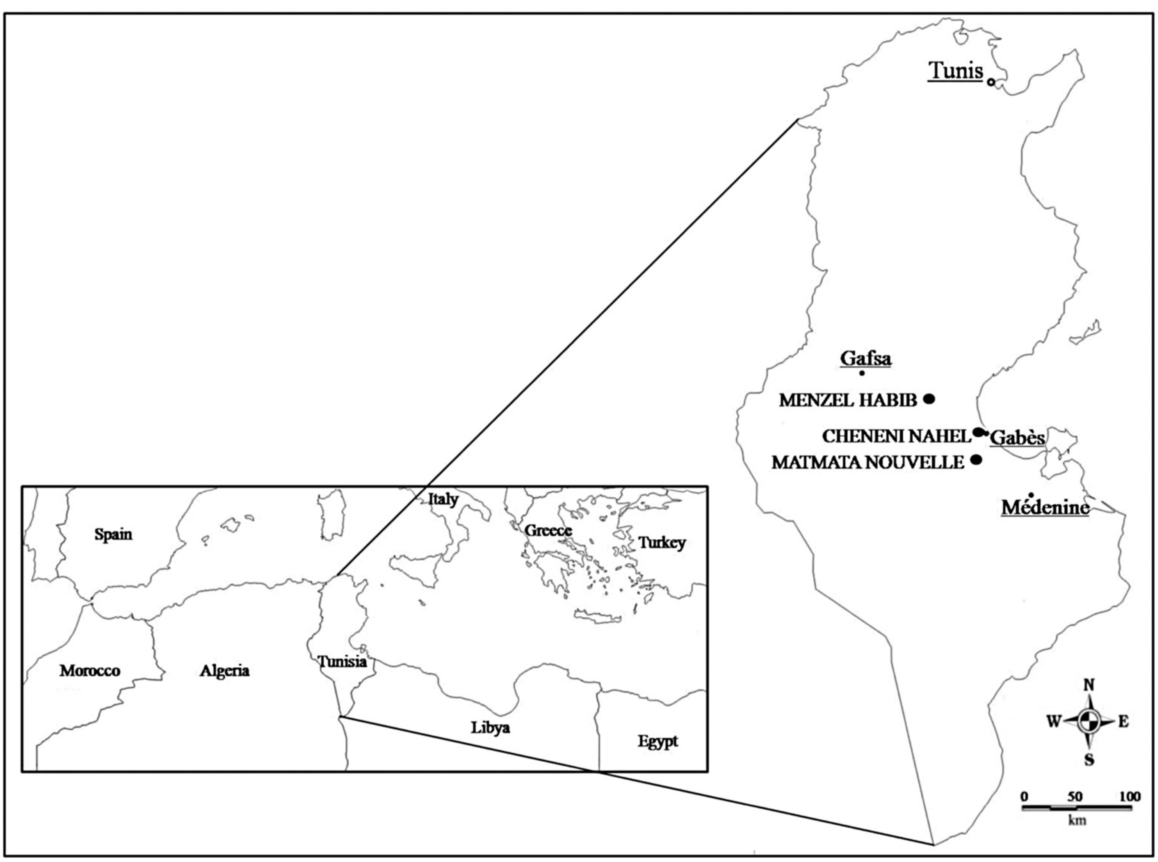

Fig. 1. Map of Tunisia with indication of the study sites (Governorat de Gabès, Tunisia).