Flux of carbon dioxide and storage of the carbon by soils: inventory in Tunisia

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1. Abstract

The currently awaited climatic changes will be the result of the increase in the atmospheric gas concentration of greenhouse. Soils play a significant role in the storage of atmospheric carbon dioxide, but it can release it after mineralization. From this double characteristic to absorb and to emit CO_2, estimation of the carbon dioxide of Tunisian soils gives an idea about its organic carbon, which in addition to its importance in pedogenesis and fertility of soil, has an environmental interest. The estimation of the carbon dioxide assessment is based on seven profiles that represent the big soil areas of the country and the annual organic matter restitution, which takes into account the most dominant vegetation for each soil unit. In Tunisia and for one meter in depth, the total carbon stock is equal to 1.335GtC (1GtC=10^9 tons of carbons) which corresponds to 4.887Gt of CO_2. Annually, the Tunisian soils which represent a well of carbon stores 51304.34 x 10^{-6} Gt and releases 1269.80 x 10^{-6} Gt of CO_2.

Keywords: Climatic changes, soil, carbon sequestration, greenhouse effect, stock, CO_2, Tunisia.

2. Introduction

The increase of the atmospheric rate of greenhouse effect and its result of a climatic change hypothesis is the subject of more and more consensus of the international scientific community (Jean-Baptiste et al., 2003). The disastrous effects of these gases and especially of the carbon dioxide that results, will probably have some effects at the end of this century. Therefore, it is necessary to take action, in order to reduce the broadcasts of the carbon and to increase its storage. Undoubtedly, this would start by the understanding of its sources. Soil is one of the components of the carbon cycle that contributes to the carbon sequestration, but also it clears it as CO_2 after the mineralization of the organic matter (Gitz et al., 2003;. Gobat et al., 2003). If we exclude the carbonated rocks, soils will constitute the biggest superficial compartment of carbon. In fact, the global assessments for the depth of one meter go from 1184 GtC to 2946 GtC (1GtC=10^9 tons of carbon) (Kimble et al., 1990; Eswaran et al., 1993) and recently between 1500 and 2000 GtC (Batjes 1996; GIEC 2001), that is equivalent to three times the stock of the continental biomass and two times the atmospheric one.

These assessments are different for several reasons: (i) first, since the limited knowledge of the spatial distribution and the variation of the different types of soils and their uses (GIEC 2001); (ii) second, due to the misses data of soils, especially for the vertical and spatial distribution of the soil organic carbon (Bernoux et al., 1998, Arrouays et al., 2002). most evaluations of organic carbon were based on regional balances and on the depth of one meter (Batjes, 1996) or on the first 20 or 30 centimeters since it is the interface layer soil/atmosphere (Bernoux et al., 1998). The most rigorous approach for estimation of the variation of the carbon soil is to calculate the entries and the exits of carbon for the given ecosystem, and to use the difference in order to calculate the yearly net change in the storage of the carbon (GIEC 2001). The current procedures used to measure the changes in the organic carbon stock of soils are: (i) the experimental approaches (Lal, 2002), and (ii) the experimental approaches based on spatial data (Smith et al., 2000; Bernoux et al., 2002, Batjes 2006), and the dynamic models linked with the spatial data bases, as the Century and the RothC models (Cerri et al., 2004).

3. Material and methods

3.1. Study area

Tunisia is situated northern Africa between the latitudes 32° and 38° North and between the longitudes 7° and 12° Est. It is located at the junction of the western and oriental Mediterranean and covering a surface of 164000km^2 (Fig. 1). In spite of this small surface, nor the climate neither the vegetation are uniform. In fact, the geographical position and the general orientation of the main relieves are influenced at the North by the Mediterranean Sea and at the South by the Sahara. Concerning the Center, it is under the conjugated effect of these two elements. Even the dominance of calcareous rocks, geology consists of large range of type of rocks. It has for consequence an enormous variety of soils which can be regrouped in seven big classes (Mtimet, 1999).

3.2. Distribution of soils in Tunisia and sampling method

At the same time Mediterranean and Saharian country, Tunisia shows several soil resources that relates the importance of the climatic and morphological effects on its physiography. From North to South, the country

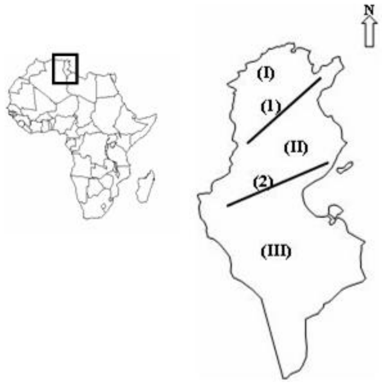

Figure 1 localization of the bioclimatic zones: ***zone I zone II zone III; (1) Dorsale; (2) Gafsa-Sfax line.***

shows remarkable variation in organic matter content, going from 20% in the humid and subhumid stage bioclimatic with dense vegetation, until 0.3% in the arid and Saharian stage bioclimatic with skinny and little abundant vegetations, except of the oases where the contents are relatively raised due to the artificial organic contributions (Ben Aissa 1993; Brahim 2004). Pragmatically, the sampling is consisted of layer of soil, for the superficial slice 0-30cm and for the depth of one meter. The northern zone (I): has three sub-climates; the humid, the sub-humid and the semi-arid, The center zone (II): characterized by the semi-arid and arid bioclimats, limited at the north by the Dorsale (mountain range system) (1) and spreads until the line of Gafsa-Sfax (2). The southern zone (III): has an arid and Saharian climate, spreads from the south of the mounts of Gafsa until the confines of the Sahara (Fig. 1).

3.3. Methodology

Bulk density: Determined directly on the land, using metallic cylinders of 100cm^3 driven horizontally in the different layers of the seven pedological profiles. The operation is repeated two times and the result is the average of the two measures. The value of the bulk density (bd) is calculated after passage by the exsicator to 105°C during 24 hours. *Estimation of the stock:* The organic carbon stocks "S" in soil are estimated by slice of soil; they are expressed in ton per hectare and calculated by the following method (Albercht et al., 1992):
S (t/ha) = C (mgC/gsoil) × bd (bulk density) × E (the soil layer in dm). *Estimation of the plant restitutions:* The plants are the natural sources of organic matter of soils. When the plant dies, it is damaged and the carbon become incorporated in soil (Gobat 2003). The organic restitution or the organic matter production is function of the floor bioclimatic. For each of the seven units of soils in the present study, we chose the most representative vegetation of the corresponding unit and we carried the different productions in organic matter in kg/ha. *Decomposition estimation of the organic matter:* In order to evaluate the coefficient of decomposition of the restitutions "K", we are based on Jenny, H. et al., formula (Jenny et al., 1949), who worked on the decomposition of the biomass in the tropical and moderate soils and they elaborated the following formula: $K = A / (M+A)$. Where; A: the yearly contribution in organic matter, and M: the stock of soil in organic matter.

4. Results

For a depth of one meter, carbon stock varies from unit to other. The values go from 35 to 186 t/ha (Tab. 1). This difference of distribution of the carbon rate is function of the vegetations joined to the bioclimatic stage (Batjes 1996). Results show that the distribution of the carbon organic stock in soil changes with the depth, and presents a decreasing rate while going downwards, in other words, the stock decrease from the superficial levels to the deeper one. In fact, the carbon stock of the superficial horizons (0-30cm) can reach 84% of the total stock (0-100cm). Soils of the units situated in the rainy climate zones have a carbon stock superior than 100t/ha for the 0-100 cm level and even close to 200t/ha, as the one of the unit of the Cambisols (186.35 t/ha). The forest soils are among those that have the majority of their resource in carbon in the first thirty centimeters. 84.21% of the carbon stock of the unit of the Cambisols is sequestrated in the superficial levels of soil. This example well illustrates the role that can play the forest soils in the sequestration of the carbon and the large quantities of carbon dioxide that these real layers can free by mineralization of the organic matter, following the changes of soils affectation (Gitz et al., 2003; Jean-Baptiste et al., 2003). From these estimations of carbon stocks, we establish a map of distribution of the organic carbon stock per hectare in the Tunisian soils (Fig. 2). The sequestration of the carbon in soil is function of vegetation. It is relatively weak in the arid climate zone, as the case of the Lithosols unit (0.348t/ha) and rich in forest zone, as the case of the Cambisols that

Table 1 Carbon stock estimation in ton per hectare.

Soil unit	Surface en (ha)	Carbon stock (t/ha)	
		Layer 0-30cm	Layer 0-100cm
Xerosols	2395023	74.88	108.48
Cambisols	3627000	156.93	186.35
Vertisol	710000	52.63	92.73
Gleysols	1510813	38.50	62.15
Regosols and Fluvisols	2179865	15.40	35074
Luvisols	90354	51.04	108.07
Lithosol	2196945	16.32	69.29

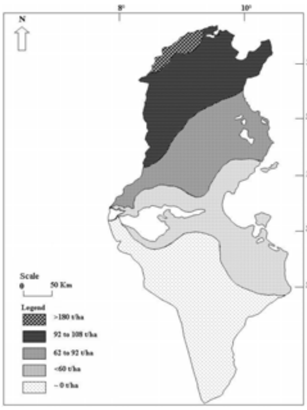

Figure 2 Distribution of the carbon stock per hectare in the Tunisian soil.

occupy the extreme west north of the country (2.25t/ha), (Tab. 2). For the organic carbon stock, the soils of Tunisia accumulate a total of 1.335 GtC for a depth of one meter which corresponds to 48847.38 $\times 10^{-3}$ Gt of CO_2 (Tab. 3). As soils can play a double role, according to their fluxes of carbon. The well function for the Tunisian soils assures the storage of 0.00964 GtC/year, which corresponds to 0.0513Gt of CO_2 yearly. Whereas the second function, in other words, the spring one, free every year 0.000346 GtC, that corresponds to 0.001269Gt of CO_2. Consequently, as the stocked quantities of carbon in the Tunisian soils pass those free, soil Tunisian is considered a well of carbon. Results of the present study show that the unit of the Cambisols has an important accumulation in organic carbon, as well as it stocks itself 2.473Gt of CO_2. That corresponds to 50% of the total stock of the country, which receives 58% of the organic matter and clears 36% of the soils carbon dioxide. These soils take advantage of the rainy climate with a dense vegetation which gives an rich contribution in organic matter for the soil.

Table 2 Carbon dioxide stock and carbon dioxide balance in ton per hectare.

Soil unit	Yearly restitution (t/ha)	Stock (t/ha)	Emission CO_2 (t/ha)
Xerosols	0.639	108.48	0.00819
Cambisols	2.25	186.351	0.0347
Vertisol	0.872	92.73	0.0142
Gleysols	0.639	62.15	0.01044
Regosols and Fluvisols	0.872	35.74	0.0467
Luvisols	0.872	108.075	0.01678
Lithosol	0.348	69.296	0.0328

Table 3 The total of the stocks, the entries and the exits of carbon dioxide in Tunisian soil

Soil unit	Inflow CO_2($\times 10^{-6}$ Gt/an)	Stock CO_2 ($\times 10^{-3}$ Gt)	Outlet CO_2($\times 10^{-6}$ Gt/an)
Xerosols	5601,33	950,911	71,809
Cambisols	29860	2473,77	461,416
Vertisol	2265,979	240,967	36,900
Gleysols	3533,39	343,663	57,747
Regosols and Fluvisols	6957,08	285,1432	372,584
Luvisols	288,364	35,739	5,548
Lithosol	2798,201	557,194	263,801
Total	51304,344	4887,3872	1269,805

5. Conclusion

The estimation of the organic carbon stock in the soils of Tunisia is 1.335 GtC for the depth between 0 and 100 cm. The superficial levels are the richest ones in organic matter. In fact, the greater part of the carbon stock is situated in the first 30 centimeters. Referring to the estimation of the organic carbon stock for all the world, which is valued to 2000GtC (GIEC 2001), the part of Tunisian soils represents 0.06675% of the global terrestrial stock in soils.Tunisian soils captures $51304,344\times10^{-6}$ Gt of CO_2 and free $1269,805\times10^{-6}$ Gt of CO_2 yearly.

For the carbon dioxide balance, the entries pass the exits. Therefore, Tunisian soils play a role of a carbon well. The appreciation of the carbon dioxide balance is too important, especially with regard to the well function which decreases the atmospheric pollution and fight against a possible future climatic change caused by the increase of greenhouse effect gases. The capacities of sequestration of soils are variable. In fact, the prairies and the forests permit to stock more than 100t/ha and close to 200t/ha respectively, while the soils of the steppes as well as the soils of the arid climate zones stock 62t/ha. The variation of the CO_2 balance from unit to other is the result of the climatic factors and occupation of soils. The minerals of soil as $CaCO_3$ and the clays seem to play a stabilizing and inhibitory role of the deterioration by mineralization of the organic matter.

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