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# Evaluation of total Carbon and total Nitrogen content in two Algeria regions under the effect of three tillage systems

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## Abstract

In agriculture, soil total carbon (TC) and total nitrogen (TN) were the major determinants for soil fertility and indicators of soil quality, were closely related to soil productivity. Numerous field studies have shown that crop management practices can either enhance or diminish quantities of soil TC and soil TN. One hypothesized goal of sustainable agriculture is to increase soil OC and soil TN, or to maintain these quantities close to optimal levels. This study aims to evaluate total Carbon and total Nitrogen content in two Algeria regions under the effect of three tillage systems (plough tillage (PT), reduced tillage (RT), no tillage (NT)). The results showed significant correlations between the content of TC and TN in the two regions and all tillage systems. Comparable differences between tillage systems and regions for TC and the C/N ratio in the entire set of samples suggest that more input of new, litter-derived organic matter with large C/N ratios promotes larger TC concentrations in two the study site. The content of TC and TN where the correlation between TC and the C / N ratio in the whole set of samples is much greater.Increases in TC were positively correlated to increases in the C / N ratio. The declining C / N ratios in NT and RT in two regions are more important than they have been in the past.

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## Introduction

In agriculture, soil total carbon (TC) and total nitrogen (TN) were the major determinants for soil fertility and indicators of soil quality, and were closely related to soil productivity. Soil is the most important and largest C reservoir in the world (Al-Kaisi *et al.*, 2005, Qadir *et al.*, 2006, Elbasiouny *et al.*, 2014). TC and TN play an important role in the understanding the functioning of soil, global sustainable development goals, control of the carbon and nitrogen cycles, environmental protection, etc. (Drohan *et al.*, 2010, Megonigal *et al.* 2010; Richter and Yaalon, 2012; Brevik *et al.*, 2015; Keesstra *et al.*, 2016). Understanding soil organic matter (SOM) and nitrogen (SON) dynamics, is essential for efficient and environmentally sustainable agricultural production (Doran and Parkin, *et al.*, 1994).

Soil organic carbon and nitrogen not only can reflect the soil fertility level, but can also explain the regional ecological system evolution. The relationship between them can be represented as soil C/Nratio, a sensitive indicator of soil quality and for assessing carbon and nitrogen nutrition cycling of soils (Zhang *et al.*, 2010). Many researches have shown that soil organic carbon and nitrogen content were not only affected by climate, altitude, terrain, but also land use management (Zhao, *et al.*, 2004). It is well established that nitrogen (N) is the macronutrient often limiting the growth of plants on soil (Vitousek, 1982; Vitousek and Farrington, 1997; Michopoulos *et al.*, 2008). Moreover, soil organic matter, and consequently soil OC is one of the most important attributes of a soil because it affects nutrient cycling, soil structure and water availability. Maintaining, or better yet, increasing soil OC content is an important measure of the sustainability of a cropping system.

Numerous field studies have shown that crop management practices can either enhanced or diminish quantities of soil OC and soil TN together (Bauer and Black, 1981; Odell *et al.*, 1984; Mann, 1986; Darmody and Peck, 1997; Dick *et al.*, 1998; Knops and Tilman, 2000; Kucharik *et al.*, 2001). One hypothesized goal of sustainable agriculture is to increase soil OC and soil TN, or to maintain these quantities close to native levels (Odell *et al.*, 1984).

This study aims to evaluate total Carbon and total Nitrogen content in two Algeria regions under the effect of three tillage systems (plough tillage (PT), reduced tillage (RT), no tillage (NT)).

## Materials and methods

*Site characteristics of the study regions*

The study was conducted in two regions in Algeria that have an important arable farming industry. These regions were selected mainly based on differences in site conditions, but also because of improvements in farming practices that have been introduced there during the past 10 years. In the two regions, approximately 30% of crop residues were left in the field and additional organic fertilisers were used.

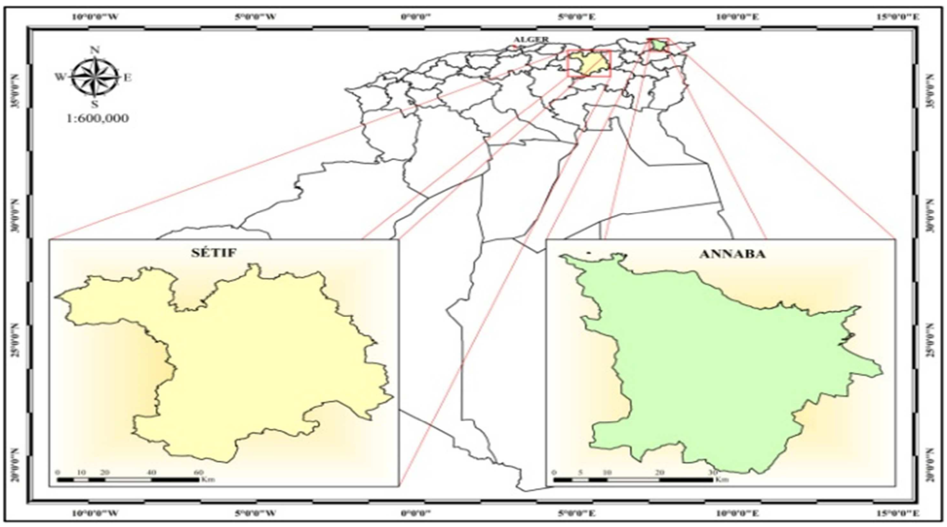


**Fig. 1.** Location of the on-farm research areas at Annaba and Sétif in Algeria.

The first region, Annaba, was located in north-east Algeria (Fig. 1), which was characterized by a Mediterranean climate. The site was a floodplain with generally flat topography, running up on the western edge to the foothills of the Edough Mountains, and the soil mainly comprises recent alluvium with a clayey texture. In the farm fields selected for the present study, the clay content was within the range 46-53%.

The second experimental region, Sétif, was also located in north-east Algeria, in a region characterized by high plains and with a semi-arid continental Mediterranean climate. In the farm fields selected for the present study, the soil was mainly clayey in tillage treatments NT and RT, whereas in the PT treatment it had a significantly higher clay content. In this region, ploughed soils were often deeper (i.e. have a greater rooting depth of around 80 cm) and have a smaller stone content than soils under reduced tillage, which were often shallower, with parent material (limestone rock) reaching up to 30 cm below surface.

In both study regions, the investigations were carried out on commercial farms on which PT and the conservation tillage techniques RT and NT have been practiced for about 10 years. On both farms, the different tillage systems were each used in several fields.

*Soil sampling was performed in two campaigns*

(1) The first sampling campaign took place during the growing season, (i) at Annaba in the beginning of June 2014, for PT in durum wheat (growth stage 'grain maturation'), for RT in chickpeas and for NT in fallow soil last tilled at the end of October in the previous year, and (ii) at Sétif in the end of May 2014 with soft wheat in PT, hard wheat in RT (growth stage 'grain development') and for NT in fallow soil last tilled in October in the previous year.

(2) The second sampling campaign was conducted after the tillage season, in early November 2014 at Annaba and in the end of October 2014 at Sétif, after harvest of common and durum wheat, respectively, and 2 weeks after soil tillage, seedbed preparation and sowing of the following crop.

In each sampling campaign, a soil profile was excavated in every tillage treatment in fields on the two commercial farms. The profiles were dug parallel to the direction of tillage in the middle of the fields, excluding any impact on soil structure from wheel tracks, but otherwise the locations of the soil profiles were chosen randomly. These profile sites were identified by GPS in the first sampling campaign and the profiles for the second sampling campaign were taken at the same sites. The soil profiles were 1.50m wide and varied in depth according to the site conditions, with 140cm for all profiles at Annaba and 80cm at Sétif for profiles in PT and RT, but only 35cm in NT.

In both sampling campaigns, three types of soil samples were collected in and around the soil profiles:

Around the soil profiles, bulk samples of loose soil composed of 20 disturbed single soil samples were taken from the all the soil profile : (TS) top soil ( 0-30cm) (SS1)subsoil 1 (30-90cm) (SS2)subsoil 2 (+90), soil samples were air-dried, sieved to 2mm and stored at room temperature until analysis.

*Laboratory analysis*

Soil pH was determined using a glass electrode (AFNOR Norm X 31- 103) in the supernatant of a 1:5 suspension of soil and distilled water.

*Total Carbon Analysis and Total Nitrogen:* The concentration of total carbon (TC) and total nitrogen (TC) were measured (by the glutamine-acid method) using a gas chromatograph with an automatic analyzer for carbon and nitrogen (vario MAX CN elementar). A sol aliquot (≈ 10mg) was accurately weighed in stainless steel or ceramic cups. The soil samples to be analyzed were burned at 850°C to 1150°C. The various gaseous components resulting from the combustion were separated by column chromatography and detected by a cathetometer. The carbon concentration of the soil sample was calculated from a calibration of the first unit performed with a level of atropine, which has a C/N ratio close to that of the analyzed soil material (149-151 Boden1000 method), (FAL *et al.*, 1996).

*Statistical analysis*

Analysis of variance (ANOVA) was used to analyze the effects of the experimental factors of soil tillage (3 levels: PT, RT, NT), region (2 levels: Annaba, Sétif), and sampling campaign (2 levels: early summer 2014 and late autumn 2014) per soil layer according to a factorized model with all the factors treated as fixed factors. ANOVA modeled the effects of the three main factors “tillage”, ”region”, “depth” and the interaction effects "tillage x region". The significance level was denominated as p ≤0.001 = very highly significant, p ≤0.01 = highly significant, p ≤0.05 = significant and p ≤ 0.1 = nearly significant. All statistical analyses were performed using Statsoft STATISTICA Version 12 (StatSoft, Tulsa/OK, USA).

**Results and discussion**

Although the soils at Annaba showed a slight tendency for lower pH values in NT and higher pH values in RT and PT, these differences were not statistically significant. As for Annaba soil, pH at Sétif was not significantly different between the tillage treatments. However, a considerable difference emerged in both regions between the two sampling campaigns: pH values in the first sampling campaign (during the growing season) were lower than the corresponding values in the second sampling campaign (after tillage).

The TC generally showed statistically significant effects in the surface layer between the regions, the means were higher in the region of Setif compared Annaba. For the region of Sétif the highest mean of TC were observed in the RT followed by NT and PT successively. Also the highest content in the soil layers was in the TS and decreases in the SS1, then in the SS2. In the case of the Annaba region, the averages in NT and RT were almost identical, and higher than PT, and the levels were concentrated in the TS and decrease in SS1 and then in SS2.

The TC averages were higher at the surface and decrease with profile depth in both regions for RT ranging from [7.92 to 4.02]. For NT averages of TC were high at the surface and decrease with depth. The TC in PT was still low and decreasing with depth. It was noted that the TC means in the RT and NT were equal in the first and second sampling campaigns. For PT the TC averages were evenly distributed throughout the profile and in the two campaigns.

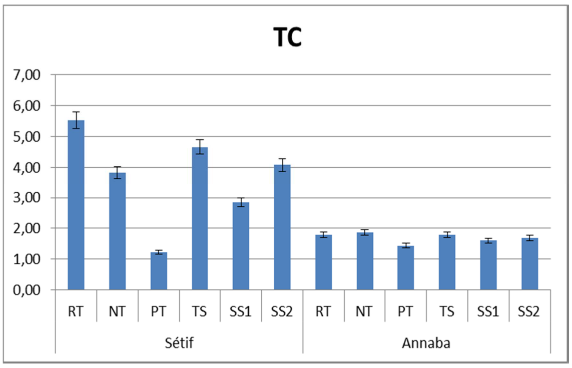


**Fig. 2.** TC for three tillage systems (plough tillage PT, reduced tillage RT, no-tillage NT), and two experimental sites (Annaba and Sétif), three soil layers (TS top soil, SS1 sub soil1, SS2 sub soil 2), and two sampling.

Soil total nitrogen was used as an important index for soil fertility evaluation, and reflects the soil nitrogen status. Total nitrogen values showed highly significant variations between experimental factors, especially at Sétif, in the TS and for all the profiles (SS1 and SS2), where the values for RT were considerably higher than those of NT and especially of PT, The high TN value for RT may be explained by for mineral fertilizer use before sampling. The highest concentrations were mainly in TS, SS2, SS1 successively.

The Nitrogen averages was low in the both region but with limit values between 0.17 and 0.28. Both parameters decrease with the depth of the profile. Where the values for RT were considerably higher than those of NT and especially of PT.

At Annaba, the TN mean was highest in RT and tended being similar between PT than in RT. The concentrations were almost equal; they were concentrated in the CS, SS1 and SS2 successively. Nitrogen contents were almost equal in both campaigns and decreasing with the depth of the profile. Overall, we found average values in the ranking of values of the region of Setif compared to that of the region of Annaba which were low and varied between [2.96% - 1.07%].

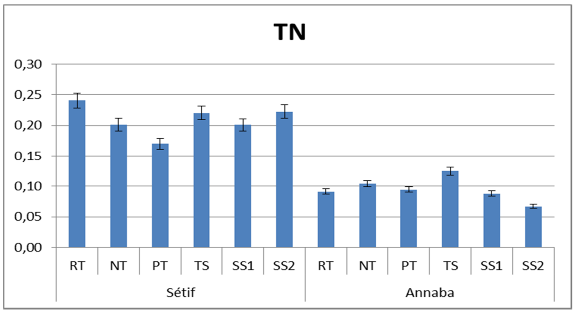


**Fig. 3.** TN for three tillage systems (plough tillage PT, reduced tillage RT, no-tillage NT), and two experimental sites (Annaba and Sétif), three soil layers (TS top soil, SS1 sub soil1, SS2 sub soil 2).

The C/Nratio shows very significant differences with the interaction of tillage systemsand tillage xregion for the surface layer. It increases successively according to the tillage systems (RT, NT, and PT), but it was distributed arbitrarily with the depth, the highest percentages were in the SS1, TSand SS2 respectively. For the Annaba region, the mean of C/N ratio increases according to the tillage systems (RT, NT and PT) and decrease with the layers (TS, SS1 and SS2).

Average percentages were found for all samples, but in traditional plowing in the Setif region, the percentages were very low. And in the last horizon of NT, we find high values compared to other horizons.

The C/N ratio in Sétif for RT in all samples (depending on depth or sampling period) was equal too and increases with depth and varies between [18.7-47.43]. InNT in the first sampling campaign, the ratiowas equal in both horizons, but in the second increases with depth. Like the other two types of tillage, the C/Nratio was almost equal in PT. In Annaba in RT C/N ratio was equal in all the samples but decreases with the depth of the profile and varies between [16.5-28.68]. In NTC/Nratio, was equal and decreases with the depth of the profile and in PT the ratio C/N ratio shows the same results as in NT and RT.

The content of TC and TN where significantly correlated in two region and with all tillage systems Positive correlations between TC and the C/Nratio in the entire set of samples suggest that more input of new, litter-derived organic matter with large C/Nratios promotes larger TC concentrations in two the study site. Similarly, increases in TC were positively correlated to increases of the C/Nratio.

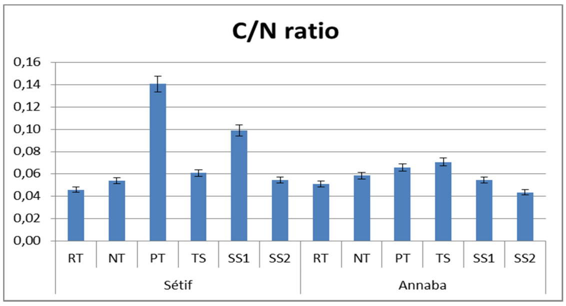


**Fig. 4.** C/N ratio for three tillage systems (plough tillage PT, reduced tillage RT, no-tillage NT), and two experimental sites (Annaba and Sétif), three soil layers (TS top soil , SS1 sub soil1, SS2 sub soil 2).

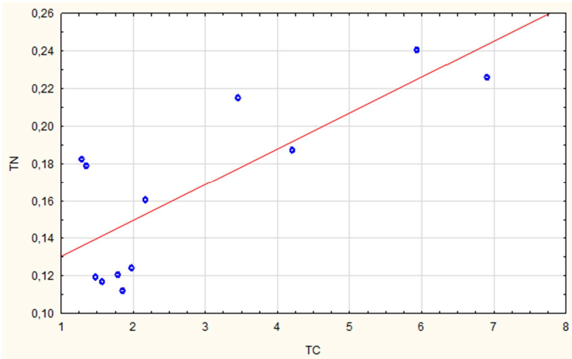


**Fig. 3.** Correlation between TC and TN of all samples of tillage systems (plough tillage PT, reduced tillage RT, no-tillage NT), experimental sites (Annaba and Sétif), soil layers TS, SS1, SS2 and two sampling campaigns.

**Table 1.** Results of ANOVA for TC, TN and C/N ratio. Significance levels for analyzed factors Regions, Tillage systems and their interaction.

| | Region | Tillage systems | Reg* Till-Sys |
|---|---|---|---|
| **TC** | (***) 0,0002 | (***) 0,0003 | (***) 0,001 |
| **TN** | (***) 0,004 | (-) 0,48 | (-) 0,33 |
| **C/N Ratio** | ((*)) 0,19 | (***) 0,000044 | (***) 0,0003 |

Soil C/N ratio was a sensitive indicator of soil quality. Soil C/N ratio was often considered as an indicator of soil nitrogen mineralization capacity. High soil C/N ratio can slow down the decomposition rate of organic matter and organic nitrogen by limiting the soil microbial activity, whereas low soil C/N ratio could accelerate the process of microbial decomposition of organic matter and nitrogen, which would not be conducive for carbon sequestration (Wu *et al.*, 2001).

Nitrogen deposition or fertilization was assumed to enhance soil C storage by causing reduced decomposition rates as well as increased litter input (Frey *et al.*, 2004., Hagedorn *et al.*, 2003). The declining C/N ratios in NT and RT in two regions with a lower average in Sétif may show that soils at two regions were currently an even stronger sink of TN than of TC. Deposition and accumulation of inorganic N was one possible explanation.

The soil in PT in two regions was rich in clay, and the clay mineral assemblage (Wäldchen *et al.*, 2012). Due to mineral assemblage, the site has a high capacity to fix ammonium (Nieder *et al.*, 2011). Therefore, part of the increase in soil N could be due to ammonium fixation by clay minerals.

**Conclusion**

Our approach of this study was to evaluate the TC and TN content in two Algeria regions under the effect of three tillage systems. We found that Tillage practices had a significant effect on the soil mainly for RT and NT in the top soil, whereas minimal influence was observed mainly in PT.

The concentrations of TC and TN under RT were the highest among in Sétif treatments, compared to Annaba.

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