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Carbon sinks in small Sahelian lakes as an unexpected effect of land use changes since the 1960s (Saga Gorou and Dallol Bosso, SW Niger)

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ABSTRACT

For several decades, global change has resulted in an increase in runoff in the Sahelian belt, provoking major changes in the quality and quantity of sediments transported by drainage networks. One of the astonishing consequences is the establishment of numerous permanent lakes. The origins of particulate organic matter (OM) preserved within lacustrine sediments of three lakes were investigated by coupling optical observations (palynofacies) and bulk geochemistry (Rock-Eval 6 pyrolysis). An initial estimate of particulate organic carbon (OC) stored in these lacustrine sediments was assessed. Soil organic matter (SOM) was sampled from the surface (0-10 cm) of various land-use and land-cover areas and was characterized and compared with sedimentary organic matter. Our results reveal that Lake Tankalawal is subjected to high autochthonous organic sedimentation (TOC ranges between 3.0 and 10.0 wt.%), while lakes Bangou Kirey and Bi are characterized by weak sedimentation of non-indigenous OM originating from the soil erosion and shore vegetation (TOC < 3.0 wt.%). In sediments, the effects of early diagenesis on the OM induce not only a loss of labile and aquatic OM but also a significant loss of terrestrial OM, which is supposed to be more resistant than its aquatic counterpart. Both the preservation of OM in top sediments and the relative preservation of terrestrial OM impact the OC storage in lakes. Indeed, OC storage in lacustrine sediments (Lake Bangou Kirey) was two to seven times higher than the OC storage in Sahelian soils, where greater contributions of terrestrial OM to sedimentary OM are associated with lower OC storage in lacustrine sediments. For lakes Bangou Kirey and Bi, OC accumulation rates were also assessed; due to the identification of a sedimentary limit corresponding to the establishment of permanent lakes dated earlier 1960s. High OC fluxes were estimated and ranged between 104 and 213 g OC m^{-2} yr^{-1}. Compared with other OC accumulation rates for various African lakes, these high values are similar to those calculated for reservoirs and are related to anthropogenic pressure, soil textures favoring erosion, and proper physical and chemical conditions for OM preservation in sediments. Accordingly, in these Sahelian environments that are generally viewed as non-efficient in storing OC, we claim that global change could promote a new OC sink. If other similar studies reinforce our assertion, then regional C budgets should be revisited.

1. Introduction

Since the 1960s, Sahel has been subjected to a spectacular climatic shift toward a strong deficit in precipitation with a decrease of 20 to 50% (e.g., L'Hôte et al., 2002; Lebel et al., 2009). Simultaneously, this region has experienced vigorous population growth, from 1.5% to 3.0% per year in the period from the 1950s to the 2000s (e.g., ECOWAS-SWAC/OECD, 2007; Raynaut, 2001). The combination of climatic shifts and anthropogenic pressure are responsible for drastic environmental changes

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in this harsh environment (Niang et al., 2007). Southwestern part of Niger is not exempt from these changes. The increase in runoff, which modified the water budget in watersheds, was broadly examined (e.g., Cappelaere et al., 2009; Descroix et al., 2012; Leblanc et al., 2008). In particular, the causes of this increase in runoff were investigated in the context of changes in land use accompanied by progressive soil crusting. Surprisingly, despite the persistence of desertification, the regional water table, regionally named "le paradoxe de Niamey," has risen (Leduc et al., 1997, 2001). This rise of the water table has involved the establishment of numerous permanent or ephemeral small lakes throughout the Sahelian belt (e.g. Cappelaere et al., 2009; Desconnets et al., 1997).

The intensification of surface runoff due to land use changes have triggered some changes in the budget of sediments within watersheds, which can be expressed by (i) a rise in erosion intensity, (ii) changes in erosion sources and (iii) an increase in sediment accumulation rates in lakes. The increase of cultivated areas implies that there are sediment and nutrient supplies in ponds and lakes (Descroix et al., 2012 and references therein). These changes also affect the quality and the amount of terrestrial organic supplies (allochthonous OM) carried by rivers to lakes and the primary organic productivity in lakes (autochthonous OM). Sahelian soils and sediments have been considered as weak C sinks and are poorly studied (Feller et al., 1991; Fofana et al., 2008); these recent environmental changes may significantly modify the organic C budget and exchange between terrestrial and aquatic environments.

The goal of this preliminary study was to focus on these new lacustrine C reservoirs by proposing the first quantification of OC stocks in lacustrine sediments. For this purpose, three representative lakes of the surrounding of Niamey, showing variable anthropogenic pressures, variable sedimentary dynamics and variable water quality levels were examined. We first characterized the optical and geochemical aspects of the OM to seek its origin, weathered stage and the ability to record these environmental changes. Next, OC stocks in Sahelian sediments were assessed and compared with the surficial Sahelian soil OC (SOC) storage, as well as with the OC storage potential of other African lakes.

2. Local settings and sampling strategy

2.1. Geographic and environmental settings

The limnic complex of Saga Gorou, including lakes Bangou Kirey and Bi, and the Lake Tankalawal are located in southwestern part of Niger (Fig. 1). The regional climate is semi-arid with yearly precipitation ranges between 400 and 700 mm and a potential evapostranspiration of 2500 mm (D'Amato and Lebel, 1998). The bedrocks consist of unconsolidated material composed of silts and clays from the Tertiary Continental Terminal (Greigert, 1966), and are overlaid by Quaternary eolian sands. These thick sandy deposits cover the valleys and can form dunes over the Continental Terminal plateau. Dry and sandy valley and plateaus are considered as the main geomorphic units in this catchment representing 78% and 22% of the surface catchment area respectively. Soils consist in tropical ferruginous soils slightly leached on sands (Cambic Arenosols, IUSS-WRB, 2006) and little evolved tropical soils exhibiting a ferruginous facies (Skeletic Leptosols, IUSS-WRB, 2006) developed on plateaus

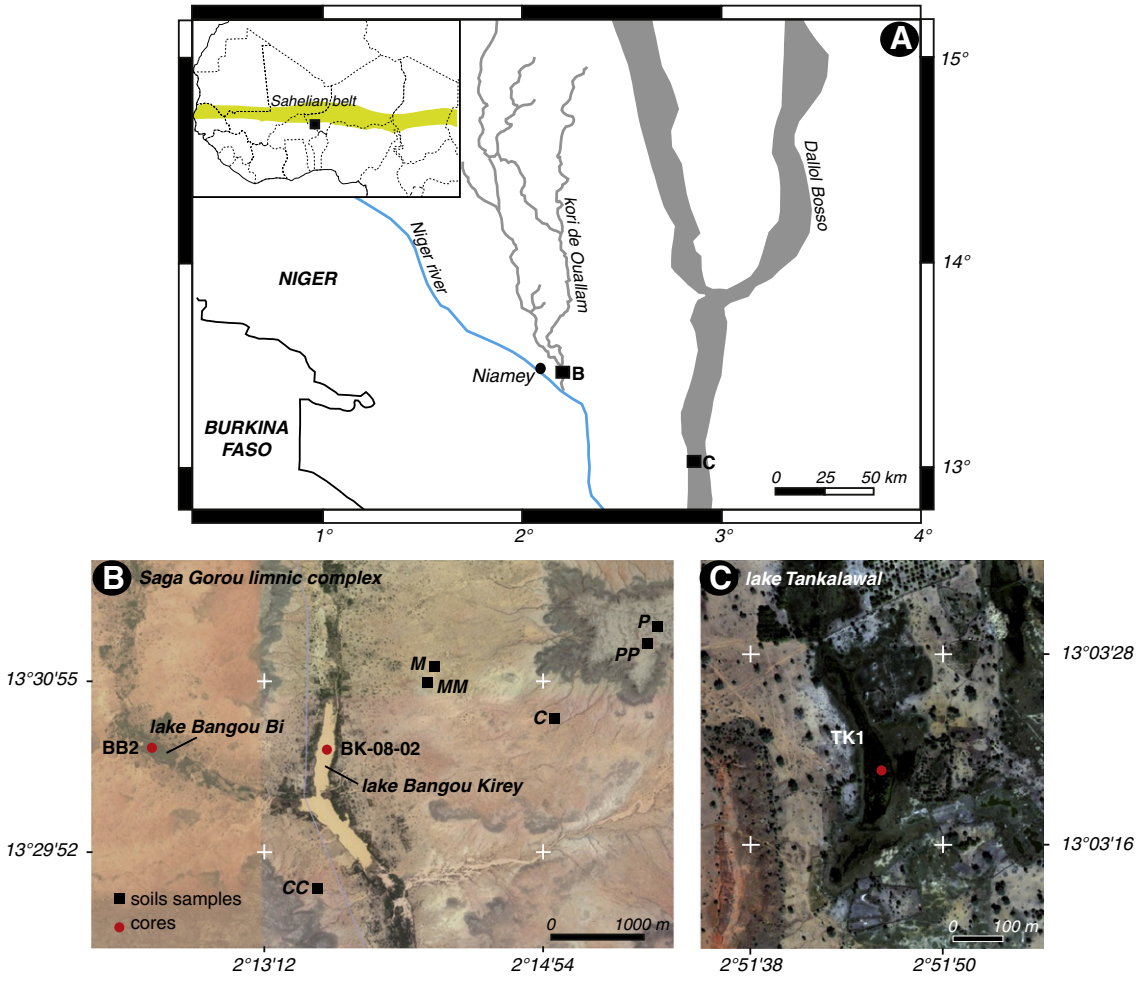

Fig. 1. Geographic context of the studied site and samples location.