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The role of environmental land use conflicts in soil fertility: A study on the Uberaba River basin, Brazil

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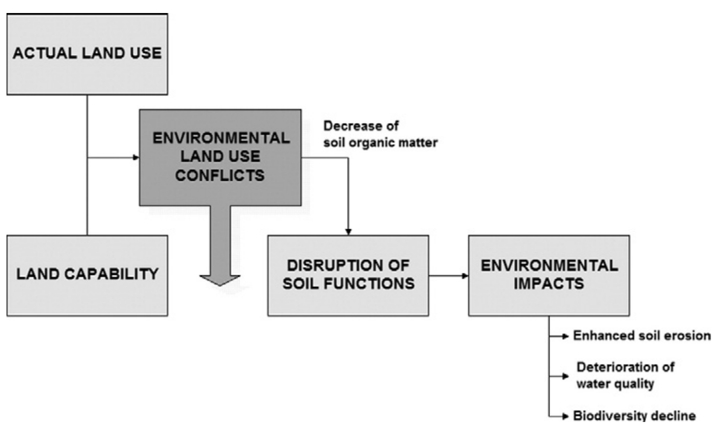
HIGHLIGHTS

- Environmental Land Use Conflicts (ELUC) relate to uses that ignore soil capability.
- ELUC may cause a decrease in soil's organic matter and exchangeable potassium.
- ELUC disrupt soil functions triggering a cascade of environmental impacts.
- Conservation measures may be used as tools to mitigate the impacts of ELUC.

GRAPHICAL ABSTRACT



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ABSTRACT

In the Uberaba River basin (state of Minas Gerais, Brazil), pastures for livestock production have invaded areas of native vegetation (Cerrado biome), while already existing pastures were invaded by crop agriculture, with an expansion of sugar cane plantations in the most recent years. In some areas of the basin, these land use changes were classified as environmental land use conflicts because the new uses were not conforming to land capability, i.e. the soil's natural use. Where the areas in conflict became dense, some soil properties have changed significantly, namely the organic matter content and the exchangeable potassium concentration, which have decreased drastically (5 kg/m^3 per 10% increase in the conflict area) threatening the fertility of soil. Besides, these changes may have triggered a cascade of other environmental damages, specifically the increase of soil erosion and the degradation of water quality with negative impacts on aquatic biodiversity, related to a disruption of soil organic matter structural functions. Because half the Uberaba catchment has been considered is a state of accentuated environmental degradation, not only caused by environmental land use conflicts, conservation measures have been proposed and requested for immediate implementation across the watershed.

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1. Introduction

Environmental land use conflicts develop on soils that are used for an activity not conforming to the soils' natural capability. The invasion of forested areas by agriculture is an example of a severe conflict. The concept of environmental land use conflict was introduced by Mello Filho (1992) and developed by Valle Junior (2008). Since these precursory studies, a considerable attention has been given to specific environmental impacts resulting from the persistence of land use conflicts in a region. A major effect of conflicts refers to the amplification of soil erosion and reduction of retention processes, as reported in Pacheco et al. (2014) and recognized by López et al. (2016), Perks et al. (2015), Sánchez-Canales et al. (2015) or Vilmin et al. (2015). In the study of Pacheco et al. (2014), soil losses in no conflict areas of a Portuguese watershed (Meia Légua River basin) were found to be half the losses in regions of severe conflict. According to Valle Junior et al. (2014a), land use conflicts may become a critical threat to soil conservation. Another recent observation is that environmental land use conflicts may impact the quality of surface water (Pacheco and Sanches Fernandes, 2016) as well as of groundwater (Valle Junior et al., 2014b). According to these authors, the impact is expressed by increased concentrations of nutrients (e.g. nitrogen or phosphorus) or other dissolved compounds (e.g. calcium or bicarbonate), caused by enhanced leaching of soils through runoff or infiltration. These findings have been quoted by other authors, namely in the studies of Kellner and Hubbart (2016), Mellander et al. (2016) or Meneses et al. (2015). Soil erosion and nutrient leaching are known to potentially damage riverine ecosystems through eutrophication and concomitant biodiversity decline. Thus, amplified erosion and/or nutrient leaching caused by land use conflicts are expected to worsen these problems. In a study of a small catchment located in northern Portugal (Sordo River basin), Valle Junior et al. (2015) reported a significant impact of land use conflicts on soil erosion and water quality, which had direct influence on the distribution of biota, namely of macroinvertebrate assemblages. The highest impacts on macroinvertebrates were chiefly associated to changes in water quality parameters such as temperature, oxygen saturation, turbidity, total suspended solids, nitrates, phosphates and sulphates, conductivity and dissolved oxygen. But they were also linked to hydromorphological alterations driven by the total absence of riparian vegetation along the streams, as a consequence of terrace building, agriculture and the resectioning or reinforcement of river banks associated with local viticulture. According to Guse et al. (2015), the distribution and composition of macroinvertebrates on the catchment scale are primarily affected by water quality and land use change at the catchment scale. Working in an urban area, Żelazna-Wieczorek and Nowicka-Krawczyk (2015) pointed out on the conflict between land use policy and the improvement of the ecological status of surface water ecosystems. According to these authors, the influence of the urban area in the ecosystem could be minimized without site-scale restoration measures, if proper management of the catchment was implemented through the replanting of riparian vegetation along the water courses.

The aforementioned studies have clearly identified and sometimes quantified a number of relevant impacts that land use conflicts exert on the environment. But the underlying triggers of those impacts remain poorly understood. As conflicts are disturbances of soil layers, triggers are ought to relate with the transformation of soil properties in the course of that perturbation. The objective of this study is therefore to identify which soil properties are transformed as regions become more densely covered by conflict areas. To accomplish this goal, a small catchment in the Minas Gerais State of Brazil (Uberaba River basin) has been extensively sampled and analyzed for soil properties such as texture (percentages of sand, silt and clay), phosphorus and organic matter contents, pH and exchangeable cations (potassium, calcium and magnesium). Besides, actual land uses have been compared with concomitant land capabilities set up by the ruggedness number of Strahler (1952), and a map of land use conflicts has been derived therefrom. Finally, correlation coefficients have been calculated between the soil properties and conflict areas around the sites of soil sampling, to check whether or not soil properties are influenced by variations in conflict area density. Having identified significant correlations, a discussion on their role is presented and conclusions are taken in conformity.

2. Study area

The hydrographic basin of Uberaba River occupies an area of approximately 2419 km^2, with a perimeter of 308 km, being located in the Triângulo Mineiro region and Minas Gerais state of Brazil between the following geographic coordinates: south latitude – 19°30′37″–20°07′40″; west longitude – 47°39′02″–48°34′34″. The catchment is located between the altitudes of 522 m and 1031 m (Fig. 1) and the region is subject to different weather regimes in winter and summer seasons (EMBRAPA, 1982). The winter season is cold and dry and lasts from October to April, while summer is hot and rainy and extends from October to April. Average precipitation in the basin is about 1584.2 mm/year, but most precipitation is concentrated in the months of December and January that can bring >540 mm/month of rainfall to the catchment (Silva et al., 2007). Average temperature approaches 23.2 °C. In the hottest months of summer (December and January) temperature can raise up to 31.4 °C, whereas in the coldest months of winter (May to July) it can drop down to 13.6 °C. According to the international classification of Köppen, the climate in the Uberaba region is Tropical (Cruz, 2003). A sector in the watershed headwaters (Fig. 1) is assumed to be a fundamental area for the protection of water resources, the riverine ecosystem and the remnants of native vegetation, and for that reason has been declared as Environmental Protection Area in 1999 (Minas Gerais State Law 13,183/1999).

The Uberaba River basin is situated in the N/NE portion of the Parana sedimentary basin, where Pre-Cambrian quartzites and micaschists (Canastra Group) are overlaid by sandstones and basalts of São Bento Group as well as by sandstones and conglomerates of Bauru Group. Close to the streams, these sequences are covered by Cenozoic alluvial and colluvial deposits. The outcropping rocks are solely those from the Bauru Group (Valle Junior et al., 2010). Soils developed on these rocks are mostly represented by latosols (Fig. 2) with average texture and various degrees of fertility (Valle Junior et al., 2013). These soils are particularly prone to erosion because field preparation for seeding (which occurs from October to December) usually coincides with the occurrence of rather erosive rainfall events (Valle Junior et al., 2012).

The resident population of Uberaba municipality approaches 260,000 individuals (http://www.ibge.gov.br). Economic activity in this region is mostly related to agriculture and livestock production, being significant at the regional scale (Valle Junior, 2008). Farmlands are mostly located in the southern half of the Uberaba River basin, the northern half being used essentially for livestock pasturing. Apart from these major uses, land occupation in the catchment is characterized by spots of native vegetation in the Cerrado biome (Fig. 3). The landscape has changed significantly after 1964. In those days, the native vegetation covered almost 40% of the basin area. This vegetation cover has been removed in the following decades, being replaced by managed pastures used for livestock production and to a smaller extent by areas used for short-cycle agriculture (mostly corn and rice). More recently, large areas in the southern part of the basin have been converted to a monoculture of sugar cane related to production of energy from ethanol (Candido, 2008). In the municipality of Uberaba, the area cultivated with sugar cane has exponentially increased in one decade, rising from 1240 ha in 2003 to 90,791 ha in 2013, and a similar trend was observed in the municipality of Conceição das Alagoas also located in the Uberaba River basin. In both regions, the average production of cane has stabilized in approximately 80 tons/ha (http://www.siamig.com.br/).