Soil and water degradation in a heavily modified meso-scale catchment in the Brazilian Cerrado of Mato Grosso

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(1) Introduction and Objectives

The Brazilian Cerrado, a neotropical savannah, is after the Amazon Basin the second largest biome in South America with an original extent of 2 million km^2. In the last decades extensive forest clearance has been ascertained for mechanised agriculture in the Cerrado. At present, 50% of the Cerrado is agriculturally influenced (Fig. 1) but has not received much attention in research. Future projections of land-use show that the trend towards intensive agricultural use is likely to continue for the entire biome. To produce high biomass yields it is required to apply large amounts of fertilizer and lime because the dominating dystrophic soil type Ferralsol shows an acidic reaction which reduces the P availability

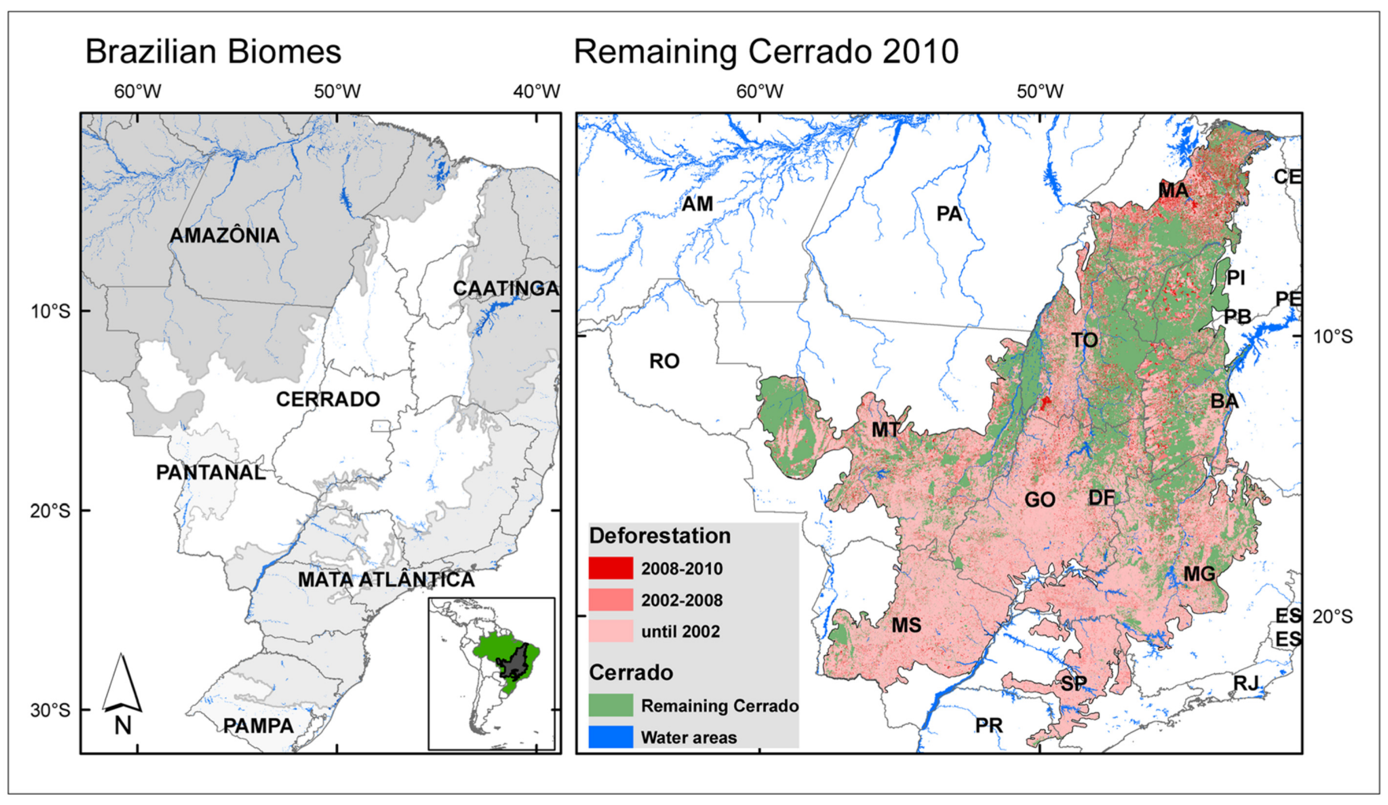
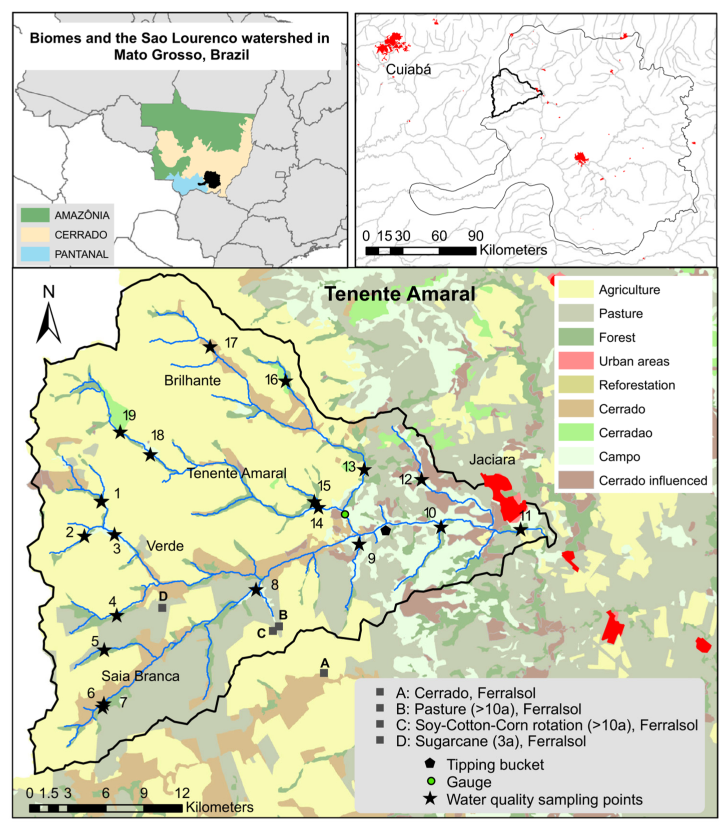


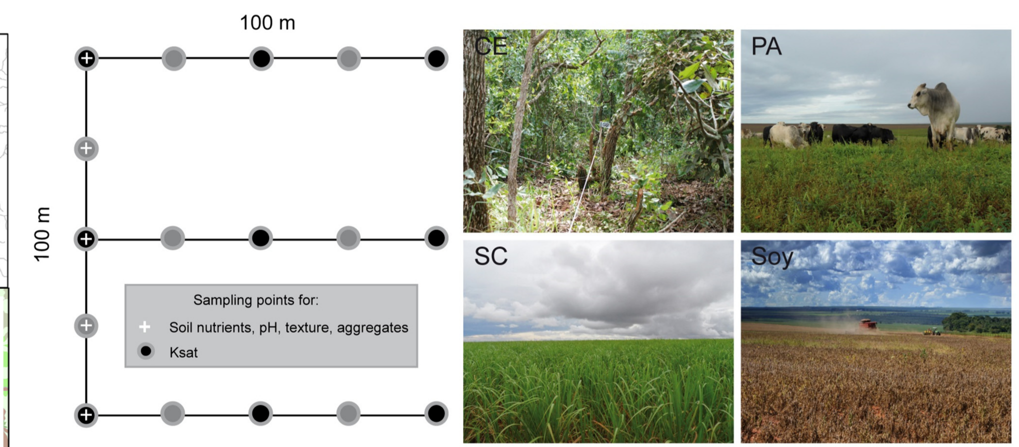
Figure 1: Original and remaining Cerrado in Brazil (data source IBAMA)

This study aimed to (1) examine the effects of land-use change on the soils of natural Cerrado transformed to common croplands (soybean/cotton/maize rotation and sugarcane) and pasture and (2) indicate how agricultural production affects water quality in the dry and wet season.

(2) Study site, methods and sampling design

The catchment covers ca. 865 km^2, elevation is ranging from 225 to 800 m above sea level (a.s.l.). Mean annual precipitation is 1500 mm, of which about 80% falls as heavy rain from October to April. About 70% of the catchment area is used for sugarcane and soybean production in rotation with maize and cotton. About 18% of the catchment are used for cattle grazing. Double-cropping without irrigation is mainly used within the Tenente Amaral. The pastures are planted with *Brachiaria*, *Andropogon*, and *Panicum sp.*, and are regularly fertilised. Depending on the crop fertilisers (NPK 400-600 kg ha^{-1} a^{-1}), lime (3 t ha^{-1}), and between 10 and 13 pesticides of about 2 kg ha^{-1} are applied. The soil and water sampling were conducted in the dry and rainy season between 2011 and 2013.





Parameter	Method	n per plot
Infiltrability [mm/h]	Single ring	17 at surface
Ksat	Amoozemeter	11 at each depth, 3 depths
Aggregate stability	Herrick-Test-Kit (Herrick et al. 2001)	5 locations 46 tests at 2 depths
Texture (3 soil depth), pH	Aerometer, pHCaCl$_2$	5 locations at 3 depths
Soil nutrients (NPK) [g or mg/kg]	N-Kjedahl, PK-Mehlich-1	5 locations at 3 depths
Precipitation [mm]	Tipping bucket (0.2 mm resolution)	1 year of recording
Water quality samples on temp., O$_2$, el. conductivity, ORP, Cl$^-$, NO^{3-}, SO$_4^{2-}$, NO^{2-}, and PO$_4^{3-}$	Snapshot sampling (Grayson et al. 1997) with a multiparameter probe and lab analysis (ion chromatography)	19 (triplicate) in the dry and rainy season

Figure 2. Soil and water sampling in the Tenente Amaral study area. Sampling design on four single hectare plots (CE—Cerrado, PA—Pasture, SC—Sugar cane, Soy—Soybean) on Ferralsol with the methods to determine soil and water parameters.

(3) Results

I. Effects of land use on soil physical and chemical properties

Decreased infiltrability and Ksat under pasture and croplands

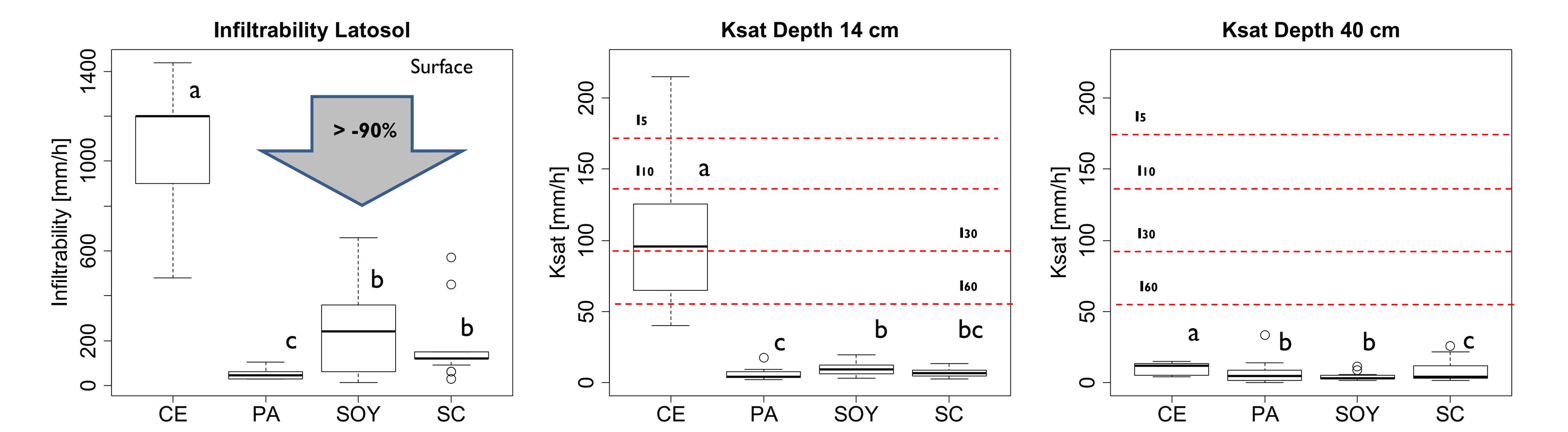
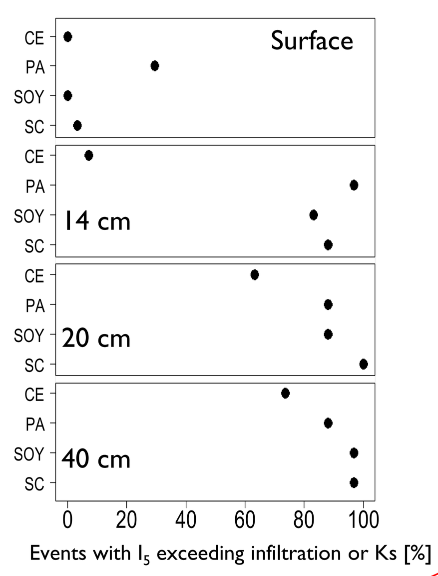


Figure 3. Surface infiltrability and Ksat at 14 cm and 40 cm soil depth as a function of land-use type (CE—Cerrado, PA—Pasture, SOY—Soybean/cotton, and SC—Sugarcane) on Ferralsols. Lower-case letters denote significant differences (p < 0.05) after the Kruskal–Wallis multicomparison procedure. n = 17 (infiltration) and n = 11 (Ksat) for each plot and depth, respectively. The red dotted line indicates different rainfall intensities (5 to 60 minutes) for the catchment

Increased overland flow after land conversion

Figure 4. Even smaller rainfall events cause overland flow and ponding on pasture by saturation excess and Hortonian overland flow



Surface

- I_5 intensities do not exceed infiltrability for CE and SOY
- only for PA about 30% of the events with I_5 were higher than infiltration resulting in overland flow (OLF).

14 cm: decrease in permeability for agric. LU

- >80% of all I_5 events exceeding Ksat for agricultural LU
- Perched water table in 14 cm (Fig. 3) resulting in ponding, saturation excess and Hortonian overland flow

Decreased soil aggregate stability and erosion risk under croplands

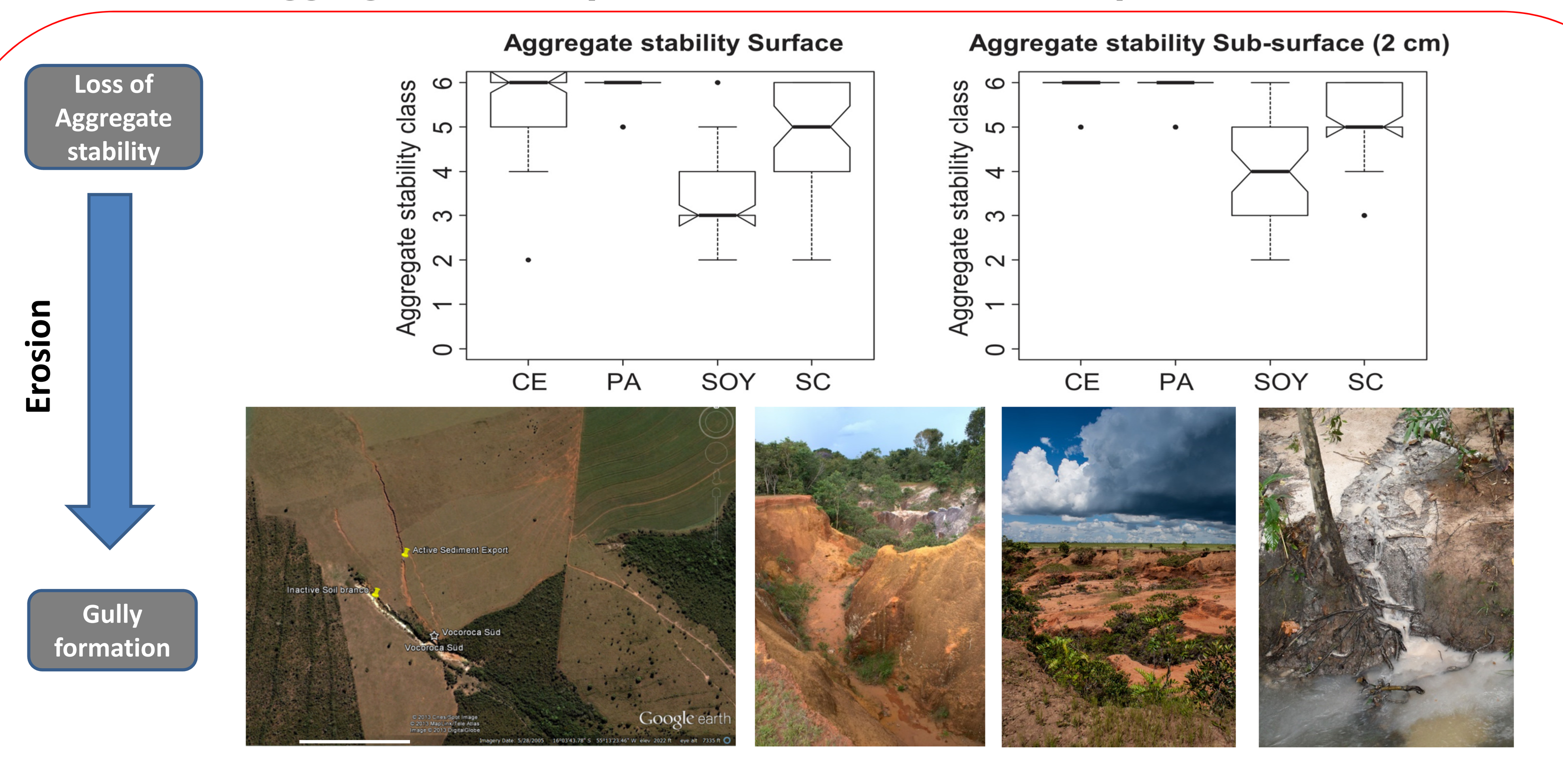


Figure 5. Boxplots of soil aggregate stability classes (Classes 5-6=resistant to erosion, 3-4=prone to erosion, 1-3= very prone to erosion) of land-use type (CE—Cerrado, PA—Pasture, SOY—Soybean, SC—Sugarcane) on Ferralsols at the soil surface and at 2 cm depth (n = 45). The width of the boxplot notches represents the 95% confidence interval of the median value (notch = ±1.58 × interquartile range (IQR) / √n). Non-overlapping notches from two boxplots indicate roughly significant differences between the medians. The catchment is already faced by gully erosion with breakthroughs of overland flow events which are not buffered by the riparian zone. .

Increased pH under pasture and croplands. Increased topsoil K and extremely high P under soybeans. N is not elevated under agricultural land uses.

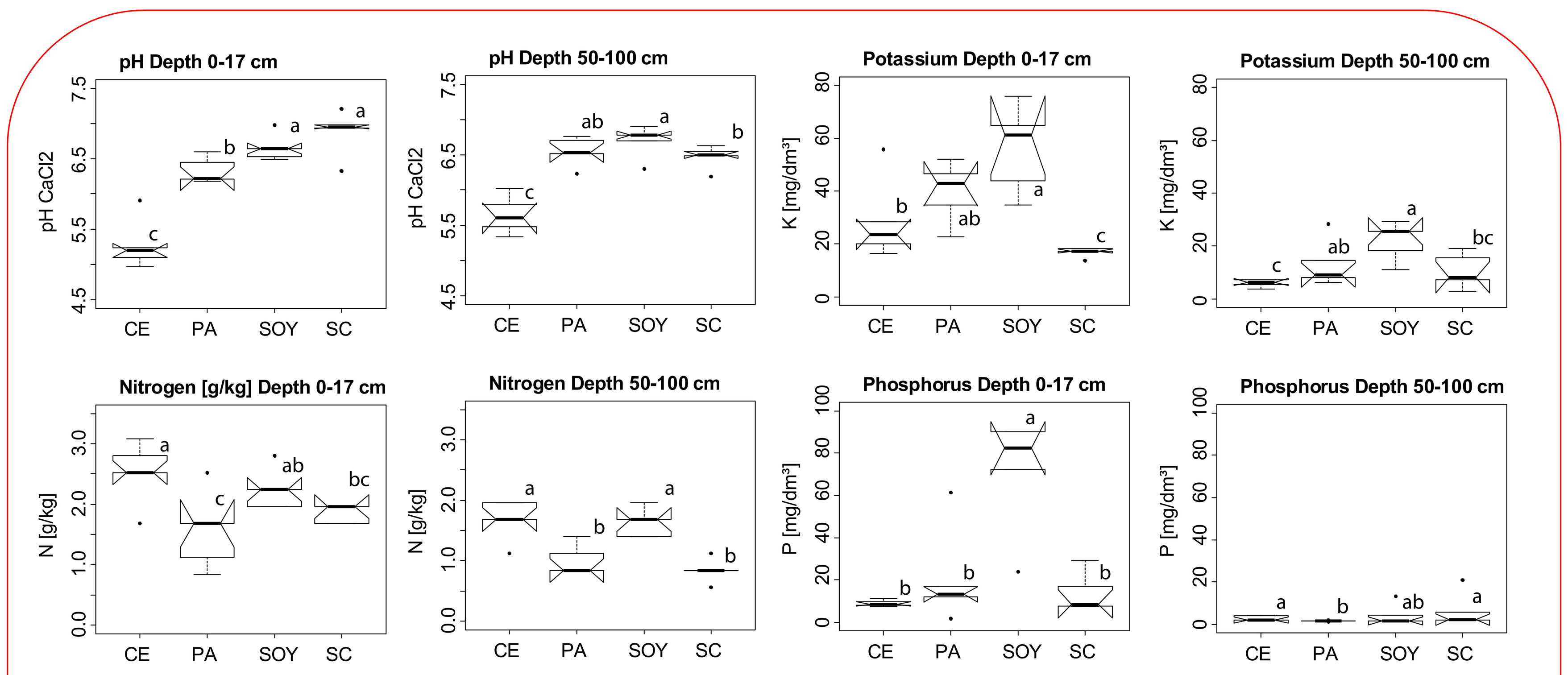
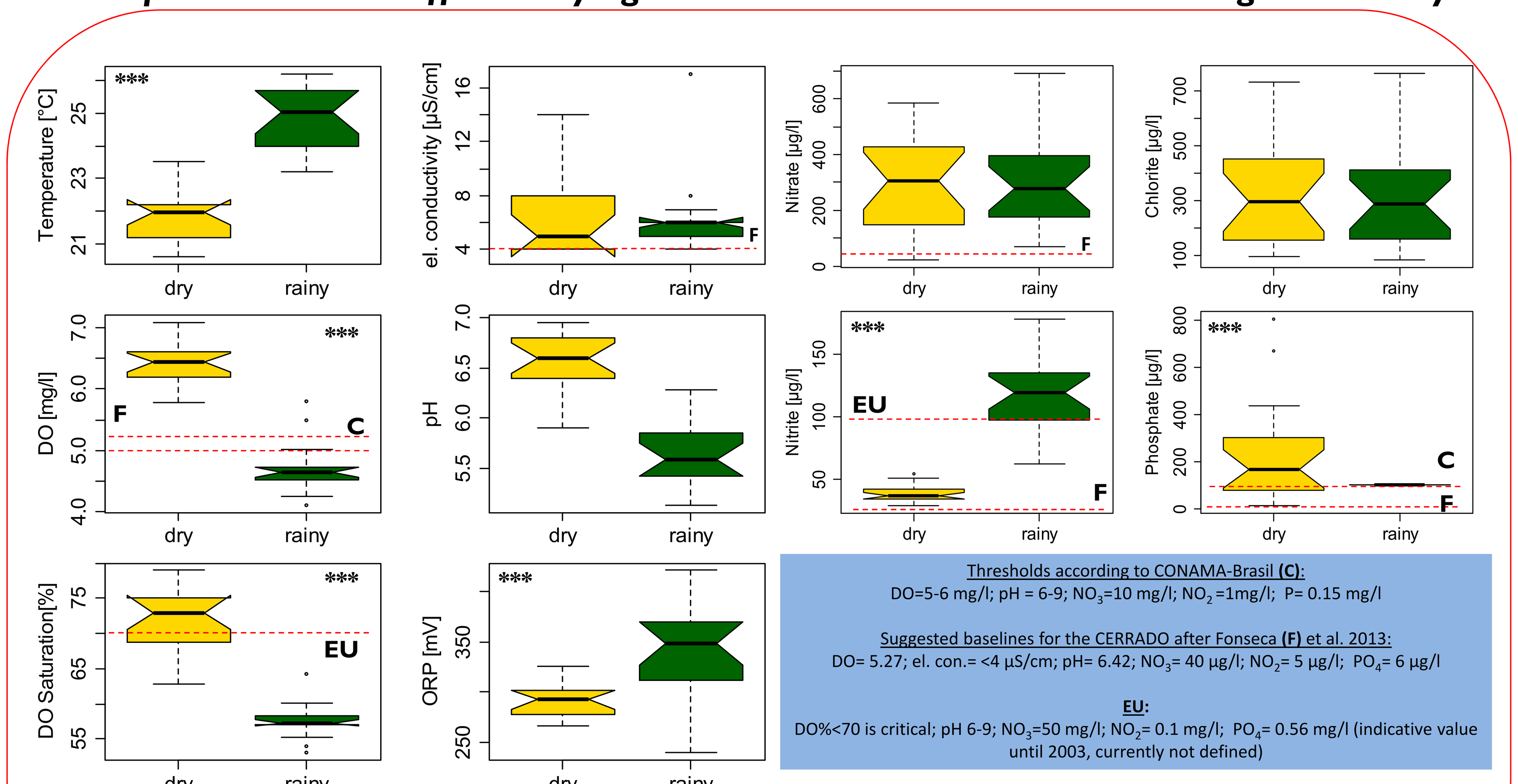


Figure 6. Boxplots for soil pH, total nitrogen, available potassium, and available phosphorus at two soil depths (0–17 cm and 50–100 cm) for different land-use types (CE—Cerrado, PA—Pasture, SOY—Soybean and SC—Sugarcane) in the Tenente Amaral Catchment. The width of the boxplot notches represents the 95% confidence interval of the median value (notch = ±1.58 × interquartile range (IQR) / √n). Non overlapping notches from two boxplots indicate significant differences between the medians. Different letters indicate significant (p < 0.05) differences between the sites after Kruskal–Wallis multicomparison procedure (n = 5)

II. Seasonal effects on water quality in an agricultural catchment

Water parameters are affected by agricultural activities and show a strong seasonality



<u>Thresholds according to CONAMA-Brasil **(C)**:</u>
DO=5-6 mg/l; pH = 6-9; NO$_3$=10 mg/l; NO$_2$ =1mg/l; P= 0.15 mg/l

<u>Suggested baselines for the CERRADO after Fonseca **(F)** et al. 2013:</u>
DO= 5.27; el. con.= <4 µS/cm; pH= 6.42; NO$_3$= 40 µg/l; NO$_2$= 5 µg/l; PO$_4$= 6 µg/l

<u>**EU**</u>:
DO%<70 is critical; pH 6-9; NO$_3$=50 mg/l; NO$_2$= 0.1 mg/l; PO$_4$= 0.56 mg/l (indicative value until 2003, currently not defined)

Figure 7. Boxplots of physical and chemical water parameters of the snapshot sampling locations in the dry and rainy season. Each sampling location (n = 19) is represented by the mean of three replicates. There was no spatial pattern across the catchment evident (not shown). Remarkably low dissolved oxygen (DO) concentrations in the rainy season and in contrast high phosphate concentrations in all subcatchments in the dry season. The three asterisks (***) indicate significant differences between the seasons (α = 0.05) after the Wilcoxon test.

(4) Conclusion

- Land conversion affects hydrological flow paths
- Land conversion risks increased surface erosion and nutrient transport to streams
- Soybean sites showed P over-fertilisation with high risk of P displacement
- Snapshot water sampling showed strong seasonality in water quality parameters
- Water quality parameters were affected by agricultural activities
- Expectation of serious limitations of future productivity and ecosystem stability

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