Drivers of soil organic carbon spatial variability at watershed scale, Itasy Region, Madagascar

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INTRODUCTION

Soil organic carbon (SOC) is an indicator of soil quality and sustainability of agro ecosystems. The soil carbon sequestration restores degraded soils, enhances biomass production, purifies surface and ground waters, and reduces the rate of enrichment of atmospheric CO_2 (Lal, 2004). Understanding the drivers of the spatial variability of soil organic carbon (SOC) is essential for recommendations concerning sustainable land management. This work is part of an ongoing project aiming to disseminate agro ecological practices in the Itasy region by demonstrating their potential in terms of carbon sequestration and climate change mitigation. In this framework, this study aims to contribute to a better knowledge of the different factors determining spatial heterogeneity of SOC at watershed scale.

MATERIAL AND METHODS

Study area

This study was conducted in three watersheds located in the Itasy region, Highlands of Madagascar. The watersheds were chosen to be representative of the dominant soil types encountered in the Itasy region. Each watershed corresponds to a main soil type (table 1) and six main land use systems such as forestry, agroforestry, conventional and intensified cropping systems, paddy rice fields and fallows were identified.

Table 1: Location and soil type of each watershed

Watersheds	Location	Soil type
Imerintsiatosika	18°58'15.50"S 47°17'52.76"E	Cambisols
Alatsinainikely	18°56'21.53"S 46°34'21.12"E	Ferralsols
Analavory	18°59'6.27"S 46°38'58.63"E	Andic soils

Soil sampling

The soil sampling work was carried out taking into account the representativity of the landscape of each watershed and the land use systems. Along transects, 109 representative plots with different landscape location (upper, middle and lower position) and different land uses systems were selected in order to determine the influences of each factor on SOC concentration. Four composite samples from 0-40 cm depths of soil were taken from each plot.

Laboratory analysis

Soil samples were dried, sieved, ground to 0.2 mm and scanned using the mid-infrared spectrometry. SOC concentration was determined by Walkey-Black method for 60% of the samples. These samples were used to perform a model of SOC prediction. SOC of 40% of the samples were predicted using the model performed.

Data analysis

Basic statistical parameters including mean, standard deviation, variance, coefficients of variation and normality tests were analysed using Microsoft Excel (2010) and XLSTAT (2008). Analysis of variance (ANOVA) using the Fisher tests were performed to determine and compare the influences of each factor to the SOC spatial variability between and within each watershed. The significance level of 0.05 was used in this study.

RESULTS

Descriptive statistics

Descriptive statistical traits of all the 109 soil samples and for each watershed, corresponding to a main type of soil are shown in table 2. The original data were transformed using logarithmic function to obtain a normal distribution.

Table 2

Watershed	N	Mean (‰)	Minimum (‰)	Median (‰)	Maximum (‰)	Standard deviation	Coefficient of Variation (%)
Cambisols	37	22.17	10.37	19.43	39.88	7.58	34.21
Ferralsols	36	16.74	7.17	17.85	31.68	5.80	34.65
Andic soils	36	25.97	5.34	22.85	77.88	17.03	65.57
Overall samples	109	21.63	5.34	19.83	77.88	11.76	54.38

The SOC concentrations for the overall sample were moderately variable with a coefficient of variation CV= 54%. The watershed dominated by andic soils showed the highest SOC variability (CV= 65%). Coefficients of variation of the watersheds dominated by cambisols and ferralsols are more or less equal.

Influences of the factors considered on SOC spatial variability

Soil type

For the overall samples, the andic soils showed the highest SOC concentration while the ferralsols the lowest. The ANOVA showed that there is no significant difference between andic and cambisols at P=0.05. However, the difference was statistically significant between ferralsols *vs* andic soils (p-value=0.002) and ferralsols *vs* cambisols (p-value=0.005) (fig. 1).

Landscape location

Statistical analyses showed that lower position in the landscape was associated with higher SOC concentration while the upper position was associated with lower concentration. The ANOVA showed a significant difference between lower *vs* middle position (p-value= 0.007) and lower vs upper position (p-value= 0.003). No significant difference was observed between upper and middle position (fig. 2).

Land use

Statistical analyses showed that agroforestry and paddy rice field were associated with high amount of SOC concentration whereas fallow and conventional crops were characterized by low amount of SOC concentration. Based on land use, the ANOVA divided all the samples in four groups (fig. 3). A significant difference was observed between agroforestry and conventional crops (p-value < 0.0001) and between agroforestry and fallow (p-value=0.001). SOC concentration of paddy rice field was also significantly different from conventional crops and fallow with p-value equal to 0.001 and 0.004 respectively.

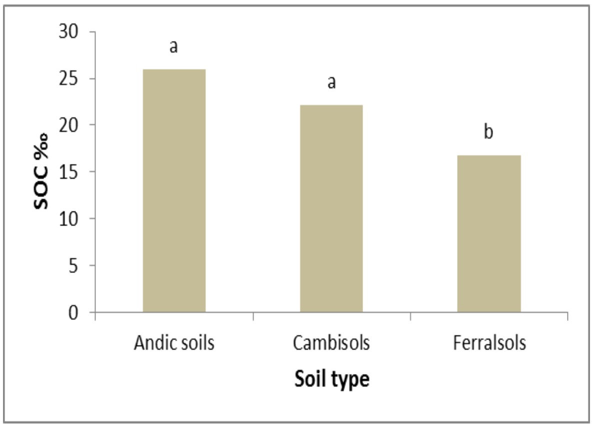

Fig. 1 : Influence of soil type on SOC

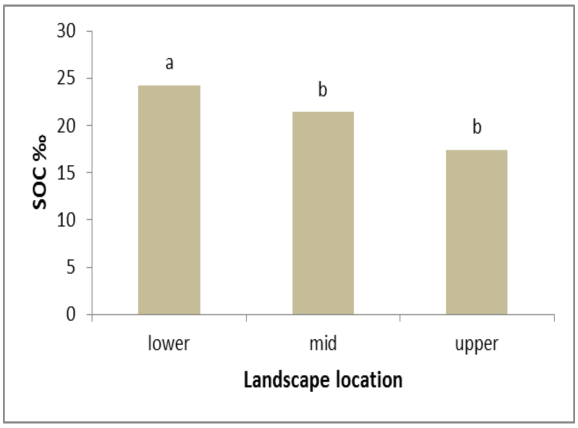

Fig.2: Influence of landscape location on SOC

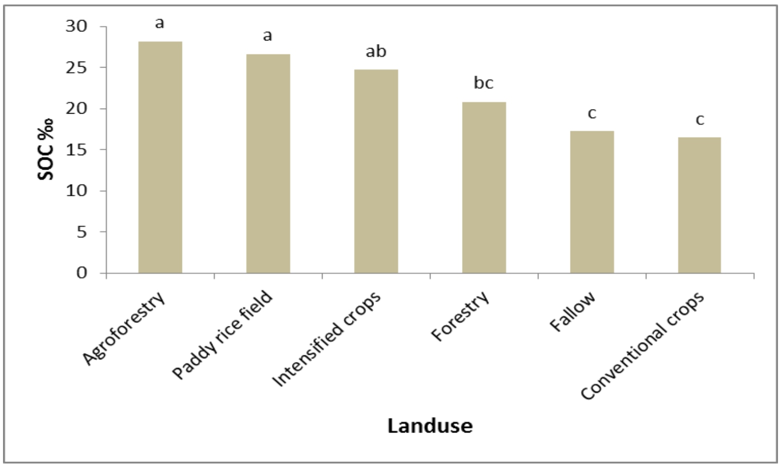

Fig.3: Influence of land use location on SOC

CONCLUSION

Soil organic carbon concentrations showed moderate spatial variability based on the values of the coefficient of variation with the exception of andic soil watershed. For the overall sample, lower SOC concentrations were associated with upper landscape, fallows and conventional crops whereas higher SOC concentrations were associated with lower landscape, agroforestry, and flooded rice fields. In order to complete this work, geostatistical analyses are still needed.

ACKNOWLEDGEMENTS

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REFERENCE

Lal, R. 2004. Soil carbon sequestration impacts on global climate change and food security. Science. 304: 1623–1627.