Assessing change in soil fertility and soil carbon storage under conversion of forest to croplands in Eastern Region of Madagascar - Case of Moramanga, and Taolagnaro

Nandrianina RAMIFEHIARIVO[1], Herintsitohaina R. RAZAKAMANARIVO[1], Clovis GRINAND[1], Tantely RAZAFIMBELO[1], Jeannicq RANDRIANARISOA[1], Nantenaina RAMBOATIANA[1]

[1] Laboratoire des Radioisotopes, Université d'Antananarivo, Route d'Andraisoro BP 3383, Madagascar; ranandrianina@hotmail.fr

Introduction

Since tropical deforestations are the second main source of around 20% Green House Gas (GHG) emissions, Reducing Emissions of GHG from Deforestation and forest Degradation (REDD) initiatives became crucial for developed tropical countries like Madagascar (Bellassen et *al. 2008)*. Actually, a part from biomass loss, forest conversion into croplands involves changes in soil properties related to carbon storage and crop productivity (*Wolde et al,* 2009). Those are both crucial for facing challenges in climate change mitigation and ensuring food security. And as knowledge in soil "response" to Land Use (LU) change as forest conversion are still scarce in Madagascar, this study aimed to assess impact of *slash and burn* practice of forest conversion with focus (i) on soil carbon storage capacity according to the LU (ii) and soil fertility according to the chronosequence.

Materials and Methods

Area of study and Study Sites

Area of study is in Eastern and Southern Region of Madagascar (Moramanga and Taolagnaro). These regions are specified by the presence of natural forest with a high level of forest degradation. The study site is located at Ambohibary (District Moramanga, Region Alaotra Mangoro) and Beapingaratsy (District Taolagnaro, Region Anosy). Identification of plots based on chronosequence establishment and LU change monitoring (use of aerial photos and remote sensing). Remote sensing works are based by using and comparing Google Earth maps and some deforestation's maps (2000-2005, 2005-2008, 2005-2010 and 2008-2012). Theoretical points were specified to facilitate and prepare the field visit.

Design sampling

Once the different LU located and chronosequence determined, field worked (i) for investigation historic-survey (ii) and for soil sampling. In total, samples were collected from 100 plots for Moramanga and 25 plots for Taolagnaro according to the land use (Table 1) and chronosequence. Soil sampling was done on three depths (0-10 cm, 10-20 cm and 20-30 cm).

Table 1 : Number of plots according to the land use

Sites	Land use	Plots	Subtotal	Total
Moramanga	**Forest**	20	100	125
	Non Forest	80		
Taolagnaro	**Forest**	7	25	
	Grassland	2		
	Cropland	16		

Analysis of soil properties

In order to quantify soil carbon stocks and soil fertility per plots, some soil analysis and "parameter" calculation as followed were performed by i) determination of soil humidity and coarse element (CE) (ii) analysis of Soil Organic Carbon (SOC), N content and CEC (iii) calculations of studied soil properties: Bulk Density (Bd), SOC stocks, C/N report and CEC.

Determination of coarse element (CE)

The coarse elements (CE) are elements of soil sample more than 2 mm in diameter. They are considered to have no organic matter content. For having CE, soil samples were sieved on 2 mm. CE was weighed to obtain its percentage compared to the total mass of the sample.

Soil Organic Carbon (SOC) contents

Soil Organic Carbon (SOC) contents (Corg) were estimated by using Walkley and Black conventional methods first combined with alternatives mid infrared spectroscopy (MIRS) analysis. 75% of samples were used for calibration and 25% for validation. Soil samples were ground to 0.2 mm for analysis.

Evaluation of the content in total Nitrogen and C/N report.

The total nitrogen regroups all shapes of mineral and organic nitrogen in a sample of soil. It doesn't provide any information on the available mineral nitrogen for the plant. It's essentially interpreted through the C/N report. The method of mineralization by sulphuric acid has been used follow-up of the dosage skalar in NH_4. Only Taolagnaro samples were analyzed in labs for soil fertility (C/N ratio and CEC). More the C/N report is high (>12), more the biologic activity is reduced and the mineralization meets some difficulties.

Bulk density (Bd)

On the field, undisturbed soil samples were taken with metal cylinder (502,4 cm^3) for determining Bulk density. The soils were then dried and weighed. The density was calculated according to equation 1.

Bd (g/cm^3)=Dry mass of sample (g)/Volume of sample (cm^3)

Equation 1 : Bulk density

Soil Organic Carbon stocks (SCO)

SOC stocks (SCO *(Mg /ha)*) were obtained (Equation 2) from the SOC contents (Corg *(g/kg)*), bulk density (Bd *(g/cm^3)*), the thickness of the horizon during the sampling (E *(cm)*) and the proportion of coarse matter (CE *(%)*).

SCO = Bd x 0,1 x (1 – CE) x Corg x E

Equation 2 : SOC stocks

SCO in the depth of 0-30 cm were determinate by summing stocks on each horizon thickness.

Determination of Cations Exchange Capacity (CEC)

Cations Exchange Capacity (CEC) is the maximal quantity of cations that a weight determined of soil can keep. It has a fundamental role for the food in mineral elements of the plant. The CEC have been gotten by measure of the absorbance of the chloride of cobaltihexamine with an atomic absorption spectrophotometer. The equation 3 showed the calculations of CEC (meq/100g) which used concentration of chloride of cobaltihexamine extract ([Cohex]) and the percentage of humidity of analysis sample (H%)

$$\boldsymbol{CEC} = ([\boldsymbol{Cohex}]\boldsymbol{initial} - [\boldsymbol{Cohex}]\boldsymbol{final}) \times (\mathbf{100}/(\mathbf{100} - \boldsymbol{H}\%))$$

Equation 3 : CEC calculations

Results and discussion

SOC stocks according to the land use

SOC stocks in Moramanga (Fig.1) showed that there was no significant differences between SOC stocks of forest soils (82 ±4,84 Mg/ha) and deforested soils (88,6 ±2,49 Mg/ha). For Taolagnaro (Fig.2), according to the land use, SOC stocks were varied: 123,79 ±23,61 Mg/ha for forest soil, 116,01 ±7,86Mg/ha for grassland , 117±21,99Mg/ha for cropland (rotation crop/fallow) but the variation are not significant according ANOVA (p>0,05). Perrin and al, (2013) showed that it's due to the mineralization of SOC which varies according to the land-use, especially the plant cover.

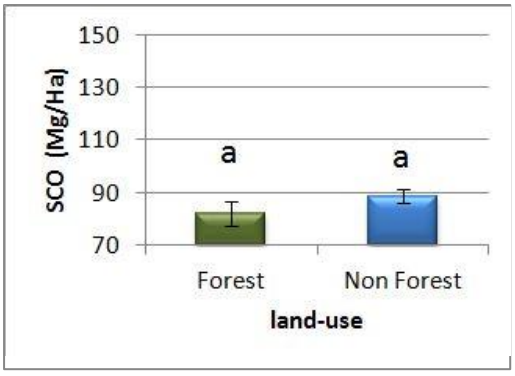

Fig.1 : ***SOC stocks (0-30cm) according to the land use (Moramanga)***

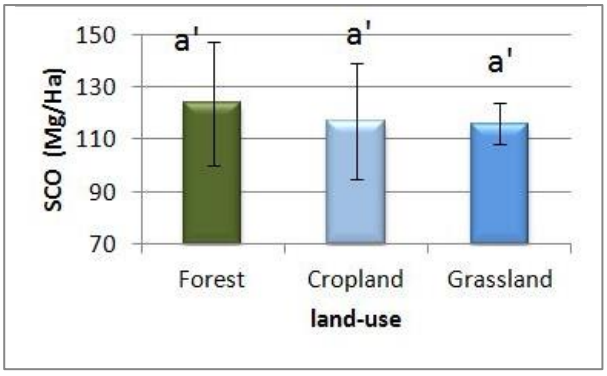

Fig.2: ***SOC stocks (0-30cm) according to the land use (Taolagnaro)***

Evolution of soil fertility according to the age of deforestation

There is an important reduction of the two parameters (C/N and CEC) until the tenth year of deforestation, 17 to 13 for C/N (Fig.3) and 3,76 to 1,15 meq/100g for the CEC (Fig.4). After the ten year, CEC and C/N had known a stability and increase. The decrease was reflect crops period. Clearing and loss of litter brought a rapid decrease in soil organic matter and the beginning of chemical, biological and physical degradation of surface's horizons. The increase correspond fallow period where there is non-disturbance of soil, that leads to a reduction in mineralization by microorganisms (Wolde et al, 2009).

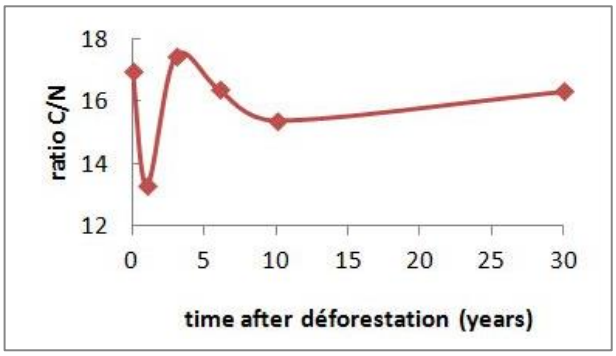

Fig 3 : ***Ratio C/N according to the age of deforestation (Taolagnaro)***

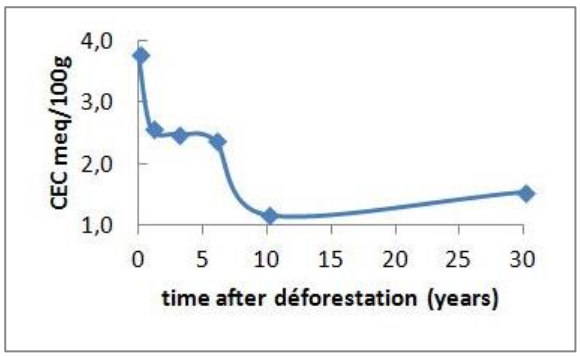

Fig 4 : ***CEC according to the age of deforestation(Taolagnaro)***

Conclusion

Conversion of forest to cropland was trend a depletion of soil fertility but LU change should well be managed. In the optics of a sustainable development for local-people we need to promote practices which both assure crop productivity and preserve forest area while considering their impacts on the climate. Thus, under REDD, a better management of forestland and cropland at first edge is suggested.

References

Bellassen V et al. (2008).Réduction des Emissions dues à la Déforestation et à la Dégradation des forets: quelle contribution de la part des marches du carbone ? *Etude Climat n°14*.

Perrin A ., Fujisaki K., Petitjean C., Sarrazin M., Godet M., Garric B., Horth J., Balbino L., Filho A., Machado P., Brossard M. (2014). Conversion of forest to agriculture in Amazonia with thechop-and-mulch method: Does it improve the soil carbon stock? *Agriculture, Ecosystems and Environment .101– 114p.*

Wolde M., Edzo V., Mitiku. (2009), Carbon stock changes with relation to land use conversion in the lowlands of Tigray, Ethiopia, *Conference on International Research on Food Security, Natural Resource Management and Rural Development. 5p*