EXPLORATION OF THE OXALATE-CARBONATE PATHWAY FOR SOIL FERTILITY AND CARBON STORAGE (REGIONS OF SAKARAHA AND MORONDAVA, MADAGASCAR)

Manony ANDRIAMPIOLAZANA [1]**,** Finaritra Manohiaina RANDEVOSON [2], Gabrielle Lalanirina RAJOELISON [3], Guillaume CAILLEAU [4], Eric VERRECCHIA [5], Herintsitohaina Ramarson RAZAKAMANARIVO [6]
[1 2 3] Département des Eaux et Forêts, Ecole Supérieure des Sciences Agronomiques- Université d'Antananarivo, BP 175 Madagascar, and.manony@gmail.com [1]; finaritraran@gmail.com [2]; g.rajoelison@yahoo.fr [3] ; [4 5] Faculté des géosciences et de l'environnement, Institut des dynamiques de la surface terrestre, Université de Lausanne, Quartier UNIL-Mouline, CH-1015 Lausanne, Guillaume.Cailleau@unil.ch [4] ; Eric.Verrecchia@unil.ch [5]. [6] Laboratoire des Radioisotopes, Université d'Antananarivo, Route d'Andraisoro BP 3383, razakamanarivo@gmail.com [6]

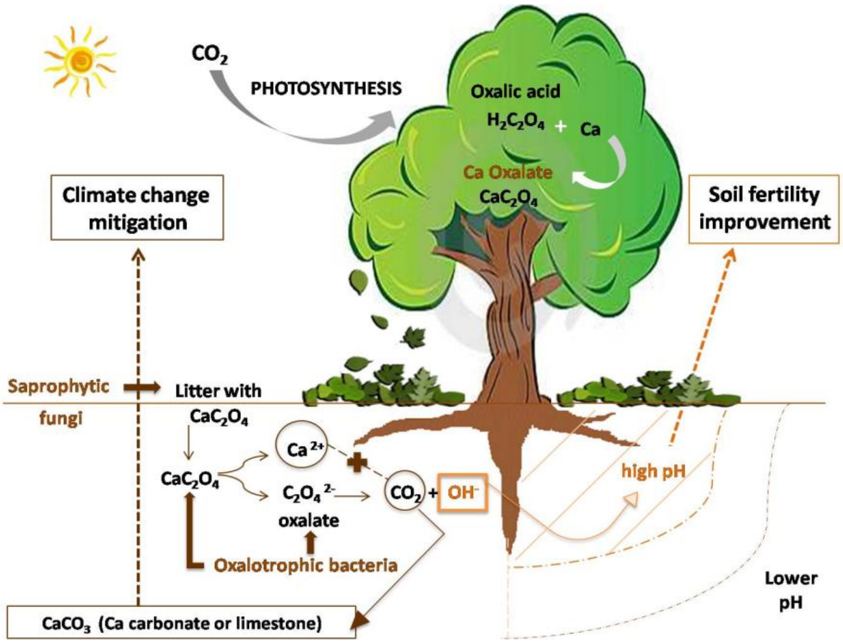
1. Introduction

Forests sequester atmospheric CO_2 through photosynthesis and store it as biomass and soil organic matter. Besides this conventional process, there is another phenomenon called the "oxalate-carbonate pathway" (OCP) which leads some “oxalogenic” tree ecosystems to store atmospheric CO_2, as calcium carbonate ($CaCO_3$) in tropical acid soils (Aragno et *al.*, 2010). This phenomenon begins also by atmospheric CO_2 sequestration. CO_2 sequestered will be used for oxalic acid production, which will be associated with calcium in plant tissues to produce Ca oxalate. With falling of leaves, this insoluble salt arrives at the litter where it will be attacked by saprophytic fungi. The Ca oxalate is then released into the soil where oxalotrophic bacteria will dissolve it in order to feed on the C of the oxalate. CO_2 and hydroxide ions (OH^-) are therefore released in the soil where CO_2 will be associated with the Ca, to form Ca carbonate ($CaCO_3$), and the OH^- will allow an increase in soil pH around the rhizosphere (Figure 1).

This ecological process which allows: (i) mitigating climate change by limestone biomineralization that store CO_2 in inorganic form for millions of years, (ii) improving soil fertility by correcting their acidity, is then very interesting for tropical acid soils.

Indeed, the OCP was discovered in West Africa (Ivory Coast, Cameroon and Burkina Faso) in 1999 with Iroko (*Milicia exelsa*). It was also observed in Bolivia (2006) and in India (2010). It seems then that OCP is associated with tropical countries with acid soils and semi-arid climate. Madagascar, a tropical country characterized by the predominance of lateritic and ferruginous soils that are at acid pH, is also marked by large varieties of climate and significant floristic diversity, especially, in natural forests. The southern and western regions of the island, including Sakaraha and Morondava regions, where forests are on acid soils and under semi-arid climate, would be able to fill OCP occurrence conditions. But despite these facts, does the OCP observed in other tropical countries exist in these regions of Madagascar?

Figure 1 - Oxalate-carbonate pathway process (Matteo, 2011 modified in 2012)



2. Materials and methods

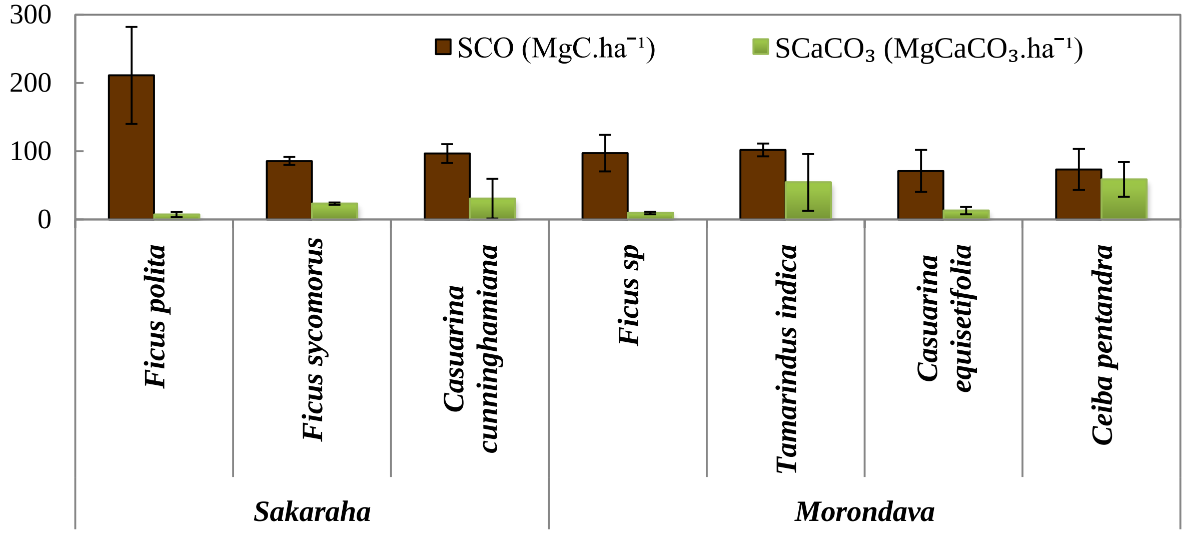
This study aimed to identify oxalogenic species from Madagascar. Factors which govern OCP process were also expected to be identified. To do so, a thorough literature exploration was conducted to identify alleged oxalogenic species. Then, mapping was carried out to determine where species habitats are on acid soil. At Morondava, exploration was conducted in Kirindy forest, in villages of Beroboka, Ampataka and Marofandilia. It was performed nearby the Zombitse forest (Zombitse-Vohibasia National Park) and in the reforestation station Cantonment of Water and Forest at Sakaraha. In the field, test with hydrochloric acid (HCl) was carried out on observed $CaCO_3$ traces, on part of biomass (deadwood, bark) or on soil. Then, a pedological study was conducted in soil pits dug at the foot of the tree and at 5 m (control profile). It consists of pedological profile description and pH measurement (with pH paper) on 0-10 and 10-20 cm depths for each of the 2 distances (0 m and 5m from the tree). Phytosociological study and forest inventory were conducted as well. Next, samples of biomass with $CaCO_3$ traces, and soil up to 30 cm deep (per 10 cm), were collected. Then, soil samples with $CaCO_3$ traces (with effervescence when tested with HCl), were analyzed in laboratory, by calcimetry and Walkley-Black method, to determine their contents in $CaCO_3$ and carbon. Specie's potentials were assessed using $CaCO_3$ stocks of soil samples. Statistical analyses concern mainly ANOVA test.

3. Results

Oxalogenic trees of 10 species in these two regions have presented effervescence with HCl test, either on part of their biomass, deadwood or on soil, or on all of these parts. They are : *Ficus polita*, *Ficus sycomorus*, *Ficus marmorata* (Moraceae) and *Casuarina cunninghamiana* (Casuarinaceae) at Sakaraha; *Ficus sp* (Moraceae), *Casuarina equisetifolia* (Casuarinaceae), *Tamarindus indica* (Cesalpiniaceae), *Ceiba pentandra* (Bombacaceae), *Cordia myxa* (Boraginaceae) and *Broussonetia greveana* (Moraceae) at Morondava. Among them, only *Ceiba pentandra* has been already discovered in other countries, the others are new oxalogenic species identified for the first time in these regions. Due to absence of effervescence on soil samples, carbon (SOC) and limestone ($SCaCO_3$) stocks of *Ficus marmorata*, *Cordia myxa* and *Broussonetia greveana* were not determined. For the seven other oxalogenic trees, pH, SOC and $SCaCO_3$ at the foot of the trees are significantly different from those observed in the control profiles at 5m. Strong positive correlation between SCO and $SCaCO_3$ was observed too. Between species, *Ficus polita* has the lowest potential (7.15 ± 3.57 $T.ha^{-1}$ $CaCO_3$ in soil on 30 cm depth) and *Ceiba pentandra* (58.54 ± 25.36 $T.ha^{-1}$) the highest. But the most promising specimen is from *Tamarindus indica* species in Morondava (54.28 ± 41.66 $T.ha^{-1}$) (Figure 2). However, oxalogenic potentials within the 2 regions have proved to be similar (p-value: 0.18).

The OCP seems to be more effective on surface horizons of the soil because differences in terms of $CaCO_3$ are significant only at 0-10 cm in depth. Phytosociological study revealed that oxalogenic trees are without grouping with specific taxa.

Figure 2 - C and $CaCO_3$ stocks in soil (30cm depth), per species and per region (Andriampiolazana, 2012)



4. Discussions

Two specimens from the same species, observed in different locations, do not have the same stocks of $CaCO_3$ and C. This is the case of *Broussonetia greveana* (Moraceae) which wasn't oxalogenic at Sakaraha whereas it was oxalogenic at Morondava. This means that there are other more important factors than species' taxonomic affiliation in the OCP's occurrence, such as environmental parameters as well as dendrometric characteristics of the tree.

Furthermore, the maximum $CaCO_3$ content observed (90,20 g $CaCO_3$/kg soil under a *Tamarindus indica* specimen) remains relatively low compared to that of other high potential oxalogenic species from other tropical countries. Indeed, an iroko can generate up to 700 g of $CaCO_3$/kg of soil (Braissant, 2005). Difference in oxalogenic trees, in terms of diameter, height and age, in addition to pedoclimatic conditions, would have caused this discrepancy.

5. Conclusions

In conclusion, this study has proved that the OCP exists in Madagascar. It has provided preliminary results on Madagascar's oxalogenic species. However, the exploratory aspect of this work does not allow drawing definitive conclusions about this phenomenon. Therefore, further explorations on this subject, including the determination of other oxalogenic species with microbiological research study, are still needed to improve knowledge for forest better management and before promoting such phenomenon in agroforestry and agroecology.

References

- Andriampiolazana M., (2012). Exploration de la voie oxalate carbonate dans les régions de Sakaraha et Morondava Madagascar. Mémoire d'ingéniorat. Spécialisation: Eaux et Forêts. ESSA, Université d'Antananarivo, Madagascar.
- Aragno M., Verrecchia E., job D., Cailleau G., Braissant O., Khammar N., Katia F., Mota M., Guggiari M. et Martin G., (2010). Calcium carbonate biomineralization in ferrallitic, tropical soils through the oxalate-carbonate pathway. Bulletin BGS 30.
- Braissant O. (2005). Carbonatogénèse bactérienne liée au cycle biogéochimique oxalate-carbonate. Thèse de Doctorat ès Science. Institut de Géologie de l'Université de Neuchâtel.
- Matteo M. (2011). The oxalate-carbonate pathway: From the scientific research to the application. http://www.asso-roots.org