## Research report

**Project title:** Restoration of degraded soil through soil organic matter management and enhancing soil carbon sequestration

**Project title:** Report of the 1st year of the project: Studies of dissolved organic matter, fungal decomposer, and soil organic matter models under a long-term experiment on decomposition if different quality organic residues


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## Abstract

The first part of the research had the objectives of investigating effects of applications of different quality (chemical composition) organic materials on changes and accumulation of soil organic matter in the long term. There were 5 treatments of organic materials: control (no organic material addition); groundnut stover, a high quality organic material with high N but low lignin and polyphenol contents; tamarind leaf+petiole litter, a medium quality organic material, with medium contents of N, lignin and polyphenols, dipterocarp leaf litter (low quality) with low N but high lignin and polyphenol contents; and rice straw (low quality) with low contents of the three compounds but highest cellulose among all organic materials used. The application rate was 10 t $ha^{-1}$ and application time was once a year starting in 1995. There are 3 studies to this first part.

1) A study on dissolved organic matter (DOM) in soil as affected by different quality organic materials employing soil samples from year13 of the long-term experiment. In this study, water soluble organic carbon in soils was analyzed. Soil sampling was conducted at 6 intervals based on the time of organic matter application, i.e., before the application (week 0), and 2, 4, 8, 16, and 52 weeks after the application. They were sampled at the following soil depths: 0-15, 15-30, 30-60, 60-80, and 80-100 cm. The soil samples were extracted with distilled water at the soil:water ratio of 1:5 for dissolved organic carbon (DOC). Groundnut stover (GN) and leaf+petiole litter of tamarind (TM) treatments had higher concentrations of total DOC in soil profiles (0-100 cm) than those under dipterocarp (DP) and rice straw (RS) treatments. There were 2 patterns of vertical distribution of DOC in

the soil profiles which were determined by quality of organic materials: 1) DOC that has high vertical mobility which accumulated in high concentration in the subsoils, 2) DOC that has low mobility which accumulated in the topsoils. RS, with its high cellulose but low N content, had the highest accumulation in the subsoils. Meanwhile, GN, TM and DP had low amount of DOC that moved vertically resulting in high contents accumulated in the topsoils and no accumulation in the subsoils throughout the decomposition period.

2) Modeling of decomposition andmaccumulation of SOM under long-term continuous applications of different quality organic materials. This part of the studies had the objectives of investigating decomposition patterns of different quality organic materials and building mathematical model to predict SOM accumulation through the use of 17 years of data from the long-term experiment.The suitable model to simulate decomposition was the 2-term exponential equation:

$$W_t = W_{0(1)}e^{-k_1 t} + W_{0(2)}e^{-k_2 t},$$

where $W_{0(1)}$ was the initial weight of the labile compounds in an organic material, $W_{0(2)}$ was the initial weight of the resistant compounds in an organic material, $k_1$ is the decomposition rate of the labile pool, and $k_2$ was the decomposition of the resistant pool. Hence, there were 2 decomposition rates. The followings are the decomposition equations for various organic materials studied: RS: $Wt = 24.10e^{-0.30t}+15.63e^{-0.11t}$ ($R^2$ = 0.998), DP: $Wt = 33.73e^{-0.01t}+6.23e^{-0.91t}$ $R^2$ = 0.976) and TM : $Wt = 20.31e^{-0.43t}+19.15e^{-0.02t}$ ($R^2$= 0.995). RS had the highest overall decomposition rate followed by TM, while DP had the lowest rate. As for GN, it was found that the 3-term exponential equation was more suitable than the 2-term one to simulate its decomposition pattern. This equation accounts for organic materials that has organic composition that decompose at 3 different rates in decreasing order, i.e. rapid, intermediate, and slow. The decomposition equation for GN was as follows: $Wt=27.6e^{-1.41t}+10.82e^{-0.12t}+ 1.56e^{-0.008t}$ ($R^2$ = 0.999).

As for modeling of organic matter accumulation, the model used for simulation of decomposition was tested employing data of decomposition in the control treatment. It was found that the model over-estimated the decomposition resulting in lower SOM accumulation, i.e. zero accumulation, than those in reality. Therefore, this model was not effective in predicting SOM accumulation.

Investigation of microbial community structure and function in decomposing different quality organic materials in soils from the long-term experiment Investigation of microbial communities, with emphasis on fungi, in a sandy soil under the long-term experiment that had received the organic materials continuously for 16 years employed molecular techniques including real time-polymerase chain reaction (RT-PCR) and conventional polymerase chain reaction (PCR) to increase gene copies. Soil from TM treatments, that had received tamarind continuously for the long term, designated as NTM had the highest gene copies indicating the highest fungal abundance followed by NGN treatment. Gene copies under NRS and NDP were significantly lower than that of NTM, but they were not significant different from the NGN and the control treatments.

Investigation on microbial function was through enzyme activities of those involved in decomposing different quality organic materials under incubation conditions. There consisted of 2 microcosm experiments.

**Experiment 1** (the long-term function) was designed to study decomposition in the long term. It employed soils from the long-term experiment that had received 4 contrasting quality organic materials yearly for 16 years designated as native or N soil including NGN, NRS, NDP, and NTM, as well as a soil from the unamended treatment (control-C soil). The enzymes studied in these soils were those C cycling enzymes including invertase, **β**-glucosidase, phenoloxidase and peroxidase which degraded different quality organic materials. Activities of all enzymes were higher in N soil than C soil. In general, activities of invertase and **β**-glucosidase increased over the control but they were significant under NGN and NTM treatments. NDP was the only treatment that had phenoloxidase activity significantly higher than the C treatment. As for NRS treatment, it had the highest peroxidase activity which was significantly higher than C and NTM treatments.

**Experiment 2** (the short-term function) was designed to study decomposition in the short term. It employed the soil that had not received organic materials from the control treatment (C soil). The soil was added with 4 types of the aforementioned organic materials. The 4 enzymes similar to experiment 1 were determined after the soils were incubated for 0 (3 hours after incorporation of organic materials) and 56 days after the incorporation. Invertase activities at day0 were significantly higher than day56 under C+RS, C+GN and C treatments. Invertase activity was highest under C+GN followed by C+RS treatment at both days. Similarly, **β**-glucosidase activities in day56 were significantly higher under C+RS and C+GN than C treatments. Meanwhile, phenoloxidase activity in day56 was highest in C+DP which was much higher than that of day0. As for peroxidase activity during day 0, C+DP had lower activity than those of C+GN and C+TM treatments. In addition, under all treatments with the exception of C+DP, peroxidase activities during day56 were lower than day 0.

The second part of the studies had the objectives of investigating effects of land uses in a farming system in the undulating terrain of the Northeast on soil carbon sequestration and transfer. This stage of the study involved literature review of methodology to quantify charcoal C at different soil depths under different land uses.

There were 3 methods of soil charcoal quantification including dry combustion, wet combustion, and integration of dry and wet combustion. An analysis of advantages and disadvantages of these methods showed that the integration method was the most suitable for using in the planned studies. The principle of this method was to eliminate non-charcoal C employing a wet combustion technique. This soil C pool was not as stable as the charcoal C, and hence, can be chemically oxidized by an oxidizing agent (wet oxidiation). There are various oxidizing agents employed for the purpose, e.g., $O_2$-free trifluoroacetic acid (TFA: $C_2HF_3O_2$) or mixture of peroxide and diluted nitric acid. The peroxide/nitric acid method employed 30% $H_2O_2$ in conjunction with 1*M* $HNO_3$ to eliminate non-charcoal C. The remaining C was considered charcoal C which was determined by a dry combustion technique involving burning of a sample under high temperature. The advantages of this method were that it was not complicated and it gave accurate results as indicated by the outcome from the use of standard charcoal with known C content.