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Assessment of soil microbial activity measurements to distinguish land uses in Leyte, Philippines

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Abstract

The influence of land use systems on soil microbial activity was compared across seven sites with different soils of volcanic and limestone origin in Leyte, Philippines. On each site, plots of different land uses, namely traditional fallow/grassland, improved fallow with exotic species and agroforestry based on indigenous species, were investigated. Basal respiration, microbial C and the metabolic quotient qCO_2 were found to be sensitive parameters to distinguish between sites and land use systems in most cases. There was no clear tendency comparing traditional fallow and agroforestry, but plots planted with fast growing exotic tree species showed a higher microbial activity, when compared to either system.

Introduction

Since the 1960s most primary forests on Leyte have been cleared and replaced by shifting cultivation, bushland or pastures and coconut plantations (NAMRIA, 2003). This led to increased soil erosion and loss of biodiversity. In the 1980s a logging ban was put into force and since efforts have been undertaken to reverse these trends through reforestation. The classical approach was to plant fast-growing exotic tree species like *Gmelina sp.* In the mid 1990s, an agroforestry scheme called rainforestation used indigenous timber species planted in high density and diversity. This system intends to imitate natural forest ecosystems and is claimed to be more resilient than the alternative using exotics (MARGRAF & MILAN 1996). As an agroforestry system rainforestation includes the use of annual crops during the first years of establishment and consecutively of shade-tolerant crops as permanent undergrowth.

One of the central advantages attributed to agroforestry systems is that deep-rooting trees can transfer nutrients from the subsoil via leaf litter to the topsoil, where they also become accessible to crops (CANNELL ET AL. 1996). Besides this, increased litter production and humus formation improve soil structure and nutrient availability for plants. In this context biological activity of soils is a crucial factor influencing litter decomposition, humus mineralisation and accumulation.

This study aimed at comparing the effects of the aforementioned land use systems – grass-dominated fallow/grassland, systems including exotic species and rainforestation - on biological activity across a range of typical Leyte soils. For this purpose, the live microbial pool, expressed as C_{mic} and its activity, as basal respiration were determined. Both have been reported to be sensitive indicators for effects of land use changes in Europe (SVENSSON & PELL 2000).

Materials and Methods

Study region

Leyte island is part of the Eastern Visayas (Philippines) and is situated at the interface of two tectonic plates. Uplift and faulting formed the Leyte Central Cordillera, which was a center of volcanism from Miocene to Quarternary. As a consequence, andesitic and dacitic lava flows and pyroclastics are the dominating parent materials for soil formation in central Leyte. On the other hand coralline limestone shaped large parts of Leyte´s Karst landscapes. The research area is

situated in a transition zone of volcanic and calcareous soils. Most soils in this part of Leyte are young, as they are of quarternary volcanic material (ASIO ET AL. 1998) or colluvial origin. Due to the humid tropical monsoon climate (ASIO 1996) with its heavy rains and the high relief energy landslides and erosion have a strong impact on soil formation even in absence of any human influence. A catena of mid-western Leyte slopes would show Andosols in the high-gradient mountains, Alisols, Acrisols and Cambisols on the middle and lower slopes, and Vertisols/Gleysols in the lowlands. Calcareous soils in Leyte are often shallow and high in clay contents, which has led to classifications such as *Maasin Clay* etc. in the Leyte soil survey by BARRERA ET AL. (1954). Potential reforestation areas are typically situated on marginal medium to high-gradient hills on both calcareous and volcanic ground.

Approach, sampling and soil analyses

On seven sites in Baybay and Inopacan municipalities, two to three adjacent existing plots comprising different land use systems were compared. Three categories of 10-15 years old systems were investigated: a.) spontaneous fallow or grassland, b.) managed fallow (*Pueraria sp.*) or *Gmelina sp.* plantations and c.) rainforestation. One soil profile per site was classified according to WRB (ISSS-ISRIC-FAO 1998) after determination of particle size distribution, pH $CaCl_2$ and ECEC. Semi-structured interviews with landowners or tenants were conducted to obtain information on land use history.

Five to eight composite soil samples of 5-20 single samples each (to a depth of 20cm) were collected with a Pürckhauer auger at representative places within each plot, i.e. margins, pathways and landslide areas were not sampled. Samples were stored in the refrigerator at 4-8°C while processing took place: Roots were discarded using forceps and for Substrate-Induced Respiration the fresh soil was sieved to 2mm. After these preparations samples were frozen at approx. –10°C. Five days before analysis, soil samples were conditioned (in the dark at room temperature of 20-32°C) and water content adjusted to 55% of water holding capacity. Due to the large number of replicates, only samples of one site were analysed at the same time.

Basal Respiration (BR) method as described by SCHINNER ET AL. (1993) was used to determine microbial respiration at equilibrium state. Differing from the original procedure, incubation was at room temperature and samples were analysed in four technical replicates.

Substrate Induced Respiration (SIR) method was carried out to determine microbial biomass from increased respiration rates after soil amendment with glucose. SIR was carried out according to the description given by SCHINNER ET AL. (1993), but with fivefold technical replicates including one unamended control. Incubation temperature was 22°C under air-condition after 4h adaptation from ambient temperature (30-32°C).

Statistics: Statistical analysis of data was performed using SigmaPlot™ (SPSS Inc., 2000) and MINITAB™ (MiniTab Inc., 2000). BR and SIR data were checked for normality using the Anderson-Darling test before a 2-sample t-test between the statistically independent samples of the land uses of each site was conducted.

Results

Soil units classified according to ISSS-ISRIC-FAO (1998) and land uses of plots are given in table 1.

Table 1: Soils as classified on the basis of profile description, pH, ECEC and particle size analysis and land use systems of surveyed plots. According to the interviews the plots have been under the given land use for more than 10 years.

Soil unit (WRB) and site designation		**Land use and plot designation**		
		Rainfo. (A)	**Spontaneous fallow / grassland (E)**	**Managed fallow (I)**
Haplic Acrisol	Ci-	High density and diversity, closed canopy system	Grass-dominated fallow	
Chromic Acrisol	Mo-		Grassland	
Stagnic Luvisol	MP-		Grassland	*Gmelina* plantation
Stagnic Cambisol	PP-		Grass-dominated fallow, recently slashed	*Gmelina* plantation
Haplic Cambisol	TF-		Crops after > 10 years fallow[1]	Pasture, *Pueraria*
Stagnic Cambisol	J-		Grassland	
Mollic Cambisol	AP-		Grassland	

[1] Recently planted with *Ipomoea batatas* and *Musa textilis*

BR and SIR data are normally distributed. A 2-sample t-test (α=0.05) showed, that land uses could be distinguished by BR on most sites (symbols between columns in fig. 1). Overall microbial respiration tended to be equal or higher in spontaneous systems than under rainforestation. Managed fallow systems always showed markedly higher respiration rates than either of the other land uses. No significant difference (P=0.848, α=0.01) was found between results of a simultaneous BR experiment with composite samples and the one shown in fig. 1.

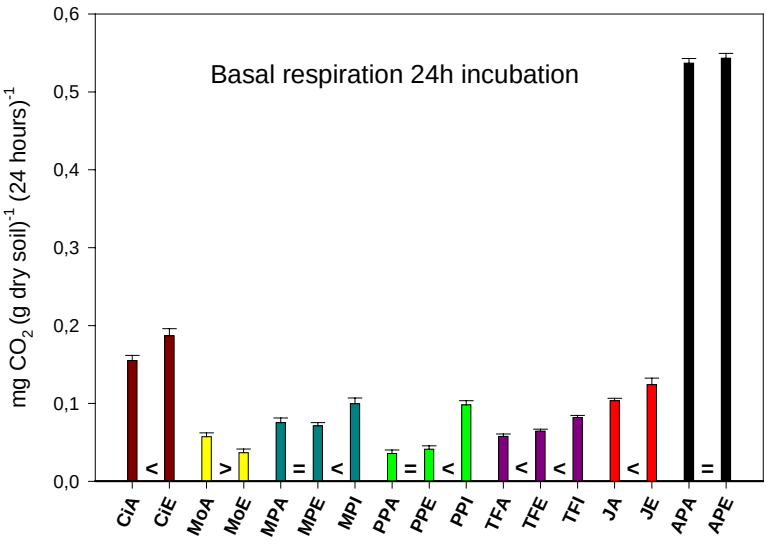

Figure 1: Basal respiration of different land uses on 7 sites in Leyte; t-test results given between columns. Standard deviations refer to means of technical replicates.

Generally there was a fairly linear relationship between basal respiration and size of the microbial population (C_{mic} SIR) across sites with exception of the calcareous AP site (fig. 2). Metabolic quotient qCO_2 (=BR/SIR) as a measure of microbial respiration per active metabolising microbial biomass C showed similar trends between plots as BR. In contrast to BR, for the recently slashed TFE and PPE plots qCO_2 was significantly lower than TFA and PPA, respectively.

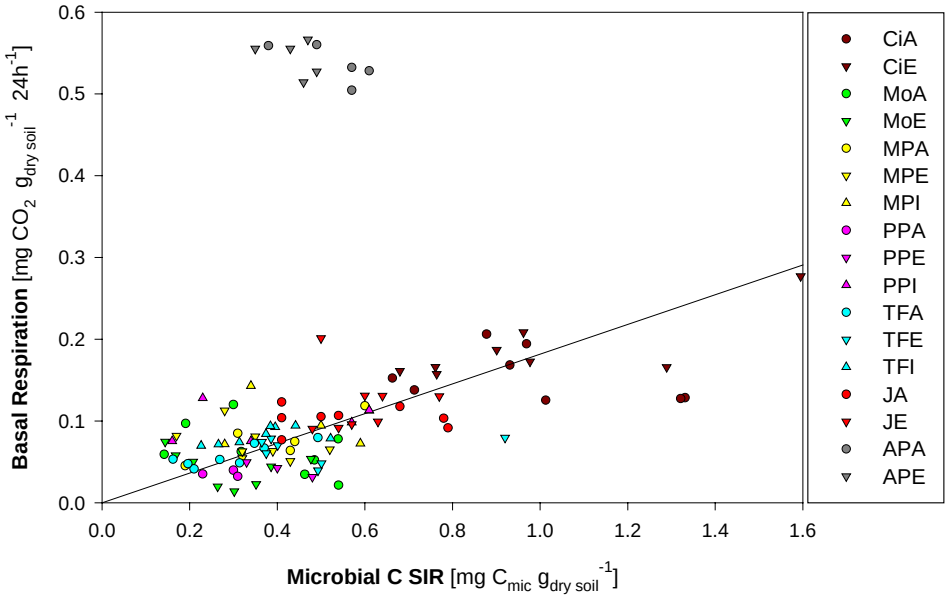

Figure 2: Metabolic quotient qCO_2 describing respiration of the active metabolising microbial biomass.

Discussion

There have been findings, that SIR and BR are useful indicators of land use in tropical China (MAO ET AL. 1992). For N-limited amazonian soils MENYAILO ET AL. (2003) concluded, that N-related processes are more meaningful. Our results showed, that BR is appropriate to detect differences between sites and (with restrictions) for land uses, when combined with C_{mic} data. Simultaneous experiments over all plots confirmed for BR and SIR that results are generally reproducible and variation between laboratory days are negligible. However, SIR results can only be interpreted for comparisons under similar conditions as the method and K_C factor have not been standardised for tropical soils yet (SCHINNER ET AL. 1993).

A generally higher microbial activity or larger microbial pool for either rainforestation or spontaneous fallow could not be proven. This may be due to heterogeneity of plots within the category 'spontaneous systems': For the recently disturbed TFE (cropped) and PPE (slashed) higher BR may have been caused by disequilibrium. After an initial exponential growth of microbial populations, BR and SIR may both return to a lower level (ANDERSON & DOMSCH 1978). However, managed fallows, especially under *Gmelina*, showed markedly higher basal respiration than either of the other land uses. For qCO_2, the differences were less pronounced, which points to higher metabolising efficiency due to substrate quality (MAO ET AL. 1992): *Gmelina* and *Pueraria* produce large amounts of easily decomposable leaf litter compared to the rainforestation and spontaneous plots. Differences in leaf litter decomposition have already been found between *Gmelina sp.* and *Dipterocarpus validus* (ARAGON 2004).
Particularly high respiration rates were measured for the calcareous mollic Cambisol, which may in part be attributed to CO_2 volatilised from carbonates or to changing partial pressures. On the other hand the high biological activity of this soil, previously described by DAUB (2002) with respect to the macrofauna, suggests, that microbial activity on this site was in fact outstanding. qCO_2 confirms, that high respiration rates of the calcareous soil are not mainly a result of large microbial populations (expressed as C_{mic}) but rather of high microbial respiration. The opposite can be found for the haplic Acrisol, where a large microbial population shows relatively low activity. These findings are plausible, when the low pH and relatively high $Al_{oxalate}$ (data not shown) of the haplic Acrisol are taken into consideration.
In terms of nutrient cycling a rapid turnover of litter may be desirable for agroforestry systems, especially for limiting elements; leaching should not be a major problem in Leyte as litter fall peaks during dry season. Considering soil structure, cation and water storage, slower mineralisation of SOM may be preferable.

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