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Selection and interpretation of soil quality indicators for forest recovery after clearing of a tropical montane cloud forest in Mexico

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ABSTRACT

Through slash-and-burn techniques, vast areas formerly occupied by tropical montane cloud forest (TMCF) in Mexico have been converted into croplands and secondary forest of different ages. Despite the dramatic changes in soil properties and processes detected during cropping and forest regeneration, no attempts have been made to develop soil quality indicators (SQI) to assist in the assessment of soil conditions during such changes. SQI are considered to be essential in evaluating plans of forest restoration or management; as such, the objectives of this study were to (i) select soil properties that can be used as SQI during forest regeneration for abandoned crop fields in a TMCF area managed under the slash-and-burn method; and (ii) examine the ecological significance of stand age for function-based interpretations of the selected SQI. To this end, the soil properties of three adjacent chronosequences in El Rincón, Sierra Norte, Southern Mexico were analyzed. Each chronosequence consisted of ordered series of five stands of different age after abandonment: a cornfield and adjacent forests of ~15 (incipient forest), ~45 (young forest), ~75 (mature forest), and ⩾100 (old-growth forest) years after abandonment. The soil properties of undisturbed old-growth forest stands were used as a reference. After inspection of principal component analysis results and control charts, the following soil properties were chosen as SQI in TMCF areas: soil organic carbon, pH, plant-available P, O horizon thickness and exchangeable Al^{3+}. The selected SQI displayed different rates of change during forest regeneration. Soil organic carbon had a fast recovery rate and, therefore, a greater ability to return to its original level after disturbance. In contrast, O horizon thickness, soil pH, plant-available P, and exchangeable Al^{3+} showed a slow rate of change during the fallow period. SQI did not always change linearly nor improve with the age of the forest. The highest exchangeable Al^{3+} concentration was detected in 45-year-old forests, suggesting that at this forest age, soil become an important filter against Al^{3+} sensitive species, potentially affecting vegetation composition. Considering the slow recovery rate of some SQI, we estimate that fallow periods of at least 100 years are required in order to reach good soil quality in TMCF ecosystems. Management practices should therefore consider the maintenance of forest of different ages spanning at least 100 years in the landscape. Doing so would achieve more sustainable management practices by allowing a relatively continuous recovery of the ecosystem without prolonged interruptions of land utilization.

1. Introduction

The deforestation and degradation of natural ecosystems have accelerated as a result of increasing population pressure. However, isolated efforts have been made to regenerate the degraded land. In general, the criteria for judging the regeneration success of disturbed ecosystems have been based on inspection of visual aboveground indicators (Mummey et al., 2002); soil components, in most cases, have received little attention. Ignoring soil components is a grave mistake, considering the importance of soil in ecosystem recovery: soil (i) sustains biological activity, diversity and productivity; (ii) regulates and partitions water and solute flow; (iii) filters, buffers, degrades, immobilizes, and detoxifies organic and inorganic contaminants; and (iv) is involved in nutrient storing and cycling (Karlen et al., 1997).

Abbreviations: D_B, soil bulk density; MDS, minimum data set; PC, principal component; PCA, principal component analysis; SMBC, soil microbial biomass carbon; SOC, soil organic carbon; SQI, soil quality indicators; TMCF, tropical montane cloud forest; TN, total nitrogen.

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