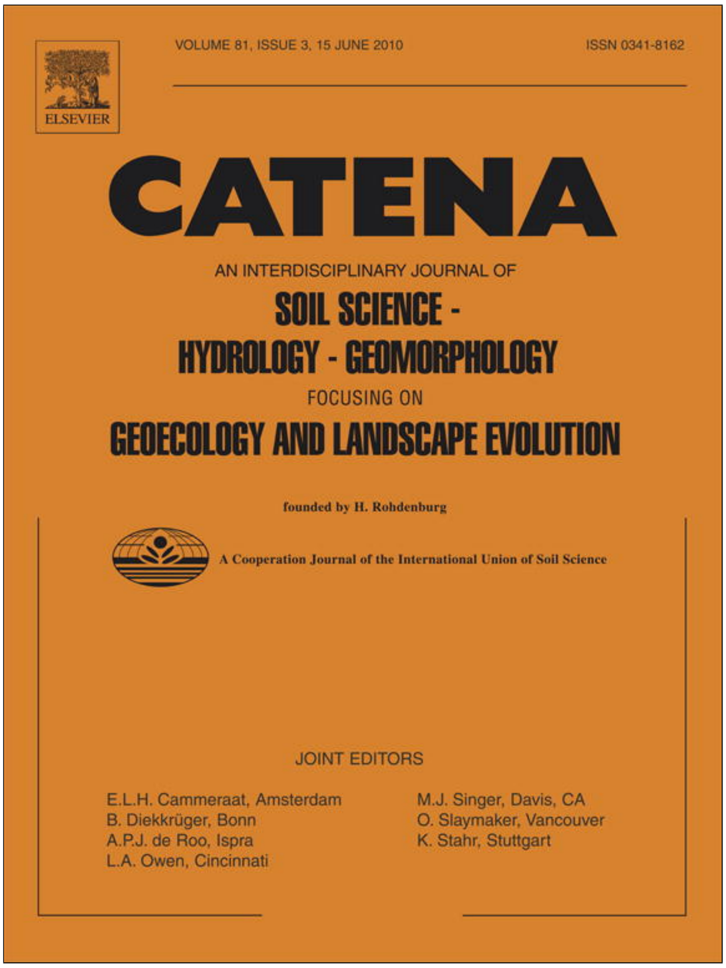
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Landscape and land use effects on soil resources in a Himalayan watershed

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ABSTRACT

Sustainable land management decisions at all scales require solid, science-based information. Soil quality assessment can provide this regarding soil physical, chemical, and biological characteristics and the ability to provide ecosystem and societal services. Our objective was to make a regional assessment of soils in the Garhwal Himalayas to determine their ability to perform various functions and respond to external influences. Five functional categories were assessed using 13 soil parameters focused on ecological sustainability. Human land use effects on soils were referenced to natural woodlands at each landscape position. Within upper-slope regions, flora and fauna habitat, moisture retention, organic matter and nutrient cycling, air and water infiltration and resistance to erosion were decreased 35, 27, 24, 24, and 9%, respectively. At mid-slope positions the order and magnitude of decrease were organic matter and nutrient cycling, flora and fauna habitat, and moisture retention (26, 22, and 16%, respectively). Changes within the valley were lowest, averaging −3% for flora and fauna habitat and −13% for organic matter and nutrient cycling. We conclude that the minimum data set (MDS) used provided a representative assessment of soil quality and could serve as a basis for assessment in similar tropical watersheds.

1. Introduction

Environmental degradation due to poor land use decisions is a worldwide problem that threatens sustainability (Pierce and Larson, 1993; Zinck and Frashad, 1995; Hurni, 1997; Hebel, 1998) and has caused severe soil quality degradation in the tropics (Lal, 1990). Principal causes of degradation in mountainous ecosystems are soil erosion and water deficits (Torrent, 1995; Hill et al., 1996; De la Rosa et al., 1999; Sharma, 2004; Saxena et al., 2005). For example, in the Garhwal Himalayan region, most soils are classified as Entisols with many being degraded due to water erosion. Recent studies (NBSSLUP, 2004; Sharma, 2004) have shown that 72% of this geographical area has suffered severe water erosion at rates often exceeding 20 Mg ha^{-1} yr^{-1}.

Land use profoundly influences soil functions at multiple levels within agro-ecosystems. In many areas, human pressure for production has modified land use and is causing unknown ecological effects (Sharma, 2004). When adversely affected, the soil is often dysfunctional in many respects. Ecological sustainability requires that several functions be maintained (De Kimpe and Warkentin, 1998; Shaxson, 1998). This includes: water flow and retention, solute transport and retention, physical stability and support, retention and cycling of nutrients, buffering and filtering of potentially toxic materials, and maintenance of biodiversity and habitat (Daily et al., 1997).

In the Himalayan region, agricultural production has direct linkage to surrounding ecosystems. Therefore, even though the most important concerns are to protect soil productivity and sustain production, an equilibrium should be maintained between agricultural production and surrounding natural ecosystems (Lefroy et al., 2000; Saxena et al., 2005). Failing to stop the continued degradation of the fragile Himalayan region would adversely affect socio-economic and environmental stability not only in the highlands, but also in the lowlands (Sharma, 2004).

To improve land use decisions, information is needed to understand effects of various management practices at multiple scales. Doing so by integrating appropriate factors within a landscape would provide a better recognition of the quality and management of entire agro-ecosystems (Kessel and Wendroth, 2001). One way to accomplish this is to use soil quality indicators that correlate well with ecosystem processes. These indicators should also integrate soil properties and processes, be accessible to many user, sensitive to management and climate, and wherever possible, be components of existing databases.

The direction and degree of soil quality change in managed mountain ecosystems depend on climate, soil conditions, and land use. The majority of previous studies (e.g. Wang and Gong, 1998; Perie and Munson, 2000; Islam and Weil, 2000) have focused on individual aspects of soil quality such as biological productivity, water cycling, or environmental quality. Many have also occurred in temperate regions with few studies undertaken in the sub-tropics and tropics. To reverse degradation processes in the sub-tropics and tropics, assessments of soil functions are urgently needed (Stocking, 2003). Our objectives were to (i) numerically assess soil quality using a systematic framework and

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