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Transition to agroforestry significantly improves soil quality: A case study in the central mid-hills of Nepal

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ABSTRACT

Agricultural intensification continues to be a major threat to sustainable development in mountain regions of the world since it is largely associated with lower soil fertility, increased soil erosion, pollution and eutrophication of water bodies, reduced biodiversity, and livelihood challenges. Agroforestry, the purposeful cultivation of trees and crops in interacting combinations, has the potential to provide environmental benefits and to contribute to livelihood security, and is receiving increasing attention as a sustainable land management option. Whereas many studies highlight general positive environmental and socio-economic effects of agroforestry systems, effects of the transition to agroforestry practices have rarely been quantified and studied in detail, in particular in Nepal. This paper analyses alterations of soil properties after the adoption of agroforestry practices in a typical mid-hill region of Nepal. Three agrosystems were compared with a special focus on soil fertility: (i) a mature, fully developed agroforestry system (AF); (ii) the predominant conventional system (CS) characterized by monocropping; and (iii) a system that has been in transition to AF for two years (TS). The results show significant differences in soil pH, aluminium content, base saturation, electric conductivity, organic matter and nitrogen content, and cation exchange capacity between AF and CS soils, indicating a higher soil quality and more fertile soil conditions in the AF soils. The contrasting soil quality has to be largely attributed to the differing land management practices. After two years of transition, the TS soil data already show a convergence towards the AF values in several parameters. This study gives quantitative evidence that agroforestry systems have the potential to significantly enhance soil quality and long-term soil productivity, with positive effects appearing shortly after the conversion from conventional monocropping systems.

1. Introduction

The vast majority of Nepal's population in rural areas continues to depend heavily on the agricultural sector for income and employment opportunities although the share of agriculture in the gross domestic product (GDP) has fallen significantly from 72% in 1975 to c. 35% in recent years (Upadhyaya, 2000; IIDS, 2013). However, agriculture still employs c. 75% of the total labour force, thus representing the driving engine of economic growth in Nepal, and at the same time constituting the key for poverty alleviation. But the growth of the agricultural sector underachieved in recent decades despite agricultural intensification.

Several agricultural development programmes had been initialized during the first decades of the 20th century aiming to promote the extension of agricultural activities (Raut et al., 2011) and providing information on improved seeds, chemical fertilizers and agro-tools (Dahal, 1997). The total production of cereals greatly increased indeed between the 1960s and 1990s, but in contrast to other countries this increase has to be attributed to the enlargement of the area under food crops (in particular in the Terai region) rather than to an increase in their yields. Actually, the per capita cereal production declined because the annual cereal production increase rate of 2.3% (between 1980 and 1990) could not keep pace with the population growth rate of 2.5% (HMG/NPC, 1994). Poor irrigation facilities, dependence on fluctuating monsoonal precipitation under rainfed conditions, lack of marketing infrastructure and networks, inadequate supplies of key inputs, and a weak extension and research system are among the most prominent causes for low agricultural growth rates.

Agricultural performance during the past two decades is still lagging behind expectations in spite of the formulation and implementation of various agricultural plans and policies such as

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the twenty-year Agriculture Perspective Plan (1995), the National Agriculture Policy (2004), or the Three Year Interim Plan (2007/08–2009/10). More than half of Nepal's districts are unable to produce sufficient food to meet the basic needs of the people with 60% of households in these districts – located largely in the mountain physiographic region and the mid- and far-western development regions – experiencing food insufficiencies (Upreti, 2010).

Nevertheless, the total production of agricultural commodities more or less steadily increased from 11.8 million metric tons in 1998/99 to 18.9 million metric tons in 2010/11, with a particularly high gain in cash crops such as potatoes, vegetables and fruits (CBS, 2012). The increased agricultural output as well as the extended variety and number of crops reflect a recent agricultural intensification process with an increasing commercialization of the prevailing subsistence production system. The general shift from a subsistence-based farming system to an intensified farming system has been facilitated by government extension services and a proliferation of NGOs. The adoption of agricultural inputs such as fertilizers, pesticides and hybrid seeds, and improved irrigation and road network systems essentially contributed to changes in cropping patterns, use of agro-chemicals, irrigation and mechanization (Dahal et al., 2009; Raut et al., 2011). However, the agricultural intensification process threatens the sustainability of upland farming systems in the long run since it can have serious environmental consequences at various spatial scales – increased soil erosion, lower soil fertility and reduced biodiversity at the local scale, pollution of ground water and eutrophication of rivers and lakes at the regional scale, and impacts on atmospheric constituents and climate at the global scale (Matson et al., 1997). Several case studies from the mid-hills of Nepal highlighted higher amounts of nutrient loss, soil erosion and a general soil quality degradation as a consequence of the shift to intensified farming systems (Gardner and Gerrard, 2003; Shrestha et al., 2004; for a review see Raut et al., 2010). E.g. Tiwari et al. (2008, 2009a,b),),) compared traditional and commercial cropping patterns and assessed higher amounts of soil and nutrient losses, and a deterioration of soil physical and chemical properties. Exchangeable soil K deficits, higher potential for soil acidification (decline in base cation content), and significant increases in available soil P (due to excess P input) after several years of agricultural intensification in irrigated sites were reported by von Westarp et al. (2004). Higher concentration of N, P, and K in water bodies near intensification areas due to excessive use of chemical fertilizers was found by Dahal et al. (2007).

A promising option to counteract unsustainable agricultural intensification is the adoption of more integrated farming systems such as agroforestry. Commonly understood as an integrated approach of producing food, fodder, fuelwood and/or timber by combining trees and shrubs with crops on agricultural land, agroforestry has the potential of providing additional benefits such as preventing soil erosion, maintaining soil fertility, enhancing water quality, conserving biodiversity, and mitigation of climate change by carbon sequestration (Young, 1997; Jose, 2009; Nuberg et al., 2009; Powlson et al., 2011; Nair and Garrity, 2012). In Nepal, agroforestry systems generally involve agricultural crops, tree crops, and livestock (Amatya, 1996), but have evolved from simple agriculture into a range of farming systems with varying degrees of integration (less integrated, semi-integrated, and highly integrated agroforestry) including specific agroforestry practices such as home gardens, silvo-pastoral and forest-based systems (Amatya and Newman, 1993; Dhakal et al., 2012).

An increasing number of studies highlight positive socio-economic and environmental effects of agroforestry systems in Nepal (e.g. Garforth et al., 1999; Schmidt-Vogt, 1999; Acharya and Kafle, 2009; Biggs et al., 2013; Pandit and Paudel, 2013) and in South Asia in general (e.g. Maikhuri et al., 1997; Yadav et al., 2008; Sharma et al., 2009; Saha et al., 2010; Bhadauria et al., 2012), very few of them, however, provide precise facts and figures on changes of environmental parameters after the transition to agroforestry practices. In particular, alterations of soil physical and chemical parameters in the course of transition to agroforestry systems have received little attention. Neupane and Thapa (2001) explored differences in soil fertility between agroforestry and non-agroforestry fields in the mid-hills of Dhading District. Further respective studies are hardly available. In view of this knowledge deficit, the objective of this paper is to analyse the effects of transition to agroforestry practices on soil properties with a special focus on soil fertility. As the maintenance of soil resources is critical in the agricultural landscape of Nepal's mid-hills, we want to examine on the basis of quantitative data whether agroforestry practices result in improved soil quality and contribute to soil conservation and thus to enhanced sustainability and resilience of land use. We hypothesize that differences in land management practices between conventional and agroforestry systems are reflected in the short term by more favourable soil conditions as indicated by soil chemical parameters such as soil pH, base saturation, electric conductivity, organic matter, nitrogen, phosphorous, and cation exchange capacity.

2. Materials and methods

2.1. Study area

The study was conducted on the upper slope of the Kolpu Khola watershed in the area of Kaule village (1860 m a.s.l.), Okaharpauwa Village Development Committee of Nuwakot District (Fig. 1). The study area represents a typical mid hill region of Nepal with respect to land management conditions. It has a subtropical

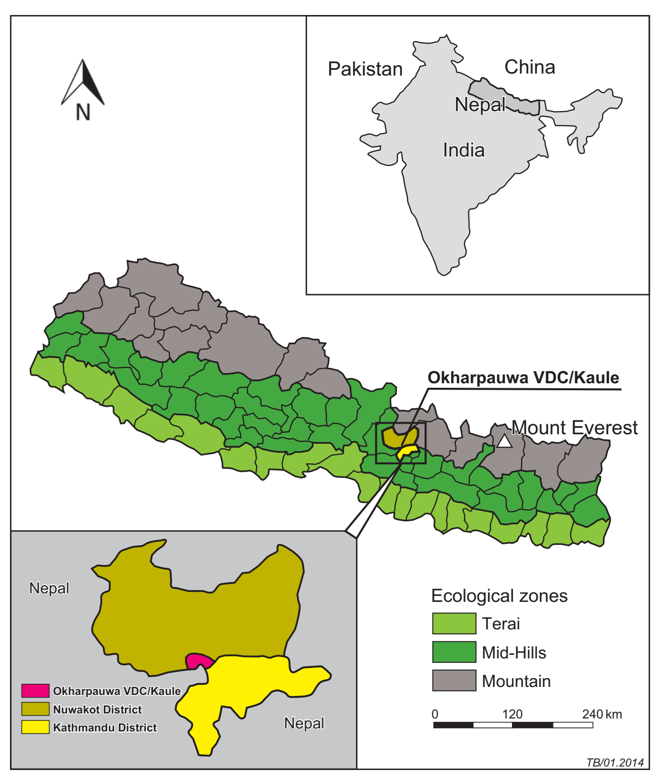

Fig. 1. Study area in the mid hill region of Nepal.