CONCLUSIONS
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Traditional farmers respond to changes in socio-economic and environmental conditions through minor/major adjustments in land use strategies resulting in reallocation of inputs and changes in cropping patterns. In marginal environments, such as the Himalayas, where integration into mainstream social setup and market economy has been only partial, limited buffering capacity against environmental risks and market uncertainties fosters maintenance of traditional, subsistence oriented cropping systems together with adoption of altered/new agricultural practices in response to emerging commercial opportunities rather than a radical transformation of traditional subsistence farming to commercial farming as observed in areas like Indo-Gangetic plains.

Most studies on agroecosystems and forest ecosystems in the Himalayas have adopted an approach where different land uses behave as independent production systems. The present study effectively demonstrated that land uses do not occur as isolated elements but as dynamic and interlinked components within the village/landscape territory. They are therefore most appropriately analysed in relation to each other. In the study village Pali, distinct differentiation (in terms of structure, function and management) of ecosystems in the landscape was observed. The landscape could thus be described as a mosaic of various land use/cover types, managed differentially, and resolved into a range of ecosystems ranging from relatively less disturbed forests to shifting agriculture land use represented by different cropping and fallow stages and finally to settled agroecosystems, along a gradient of land use intensity. Assuming all land uses to have originated from an undisturbed forest ecosystem, Reserve forest being the closest representative of a protected natural state, considerable loss of soil organic matter and nutrients, and modification of species composition has taken place. However, in the most intensively managed agroecosystems, such as home gardens and settled rainfed agroforestry on upper slopes (settled agroecosystems representing the highest stage of human modification), high organic matter inputs seem to have conserved or even enhanced soil fertility as compared to forest land uses. These agroecosystems were also characterized by high species richness and structural complexity. Highly
disturbed forest ecosystems and less intensively managed/neglected agroecosystems like rainfed agroforestry on lower slopes showed the most inferior ecological status in terms of both soil fertility as well as ecosystem structure.

Land use complexity has been linked to habitat enrichment leading to an increase in landscape level species diversity. Indeed, overall species diversity in the managed village landscape might have been enhanced with forest species occurring in more protected environments, species occurring under various intensities of disturbance in natural/forest slash and burn ecosystems, arable weeds and selectively protected tree species in agroecosystems and finally components of planned plant biodiversity. In different non-agricultural land use/cover types, overall species richness remained almost constant although there were prominent differences in vegetation structure and species composition. However, even a slight alteration in management strategy led to absence of regeneration of climax forest species like *Shorea robusta* and its top canopy co-dominants as evident from absence of these species even in the less disturbed Civil forest. High sensitivity of these species may lead to local species extinctions, given the limited area of occurrence, if pressure on forest increases. Although differences in overall species richness between different non-agricultural land uses were not appreciable, loss of structural complexity and biomass/tree cover may delimit the ecological functions of highly disturbed forest ecosystems.

Although all forest/non-agricultural land uses occurred within a narrow spatial area, distance from the habitations in combination with legal restrictions seemed to exert strong influences on resource extraction practices which had direct effects on ecosystem structure and soil fertility status. Less disturbed Reserve/Civil forests with high tree density/basal cover occurred away from the habitations while Community forest under uncontrolled grazing, fodder and fuelwood removal, occurring close to the dwellings was characterized by low tree density and low soil fertility status. The study revealed that vesting of forest ownership and management rights in the community may not always result in protection and judicious management of forest resources. Formal mechanisms restricting intensity of use, such as legal restrictions in the present study, seem to accord a certain degree of protection as evident from the superior ecological status of Government owned Reserve forest.
Agroecosystem differentiation in the village could be clearly related to risk perception by the farmer, distance from the dwellings and water availability being the two major risks affecting farmer’s land use strategies. Therefore settled rainfed agroforestry on upper slopes and irrigated agriculture on lower slopes, the former being less risky due to proximity to the dwellings and the latter due to water availability were allocated a greater share of inputs as compared to rainfed agroforestry on lower slopes lacking either of the advantages. A single uniform indicator of sustainability may not be able to assess the way in which farmers value different agroecosystems. For instance, some agroecosystems were efficient in terms of energy/monetary output/input ratio, some in terms of gross outputs and yet others in terms of soil fertility status or species diversity. Extensive cultivation of millets was an important strategy adopted to cope with environmental uncertainties but emergence of market opportunities led to cultivation of demanding crops vulnerable to soil fertility stresses and climatic fluctuations, e.g. maize + soyabean mixed crop in least risky conditions in rainfed agroforestry on upper slopes. However, such modifications, which resulted in reallocation of labour and manure to more intensive land uses and accentuated land use heterogeneity, took place at the cost of land uses perceived to be more risky resulting in land abandonment and soil fertility deterioration over extensive areas.

Shifting cultivation land use, despite of its high energy and monetary efficiency (output/input ratio), does not seem to be an ecologically suitable land use option, at least in its present form, particularly due to losses of soil exchangeable Ca and Mg over the 7 year fallow period practiced in the study site, of available P during the cropping phase (although estimation of ecosystem level total nutrient stocks is necessary to assess the exact nature of nutrient depletion), and a huge depletion of soil carbon stocks as compared to forest land uses in shifting cultivation lands. The currently practiced fallow period allows only for partial recovery/vegetation regeneration, arrested at a stage dominated by shrubs which seems to retard tree regeneration. Also, the fallow function of delaying weed establishment does not seem to be much effective, as evident from a rapid establishment (from 2nd year of cropping onwards) of arable weeds in cropped fields. As such, under conditions of labour shortage driven by continued rural to
urban migration, probability of shifting cultivation to continue in future in its present form seems remote.

In the absence of agricultural extensification into forests, no further shortening of fallow period in shifting cultivation or frequency of cropping and increasing land abandonment, pressure on forests may not necessarily intensify with time, unlike the commonly stated direct correlation between increasing deforestation and agricultural intensification. Unless a major shift to fossil fuel based subsidy use is adopted, existing level of resource availability may delimit the area allocated to arable agriculture, given the additional requirements of valuable crops cultivated in select/limited area under least risky conditions.

The present study indicated that soil organic carbon may be a useful indicator of soil fertility/nutrient status and may be correlated with most nutrients in agricultural soils. However, over a wider range of land uses, as in non-agricultural soils, soil organic carbon showed a much weaker correlation with different nutrients. Organic carbon associated with the more labile/coarser fractions was found to be more sensitive to differences in land use practices as compared to both total soil organic carbon or mineral associated soil organic carbon, in both agricultural as well as non-agricultural soils.

Agroforestry land use/establishment of mixed species plantations was found to have tremendous potential in improving soil bio-chemical parameters. The redundancy exhibited by the selected, commonly valued, multipurpose tree species, in respect of their ability to improve key soil fertility parameters implies that a wide range of species may be incorporated to achieve soil fertility amelioration and to enable flow of diverse direct and indirect benefits to the farmers, thus ensuring an enhanced community participation in plantation programs.

Although, the study attempted to analyse land use/cover diversification and dynamics as driven by socio-economic and ecological factors, the precise nature of linkages between the two could have been worked out better, had one taken into account the historical data on spatio-temporal land use changes and socio-economic status of the local population. Agricultural land uses in the present study were differentiated based on the intensity of use where the rate of application of inputs was used as a measure of land use intensity. However, influence of finer
variations in/within land use such as crop species, biomass/nutrient removal rates and tree cover on ecosystem function was not enquired into. Land use/cover changes may often lead to a redistribution of nutrients in the different landscape components without a net change in landscape level nutrient stocks. Quantitative information on total nutrient stocks and transfers from one component to another and identification of processes accompanying losses may help in identifying critical links/issues which have to be addressed in order to devise suitable management strategies for the area. The study could not characterize the resource use intensity which forest ecosystems could sustain. Likewise, in the absence of a completely undisturbed natural ecosystem as a reference, only the existing status of different land uses could be illustrated and compared.

Interventions that recognize the rationale behind human mediated land use diversification and also address sustainability issues may find better acceptance among farmers. Measures that can enhance production from the system without putting undue pressure on forest resources or even reduce pressure on forests would be desirable both for the farmer as well as for restoring the ecological functions of the land uses. Following are a few possible ecologically sound and socio-economically viable options for the area:

a) Use of chemical fertilizers may arrest further nutrient depletion and relieve pressure on forest based resources and/crop residue. In the absence of irrigation facilities, fertilizer use confers limited benefits and therefore its application becomes economically unviable for the farmer. Substantial increases in productivity may be achieved if irrigation accompanies some mechanization and use of chemical fertilizers. The latter two may do away with the need for maintaining a high livestock density for draught and organic manure, thus relieving a lot of pressure off forest based resources. Most of the upper slope region in the present study area characterized by steeper slopes and smaller slopes may not be amenable to mechanization and may be prone to rapid leaching/erosion losses. Lower slope region characterized by a gentler slope, if brought under irrigation/fertilizer use could substantially augment farmer’s income in the village and could help reverse the trend towards deterioration in soil fertility.
b) Establishment of agroforestry land use or even mixed tree plantations on degraded lands could bring about substantial improvement in soil fertility status, carbon sequestration ability of the land use and may translate into flow of fodder and fuelwood for the farmer. Distant and neglected agricultural land uses like rainfed agroforestry on lower slopes could be converted to plantation of multipurpose tree species. Such a change would reduce local pressure on existing forests on one hand and would improve local economy on the other.

c) Management of shifting cultivation fallows could bring down the ecological cost of this land use as practiced in the area. Moderately fertile soils characteristic of the study site are particularly suitable for soil fertility restoration through establishment of short-duration managed fallows because such soils are limited mostly by nitrogen and incomplete restoration of ecosystem stocks of Ca and other cations may have a lesser effect on crop productivity due to their abundance in soil. However selection of species and fallow duration has to be decided based on fallow properties and nature of nutrient limitation experienced by the crop. Fallows should be able to accumulate large biomass and nutrients and provide either secondary outputs (fodder/fuelwood) during the fallow phase or appreciable improvement in crop yields in order to have an adoption potential.

d) Apart from the drastic shifts in land management suggested above, more subtle changes which might be easier to adopt include intercropping of grain legumes with low harvest index, even if at low densities, along with cereal/millet crops in low fertility areas. In slash and burn agriculture, mulching might be tried as an alternative to burning along with N or P fertilization depending on the nutrient limitation. Farmers could be discouraged from clearcutting the vegetation as retention of even a few trees may enhance ecosystem recovery.