Improving Soil Health for Sustainable Development of Agriculture in Himalaya

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The Himalayan region characterized by varied physiography and climate is endowed with a variety of land use types and agricultural systems. With over eighty percent area under forests and wastelands, the cultivated area is hardly twelve percent. The per capita availability of land is only about 0.17 ha. Notwithstanding small arable land resource, the agriculture remains to be main source of livelihood to the people of mountainous regions. The major food crops of the region are cereals, pulses, oilseeds and potato (Anonymous, 1998). Rice is the main crop followed by maize in the north-east. In western part, wheat is main crop followed closely by rice and maize. The agro-climatic conditions of the region are suitable for the production of temperate to sub-tropical fruits such as apple, pear, plum, peach, apricot, persimmon, pecannut, kiwifruit, strawberry, grape, cherry, almond, walnut, citrus, mango, litchi, guava, banana, pineapple, passion fruit and amla etc. The areas are also suitable for the production of ancillary horticultural produce like flowers (orchids, gladiolus, marigold, chrysanthemum, cut flowers), spices (ginger, saffron, chillies, cardamom, black pepper), mushroom, honey, hops and edible bamboo etc.

Of late, the region is witnessing rapid strides in the transformation of consumption based hill economy to production based one with diversification of least remunerative cropping systems with off season vegetables, large cardamom, edible bamboo, aromatic and medicinal plants, organic farming and host of agri-enterprizes. Many Himalayan states are showing increase in area and production of fruits and off-season vegetables over the years (Sharma and Minhas, 1993; Sharma *et al.*, 1998; NHB, 2003; Sharma, 2004). The area under large cardamom farming has increased by 135 percent in 20 years from 1975 to 1995 in Sikkim, contributing 53 percent of world's production (Sharma *et al.*, 2000). The edible bamboo cultivation picking up in North-Eastern Hill region assures net income of over Rs. 5.56 crores for the region from the sales of edible bamboo shoots (Bhatt and Bujarbaruah, 2004). For sustaining the new ventures and improving the overall agricultural productivity in the Himalayan region, we have to direct concerted efforts towards removal of different

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production constraints confronting agriculture. The impaired soil health as a result of unfavourable soil and environmental conditions is one of the major factors affecting soil and crop productivity in the Himalayan region. Presently, the productivity of major crops of the region is generally low (Sharma, 2004). The productivity of apple in Himachal Pradesh and Uttarakhand is still 1-2 t /ha compared to over 10 t/ha in Jammu and Kashmir. The overall productivity of 4 t/ha of the region is, however, much below the international level of 30 t/ha.

Concept and Meaning of Soil health:

From agricultural point of view, the soil health may be referred to as the ability of the soil to produce crops. It is conditioned by a number of physical, chemical and biological attributes and processes like soil erosion, water retention and transmission characteristics, mechanical impedance, soil temperature, soil aeration, water logging, soil salinity, alkalinity, acidity, nutrient status, organic matter content, microbial biomass carbon and potentially mineralizable nitrogen etc. Prevalence of one or more unfavourable soil conditions over time will lead to unsustainability of an agricultural system. Many indicators related to soil function have been suggested by different workers for evaluation of soil quality/health (Doran and Parkin, 1994; Larson and Pierce, 1994). These indicators could be qualitative, such as the observational features of the soils or plants growing on the soils or quantitative in having measure of the physical, chemical and biological attributes. It is worthwhile to employ visual and analytical soil-site suitability criteria and a number of other simple indicators that have meaning to farmers and other land managers. The farmers in U.S. ranked soil organic matter content, crop appearance and risk to erosion as three most important properties for describing soil health and sustainable management (Romig *et al.*, 1995). Similarly, Parr *et al.* (1992) have suggested a more generic set of indicators of soil quality/soil health and management options for sustainable agriculture (Figure 1).

India is faced, today, with stagnation in crop productivity and slow down in agricultural growth. Declining soil health is considered as one of the factors for such a decline. The restoration of soil health is, therefore, a formidable challenge before us to ensure higher productivity, profitability and national food security. The United Nations Millennium Task Force on hunger has, accordingly, made Soil Health Enhancement as one of the five recommendations for increasing agricultural productivity and fight hunger in India in its report (Saanchez and Swaminathan, 2005). Therefore, we need to constantly monitor the health of soil resources and devise appropriate management strategies for sustained productivity and least environmental degradation.

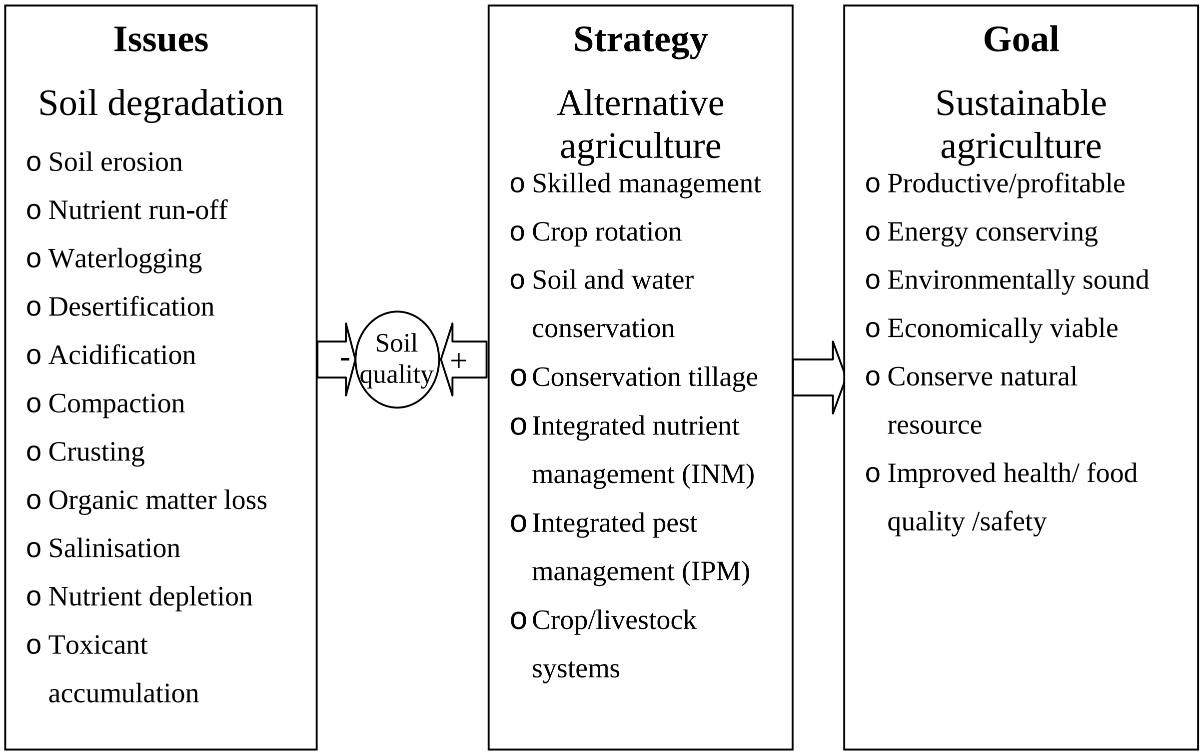

Figure 1. Conceptual relationship of soil quality with different attributes of soil and management options for sustainable agriculture (Adapted from Parr *et al*., 1992)

Improving Soil Health:

Arresting soil erosion and degradation: The areas characterized by high intensity rainstorms, sloping lands and highly erodible soils are vulnerable to more soil erosion. The increased soil erosion results into loss of top fertile soil forcing reduction in the crop productivity. Over one-third of the area in Himalayan region suffers due to soil erosion and degradation (Table 1), the severity being more in Mizoram, Himachal Pradesh, Uttarakhand, Nagaland and Tripura. The north-western hills of Jammu and Kashmir, Himachal Pradesh and Uttarakhand and hills of north-eastern states suffer due to severe soil erosion of more than 20 t/ha/year (Singh *et al.*, 1997). The rates were quite high for Siwalik hills (> 80 t/ha/year) and shifting cultivation areas of the north-east (>40 t/ha/year). The torrent erosion is a big menace in Siwaliks and renders large areas of fertile piedmonts and flood plains as unproductive with the spread of barren sand and gravels on them. The shifting cultivation with short cycle of 3-4 years is the major cause of soil erosion in the NEH region. There are about 4.4 lakh tribal families depending on shifting cultivation and covering over 12 percent of total geographical area in the region.

Table 1. Soil Degradation (000 ha) in Himalayan Region (Provisional)

State	Water erosion	Wind erosion	Physical deteriora-tion	Complex problem	Total degraded area	Total Geographical Area
Jammu & Kashmir	5460	1360	200	--	7020 (31)*	22224
Himachal Pradesh	2875	--	1303	--	4178 (75)	5567
Uttaranchal	1554	--	2280	--	3834 (72)	5348
Sikkim	235	--	--	--	235 (33)	710
Arunachal Pradesh	4327	--	176	--	4503 (54)	8374
Mizoram	1187	--	--	694	1881 (89)	2108
Manipur	133	--	111	708	952 (42)	2233
Nagaland	390	--	--	605	995 (60)	1658
Tripura	425	--	203	--	628 (60)	1049
Meghalaya	1168	--	146	34	1208 (53)	2243
TOTAL	17754	1360	4279	2041	25434(49)	51514

* Figures in parentheses are percent of total geographical area
Source : NBSS&LUP (2004)

The adoption of appropriate soil and water conservation measures is essential for protecting the lands from soil erosion and deterioration in soil health. A number of mechanical and cultural management practices like land leveling, contour bunding, contour trenching, bench terracing, contour farming, intercropping, strip cropping, mixed cropping, mulching, crop geometry and vegetative barriers etc. are recommended for checking soil and water loss from the sloping lands. The runoff water could be harvested and stored in suitable storage structures for supplemental irrigations during moisture stress periods for the crops. The yield increases are over 100-200 % with even one supplemental irrigation of 5 cm (Samra and Pratap Narain, 1998). There are many success stories of water resource development through water harvesting in watershed projects (Samra *et al.*, 2002) in sub-montane Siwaliks (Sukhomajri), western Himalaya (Palampur in H.P. and Fakot in Uttarakhand and north-eastern Himalayan region (Barapani, Meghalaya). The created water resource increased dramatically the productivity of agricultural lands in the areas. The cheaper ways and means to reduce seepage from the reservoirs have been worked out to enhance water storage efficiency. The small perennial water sources could also be tapped in a participatory mode in certain locations. The technology has been demonstrated in villages of Kalimati, Badasi, Bhopalpani and Sainji, Dehradun, providing irrigation water to a large number of rural families (Sharda *et al.*, 2006).

Adopting integrated nutrient supply system: The soils of Himalayan region are, generally, deficient in nutrients like nitrogen, phosphorus, calcium, magnesium, sulphur, zinc, boron, molybdenum and iodine. These need to be supplied by addition of inorganic and organic fertilizers to maintain steady supply of essential nutrients to crops. But, the supplies are seldom met by the farmers by applying very little of fertilizers. The fertilizer use ($N+P_2O_5+K_2O$) is still below the national average of 104 kg/ha in Himalayan states; the figures being 84, 50, 92 and 50 kg/ha for Jammu and Kashmir, Himachal Pradesh, Uttarakhand and Assam, respectively (Fertilizer Statistics, 2005-06). Besides inadequate use, the fertilizer use is highly imbalanced with the addition of urea alone supplying only single nutrient nitrogen. The inadequate and imbalanced fertilizer use coupled with no addition of organic manures has led to the emergence of multi-nutrient deficiencies in many areas. The deficiencies of micronutrients, particularly of zinc, are becoming more conspicuous in some areas. About 57, 34, 42 and 12 percent soil samples were found to be deficient in zinc in Meghalaya, Assam, Himachal Pradesh and Jammu & Kashmir, respectively (Singh, 2001). The soils of the cold arid region are, generally, found to be poor in soil fertility, especially of Leh (Ladakh). The Leh soils were low to medium in organic carbon and available P and K (Sharma *et al.*, 2006). On an average, 72, 87 and 87 percent soil samples collected from different blocks of Leh district (Leh, Kharu, Nubra, Nyoma, Khaltse and Durbuk) were deficient in DTPA-extractable Zn, Mn and Fe, respectively. The deficiencies were 100 percent for Mn and Fe in all the blocks except Nubra block. Likewise, the soils of Spiti cold desert were deficient in Zn, Mn and Fe to the tune of 38 to 65, 18 to 34 and 28 to 42, percent, respectively (Parmar *et al.*, 1999). The continuous use of high analysis fertilizers (devoid of sulphur impurities) has made sulphur a deficient and limiting nutrient in Typic Hapludalf soils of Palampur, Himachal Pradesh (Sharma *et al.*, 2005).

The limiting nutrients not allowing the full expression of other nutrients lower the overall fertilizer use efficiency and crop productivity. This has been made explicitly clear by the long term fertilizer experiments by Indian Council of Agricultural Research (ICAR) since 1970-71. The application of nitrogen alone caused reduction in fertilizer response ratio (from initial 12.5 to 5 over 30 years) primarily due to deficiencies of phosphorus and potassium (Figure 2). The response ratio increased with the application of phosphorus along with nitrogen, but its reduction with time was again conspicuous in the absence of potassium

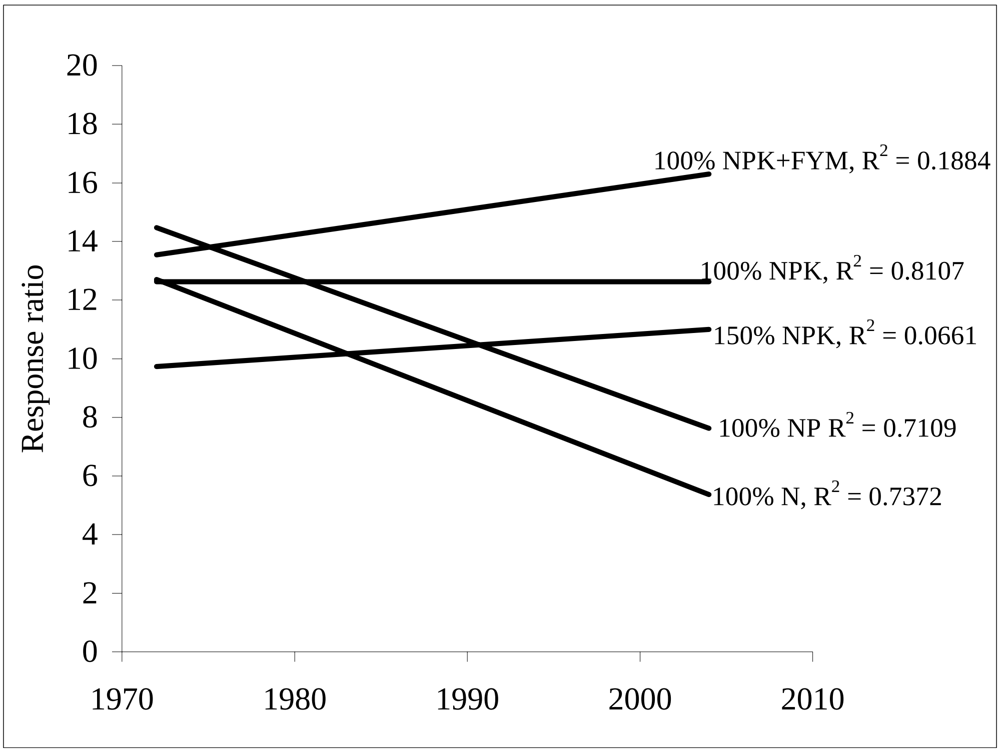

Figure 2. Nutrient response ratios (kg grain/kg nutrient) in cereals (LTFE data averaged over 1972-2003)

addition. The ratio got stabilized at a higher level only with the balanced application of NPK. Any further improvement in the response ratio beyond this level could not be effected merely with the addition of higher amounts of chemical fertilizers (as for 150 % NPK). The response ratios appreciated with a rising trend only when chemical fertilizers were supplemented with organic manure (100 % NPK+FYM). The average response ratios of N, NP, NPK and NPK+FYM were 8.1, 10.1, 12.8 and 15.2, respectively (Figure 3).

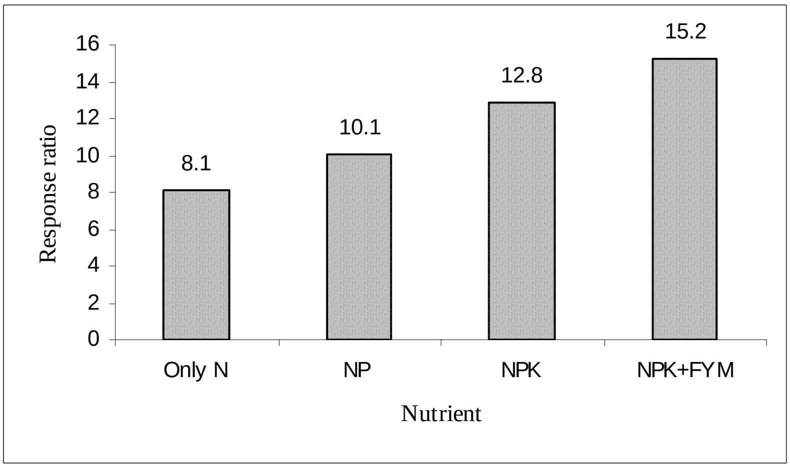

Figure 3. Average response ratios (kg grain/kg nutrient) of nutrients in cereals (LTFE data, 1972-2003).

The continued additions of NPK at higher rate without organic manures would induce deficiencies of secondary and micronutrients, thereby, lowering the response ratios. The continued omission of sulphur and zinc from the fertilization schedule has led to their deficiencies in soils forcing drop in the fertilizer response ratios in crops at different locations (Figures 4, 5, 6, 7).

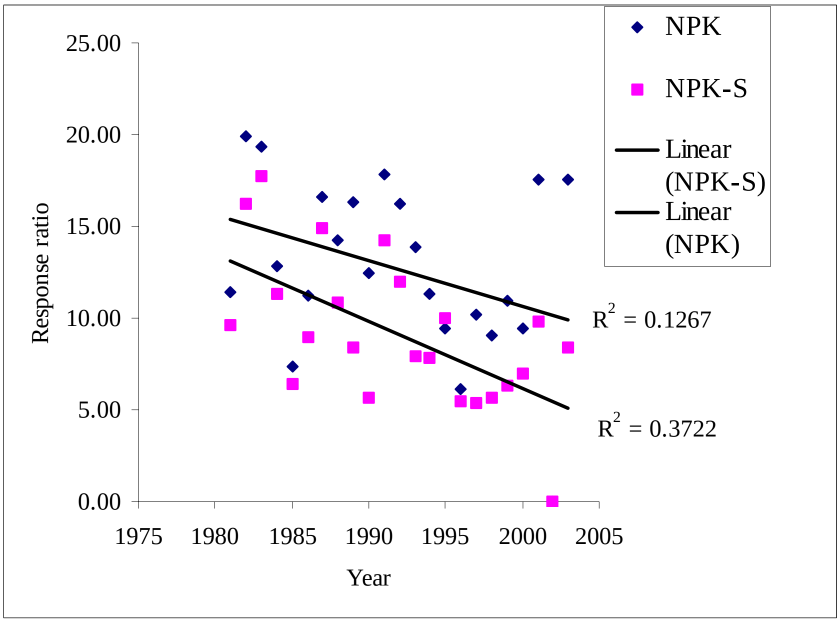

Figure 4. Response ratios (kg grain/kg nutrient) of sulphur in maize at Palampur (Data averaged over 1980-2003 under LTFE).

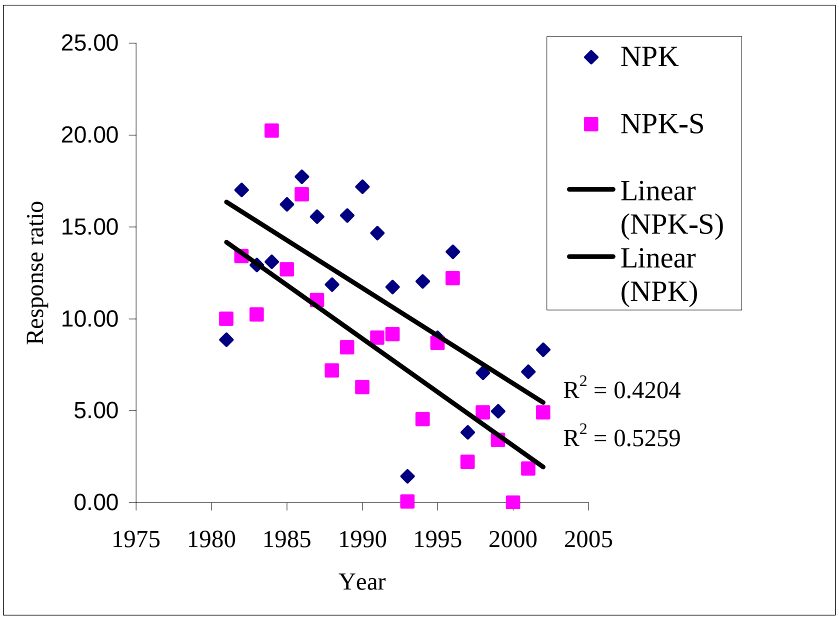

Figure 5. Response ratios (kg grain/kg nutrient) of sulphur in wheat at Palampur (Data averaged over 1980-2003 under LTFE).

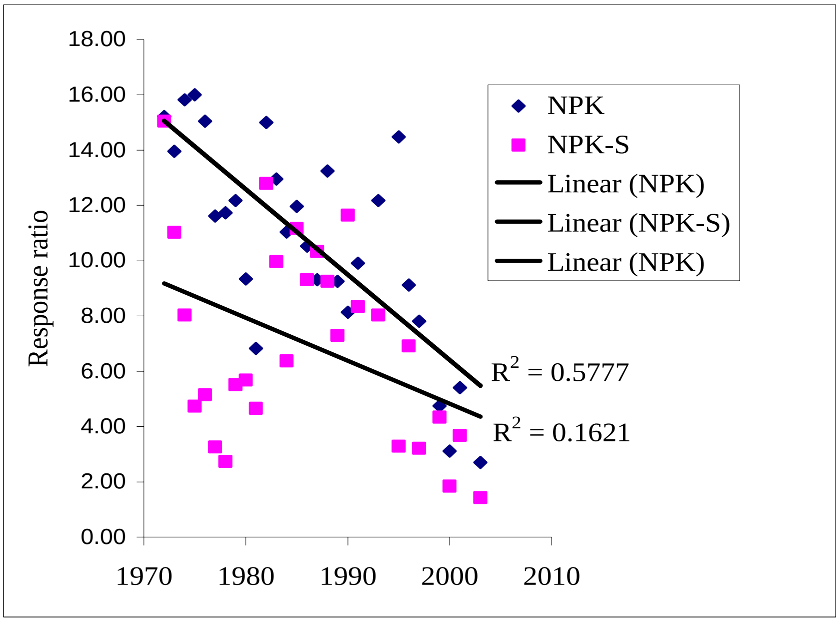

Figure 6. Response ratio (kg grain/kg nutrient) of sulphur in rice at Barrackpore (LTFE data)

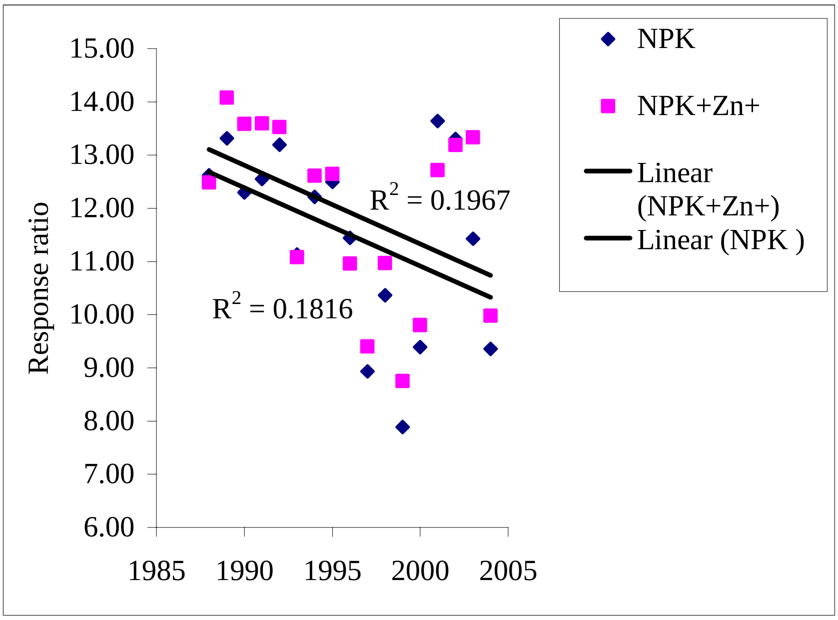

Figure 7. Response ratio (kg grain/kg nutrient) of Zn in cereals (LTFE data)

The beneficial effects of balanced and integrated nutrient management on soil health in terms of physical, chemical and biological attributes and overall crop productivity have very well been demonstrated by the Long Term Fertilizer Experiments at Palampur, Himachal Pradesh (Sharma *et al.*, 2005). The conjunctive use of chemical fertilizers and organic manure (NPK+FYM) enhanced organic carbon, soil available nutrients, soil aggregation, water infiltrability, microbial biomass-C and microbial population compared to use of chemical fertilizers alone (Table 2). The total productivity of the maize-wheat cropping system under integrated use of inorganic and organic fertilizers was significantly higher over use of inorganic fertilizers alone (Figure 8).

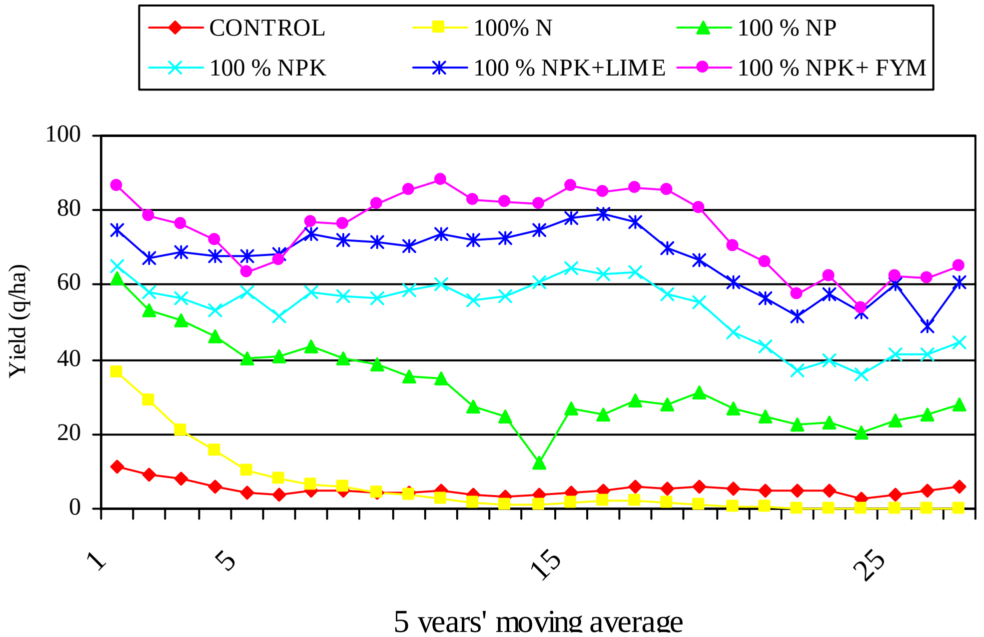

Figure 8. Effect of chemical fertilizers, lime and FYM on total productivity of

Table 2. Effect of chemical fertilizers, lime and FYM on soil microbial population and biomass-C

Treatment	Soil Microbial parameter				
	Bacteria ($CFUx10^5$ per g soil)	Fungi ($CFUx10^4$ per g soil)	Actinomycetes ($CFUx10^3$ per g soil)	Azotobactor ($CFUx10^3$ per g soil)	Microbial biomass – C (mg/kg)
50 % NPK	24.56	4.39	52.4	55.16	230
100 % NPK	11.49	7.83	20.30	17.5	316
150 % NPK	6.94	8.06	5.75	14.61	279
100 % NPK+ HW	9.21	5.75	12.10	68.53	305
100 % NPK+ Zn	18.23	2.61	8.86	15.93	312
100 % NP	7.96	5.13	24.33	45.50	205
100 % N	4.55	6.98	46.63	11.86	190
100 % NPK+ FYM	28.08	2.78	73.20	226.16	410
100 % NPK (-S)	13.76	5.04	34.63	14.60	207
100 % NPK+ Lime	18.88	0.45	87.86	92.66	350
Control	9.53	4.45	19.76	127.83	257
CD (P=0.05)	*0.787*	*2.993*	*2.993*	*7.964*	*19*

Source: Sharma *et al.*, 2005

The usefulness of integrated nutrient management has also been demonstrated in improving soil health and productivity of important vegetables in cold desert / dry temperate areas (Parmar, 2005). The combined use of major and micronutrient fertilizers, bio-fertilizers and FYM helped obtain quite higher yields of green peas, potato and cabbage in Lahaul, Spiti and Kinnaur compared to farmers' practice (Table 3). For instance, the yields of pea, potato and cabbage were higher by 36, 42 and 39 percent, respectively under IPNS over farmers' practice, in Spiti. The net economic returns over farmers' practice were also quite attractive. The returns were to the tune of Rs 1,03,222; 1,07,925 and 84,662 for peas, potato and cabbage in Spiti, respectively. The integrated nutrient management also improved quality of produce in terms of protein, starch, total soluble sugars and vitamins.

Table 3. Yield and economics of off-season vegetable production in cold arid areas of Himachal Pradesh.

Crop/Practice	Lahaul		Spiti		Kinnaur	
	Yield (q/ha)	Net returns (Rs.)	Yield (q/ha)	Net returns (Rs.)	Yield (q/ha)	Net returns (Rs.)
Green peas						
Farmer's Practice	91.6	72,052	101.8	70,438	113.5	89,666
IPNS	166.3	1,32,640	159.5	1,03,222	182.2	1,52,182
Potato						
Farmer's Practice	139.9	54,835	126.3	54,199	139.2	57,704
IPNS	187.6	72,091	218.0	1,07,925	206.6	92,527
Cabbage						
Farmer's Practice	173.2	53,690	152.1	51,040	123.8	33,069
IPNS	242.8	72,228	243.8	84,662	208.5	61,111

Farmer's Practice = 40% recommended N + FYM *Source: Parmar (2005)*
IPNS (Fertilizers+Micronutrients+ Organic Manure+Biofertilizer)

The integrated nutrient supply system envisaging conjunctive use of chemical and organic fertilizers is, therefore, the most ideal system of nutrient management. The system enhances nutrient-use efficiency, maintains soil health, enhances yields and reduces cost of cultivation. There is need to augment the supplies of organic manures (farm yard manure, green manure, compost/vermicompost) and fortified & customized fertilizers supplying secondary and micronutrients to have IPNS on a sound footing. The use of biofertilizers is still minimal in hilly and mountainous regions and requires to be promoted by producing effective strains with enhanced shelf life. A variety of biofertilizers that could be popularized are nitrogen fixers (Rhizobium, Azotobacter, Azospirillum), phosphate solubilizing bacteria (PSB), blue-green algae, mycorrhizae and plant growth promoting rhizobacteria (PGPR).

Ameliorating acid soils: The Himalayan region has large area under acid soils with maximum under Arunachal Pradesh followed by Assam (Table 4). About 17.6 million ha of lands with pH value less than 5.5 are critically degraded with very poor physical, chemical and biological characteristics. The soils suffer due to deficiencies of phosphorus, calcium, magnesium, molybdenum and boron and toxicities of aluminum and iron. The fertilizer use is still low in the region. The productivity of the soils is, therefore, low due to poor soil health. The addition of lime to these soils neutralizes soil acidity and creates favourable environment for microbial activity, nutrient release and their availability to plants. The conjunctive use of lime and adequate fertilizers, therefore, holds key for higher productivity of these soils. Indian Council of Agricultural Research (ICAR) has evolved a cost-effective technology for

Table 4. Extent of Acid Soils in India

States	Strongly acidic (pH<4.5)	Moderately acidic (pH 4.5-5.5)	Slightly acidic (pH 5.5-6.5)	Total
Arunachal Pradesh	4.78	1.74	0.27	6.79
Assam	0.02	2.31	2.33	4.66
Himachal Pradesh	-	0.16	1.62	1.78
Jammu &Kashmir	-	0.09	1.48	1.57
Manipur	0.43	1.44	0.32	2.19
Meghalaya	-	1.19	1.05	2.24
Mizoram	-	1.27	0.78	2.05
Nagaland	0.12	1.48	0.05	1,65
Sikkim	0.28	0.32	-	0.60
Tripura	0.06	0.75	0.24	1.05
Uttranchal	-	1.18	2.30	3.48
Total	5.69	11.93	10.44	28.06

Source: NBSS&LUP, Nagpur

amelioration of the acid soils by conducting large number of field trials in important acid soil regions of the country, including Himalayan region (Sharma and Sarkar, 2005). Application of lime @ 2-4 q/ha along with 100 percent recommended doze of NPK fertilizers in furrows at the time of sowing promised significant increase in the yields of crops, especially legumes and pulses, over farmers' practice (Figure 8). The benefit:cost ratios were 3.4 and 3.2 for rape seed and summer green gram, respectively in Assam; 1.7 and 1.8 for maize and wheat, respectively in Himachal Pradesh; and 3.5 and 2.4 for maize and mustard, respectively in Meghalaya. The crop varieties tolerant to soil acidity were Varuna & Sonmukhi of rapeseed and K851 & Sonmugu of summer greengram for Assam; Bragg, PB1 & Harasoya of soybean and ONK1, Hoyala &HPN-3 of gobhi sarson for Himachal Pradesh; and HUR-15 of french bean for Meghalaya.

The cheap and effective liming materials must be made available for the success of acid soil amelioration programme. Although agricultural grade limestone powder and marketable lime are effective, these are not economical and available in plenty at all the

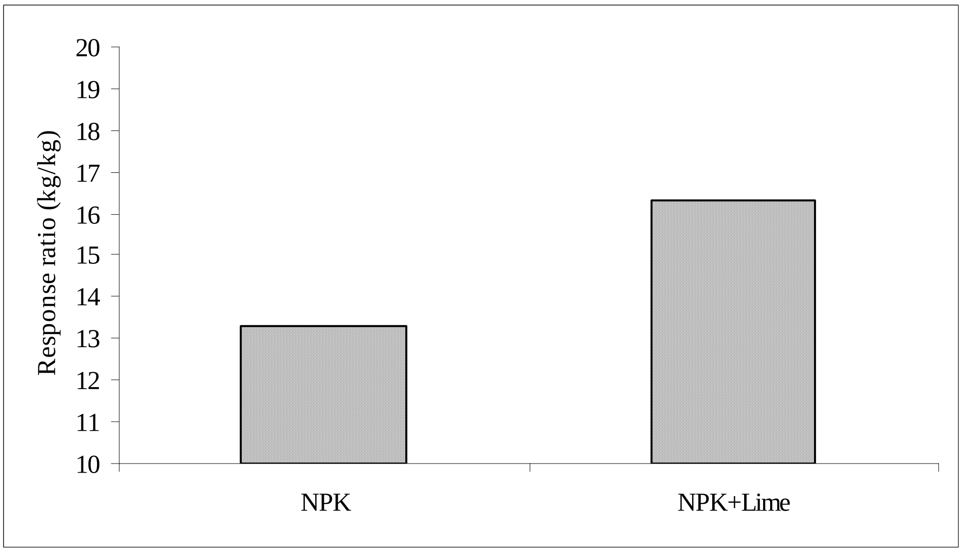

Figure 8. Average response ratio to applied NPK in cereals in presence or absence of lime (LTFE data)

places. The by-products of industries like basic slag, lime sludges, phosphogypsum and press mud etc. are rich sources of calcium and serve as cheap liming materials. The availability of basic slag is around 30 million tonnes, accumulated as waste over the years with different steel industries. The Tata Steel Industries, Jamshedpur generate about 3 lakh tonnes of basic slag annually. Likewise, the paper mills in Assam, Nagaland, West Bengal, Orissa, Madhya Pradesh and Andhra Pradesh produce around 2 lakh tonnes of lime sludge. Besides, there are large deposits of limestone in north – eastern states of Arunachal Pradesh, Manipur, Assam, Meghalaya and Nagaland that could be exploited for producing agricultural grade lime at affordable prices. The materials should meet the specifications of at least 25% calcium oxide and be ground to > 80 mesh size. The Tata Steel Industries is keen to supply basic slag of desired specifications as an amendment for the acid soils at the nominal price of about Rs.

1000/tonne. The Government should facilitate requisite tie-ups with the industry to regulate marketing and distribution of materials to farmers.

Strengthening Soil Testing Service: The soil testing laboratories need to be computerized and equipped with the facility for analyses of all nutrients including secondary and micro nutrients. These should be manned by soil scientists to ensure precise analyses and proper interpretation of results. The State Agricultural Departments should have a policy intervention in this regard. The states should also come forward for preparation of geo-referenced soil fertility maps at district and block levels in partnership with State Agricultural Universities and ICAR to have precise fertilizer recommendations. The soil testing service, presently, is inadequate in having the capacity to analyze only 7 million soil samples/annum against 115 million farm holdings at the country level. A farm holding, therefore, has a fare chance of its testing only after 15 years or so. Obviously, there is an urgent need to open up more soil testing laboratories, at least one each in different districts/blocks of the Himalayan region for more coverage and enhanced capacity. In NEH region, only 17 districts out of 77 have soil testing laboratories catering to the soil testing needs. The National Commission on Farmers has, therefore, recommended a countrywide network of 1000 advanced soil testing laboratories to strengthen the soil testing service. Each laboratory would cost about Rs 0.5 crore.

Conclusion

The Himalayan region endowed with varied physiography and fine mosaic of micro-climates, offers niches for a variety of cereal, horticultural plantation and aromatic and medicinal crops. But, the productivity of majority of crops is low due to a number of production constraints. The impaired soil health influenced by increased soil erosion, deficiencies and toxicities of nutrients, frequent moisture stress and low soil biological activity etc., is one of the major factors for low productivity. The future gains in productivity and agricultural transformation in the region can not be realized on a deteriorating natural resource base. There is need for effective soil water conservation programmes within the perspective of participatory watershed management, integrated plant nutrient supply system envisaging conjunctive use of chemical and organic fertilizers and amelioration of cid soils for sustained soil health, crop productivity, profitability and environmental balance in Himalayan region.

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