CHALLENGE OF MANAGING SOIL FERTILITY DEPLETION: A CASE OF *TARAI* AREAS OF UTTARAKHAND, INDIA

Sucheta Singh* and Chandeshwar Tiwari
Farm Science Center, Bajpur Road, Kashipur
(G. B. Pant University of Agriculture & Technology, Pantnagar)
U.S.Nagar, Uttarakhand I 244713
***Email: drsuchetasingh@gmail.com**

ABSTRACT
Modern technology for increasing agricultural output has had environmental costs. The green revolution technology, in particular, with its high dependence on chemical input, has, over time, led to declining soil fertility with excessive fertilizer use, water pollution from pesticides, loss of genetic varieties because of monoculture cultivation and marginalization of indigenous knowledge systems. Population growth has impinged on these processes more as an exacerbating cause than as a primary cause of degradation. The manifold environmental problems that arise out of agricultural activities show that greater emphasis must be given to the environment-friendly management of agriculture. The present study was carried out in district Udham Singh Nagar, selecting 200 soil sample surveys and then the findings were interpreted by comparing with earlier results. In Uttarakhand, in the 1950s, soils in *tarai* areas had less than 2% organic carbon and 6.0 – 7.0 pH which has now been reduced to 0.5% whereas pH has increased to 8.5. Depletion of the water table also has been observed by many surveyors. Imbalanced fertilization by farmers, continuous cereal-cereal cropping, over-mining of ground water, development of plough pan, injudicious use of agro chemicals like synthetite, Pyrathrins and growth hormones have all resulted in poor soil. This in turn has led to poor crop yield, more disease, increased pest attack and increased cost of production.

INTRODUCTION
The first Green Revolution witnessed in the early 70's culminated in tremendous yield increase through four basic elements of production viz. semi-dwarf high yielding varieties of rice and wheat, improved irrigation and increased use of fertilizers and agro-chemicals. However, due to population pressure, the country is again approaching a period of food shortage. As the availability of arable land for agriculture will decrease in future due to industrialization, the only way out is through greater productivity.

The present paper analyses and emphasizes soil fertility depletion and its management practice in the *Tarai* region of Uttarakhand, based on primary studies carried out by scientists, farmers' interaction and secondary data available in the area. It shows how better productivity could be managed without exploiting our natural resources.

The study was carried out in district Udham Singh Nagar, selecting 200 soil sample surveys and then the findings were interpreted by comparing with the earlier results. The soil samples collected were mainly from fields following rice-wheat-rice-vegetable pea-rice or rice vegetable pea-sugarcane-ratoon-wheat cropping. The objective of the study was to depict the problem of soil depletion, find the underlying causes and suggest corrective measures.

DEVELOPMENTAL PROFILE OF *TARAI* REGION OF UTTARAKHAND
In the 1950's, soils in *tarai* areas had less than 2% organic carbon and 6.0-7.0 pH which over the ensuing period has been reduced to 0.5% while the pH has increased to 8.5. Many surveyors have also noticed depletion of the water table.

Profile of water table, organic carbon, ph and nutrient status
In the 1960s, the water table was at the surface, in the 1970s, it rose to 2 metres and in successive decades to 7-8 metres. Organic carbon was more than 2% in the 1960s whereas it declined to less than half a percent in the decades that followed.

Table 1: Profile of water table, organic carbon, pH and nutrient status in *Tarai* region of Uttarakhand

Year	Water	Organic carbon %	pH	Nutrient status		
				N	P	K
1960s	At the surface	>2.0	<6.5	3000	24.0	210.00

1970s	2 m	1.5	6.5-7.0	2500	22.1	200.00
1980s	3 m	1.0	6.5-7.0	1800	17.0	192.00
1990s	5 m	0.5	7.0-8.0	1200	13.0	185.00
2000s	7-8 m	<0.5	>8.5	800	11.0	180.00

Nutrient status shows a declining trend from 3000 to 800, 24 to 11 and 210 to 180 for N,P and K respectively. (Table 1)

Cropping system, fertilizer application and productivity

Table 2 shows that the cropping system in the 1960s was maize-barley/mustard/gram, in the 1970s maize/rice-wheat/barley and in the 1980s and 1990s, rice-wheat whereas nowadays it is either rice-wheat-rice-vegetable pea-rice or rice vegetable pea-sugarcane-ratoon-wheat.

Table 2: Cropping system, fertilizer application and productivity in *tarai* region of Uttarakhand

Year	Cropping system	Fertilizer application	Productivity/ha	Remarks
1960s	Maize- barly/mustard/gram	60 kg N	4.0 t	--
1970s	Maize/rice-wheat/barley	100:40:20	6.0 t	30 kg Sulphur as SSP
1980s	Rice-wheat	120:40:20	8.0 t	20 kg Zinc
1990s	Rice-wheat	150:40:20	9.0 t	20 kg Zinc
2000s	Rice-wheat-rice Rice-veg.pea-rice Rice-veg.-pea-sugarcane-ratoon-wheat	180:40:20	12.0 t	20 kg Zinc

Fertilizer application shows a trend of 60 kg nitrogen to 100:40:20 in 1970s; 120:40:20 in 1980s; and 150:40:20 in 1990s. At present, farmers applying at the rate of 180:40:20 NPK. Productivity has risen from 4.0 t/ha in the 1960s to 12.0 t/ha now. However, the cost of producing wheat has also risen.

Technological input and major problems

Table 3 shows that in the 1960s, the major technological input was indigenous seed and farmers followed traditional practices for agriculture. The major problem in the *tarai* region then was swamp areas. At the advent of the green revolution, farmers started to use high yielding variety seeds and chemical fertilizers but traditional practices of cultivation still exist.

Table 3: Technological input and major problems in *tarai* region of Uttarakhand

Year	Technological Input	Major Problems
1960s	· Indigenous seed · Traditional	· Swamp areas
1970s	· HYV · Chemical fertilizers · Traditional	· Poor mechanization · Weeds
1980s	· HYV chemical · Intensive cropping · Partial mechanization	· Phalaris minor
1990s	· HYV chemical · Chemical fertilizers · Technological awareness	· Monocropping · Yield stabilization
2000s	· HYV chemical · Chemical fertilizers · Technological awareness	· Imbalanced fertilization · Continuous cereal-cereal cropping · Over mining of ground water · Development of plough pan · Non judicious use of agro chemicals like synthetite,

		Pyrathrins and growth hormones

From the 1980s onward, farmers continued to use high yielding variety seeds and chemical fertilizer; intensive cropping was carried out and partial mechanization was also introduced mainly for land preparation and harvesting of crops. Phalaris minor emerged as the major problem of weeds in standing crops. A sudden change in the 1990s emerged when farmers restricted agriculture to mono-cropping for higher economical returns and lesser risks, leading to yield stabilization. However, technological awareness was also increasing among farmers.

Imbalanced fertilization by farmers, continuous cereal-cereal cropping, over-mining of ground water, development of plough pan, injudicious use of agro chemicals like synthetite, Pyrathrins and growth hormones all resulted in poor soil. This in turn led to poor crop yield, more disease incidence, increased pest attack and increased cost of production.

SOIL FERTILITY MANAGEMENT/CORRECTIVE MEASURES IN *TARAI* AREAS OF UTTARAKHAND

The major problems leading to depletion of the soil in the area are:

- Imbalanced use of fertilizers in the rice-wheat system
- Development of plough pan
- Depletion of organic matter and ground water
- Shift of pests and pathogens

Imbalanced use of fertilizers in rice-wheat system

Imbalanced use of fertilizers in the rice-wheat system leads to resistance in plant vigour, poor grain quality and heavy attack from insects and pests. Ultimately it results in reduced yield. Appropriate training programmes, awareness-generation camps and wall paintings at gram panchayat level regarding proper use of fertilizers in crops could result in the management of this problem.

The raised bed planting method of wheat has proved to be a boon in regions where water is scarce. In this method, the field is prepared by conventional methods but afterwards the beds are formed and drilled simultaneously, with a FIRB planter. The width of the beds is kept to 65-70 cm and generally 2-3 rows of wheat are drilled on top of the bed.

Through this technology over 25% seeds and nitrogen can be saved without any yield reduction as compared to traditional flat bed cultivation of wheat. The FIRB saves irrigation water by over 30% depending upon the soil type and agro-climatic conditions. Crops such as soybean, maize, cotton, rice, pea, pigeon pea, mustard etc. have been successfully grown on beds. The beds are reshaped without dismantling the original beds thereby saving fuel, time, labour and machinery operation. Dry seeding of rice on beds is also being evaluated at a number of locations. It provides an opportunity to enhance cropping intensity and use land more efficiently to achieve sustainable yields.

Development of plough pan

There are four main types of soil compaction, each of which has different causes and treatments. 'Surface Crusting' reduces seed emergence and water infiltration and is caused by the impact of rain drops on weak soil aggregate. 'Surface Compaction' occurs from the surface down to the tillage depth and can be loosened by normal tillage. Two other types of soil compaction, which are normally overlooked, are 'Subsoil Compaction' and 'Plough or Tillage Pan'. (Spoor and Godwin, 1978)

In a sandy clay loam soil, the movement of a tractor with 2.5 t trailer reduced the porosity by 10% and increased the bulk density from 1.30 to 1.55 Mg/m 'and a consequent reduction in millable cane stalks by 22.7% due' to compaction (Cleasby, 1964). Because of reduced large pores under compaction, the resistance to flow of water increases. An increase in bulk density from 1.2 to 1.4 Mg/rn 'has been found to cause a tenfold decrease in hydraulic conductivity resulting in poor drainage condition in the rainy season' (Yang, 1974).

In the *tarai* region of Uttarakhand, the effect of sub-soiling on sugarcane yield has been substantial, as compact layers have been observed between 30 ern and 60 ern depth at a number of locations (Thakur, 2007). The bursting of compacted soil layers allows plant roots to penetrate deeper into the moist soil zone, thereby enhancing the water and nutrient utilization efficiency as well as less lodging of crop with better plant anchorage leading to higher yield. In one of the subsoiling trials conducted in farmers' participatory research mode in village Anandpur (Kichha), Distt. U.S. Nagar in 2005 on CoPant 94222 variety, farmers' practice yield was about 59.3 t/ha whereas the use of Pant-winged subsoiler up to a depth of 40 cm gave a yield of 72.33 t/ha; thus an increase in yield of over 22% was obtained. This was mainly due to proper drainage of fields, no lodging of sugarcane and destruction of termites' colonies as the field was heavily infected with termites. Many farmers/sugarmills of Uttarakhand have adopted the subsoiling technique which is giving very positive results.

Depletion of organic matter and ground water organic matter and humus

Soil organic matter improves cation exchange capacity and serves as a reservoir of nutrients for the growing crop. Incorporation of organic matter, also improves soil aeration, drainage and water-holding capacity. Green manure crops are an economical means for elevating soil organic matter temporarily and providing nitrogen for the next crop.

Compost is a relatively economical organic source of nutrients but different composts can be quite variable depending upon the source. Growers need to understand the factors that contribute to compost quality. Incorporation of crop residue, if not used as cattle feed or for composting, can also add organic matter to the soil and help recycle the nutrients, particularly potassium.

The decomposition of organic matter in soils can provide much of the nitrogen (N), phosphorus (P), and sulfur (S) needed for crop nutrition. A portion of the N from many organic materials is readily converted into available mineral forms. Phosphorus reacts quickly, is bound to soil minerals and moves very little from where it is placed. Potassium (K), calcium (Ca), and magnesium (Mg) are relatively soluble from plant residues or soil organic matter fractions and also contribute to the soil pool of these nutrients. Organic matter is also a valuable balanced source of many minor elements. It releases nutrients as it decomposes and provides slow, constant availability. Soil organic matter contains a number of fractions that vary in composition and activity. Humus is the most resistant and mature fraction. It is very slow to decompose and can last for hundreds of years. Residues that are slow to decompose (such as hay or corn stalks) are more efficient producers of humus than are more readily decomposed materials. However, relatively little is understood about the benefits of humus or other specific organic matter fractions for crop growth, and an organic grower's crop management efforts should be directed toward increasing total soil organic matter.

In the *tarai* region of Uttarakhand, continuous cereal - cereal production leads to nutritional imbalance which ultimately leads to increased pH (8.5) and decreased organic matter (0.5). Possible management strategies to overcome this problem are balanced use of fertilizer, crop residue management and organic farming.

Shift of pests and pathogens

In the *tarai* area, cultivation of summer rice instead of following the wheat - rice cropping system resulted in mono-cropping of rice and led to a high incidence of stem borer and leaf blight in wheat; in the last season, other pests also observed.

Throughout the course of agricultural activities, man has to compete with more than one million species. Many insects, rodents, birds, fungi, bacteria etc. find his crops to their liking and his dwelling provides shelter not only for man himself but also for a host of his competitors. With the competition becoming more intense, organized patterns of pest control have evolved.

The tools of pest control have so far been largely synthetic chemicals. These chemicals-pesticides are designed to kill or in some way inhibit the plant and animal competitors that interfere with our health, comfort or production of foods and fibers. Some 200 basic chemicals are used in agriculture and these are commercially presented in thousands of different formulations under many trade names. Generally speaking, the purpose of pesticidal use is clear and widely accepted. Although the benefits of pesticides are undeniable, even then we argue against them. There are several reasons for this:

- Most pesticides are non-selective; they kill other forms of life as well as their pest targets.
- Their manner of use, though often increasing selectivity, is not precise, the pesticide being restricted neither to the

pest species nor to the area where applied.

- Pesticide reduces faunal diversity-a natural control-and ensures instability.
- Many kinds of chemicals are chemically stable; their survival in soil, water and living tissue is assured.
- Insidious pathways of biological transfer of toxic chemicals causes potential harm to humans, animals and other living organisms.

Thus, modem technology for increasing agricultural output has had environmental costs. The green revolution with its high dependence on chemical input has over time led to declining soil fertility with excess fertilizer use, water pollution from pesticides, loss of genetic variety with monoculture cultivation and marginalization of indigenous knowledge systems. Population growth has impinged on these processes more as an exacerbating cause than as a primary cause of degradation. The manifold environmental problems that arise out of agricultural activities have shown that greater emphasis must be given to the environment friendly management of agriculture. Control of soil borne diseases such as damping-off of seedlings and wilting of various crops through soil solarization has gained importance.

Soil solarization, crop diversification and rhizosphere management are the corrective measures necessary to face the challenge of pests and pathogens.

CONCLUSIONS

The major causes for soil fertility depletion in the *tarai* region of Uttarakhand are imbalanced fertilization by the farmers, continuous cereal-cereal cropping, over mining of ground water, development of plough pan and injudicious use of agro chemicals like synthetite, Pyrathrins and growth hormones. This in turn has led to poor crop yield, more disease incidence, increased pest attack and increased cost of production.

For proper management of the soil, corrective measures could include training programmes, awareness camps, assessment of losses, wall paintings at village level, mechanization, promotion of sub soiler, deep ploughing, green manuring, organic farming, soil solarization, balanced use of fertilizer, crop residue management and crop diversification. (Trousse et.al. 1959; Smith, 1823; Balaton, 1971; Godwin, 1971; Godwin and Spoor, 1977; Spoor and Godwin, 1978; Singh and Hensel, 2012). Field experiments on some of the corrective measures have already been planned and executed but the results are yet to come. However,their utility has been well defined by other researchers in this field.

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