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Impact of Agricultural Inputs on Soil and Strategic Management of Soil Health in India

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ABSTRACT

Agricultural inputs paved the way towards green revolution in India. It was possible to feed its burgeoning population through the exposure of agricultural inputs which has retained its footprint in the evil sides. Its impact was extended from air to water, from soil to toil. The exigency of agricultural inputs is unavoidable and without the inputs todays agriculture cannot sustain. The only way to prolong the sustenance is through the strategic management approach. However, the strategic management approach has different layers and the systemic layer management could expose the opportunity towards the scientific management of soil health. Many countries in the world has already been rationalized the soil health management approach and accomplished the major objective through the basic commands on their input management. The increase in production of NP/NPK complex fertilizers contributed to higher production of fertilizer nutrients though it was not properly impacted towards the yield potentiality of Indian agriculture. The harmony in the nature can only be achieved through the skillful and scientific management strategy of inputs and soil which is need of the hour for further green revolution.

Keywords: Agricultural inputs, strategic management, soil health, fertilizers, pesticides, input consumption

Green Revolution in India in 1960s brought about technological breakthrough, which led to the use of short duration high yielding varieties helping intensive use of land in a year, increasing area brought under irrigation and prolific use of other agricultural inputs such as fertilizers and pesticides. With the expectation that development of agriculture would lead to overall development of the nation and help eradication of poverty India historically has had a policy in various phases for the development of agriculture. It has been of late recognized that the increasing efforts to raise agricultural growth has cost us dearly in the form of land and water degradation. Large scale ecological losses were reported in crop land, grass land and forest land, such as soil erosion, soil alkalinity and salinity, micro-nutrient deficiency, water logging and fast depletion and contamination of ground water. These factors limit future gains from the land and water resources. The specific crops grown and the cropping practices employed also determine the residuals generated by the erosion and run-off. Irrigation is considered as the principle means of water loss from the natural system and it leads to arid condition downstream and ground water depletion. Apart from on-site costs reflected in the loss of productivity of soil, the off-site costs due to agriculture is reported to be quite significant. The off-site costs are caused by soil sediments transported in the surface water from eroded agricultural land. These include river and dam siltation, damage to roadways and sewers, siltation of harbours and channels, loss of reservoir storage, disruption of stream ecology and damage to public health. In addition, by raising stream beds and burying streamside wetlands, sediment can increase the frequency of flooding.

Intensive farming practices, particularly with wheat and rice in India, have virtually mined nutrients from the soil. Due to heavy use of fertilizers, excess nitrates have leached into groundwater and contamination of groundwater with nitrates has increased dramatically. As such, the cultivable lands have become sick by over-application of chemicals. Apart from over use of chemicals, equally important issue is imbalance in the application of fertilizers and pesticides.

The 'underlying causes of degradation' has been very often the basic socio-economic structure and institutional structures of developing economies. Among them are land shortage, inappropriate land tenure arrangements, poverty, and population growth. However, the diverse factors that contribute to the problem make it necessary that a comprehensive approach is taken by the authorities responsible for policy in different areas such as food security, forests, soil conservation, and water resources.

Despite the overwhelming development of industry and other technologies, agriculture is the backbone of the modern society. A Society is so much developed its agricultural growth never expected to stops. The first Prime minister of Independent India Pundit Jawaharlal Nehru has the vision of Agricultural Independence of India. Once he reiterated that "everything may wait but agriculture". During last sixty years Indian Agriculture passes through different phases. India has, at least to some degree, been able to keep pace with its growth in numbers, and has even been able to achieve increases in per capita agricultural output for its average citizen. These gains have been accomplished through the extensification of land under agriculture, as well as the intensification of agricultural inputs, i.e. fertilizers, pesticides, and irrigation. Unfortunately, the gains resulting from these practices have not been without their consequent environmental costs. What follows is a brief outline of India's use of agricultural inputs, followed by a description of the soil degradation that has resulted.

Land Use pattern

Land is one of the natural resources of a nation and serves as the basis on which the entire superstructure is created. Environmental degradation in developing countries like India, especially its manifestation in the form of soil erosion, deforestation etc. is often attributed to rapid population growth. Agriculture extension and research played a pivotal role in increasing the utilizable land areas. India is a vast country comprising of 328 mha of land area. Half of the total geographical area in India is utilized using the maximum effort of the Government. The Beginning with agricultural extensification, the amount of India's land area dedicated to food grain cropping has grown steadily, from 99.3 million hectares in 1950, to 127.5 million hectares in 1991 (Ministry of Agriculture, 1995), and the total land used for agriculture is currently almost 170 million hectares. An additional 12 million hectares fall under the classification of 'meadows and pasture,' and are utilized for animal husbandry. Much of this increment of land over the last four decades has come from previously forested areas, as well as marginal and hill areas. There may be fair chance to increase the agricultural area and by the way it may be the agriculturally independent country.

Fertilizer consumption

Fertilizer is the key input for sustainable agriculture. In the post green Revolution period, more than 50% of additional food grains production has been contributed by the fertilizers alone. India is the third largest producer and consumer of fertilizers in the world after China and the USA, and contributes about 11.4 and 11.9% to the total world production/ consumption of NPK nutrients, respectively. After independence the use of fertilizers in India in the last 50 years has grown nearly 170 times. In 1950 use of fertilizer per hectare in India was 0.55 Kg but by 2001-02 this figure has increased to around 90.12 Kg per hectare.

During 2011-12, the consumption of fertilizers has increased by 23% as compared to 2006-07. However during 2012-13, the consumption was down by 8% as compared to previous year. The food grain production during 2012-13 was about 2553.60 LMT, marginally lower than the previous year. With more stability in international prices of fertilizers and the exchange rate of Indian Rupee, the consumption of fertilizers is expected to improve in 2013-14.

The balanced use of chemical fertilizer is important not only for increasing the agricultural productivity but also for sustaining soil fertility. The consumption of NPK ratio has also changed over a period of time.

Table 1: Agricultural land use in India

Sl. No.	Classification	1950-51	1980-81	1990-91	2000-01	2009-10	2010-11	2011-12
I.	Geographical Area	328.73	328.73	328.73	328.73	328.73	328.73	328.73
II.	Reporting Area	284.32	304.16	304.86	305.19	305.84	305.90	305.81
1.	Forest	40.48	67.46	67.81	69.84	69.99	70.01	70.02
2.	Not Available for Cultivation (A + B)	47.52	39.55	40.48	41.23	43.33	43.58	43.52
A.	Area Under Non-agricultural Uses	9.36	19.60	21.09	23.75	26.16	26.39	26.29
B.	Barren and Un-culturable Land	38.16	19.96	19.39	17.48	17.18	17.18	17.23
3.	Other Uncultivated Land excluding Fallow Land (A + B + C)	49.45	32.31	30.22	27.74	26.50	26.16	26.10
A.	Permanent Pasture and Other Grazing Land	6.68	11.99	11.40	10.66	10.34	10.30	10.30
B.	Miscellaneous Tree Crops and Groves	19.83	3.58	3.82	3.44	3.21	3.21	3.16
C.	Cultivable Waste Land	22.94	16.74	15	13.63	12.95	12.65	12.64
4.	Fallow Lands (A + B)	28.12	24.55	23.37	25.04	26.85	24.60	25.38
A.	Fallow Lands Other than Current Fallows	17.45	9.72	9.66	10.27	10.84	10.32	10.67
B.	Current Fallows	10.68	14.83	13.70	14.78	16.01	14.28	14.72
5.	Net Area Sown (6 to 7)	118.75	140.29	143	141.34	139.17	141.56	140.80
6.	Gross Cropped Area	131.89	172.63	185.74	185.34	188.99	197.32	195.25
7.	Area Sown More than Once	13.15	34.63	42.74	44	49.82	55.76	54.44
8.	Cropping Intensity	111.07	123.05	129.89	131.13	135.80	139.39	138.67
III.	Net Irrigated Area	20.85	38.72	48.02	55.20	61.94	63.60	65.26
IV.	Gross Irrigated Area	22.56	49.78	63.20	76.19	85.08	88.63	91.53

Source: *Agricultural statistics at a glance 2015-Directorate of Economics & Statistics, Ministry of Agriculture, GoI*

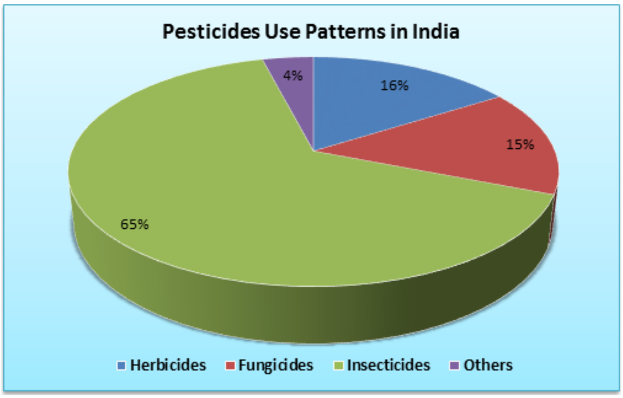
During 2008-09, the consumption of NPK ratio was 4.6:2.0:01 which has changed to 8.2:3.2:01 during 2012-13.

Production of total nutrients (N+P) increased marginally by 0.9% during 2014-15 over the previous year. N and P2 O5 production at 12.43 and 4.09 million tonnes during 2014-15 registered increase of 0.2% and 3.1%, respectively, during the period. Sharp increase in production of NP/NPK complex fertilizers by about 12.7% contributed to higher production of fertilizer nutrients. All other major fertilizers experienced negative growth during the year. Production of urea, DAP and SSP fell by 0.6%, 5.1% and 3.2%, respectively, during 2014-15 over 2013-14. Fertilizer industry continued to suffer on account of inadequate availability of natural gas from domestic sources. Gap in availability was filled through imported LNG. Limitation in availability of phosphoric acid was also experienced by some of the DAP/NP/NPK plants. Apart from this, a couple of plants reported technical/ equipment problems for part of the year. Disruption in operation of three naphtha based urea plants due to policy related issues and difficulties in supply of gas to another urea plant affected the production of urea adversely.

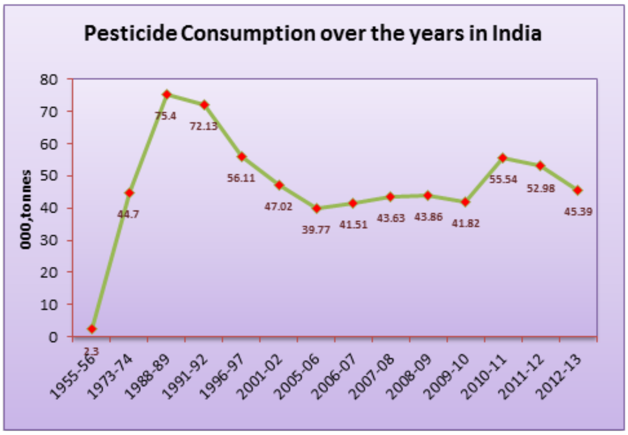
Pesticide consumption

Modern agriculture depends on the four main factors viz. water, fertilizers, seed and pesticides. Pesticides are the integral part of modern agriculture. About 35-45 % crop production is lost due to insects, weeds and diseases, while 35% crop produces are lost during storage. Indian Agrochemical Industry size in estimated to be US$ 3.8 billion in year 2012. Over the 12th plan period, the segment is expected to grow at 12-13% per annum to reach 7.0 billion.

The Indian domestic demand is growing at the rate of 8-9% and export demand at 15-16%.



The per capita consumption of pesticides in India is 0.6 Kg/ha which is the lowest in the world. The per capita pesticide consumption in China and USA is 13 Kg/ha and 7 Kg/ha, respectively. The main reason for low per capita consumption of pesticides in India is low purchasing power of farmers and small land holdings. The majority of agricultural farm land belongs to Marginal farmers but maximum contribution to the produce is also from marginal farmers. The large scale farming is increasing and therefore, there is good scope for increase of per capita consumption of pesticides in India.



In the recent past, certain change has been observed in trends of pesticides consumption. As a consequence of adoption of bio-intensive Integrated Pest Management Programme in various crops the consumption of chemical pesticide (Tech. Grade) has come down from 66.36 thousand MT during 1994-95 to 43.59 thousand MT during 2001-02 with a reduction of 27.69% (Thirty Seventh Report of Standing Committee on Petroleum and Chemicals, 2002). Consumption pattern of pesticides in India is also very different from world. In India, insecticide account for 76% of the total domestic market while herbicides & fungicides have a significantly higher share in the global market. There are wide ranges of regional variations in pesticide consumption in the country. In the year 2000-01, States of Haryana, Punjab and Uttar Pradesh by consuming more than 5,000 MT (technical grade) pesticides annually come under category I state in consumption of pesticides. States viz., Andhra Pradesh, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Rajasthan, Orissa and Tamil Nadu, which consumed between 1000 MT and 5000 MT fall in the category II states. States viz., Assam Bihar and Himachal Pradesh that consumed pesticide between 100 and 1000 MT come under category III. States viz., Arunachal Pradesh, Jammu & Kashmir, Manipur, Mizoram, Nagaland, Tripura, Delhi and Union Territory (UT) of Pondicharry consumed pesticides between 10 and 100 MT annually fall under category IV. States viz., Goa, Meghalya, Sikkim and UTs viz., Andman & Nicobar Islands, Candigarh, Dadara & Nagar Haveli, Daman & Diu and Lakshadweep consumed less than 10 MT pesticide annually as fall in the last category in pesticide consumption (Thirty Seventh Report of Standing Committee on Petroleum and Chemicals, 2002).

One of the consequences of indiscriminate use of pesticide is the adverse health impact on society in general and vulnerable population like children in particular. Some of the well-known health effects of pesticide exposure include acute poisoning, cancer, neurological effects and reproductive and developmental harm (CSE, 1997). The major causes of concern in this respect are bio-accumulation of pesticides and the prolonged time period that it takes to express the negative health consequences.

Table 2: Consumption of Pesticides in various states during 1995-96 to 1999-2000 (M.T. Technical Grade)

State	1995-1996	1996-1997	1997-1998	1998-1999	1999-2000
Andhra Pradesh	10957	8702	7298	4741	4054
Assam	316	300	284	260	260
Arunachal Pradesh	22	20	18	18	17
Bihar	1383	1039	1150	834	832
Gujrat	4560	4545	4642	4803	3646
Goa	4	2	2	4	4
Haryana	5100	5040	5045	5035	5025

Himachal Pradesh	300	300	200	276	385
Jammu & Kashmir	108	63	78	75	26
Karnataka	3924	3665	2962	2600	2484
Kerala	1280	1141	602	1161	1069
Madhya Pradesh	1748	1159	1641	1643	1528
Maharashtra	5097	4567	3649	3468	3614
Manipur	41	31	20	31	21
Meghalaya	20	20	8	9	8
Nagaland	9	9	9	9	10
Mizoram	21	18	17	16	19
Orissa	1293	885	924	942	998
Punjab	7200	7300	7150	6760	6972
Rajasthan	3210	3075	3211	3465	2547
Sikkim	26	16	16	15	0.16
Tamil Nadu	2080	1851	1809	1730	1685
Tripura	25	22	19	16	17
Uttar Pradesh	8110	7859	7444	7419	7459
West Bengal	4213	4291	3882	3678	3370
Andaman & Nicobar	7	9	4	5	5
Chandigarh	3	3	3	3	4
Delhi	76	61	65	64	62
Dadar & Nagarhaveli	7	4	4	4	2
Daman & Diu	1	1	1	1	1
Lakshadweep	1	1	1	1	1
Pondicherry	118	115	81	71	70
Total	**61260**	**56114**	**52239**	**49157**	**46195.16**

Irrigation

The area of agricultural land under irrigation has continued its growth, from 32% in 1970, to 43% in 1990. The majority of this increase has come from increases in water extracted from groundwater supplies. This is significant because in many ways, groundwater supplies can be considered a non-renewable resource. Finally, the demand for water for irrigation is expected to increase markedly over the next few decades, in line with population growth. Estimates for 1990 place the demand for irrigation water at 46 million hectare meters, and project a growth to over 85 million hectare meters by 2025 (CWC, 1993 and Shah, 1987).

Impact of Agricultural Inputs on Soil health

Soil health is based on a variety of characteristics, including organic matter, salinity, structure and compaction, available nutrients, pH, water holding capacity and erosion levels. Together, these characteristics allow soil to serve a variety of functions: supporting the growth of crops (and therefore animals), regulating the distribution of rain and irrigation water and providing filtration to improve water as it infiltrates through soils. Under current production methods, soil health and its corresponding contribution to farm production is under threat by increasing levels of soil degradation and erosion. The 1999 National Resources Inventory of the USDA reports that 1,700 megatonnes (million metric tonnes) of soil eroded from U.S. land in 1997 (Heller and Keoleian, 2003). This is enough to fill a fully loaded freight car train that would encircle the planet seven times (Heller and Keoleian, 2003). Also, soil organic matter in some areas of North America, has declined 30-60% since the start of cultivation(USDA, 2003). These effects make farmers' jobs increasingly difficult, as it becomes necessary to improve degraded soil quality with cost and time intensive inputs. Soil erosion is particularly problematic since its effects are irreversible. Healthy soils are not only important to farm production, but also to overall environmental health. When soil is eroded via runoff, sediments, in addition to being a water pollution source, can carry nutrients or pesticide residues that further pollute surface waters. Soil that is compacted worsens this problem in that impacted soils cannot absorb as much water, increasing the amount of runoff. Unhealthy soil also contributes to particulate matter air pollution when loose topsoil is transported off of the farm via wind. This module focuses on best management practices to maximize soil quality and health in order to maximize production and minimize erosion and pollution to water or air. Recommended areas of management include monitoring overall quality, minimizing erosion, maximizing organic content and preventing soil compaction.

The results of this substantial increase in use of agricultural inputs are noticeable, e.g., rice paddy production more than tripled over the same period. Although these advances in productivity have been encouraging, it must be pointed out that while total grain production has almost doubled since 1960, fertilizer and pesticide use have grown by over an order of magnitude during the same period. This chemical intensity has become a source of concern since a significant portion of fertilizer and pesticide applied to the soil runs off into surface water or leaches into groundwater. These present a grave potential for ecological damage, like eutrophication of surface water from nitrogen and phosphorous runoff, or human toxic effects, like 'Blue Baby Syndrome' from nitrates in groundwater, or cancer and organ damage from breathing and ingesting pesticides. Increases in cropped area and irrigation have their own associated impacts, like soil erosion, waterlogging, and the steady buildup of salts.

In general, India has experienced an expansion of degraded land area from 130 million hectares in 1987 to 188 million in 1993. Unfortunately, reliable time series data area not available for other degradation categories, however, Table 3 shows degradation classification for the present.

Table 3: Degradation Status of Indian Soil

Classification of Indian soil degradation	Area (Mha)	Percent
Water erosion		
loss of top soil	132.5	40.3
terrain deformation	16.4	5
Wind erosion		
loss of topsoil	6.2	4.1
terrain deformation/overblowing	4.6	1.9
Chemical deterioration		
loss of nutrients	3.7	1.1
salinization	10.1	3.1
Physical deterioration waterlogging	11.6	3.5
Land not fit for agriculture	18.2	5.5
Soils with little or no degradation	90.5	27.5
Soils under natural condition	32.2	9.8
Total	**328.7**	**100.0**

Source: *Sehgal, et al. 1994.*

The largest category by far is that of land affected by water erosion, which represents almost half of total Indian land area, and 80% of degraded land. Most of this damage is in the form of loss of topsoil. Among the remaining categories, salinization, waterlogging, and loss of top soil from wind erosion; (the former two resulting from over-irrigation) are the most pervasive problems. Of these, reliable time series data are available only for salt affected land, which has grown from 7.18 million hectares in 1987 to over 10 million in 1993. Both water erosion and wind erosion damage can be attributed to inadequate land cover, whether it be from deforestation, mono-cropping, overgrazing, or from farming on marginal and hill areas.

An additional problem, chemical deterioration in the form of nutrient loss and leaching, is the result of shortened fallow periods, which have decreased from 20 years to only a few years over a short five decades. Only 37% of Indian land area can be said to be largely free from degradation of any kind, and degraded land will continue its growth in years to come.

Impact of Fertilizer application on soil health

Several problems linking excessive use of fertilizer with environment have been identified. The increase of nitrates in the drinking water is believed to be due to the excessive use of N-fertilizers and animal manures. Nutrient enrichment, eutrophication and deterioration of surface water quality due transportation of nutrients applied through fertilizers via leaching and run off and sediment erosion is another problem. The contamination of soils by heavy metals through fertilizers such as cadmium from phosphatic fertilizers, is also receiving increasing attention of environmentalists. Fertilization as an element of intensive agriculture is also partly responsible for the less thought of impact of modern farming activities on the environment in terms of impairment, reduction in size, splitting up and destruction of natural and semi natural biotopes and rural landscape elements.

In the developed nations, there has been an intensive use of fertilizer for the last 3-4 decades. If the polluting effects of fertilizers are being observed there now, then similar problems in the developing countries like India should be expected in the near future.

Nitrate Pollution

Nitrate leaching below the root zone of crop constitutes a potential pollution threat for surface and ground water bodies. Two major factors controlling the leaching losses of nitrates are (i) concentration of nitrate in the soil profile at the time of leaching and (ii) the quantity of water passing through the soil profile. High soil nitrate levels and sufficient downward movement of water to move nitrate below the rooting depth are often encountered in soils of the humid and sub humid zones, to a lesser extent in sols of the semi-arid zone and quite infrequently, if at all, in arid zone soils.

Nitrate concentrations in groundwater have increased in several parts of the world in recent years. From 1974 to 1981, nitrate concentrations in the groundwater in USA have increased up to 60-fold, while in other parts of the world, these are rising at rates of 0.2-1 mg NO_3 –N/L/year. A significant correlation exists between the amount of fertilizer-N applied per unit area per year and nitrate-N concentration of well water in Punjab. The geometric mean of nitrate-N content has registered an increase from 0.42 to 2.29 mg/L during 1975 to 1988. At many places, nitrate levels have exceeded the safe limit of 10 mg NO_3-N/L.

The traditional animal waste disposal practices and the presence of manure pits on the village periphery possibly create potential sources of nitrate pollution of groundwater under village habitations. Although animal manures (such as Farm yard manure, poultry manure, pig manure) are applied to the cultivated area along with N-fertilizers, crop plants absorb a sizable portion of the N applied from both organic and inorganic sources, so that only a small fraction of the applied N is leached beyond the root zone.

There are several other sources of Nitrate-N, namely sewage effluents, animal excreta, natural soil nitrates and decomposition products of soil organic matter. In many regions, natural deposits of nitrate may constitute a major source of nitrate pollution of groundwater. For example, in selected locations in Punjab, Haryana and western UP, Nitrate-N concentration in well water samples is several folds higher the upper safe limit.

Eutrophication

Eutrophication refers to the process of enrichment of surface water bodies with nutrients. The nutrient enrichment of water bodies results in intense proliferation and accumulation of algae and higher aquatic plants in excessive quantities that can result in detrimental changes in the water quality and can significantly interfere with man's use of the water resources.

Not only groundwater, but surface water too receives large contribution of nutrients from non-point sources such as agricultural lands. Estimates indicate that more than 90% of the N entering surface waters originates from non-point sources and that more than 80% of that portion is from agricultural lands. High levels of total N in surface waters are generally related to the agricultural activities. The spreading of fertilizers and manures in the drainage basin enhance the nutrient load of the water body. A large part of the nutrient load generated from the agricultural land is related to the natural nutrient content of the soil. Practices that do not allow for the proper incorporation of fertilizers applied at excessive rates can cause short-term elevated nutrient concentrations in the run-off.

Both N and P are important in stimulating eutrophication. In most of the low producing oligotrophic (low in nutrients) surface water bodies, P rather than N is limiting constituents. In many of the eutrophic lake, biotic productivity is controlled by N because the N/P ratios of pollutants from many sources are far below the ratios required for the plant growth. Also in some oligotrophic lakes where n is the limiting nutrient, the input from the ground water, surface runoff or precipitation may be essential to maintain the biological productivity. The urban and industrial wastes usually account for most of the phosphate loading. However, surface runoff (including soil erosion) from cultivated land can contribute to phosphate loading of surface waters. The best management practices recommended for a particular soil, crop and region are highly effective in eliminating this possibility and at the same time, allow the most efficient use of fertilizers by crops to ensure optimum food production.

Strategies for minimizing the adverse effects of N-use in the environment

There can be two general approaches to minimize the environmental pollution arising due to N-use in agriculture. One is the optimum use of the ability of the crop plants to compete with processes that lead to losses of N from soil plant system to the environment. Second approach can be the direct reduction of the rate, duration and extent of loss of N to the environment by loss processes themselves. Some of the management practices listed in below ensures that fertilizer N is efficiently utilized by crop plants while the other practices influence the behaviour of N so as to reduce the entry into the environment.

Management practices that can reduce environmental pollution by N originating from agricultural lands

Improved Fertilizer N- use Efficiency

- Apply optimum dose of fertilizer N
- Time the fertilizer N application to coincide with crop needs
- Apply N fertilizers in split doses
- Apply balanced doses of N,P and K
- Incorporate or deep place fertilizer N into soil
- Use slow release fertilizers
- Use urea and nitrification inhibitors

Land management Techniques

- Use crop rotations and catch crops
- Improve irrigation scheduling to encourage plant growth and minimize leaching
- Conservation tillage to control surface runoff
- Crop residue recycling
- Use of animal manures
- Use of terrace, contouring and retention bases to catch sediments
- Genetic manipulation of plant material to be more efficient at N recovery and N_2- fixation.

Obviously, the fertilizer N–use efficiency as a factor dose deserve careful attention if agriculturists are to obtain maximum crop yields and prevent pollution of the environment. It varies with the type of fertilizer and the rate at which N is applied, the nature of the chemical and biochemical reactions between soil and fertilizer, the timing and placement of fertilizer, the type of crop and its N requirement, the adequacy of other nutrients and a number of soil, climatic and management factors. Under favourable conditions, 80% or more of the fertilizer N may be utilized by the crop but usually efficiencies of 50% or even less are common by the loss of N from the soil–plant system via mechanisms such as leaching, ammonia volatilization and denitrification.

Heavy Metal Contaminants in Fertilizers as Soil Pollutant

Recently, there has been increasing concern towards the health hazards associated with heavy metals entering the food cycle via soil. Fertilizers contain heavy metals as impurities; rock phosphate being a highly potential source. The application of rock phosphate or its products to soil always implies the addition of a significant amount of lead and cadmium into the soil. The analysis of lead and cadmium content of different commercial fertilizers suggests that a combination of low analysis and straight fertilizers can add more lead and cadmium to soil than high analysis and mixed fertilizers.

The heavy metals applied to the soil through the different derivatives of rock phosphates accumulate almost completely in the surface layer of the soil and in forms generally easily available to plants. In soils with coarser textures and acidic reaction, heavy metals, applied through fertilizers, are available more than in those containing large amount of clay and with alkaline reactions.

Although relevant data from soils in India are not available, it is interesting to note that less than 6 per cent of the annual deposits of cadmium to the soil of European Economy Community come from the use of phosphate fertilizers, with a further 2% from phosphoric acid manufacturer, whereas two-third is attributed to solid wastes and excrement, aerial deposition and use of pigments and stabilizers (Anonymous, 1992)

Impact of pesticides application on soil health

A sizable amount of the pesticides applied to control pests and weeds eventually finds its way into the soil which acts as a reservoir for these residues. From the soil, pesticide residues enter into the bodies n invertebrates, get transported into water or air or are broken down to innocuous substances. The effectiveness of a pesticide as well as the hazards of its harmful residues depends largely on the duration for which a pesticide remains in a soil. For example DDT has a half-life of three years in cultivated soils, while organophosphate insecticide persists for only a few days or months. The chlorinated hydrocarbons persists longer in soils having large amount of organic matter, although more amount of the chemical must be applied to this soils to kill pests. Insecticides persist longer if worked into the soil than if left on the surface. Herbicides applied to soils may not persist at all or hardly persist up to two years or so, depending on the individual compounds. For example simazine is one of the most persistent herbicides. Ultimately, pesticides disappear because of evaporation and vaporization, leaching, plant uptake, chemical and microbial decomposition and photo decomposition.

The activities of diverse soil microorganisms and the associated soil microbial processes may be adversely affected by pesticides because a) this are chemicals that have deleterious effect even on non-pest species, and b) being organic nature, these can be metabolized, resulting in modification of their activities. It is now apparent that pesticides can have unforeseen effects on non-target organisms and can thus influence crop productivity to an extent even more than the pests these are intended to control.

Insecticides

In almost all the soils that have been surveyed for insecticide residues in India, the most common chemical, and the one that is found in the largest amounts is DDT, followed by HCH and dieldrin. In a study in Punjab, out of 106 soil samples, 91 were found contaminated with insecticide residues. The highest level of 0.08 mg/g DDT -R was found in cotton growing areas which are four times its permitted level of 0.02mg/g. The presence of cholinesterase inhibitors in 19% soil samples indicated contamination with organophosphates and carbamate insecticides.

The reactions, movements and degradation of insecticides affect the persistence of these chemicals in soils and determine the risk of soil pollution. For example, organophosphates may persist in the soil only for a few days, DOT and other chlorinated hydrocarbons may last from 3 to 15 years or even longer. The biochemical degradation by soil organisms is the single most important mechanism that can remove insecticide residues from the soil. However, insecticides like DOT are subject to slow photodecomposition activated by solar radiation and organophosphates are subject to hydrolysis and subsequent degradation in the soil.

Fungicides

The residues of fungicides based on the inorganic compounds of sulphur, copper and mercury accumulate in soil because the heavy metals contained in them are irreversibly adsorbed on soil colloids. Under certain soil conditions, toxicity from the accumulation of copper-based fungicides may render the soil useless for growing crops. Similarly, the oxidation of sulphur contained in fungicides can alter the chemistry of organic matter in the surface horizon of soils in a way that decline in yield of some crop plants may occur. Other fungicides like captan, carboxin, benomyl, etc. are decomposed very rapidly through the biochemical processes. Within a few weeks of their application, the presence of these compounds becomes negligible.

Herbicides

In the intensive and diversified crop rotation systems, the herbicide applied to one crop may persist in the soil at concentrations high enough to damage the subsequent sensitive crops. For example, atrazine is the most selective and widely used herbicide for controlling weeds in several crops. It has revolutionized the cultivation of sorghum, maize and millets in the semi-arid tropics, but when applied repeatedly it starts building undesirable residues in the soil. Under Indian conditions, when a herbicide dose of 0.5 to 2.0 kg/ha is applied, it results in a buildup of residues in the range of 0.25 to 1.0 mg/g, which is safely below the potential residual effect. At several places in India it has been observed that several herbicides including fluazifop-butyl, metolachlor, oxadiazon, nitrofen, 2,4-D, metoxuron, isoproturon, oxyfluorfen and tribunil leave a little or no residual effect on the crops (Saraswat and Jayakumar, 1994). But the residues of fluchloralin, methabenzthiazuron and atrazine were detected in amounts that could adversely affect not only other crop plants but also several processes in soil leading to inefficient nutrient management and in turn, reduced crop yields. The most sensitive systems are soil organic matter decomposition and different aspects of nitrogen cycle in the soil.

A normal dose (less than 40 mg/g) of DOT does not adversely affect nodulation and nitrogen fixation by *Rhizobium.* On the other hand, lindane applied at normal rates considerably reduces the number and weight of nodules in crops like groundnut. The nodule number is not adversely affected by fungicides. The herbicide, 2,4-D, restricts the growth of *Azotobacter.* Blue green algae can tolerateendrin up to 6,000 mg/mL, but HCH has been found to be more toxic to it due to the suppression of heterocyst frequency.

Reducing the Pesticide Levels in Soil

Degradation of even the most resistant pesticides is encouraged by conditions that favour overall microbial proliferation in the soil. The biochemical degradation by soil organisms is the single most important method by which pesticides are removed from the soil. The polar groups such as – OH, -COO^- and $–NH_2$ on the pesticide molecules are the favorable points of attack by the microorganisms. The application of easily decomposable organic matter can help reduce pesticide levels in the soil. The application of large quantities of organic manures and raising high N cover crops also prove useful. Other practices suggested reducing pesticide levels in the soil include growing of crop plants that have a tendency to accumulate the pesticide or follow soil management practices leading to increased leaching of the pesticides. However, some of these practices result in only transferring the pesticide chemicals from the soil to some other part of the environment.

Application of the same pesticide on the same piece of land can lead to increased rates of microbial degradation of the chemical. This may be advantageous in the case of insecticides and fungicides in relation to environmental quality, but the rapid breakdown may result in reduced effectiveness of herbicides.

Role of Soil Organic matter in maintenance of soil Health

The elements of soil, including plant roots, that were once alive as well as the living organisms are termed 'soil organic matter.' Organic matter is essential to soil health and productivity due to the myriad of services and benefits it provides. Examples include stabilizing and holding the soil together; improving the soil's ability to store and transmit air, water and nutrients to crops; helping maintain a balanced population of soil organisms; and helping to prevent soil compaction. The net benefits are more productive crop harvests with fewer inputs, reduced runoff, and minimized soil erosion. Cover crops contribute to soil organic content by increasing the plant material that is left on the soil and by preventing erosion of topsoil that is rich in organic material. Tillage and overuse of inorganic fertilizers,particularly nitrogen, instead of using organic materials to provide fertility, accelerates the rate of decomposition of organic material in the soil, thereby causing loss of this material at a faster rate. These practices should therefore be minimized. Manures, which increase organic matter in the soil, should be used to supply soil with needed nutrients.

ROLE OF COVER CROPS AND VEGETATIVE AREAS

Plantings such as cover or perennial crops, grass, and hay hold soil in place, prevent compaction of soil, improve tilth, curb runoff and nutrient loss. Plant cover is also beneficial in that it increases organic matter and biological activity in the soil, which is beneficial to soil quality and plant growth. When cover crops are legumes such as alfalfa, clover or soybeans, they provide an added benefit of fixing nitrogen into the soil for use by future crops. Cover crops provide the additional benefit that yields can be sold or used as feed for cows. It is important to manage any plantings well by maintaining appropriate practices with respect to nutrient application and pesticide use.

CROP ROTATION

Crop rotation leads to greater quantity and diversity of soil organic material, improves nutrient availability,and can help control pests. Including legume crops in the rotation will provide the needed diversity while also fixing nitrogen in the soil. Other crops can also help prevent nutrient leaching. The Michigan State University Agriculture Experiment Station found that, with regard to nutrient leaching, wheat never loses more than 20 pounds of nitrogen per acre per year, as compared to continuous corn, which leaches up to 100 pounds.141 Various rotations may reduce nitrogen leaching 30-50% as compared to growing continuous corn.142 Crop rotation is beneficial economically, in that it can improve amount and diversity of yields and reduces the need for costly commercial fertilizers and pest-control chemicals.

TILLAGE PRACTICES

Adjusting tillage practices is beneficial for reducing soil compaction, minimizing erosion and improving organic matter content, all of which are environmentally and economically beneficial to the farmer. Soil compaction can restrict plant roots (reducing uptake of water and nutrients), affect moisture and soil temperatures (affecting organic matter and nutrient release), and decrease infiltration of water, which increases the levels of runoff and erosion. Tillage should never be done on wet soil, as it is particularly susceptible to compaction versus dry soil. Conservation tillage leaves at least 30% of the soil surface covered by crop residues after planting, thereby protecting it from erosion and contributing to the organic matter and beneficial biological activity in the soil.

Additionally, no-till or strip-tillage 2 practices minimize the area being tilled, thus minimizing soil compaction and removal of plant residues. Restrictive tillage practices can also result in cost savings by reducing the amount of fuel needed to run the equipment or eliminating the need to own and maintain the equipment.

SOIL CONSERVATION/EROSION PREVENTION

Soil erosion is the physical removal of surface soil material. Erosion can negatively impact crop production by contributing to the breakdown of soil structure and resulting in the loss of the uppermost soil layer. This top layer of soil has the highest levels of organic matter and biological activity, both of which are important for plant growth and overall soil health. It is very important to minimize erosion on the farm even if signs are not obvious that erosion is occurring. The loss of just 1/32 of an inch of topsoil, very difficult to notice on a farm, can equal a loss of 5 tons of soil per acre. 143

Soil loss can be mitigated in several ways

- Diversion ditches or windbreaks reduce soil loss by diverting excess water or wind from reaching vulnerable soils.
- Vegetated buffer strips can ‘catch’ runoff from fields, including soil, sediments, and nutrients, to help prevent water pollution and soil loss from farms.
- Adjusting tillage practices can help by leaving more crop residues on the soil, contributing to soil organic matter content and decreasing soil compaction and removal of plant residues, all of which minimize soil erosion.
- Mulches and manure or composts cover the soil and increase organic matter content, protecting soil from erosion and improving its quality. Perennial crops provide compound benefits by covering the soil and holding it in place with their roots.

SOIL QUALITY MONITORING AND SOIL MAPPING

Soil testing at regular interval (done at least once in every 3 years) is the best way to ensure that soil remains healthy and productive, maximizing benefits to your farm. Now-a-days soil test kits are available from various companies by which analysis services and corresponding management recommendations that provide information such as soil pH, organic matter,available phosphorus and other nutrient levels, and fertility recommendations are done. These are not so much costly and very much user friendly.

It is important to not only do the tests, but also to follow recommendations associated with the results. Results of these tests may include recommendations for nutrient application rates or improve soil characteristics such as pH or organic matter content. Maintaining high soil quality is increasingly beneficial over time as the soil is able to do the job that it is intended with fewer inputs (including time and money) from the farmer. If done every 1 to 3 years, soil testing is a non-time-intensive, inexpensive way to better understand and manage soil quality.

CONCLUSION

The issue of soil degradation in India must be taken very seriously by policymakers, as it presents the very real threat of limiting future gains in agricultural output and forest production, as well as risks to human health. However, the nature of soil degradation, i.e. the diverse factors that contribute to the problem, makes it difficult to create a single policy that addresses the situation. Certain areas, for example the control of deforestation which leads to erosion, fall under Central Government bodies like the Ministry of Environment and Forests. However, the benefits to soil resources which result from such policies are secondary to the main objectives, like preserving Indian forests.

The soil-related policy research gets a prime importance at the central level the major works are carried out by the Indian Council for Agricultural Research (ICAR). Much of the research carried out by ICAR is largely dedicated to the Green Revolution, which involves developing new agricultural technologies. However, one of the programs, namely, the 'lab to land' extension program, has also had the potential to improve soil conservation practices. Its objective was to use extension agents for educating rural farmers in the conservation of soil and water and in sustainable cropping practices. Unfortunately, the program was poorly administered, and has since become dysfunctional. There have also been many such efforts at the state level, but they have met with similar fates. Exacerbating the matter are government policies which encourage the degradation of resources, rather than their conservation, e.g. the nationalization of village water resources and subsidies on irrigation power and pesticides. Perhaps the hope for the future of soil resources lies in the actions of grass root-level NGOs, which are becoming increasingly active in developmental activities as well as disseminating environment-friendly technologies. Further emphasis may also be placed on resource management strategies based on the agro-ecosystems approach and on the development of integrated land use policies.

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