IFA CROSSROADS ASIA-PACIFIC 2014

Singapore
28 - 30 October 2014

Maintaining healthy soils: challenges and opportunities for the fertilizer industry

Bijay-Singh
Punjab Agricultural University, Ludhiana, India

'A soil is an entity – an object in nature which has characteristics that distinguish it from all other objects in nature'

"Upon this handful of soil our survival depends. Husband it and it will grow our food, our fuel, and our shelter and surround us with beauty. Abuse it and the soil will collapse and die, taking humanity with it"

The affairs of the soil touch our daily lives most intimately.

'Man, despite his artistic pretensions, his sophistication, and his many accomplishments, owes his existence to a 15 cm layer of topsoil and the fact that it rains.'

"Essentially, all life depends upon the soil ... There can be no life without soil and no soil without life; they have evolved together."

Soil provides us grains for our food, cotton for our clothes and timber for our homes. It is one of the most important resources for mankind

"Upon this handful of soil our survival depends. Husband it and it will grow our food, our fuel, and our shelter and surround us with beauty. Abuse it and the soil will collapse and die, taking humanity with it"

Atharava Veda, the Sanskrit Scripture, 1500 BC

It is the farming inefficiency arising from deterioration of soil health due to misuse of soil, which is at the root of non-sustainable agriculture and associated degradation of environment.

SOIL IS A LIFE SUSTAINING NATURAL RESOURCE

- Everything that lives on the earth depends on soil. More than 99.7 percent of human food (calories) comes from the terrestrial environment (FAO Food Balance Sheet)
- We have a limited supply of fertile soils. Of the total of 13 B ha of land area on Earth, cropland accounts for 11%.
- We not only need to conserve and protect our soils but also ensure that these remain healthy

Soils are not merely an accumulation of debris resulting from decay of rock and organic materials .. **These are developed as rocks are weathered and covered with organic materials**

It takes about 500 years for 1 inch of topsoil to form.

Healthy Soil: The Foundation of Life

- The birth right of all living things is health
- It is equally true for SOIL, plant, animal and humans, and the health of these four is a one connected chain.
- Healthy soil makes healthy crops, healthy people and a healthy society

Albert Howard (1940)

Defining Soil health

- An integrative property reflecting the capacity of soil to respond to agricultural intervention, so that it continues to support both the agricultural production and the provision of other ecosystem services.
- **A healthy agricultural soil is one that is capable of supporting the production of food and fibre, to a level and with a quality sufficient to meet human requirements, together with continued delivery of other ecosystem services that are essential for maintenance of the quality of life for humans and the conservation of biodiversity**

Soil Quality or Soil Health?

- The terms soil quality (favored by scientists) and soil health (favored by farmers) tend to be used interchangeably
- Characterization of soil quality by scientists focuses on analytical/quantitative properties of soil
- Characterization of soil health by farmers focuses on descriptive/qualitative properties of soil with a direct value judgment (unhealthy to healthy)

Soil Science Society of America

Why recent emphasis on soil health?

- Soil management is fundamental to all agricultural systems
- There is evidence for generally slow but widespread degradation of agricultural soils - - as erosion, loss of organic matter, nutrient imbalance, contamination, compaction, increased salinity and other harms
- Thus, in recent years research is being directed to devise measures of the health of soil and inform its management so that degradation is avoided

Agricultural goods	Soil-based delivery processes
Food and fibre	Nutrient capture and cycling
	OM input decomposition
	SOM dynamics
	Soil structure maintenance
	Biological population regulation

Non-agricultural services	Soil-based delivery processes
Water quality and supply	Soil structure maintenance
	Nutrient cycling
Erosion control	Soil structure maintenance
Atmospheric composition and climate regulation	SOM dynamics
Pollutant attenuation and degradation	Decomposition
	Nutrient cycling
Non-agricultural pest and disease control	Biological population regulation
Biodiversity conservation	Habitat provision
	Biological population regulation

Soil health depends on the maintenance of four major functions

Aggregate ecosystem functions

1. Organic carbon transformations
2. Nutrient cycling
3. Soil structure maintenance
4. Biological population regulation

The key to good soil quality is Soil Organic Matter (SOM)

- Organic C transformations, soil structure maintenance, nutrient cycling and biological population regulation – all controlled or influenced by SOM
- Two crucial characteristics of a healthy soil are the rich diversity of its biota and the high content of SOM
- SOM influences numbers, kinds and diversity of organisms in the soil as it is their basic energy source
- If the SOM is increased or maintained at a satisfactory level for productive crop growth, it can reasonably be assumed that a soil is healthy

SOM – SON

- Due to fundamental coupling of microbial C and N cycling, the loss of soil organic matter has serious implications for the storage of soil organic N (SON)
- The loss of SON decreases soil productivity and agronomic efficiency of fertilizer N because SON regulates supply of mineral N to plants.
- Even in managed agro-ecosystems, SON plays a vital role in supplying N to crop plants and thus dictates the efficiency of applied fertilizer N

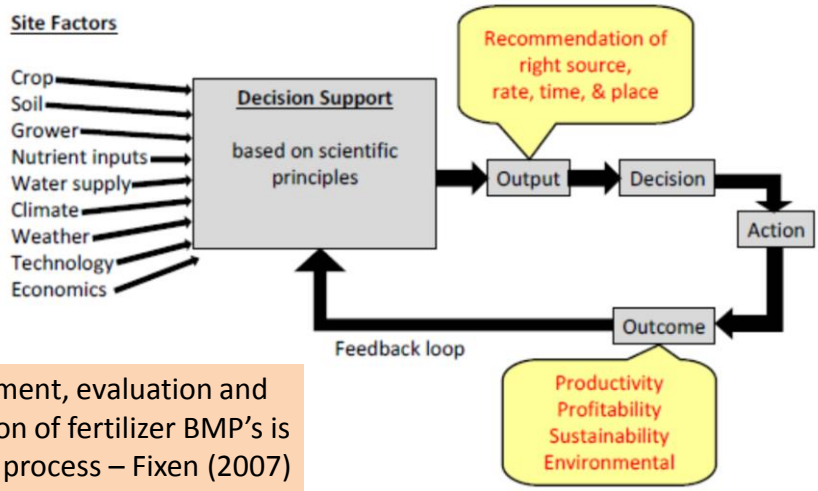
Factors controlling soil health

- **Soil type**
- **Organisms and functions**
- **Carbon and energy**
- **Nutrients** :
  - Nutrients are a controlling input to the soil system and the processes within it.
  - Their levels (including nutrient balance) and transformations are critical to soil health
  - Nutrients are recycled as well as applied to the soil through organic and inorganic sources

Fertilizers improve soil health if

- These are applied to supply to the plants adequate amount of nutrients and in a balanced proportion
- Their long-term use does not lead to reduced soil organic matter levels
- Their application does not lead to generation of excessive acidity in the soil
- Application of N fertilizers does not lead to large N deposition

Fertilizers managed following 4R Nutrient Stewardship lead to improvement in soil health



Development, evaluation and adaptation of fertilizer BMP's is dynamic process – Fixen (2007)

Concerns about availability of fertilizers

- Fertilizer affordability and availability are still the main concerns for small scale farms in developing countries in Asia-Pacific region
- Often non-availability of quality fertilizers at right time leads to nutrient imbalance in the soil and decline in productivity
- Availability of fertilizers is also influenced by stable pricing of fertilizers, equitable distribution of fertilizers across the country and enhancing domestic capacity to protect the country from volatility in prices of fertilizers in the international market

Nutrient imbalance leads to soil health deterioration

- Imbalance in N, P and K application; many a times due to non-availability of P and K at right time and at affordable prices
- Not applying deficient secondary and micronutrients
- Not following integrated management based on available organic and inorganic nutrient sources

Soil organic C after 15 years of rice-wheat cropping with different NPK treatments

Fertilizer treatment (kg ha $^{-1}$)			Organic C (%)
N	P	K	
0	0	0	0.17
40	35	33	0.52
80	35	33	0.61
120	35	33	0.65
120	0	0	0.42
120	35	0	0.63
120	0	33	0.46
CD 5%			0.05

Initial value of SOC measured in 1977 was 0.45%

Source: Yadav *et al.* (1998)

Over-use and under-use of fertilizers

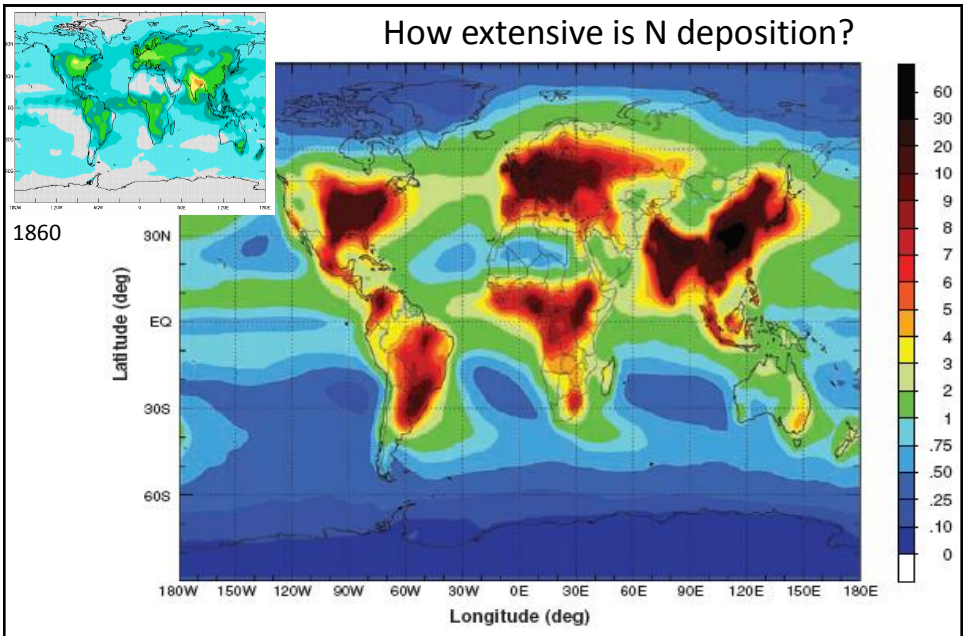
- Over-use of fertilizers, particularly N, may lead to N deposition; chronic N additions may increase soil N mineralization
- Excessive use N fertilizers leads to soil acidification – a negative soil health trait as it leads to imbalance in nutrient availability
- Under-use of fertilizers means that soil nutrients exported with crops are not being replenished, leading to soil degradation and declining yields

Atmospheric transport and subsequent deposition has become the dominant reactive N distribution process

Year	Reactive N emitted as NO_x and NH_3 and then deposited to the Earth's surface as NO_y and NH_x
1860	34 Tg N $year^{-1}$
1995	100 Tg N $year^{-1}$
2050	200 Tg N $year^{-1}$

- N deposition to ecosystems in the absence of human influence is generally ~0.5 kg N ha^{-1} yr^{-1} or less
- Average N deposition rates exceeding 10 kg N ha^{-1} yr^{-1} are already being observed in large regions of the world

How extensive is N deposition?



Estimated N deposition from global total N (NO_y and NH_x) emissions, totaling 105 Tg N y^{-1}. The unit scale is kg N ha^{-1} y^{-1}, modified from the original units (mg m^{-2} y^{-1}) (Dentener et al., 2006)

SSNM and customized fertilizers

- Current fertilizer recommendations for food crops typically consist of 'blanket' recommendations with fixed rates and timings for large tracts
- Large field-to-field variability of soil nutrient supply restricts efficient use of fertilizer when broad-based blanket recommendations for fertilizer are used
- SSNM ensures application of nutrients as per need of the crop in a given field and thus keeps the soil healthy
- Fertilizer industry is contributing to SSNM by producing customized fertilizers. These are gradually being refined.

Synthetic nitrogen undermines soil health by destroying soil organic carbon – a myth or reality

The Myth of Nitrogen Fertilization for Soil Carbon Sequestration

S. A. Khan,* R. L. Mulvaney, T. R. Ellsworth, and C. W. Boast University of Illinois

Intensive use of N fertilizers in modern agriculture is motivated by the economic value of high grain yields and is generally perceived to sequester soil organic C by increasing the input of

THE shift from biological- to chemical-based N management that provided the impetus for modern cereal agriculture originated during the late 1940s as synthetic N fertilizers became

***Journal of Environmental Quality* 36:1821-1832 (2007)**

Synthetic Nitrogen Fertilizers Deplete Soil Nitrogen: A Global Dilemma for Sustainable Cereal Production

R. L. Mulvaney,* S. A. Khan, and T. R. Ellsworth University of Illinois

Cereal production that now sustains a world population of more than 6.5 billion has tripled during the past 40 yr.

SINCE the Green Revolution of the 1960s, substantial increases in cereal production have allowed an ongoing rise

***Journal of Environmental Quality* 38:2295-2314 (2009)**

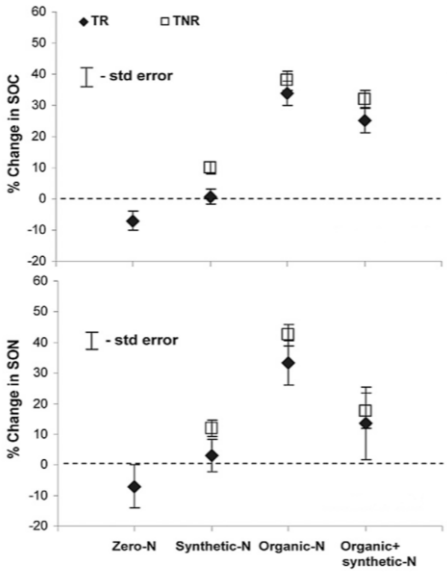
Synthetic nitrogen undermines soil health by destroying soil organic carbon – a myth or reality

Soil and cropping system	Study period	Fertilizer N applied, kg ha^{-1} yr^{-1}	Depth, cm	Total soil N, g kg^{-1}			Reference
				Initial	Final	Change	
Inceptisol (sl) Rice-Wheat	1972-1979	100 150	0-22 0-22	0.72 0.77	0.67 0.69	-0.05 -0.08	Mandal et al. (1984)
Inceptisol (sl) Rice-Wheat-Jute	1972-2002	300	0-30	0.96	0.87	-0.09	Manna et al. (2005)
Mollisl (cl), Rice -Wheat	1977-1995	80 240	0-20 0-20	1.04 1.04	0.71 0.68	-0.33 -0.36	Singh et al. (2000)
Entisol (sl), Rice-Wheat	1986-1996	100 200	0-15 0-15	0.50 0.57	0.52 0.50	-0.02 -0.07	Kundu and Samui (2000)
Inceptisol (ls) Rice-Wheat	1988-1997	240	0-15	0.83	0.67	-0.16	Bhandari et al. (2002)

- Fertilizer N application leads to loss of SOM and SON because fertilizer N promotes the decomposition of crop residues and SOM through stimulation of microbial activity
- BUT depletion in SOM and SON may also occur in no-N control plots – possibly due to cultivation of soil and other such practices which lead to soil disturbance
- Fertilizer N application leads to increased total OC inputs (aboveground plus belowground NPP minus harvested yield) into the soil

Changes in soil C content in no-N control plots in long-term rice-wheat experiments in the Indo-Gangetic plains of India

Location	Study period	Fertilizer N, kg ha^{-1} yr^{-1}	Depth, cm	Soil organic C, g kg^{-1}			Reference
				Initial	Final	Change	
Faizabad	1977-1996	0	20	4.5	1.7	-2.8	Kumar and Yadav (2001)
Ludhiana	1983-2000	0	15	3.1	3.0	-0.1	Nayak et al. (2012)
Sabour	1984-2009	0	15	4.6	3.6	-1.0	
Kalyani	1986-2009	0	15	9.2	6.0	-3.0	
Raipur	1991-2007	0	15	5.1	4.8	-0.3	Urkurkar et al. (2010)
Ludhiana	1983-1997	0	15	3.1	2.1	-1.0	Yadav et al. (2000)
Pantnagar	1983-1997	0	15	14.2	5.1	-9.1	
Faizabad	1984-1997	0	15	3.7	2.2	-1.5	
Kalyani	1986-1996	0	15	9.2	4.0	-5.2	



Percentage response in SOC and SON to N fertilizer input as calculated by time response ratio (TR) and time by fertilizer N response ratio (TNR) using mixed model

Data from 135 studies of 114 long-term experiments located at 100 sites throughout the world

Based on changes in the paired comparisons (TNR), average increase is 8% in SOC and 12 % in SON

Source: ***Ladha et al. (2011) Journal of Environmental Quality* 36:1821-1832**

Challenges and options for fertilizer industry

- To increase fertilizer production but strive to reduce the cost of production so that health of soils owned by large number of small and marginal farmers is also improved
- To ensure balanced supply of different nutrients to crop plants, fertilizers supplying P, K and micronutrient are made available in sufficient quantities at right time and at affordable prices. At present, higher cost of P fertilizers is a deterrent to balanced application of N, P and K
- To prepare customized blends of macro- and micronutrients so as to supply different nutrients as per need of the soil
- To urgently develop enhanced efficiency fertilizer products

Fertilizers in Asia-Pacific Region

- Some developed countries have declining fertilizer demand trends because of following strategies leading to increased fertilizer use efficiency and recycling of organic resources
- In most developing countries, fertilizer consumption is still increasing rapidly, and providing sufficient fertilizer supply to small-scale farmers at reasonable price remains an important policy and technological issue.
- With the growing public awareness on sustainable and environment-friendly practices in food production, there is now an increasing emphasis on 'high efficacy, ecologically-sound, and user-friendly' fertilizer products

New and improved fertilizer products

- Most of the present suite of fertilizer products was developed more than 50 years ago.
- Over the past 35 years, no "new" more substantially efficient fertilizer product has been developed – particularly no product affordable for use on food crops by farmers in less developed countries.
- New and improved fertilizers are critical to help feed the world's growing population by maintaining soil health, provide sustainable food security and protect the environment.

Enhanced efficiency N fertilizers

- **Slow release through coatings** – SCU, PCU
- **Slow release through chemical formulations** – urea formaldehyde, methylene urea
- **Inhibition of processes: urease** - N-(n-butyl) thiophosphoric triamide (NBPT)
- **Inhibition of processes: nitrification** – Nitrapyrin (N-Serve), dicyandiamide (DCD)
- **Urease + nitrification inhibitors:** NBPT+DCD, Nutrisphere-N (maleic-itaconic copolymer), N-Zone (Calcium aminoethylpiperazine and Calcium heteropolysccharide)

Resolution adopted by the UN General Assembly on 20 December 2013 to designate 5 December as World Soil Day and to declare 2015 the International Year of Soils

The sustainability of soils is key to addressing the pressures of a growing population and that recognition, advocacy and support for promoting sustainable management of soils can contribute to healthy soils and thus to food-secure world and to stable and sustainably used ecosystems

2015: The International Year of Soils

- A combination of ecosystem processes and wise use of mineral fertilizers forms the basis of a sustainable soil health management system that has the capacity to produce food necessary to meet the demands of burgeoning population
- Fertilizer use must continue and expand to satisfy the food, fibre, and fuel demands of a growing world population, while sustaining soil resources and providing a healthy economy

Sustainable nutrient management techniques allow farmers to maintain healthy and productive soil for crop production without degrading the environment

Nourish your crops, and they will nourish your soil!

Keep your soils healthy!

Thank you for your kind attention!