Agriculture: Nanotechnology's Green Field

Siddhartha S. Mukhopadhyay

Electron Microscopy and Nanoscience Laboratory, Punjab Agricultural University, Ludhiana – 141004,

[1 e-mail <siddhartha_soil@yahoo.co.in>, <ssmukho@pau.edu>]

Natural agricultural production system

- Open system
- both energy and matters are exchanged freely
- involves interactions of geosphere (especially pedosphere), biosphere, and atmosphere.

The other dimension

- Agricultural production system is rooted into social, cultural and economics state of her stake-holders

Farming remains prodigal .....

In spite of being practiced since the termination of the Quaternary ice age in the Recent epoch (10000 years ago to present),

.

Prodigal Farming

- wastages of inputs and outputs
- e.g., Fertilizer use efficiency
  - *20-50% for N*
  - *10-25% for P*
  - <1% for rock phosphate in alkaline calcareous soils

Prodigal Farming

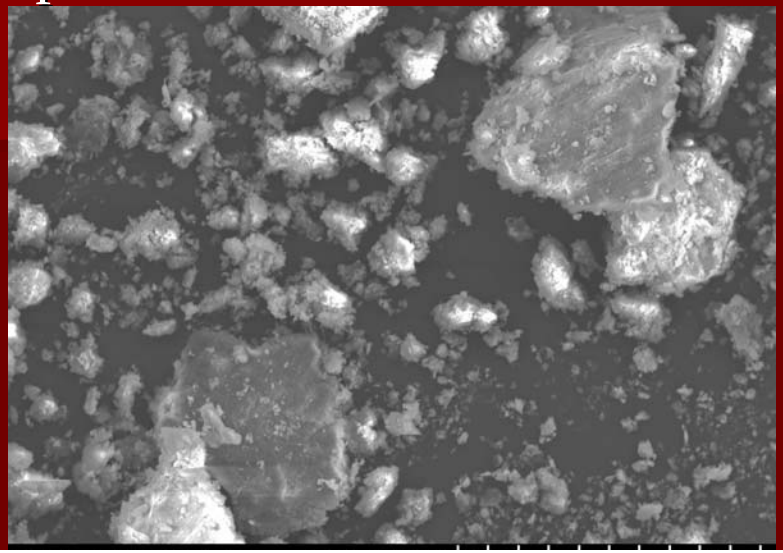
- This leads to environmental problems
  - ►e.g., Eutrophication
  - ►NO_3 accumulation in ground water

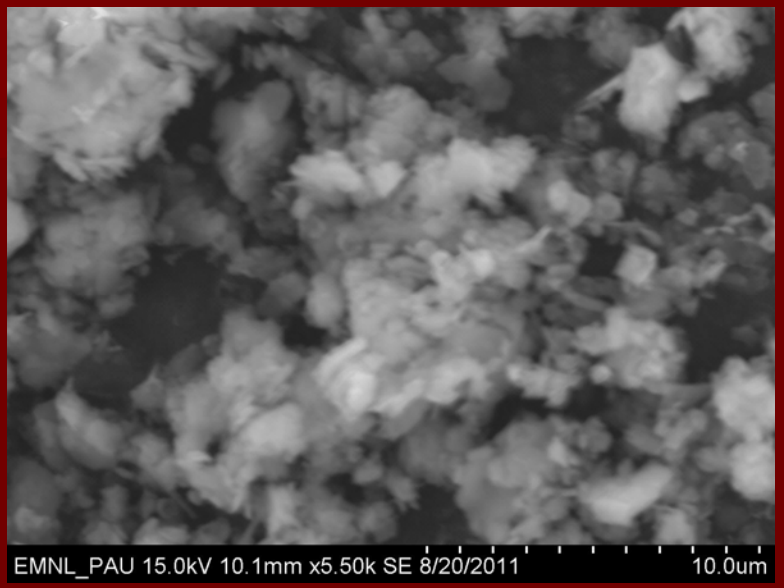
- ➢ Post-harvest losses are 25-80%

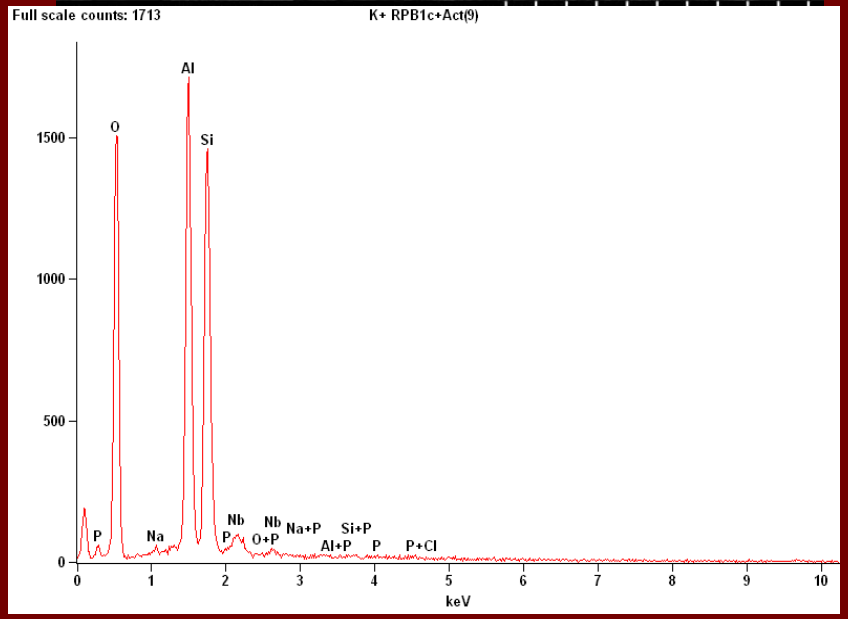
Input use efficiency in agriculture

Pesticide	**< 1 %**
Water	< 30 %
Water (arid, semi-arid)	5-10 %

- Nanofabricated plant nutrient: SEM micrograph and EDS spectrum of nano-kaolinite with adsorbed P (Mukhopadhyay – unpublished data







Element	*Atom %*

Farming scenario in NW India

- This is the birthplace of ancient agriculture and modern green revolution
- Here.

  harvests have turned toxic,

  mother’s milk a poison, and

  breathing-air venom

Why NT in Agriculture?

Boundaries for the biophysical processes that determine the Earth's capacity for self-regulation

- Seven parameters
  - climate change
  - ozone depletion
  - ocean acidification
  - biodiversity

- freshwater use
- the global nitrogen and phosphorus cycles, and
- change in land use

We must stay within all of these boundaries in order to avoid catastrophic environmental change

(Nature Editorial; *Nature* **461**, 447-448 (24 September 2009)

- Important global issues of the 21st century are:

- an increase in human population by an additional three billion by the middle of the 21st century, most of which is expected to occur in the developing countries;
- a decline in per capita availability of cultivable land and renewable fresh water resources;

- an increase in the atmospheric abundance of CO_2 (from 385 ml L^{-1} in 2008 and increasing at the rate of ca.2 ml L^{-1} $year^{-1}$) and other GHGs
- an increase in energy demand from 440 EJ in 2007 and growing at the rate of ca. 2.5% globally;

- an increase in food demand, especially in developing countries that are home to 850 million food-insecure people (Borlaug, 2007), and where the scarce natural resources (per capita land area and water) are already under great stress; and
- an increase in the extent and severity of the human-induced soil degradation (1.94 billion ha globally and increasing at the rate of 5–10 million ha annually) (Oldeman, 1994)

Promises of Nanotechnology

- greatest technological breakthrough in history, doing for our control of matter what computers did for our control of information.
- Though limits to growth will remain, we will be able to harvest solar power a trillion times greater than all the power now put to human use.

Agricultural Nanotechnology Innovations

- Nanofertilizers
- Nanopesticides
- Nanodiagnostics
- Nanodevices for precision farming

Some successful ventures of nanotechnology in agriculture (Adapted: Kalpana-Sastry, 2007)

Product	Application	Institution*
Nanocides	pesticides encapsulated in nanoparticles for controlled release	BASF
	nanoemulsions for greater efficiency	Syngenta
Bucky ball fertilizer	ammonia from buckyballs	Kyoto Univ, Japan
Nanoparticles	Adhesion-specific nanoparticles for removal of *Campylobacter jejuni* from poultry	Clemson Univ.
Food packaging	airtight plastic packaging with silicate nanoparticles	Bayer
Use of agri-cultural waste	nanofibres from cotton waste for improved strength of clothing	Cornell univ
Nano-sensors	contamination of packaged food	Nestle, Kraft
	pathogen detection	Cornell Univ
Precision agriculture	nanosensors linked to GPS for real-time monitoring of soil conditions and crop growth	USDA
Live stock and fisheries	nano-veterinary medicine (nanoparticles, buckyballs, dendrimers, nanocapsules for drug delivery, nanovaccines; smart herds, cleaning fish ponds (Nanocheck); feed (iron nanoparticles)	Cornell Univ, Nanovic, Australia

Opportunities [USDA Report, 2003]

- Microfluidics
  - -Micro Electro Mechanical Systems
  - -Nano Electro Mechanical Systems
- Nucleic Acid Bioengineering
- Smart Treatment Delivery Systems (e.g., use of halloysite)
- Nanobioprocessing
- Bioanalytical Nanosensors

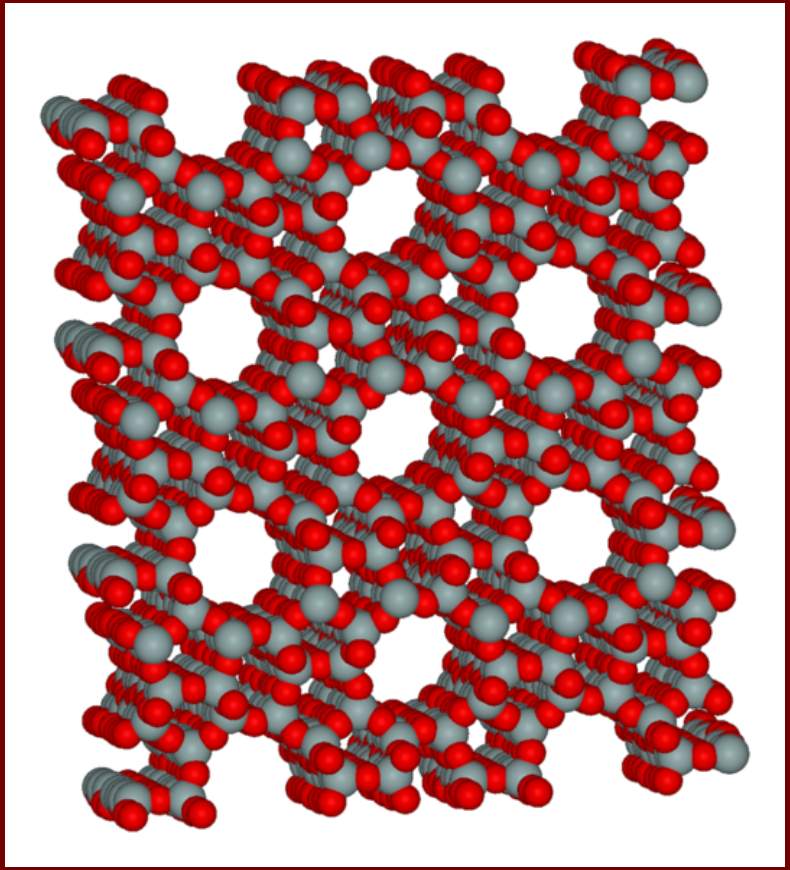
Opportunities [USDA Report, 2003]

- Nanomaterials
- Bioselective Surfaces
- Environmental processing, pathogen detection, plant/animal production
- molecular and cellular biology
- The Integrated Pest & Nutrient Management (IPNM)
- Computerized control of the environment
- Nanobiotechnology

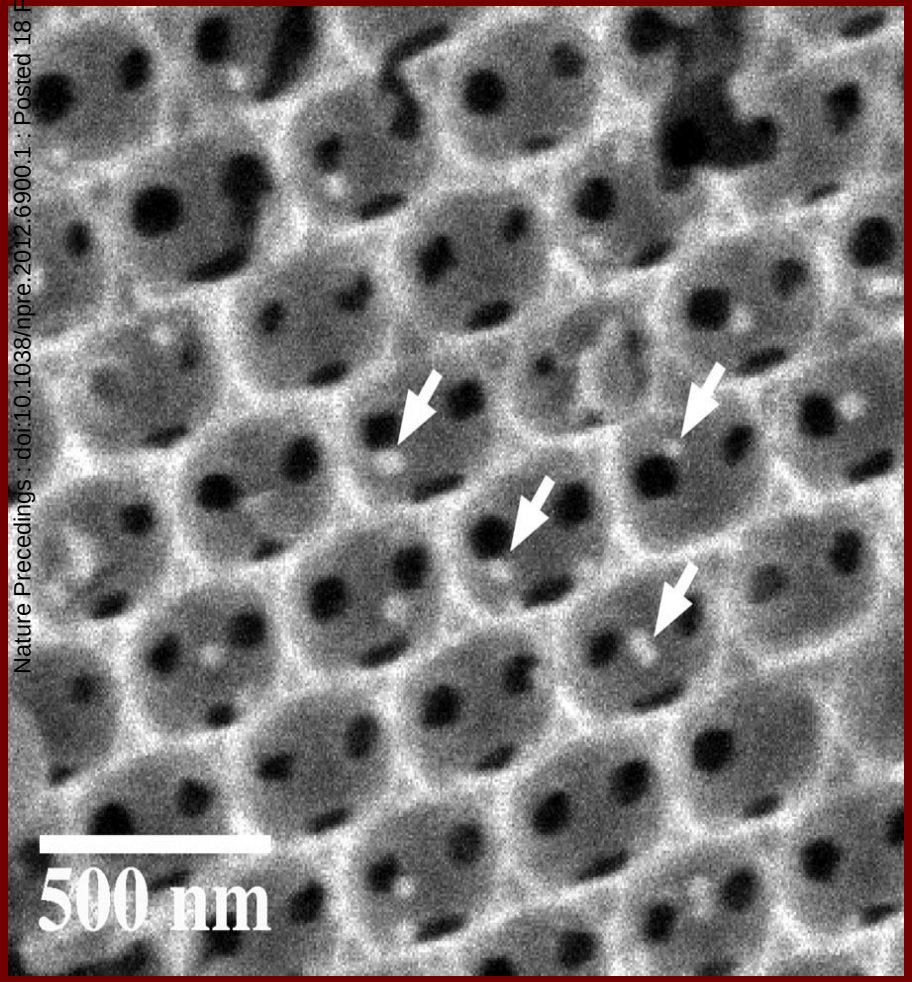
Possible innovations using nanoclays

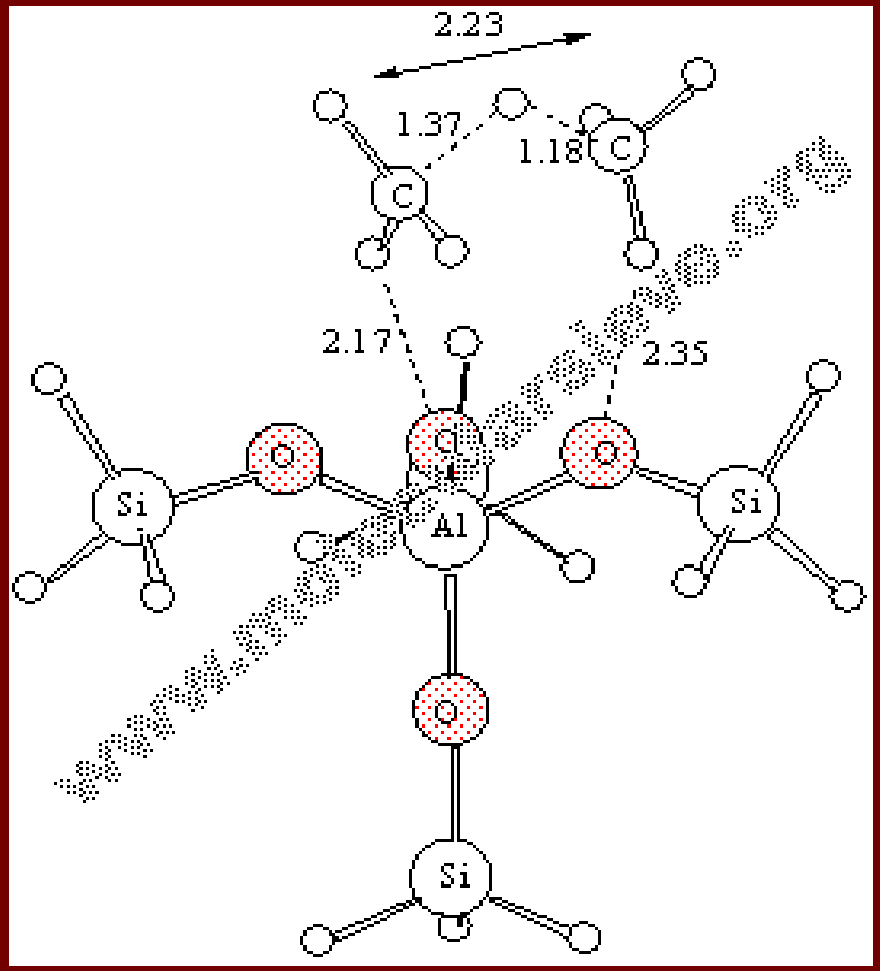
- nano-enhanced products (e.g. nanofertilizers and nanopesticides)
- nano-based smart delivery system (use of halloysite)
- Nanoporous materials (e.g. hydrogels and zeolites)
- nanoporous membranes
- Nanosorbents
- Nanocrystals of magnetite (< 12 nm)
- Nanosensors
- nanoscale precision farming

Tectosilicates: Zeolite



TEM of a zeolite





What will nano materials do to the environment? (Nowak and Bucheli, 2007)

- Our expanding ability to synthesize nanoparticles for use in electronics, biomedical, ceramics, pharmaceutical, cosmetic, energy, environmental, catalytic, material etc. has alarmed concern for these particles role in environmental safety.

Year	Amount of Engineered material used
2004	2000 tons
2011-2020	58000 tons (expected)

- *Nanotechnology in agriculture is a castle in the air.*

- *It would work, if scientists working on kindred discipline place foundation beneath it*

Thank you