



Nanotechnology in Agriculture: Propagating, Perpetuating, and Protecting Life

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A Tribute

- “All things do not simply scale down in proportion” - Richard Feynmann
- "The best way to predict the future is to invent it" - Alan Kay
- Agriculture in 21st century will be driven by “The theory of chaos”, especially ‘non-linear dynamics’

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),

▪

Input use efficiency in agriculture

Fertilizer	
N	20-50 %
P	10-25 %; < 1% in calcareous soils
K	~ 40 %
Pesticide	< 1 %
Water	< 30 %
Water (arid, semi-arid)	5-10 %

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

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
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*In the birthplace of ancient agriculture
and modern green revolution of north-
west India,*

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- ❑ mother's milk a poison, and
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□ 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 CO₂
(from 385 ml L⁻¹ in 2008 and increasing at the rate of c.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 c. 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.

Defining nanotechnology

- is a new interdisciplinary venture-field that converge science, engineering, and agriculture and food systems into one –

Dr. APJ Abdul-Kalam

- understanding and control of matter at dimensions of roughly 1-100 nm, where unique physical properties make novel applications possible (EPA, 2007).

Origin of NS

- The origins of nanoscience can be traced to clay mineralogy and crystallography (Lower et al., 2001) when it was discovered that clay minerals were crystalline and of micrometer size

Promises of nanotech

- From the resources of our solar system, we will be able to create land area a million times that of Earth.
- With assemblers, automated engineering, and the resources of space we can rapidly gain wealth of a quantity and quality beyond past dreams.”

- *Dr. K. Eric Drexler “Engines of Creation”*

Some successful ventures of nanotechnology in agriculture

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 <i>Campylobacter jejuni</i> from poultry	Clemson Univ.
Food packaging	airtight plastic packaging with silicate nanoparticles	Bayer
Use of agricultural 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

What will nano materials do to the environment?

- 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)

Zeophonics

- System founded on the concept of interconnected nature of all life-forms and life-support-forms
- Relies on recycling and operation of system-components
- The system provides a framework where impetus and response are almost equal.

- This is the only means of survival in the extraterrestrial planets, space stations, and in the Antarctica

Opportunities [USDA Report, 2003]

- ▶ Microfluidics
- ▶ BioMEMS
- ▶ 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 Management (IPM)
- ▶ Computerized control of the environment
- ▶ Nanobiotechnology

Nanotechnology in agriculture
is a castle in the air.
It works, If scientists working on
basic sciences put
foundation beneath it

Thank you