Nanotechnology for Enhancing Food Security in India

Kalpana Sastry, R*,

H. B. Rashmi and N. H. Rao

National Academy of Agricultural Research Management,
Hyderabad, India

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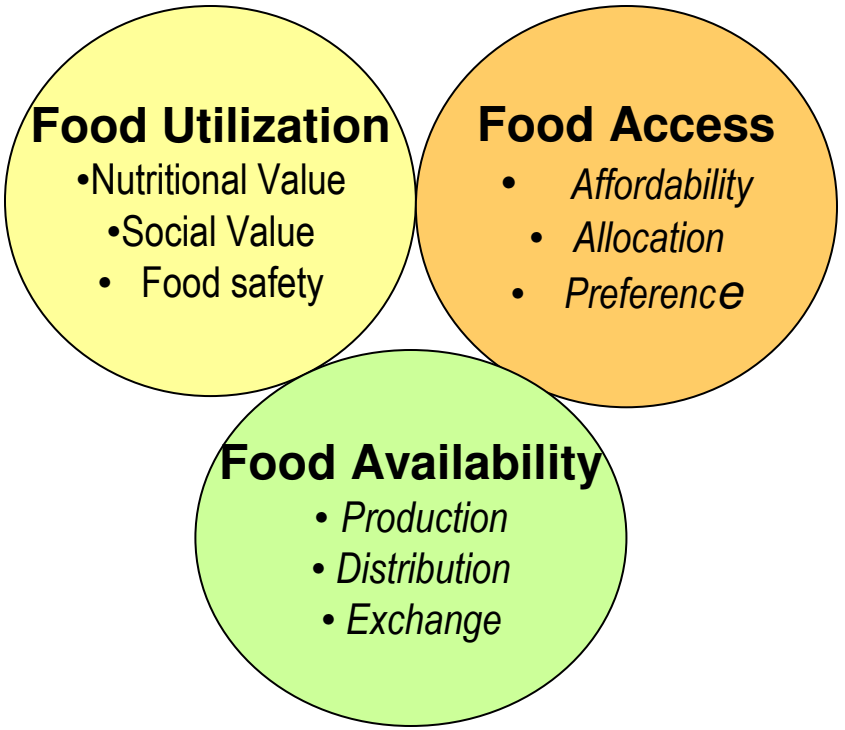
Plan of Presentation

- Introduction
- Food Security in India: Concerns and Determinants
- A comparison
  - Emerged vs Emerging Technologies in Food Systems
- Framework for Assessing Nanotechnology
- Mapping Nanotechnologies to Determinants of Food Security
- Trends in Technology Development
- Risks
- Conclusion

Food Security

- A state achieved when food systems operate :
  - such that 'all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life'
- 3 Components



Three Components of Food Systems

(adapted from Gregory et al. 2005)

In the Indian Context

- Cycles of food insecurity common prior to 1970s
- Adoption of the GR Model
  - Laid the foundation for food security
  - Dramatic increases in food production
- Incremental through higher yields
- 53 million tones of wheat and rice in the country reserves during July 2009

GR Model vs Food Security

- Addressed the food availability
- Food access
  - Public Distribution System (PDS)
- Diversification in '80s
  - Rising incomes in certain sectors of population
  - Scope for a diversified food basket
  - Struck a positive feeling
- Less emphasis on effective utilization, (a household level concern)
  - 1/5th population under-nourished

India State Hunger Index 2008 -GHI

- Developed by IFPRI
- India's Global Hunger Index (GHI) 2008 score is 23.7
  - Ranks 66th out of 88 countries
- Not a single state shows low or even moderate level is a concern for a country performing well in economic growth even in days of global recession

Indian Agriculture – Recent Concerns

- Decline in growth of AGDP: 3.6% during 1985-95 to less than 2% in the decade 1995-05
- Particular areas of concern
  - Low productivity levels of food grains
  - Impact of climate change
  - Market risks
- Threatened food security, even with respect to its first component, food availability
- Steady decline in farm incomes and rural distress
  - Affecting both access to food and its utilization

Determinants of Food Security for India

- Availability- Production base
  - Genetic productivity of the crops, quality of the natural resource base determined by the soil health and vulnerability of water resources
- Access- Rural incomes
  - Value addition
  - Ability to store/maintain
- Utilization- Quality
  - The extent to which the quality of the food is retained in storage and distribution

Addressing through NT

- If productivity, soil health, water security, and food quality in storage and distribution are the primary determinants of food security
- Essential to examine if
  - Nanotechnology can potentially impact as an enabling technology that can complement conventional technologies

Essential to Realize

- Application of nanotechnology
  - be not limited to the farm production level, but extended across all the links of the agricultural value chain to increase agricultural productivities, product quality, consumer acceptance and resource use efficiencies
- This will help to reduce farm costs, raise the value of production, increase rural incomes and enhance the quality of the natural resource base of agricultural production systems

GR Technologies, Biotechnologies vs NT in Food Systems

- Characteristics
- Focus areas
- Other products
- Applications
- Parties in technology development and dissemination
- Proprietary considerations
- Capital costs of research

- Research skills required
- Crops displaced
- Access to information
- Regulatory System
- Environment risks
- Ethical issues
- Socioeconomic risks
- Influence on society
- Public Acceptance

NT into Agri-food Systems

- Potential a capacity to influence an even wider canvas of agri-production systems
- Likely greater impact on all levels of the value chain
- Technologies also necessitate a new set of skills and building of new workforce
- Warrants more investments on training of manpower, and on infrastructure

Framework and Methodology

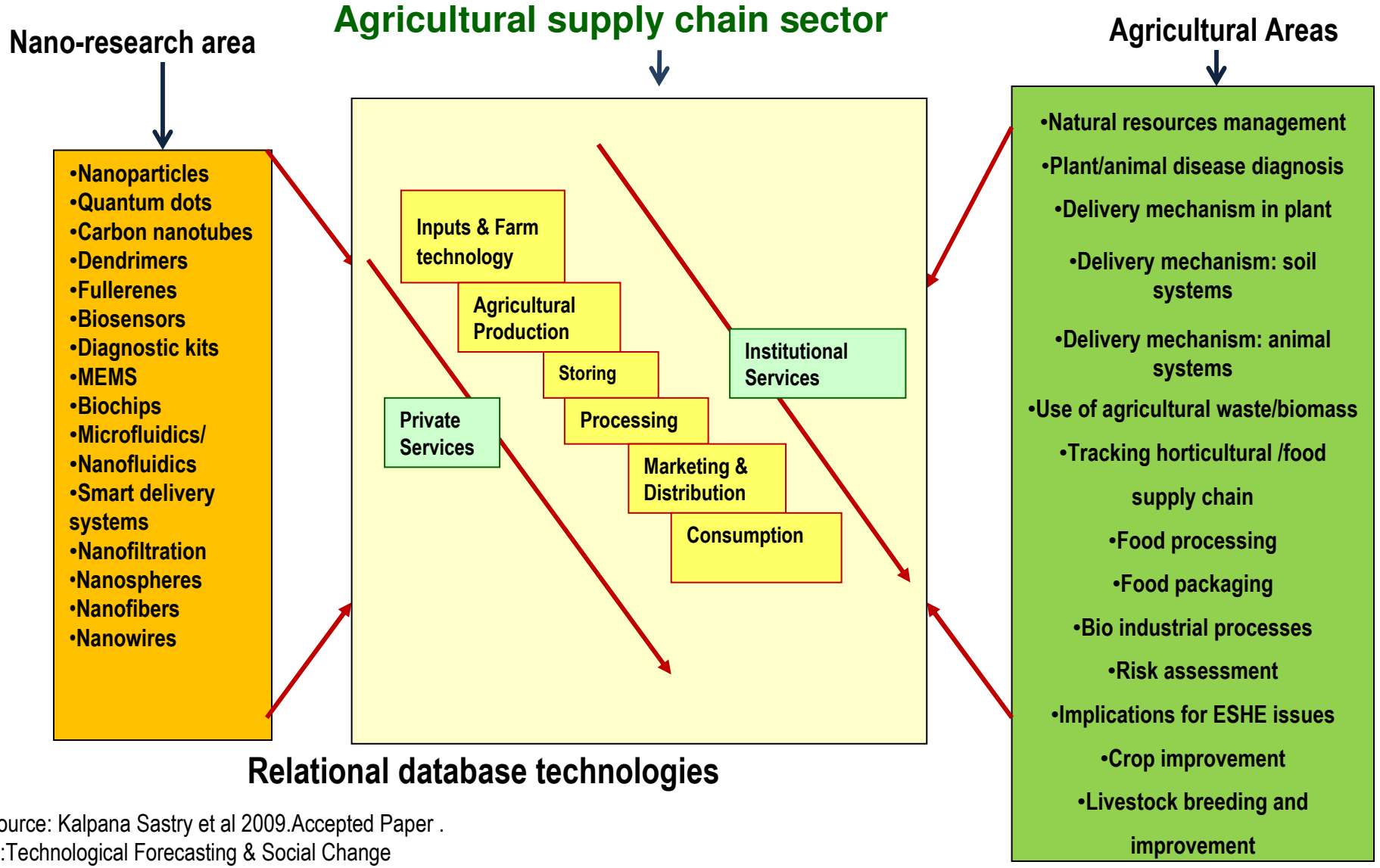
- Developed for integrating nanotechnology research in agri-food systems
- Based on bibliographic and patent search, and technology road mapping and database management concepts
- Takes into account both
  - the nature of the emerging technologies
  - And the scenario for technology generation, dissemination and transfer

Basis

- New Technologies undergo typical patterns of scientific, technological and economic developments
- The scientific –push is prior to technology pull and market pull
- Essential to estimate output indicators
  - publications, (for scientific performance)
  - patents (as indicator for technological performance)
  - products in the market (as indicators for commercial presence)

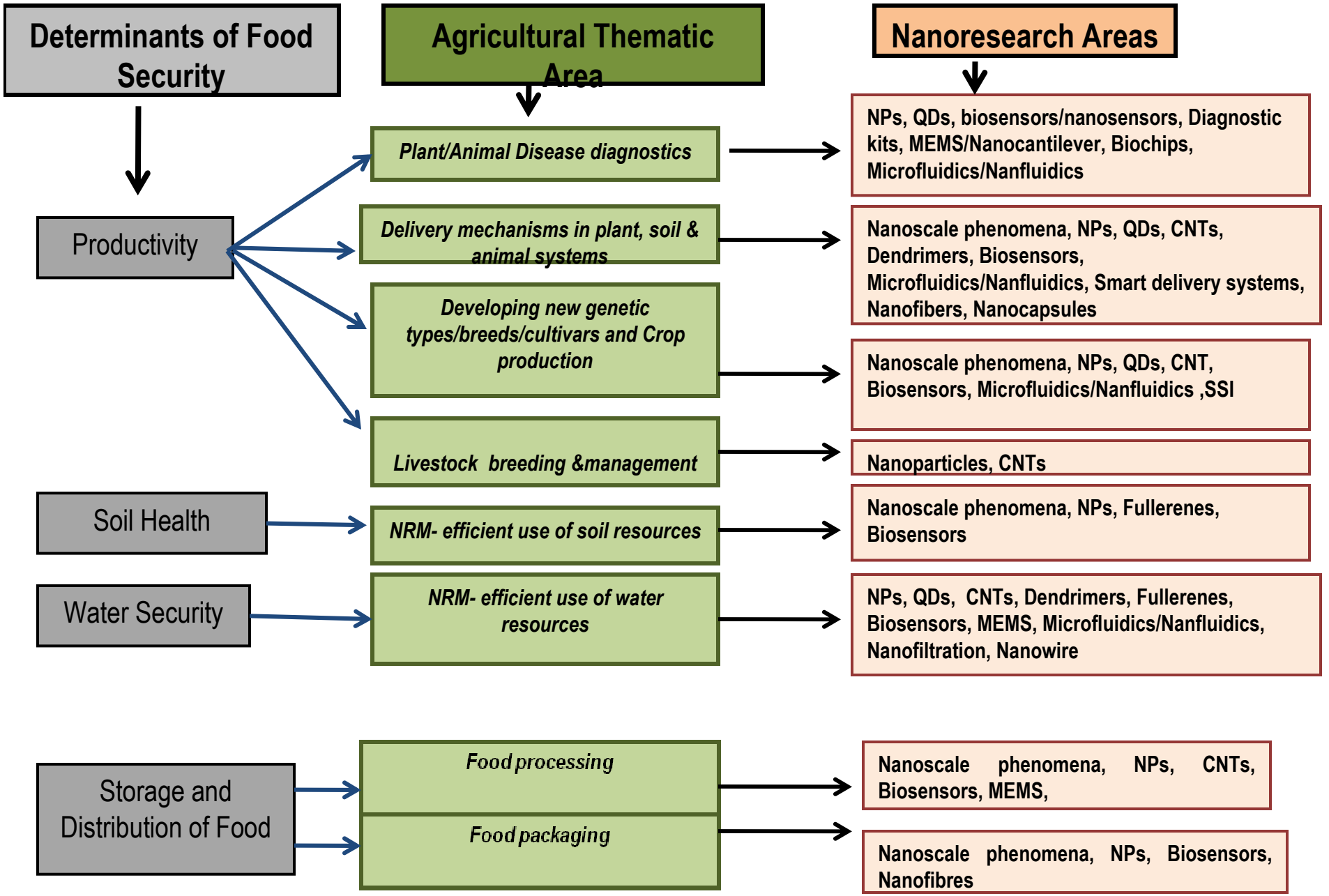
Framework Development:

for mapping nanoresearch to agri-food thematic areas



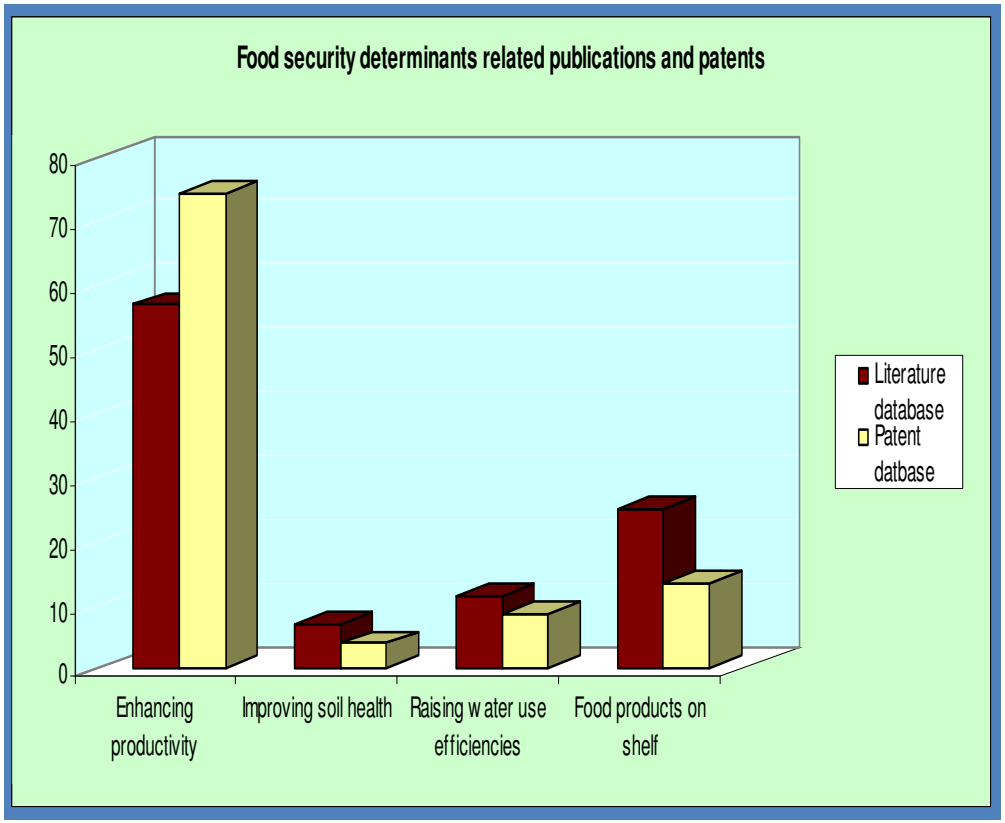
Source: Kalpana Sastry et al 2009.Accepted Paper .
In:Technological Forecasting & Social Change

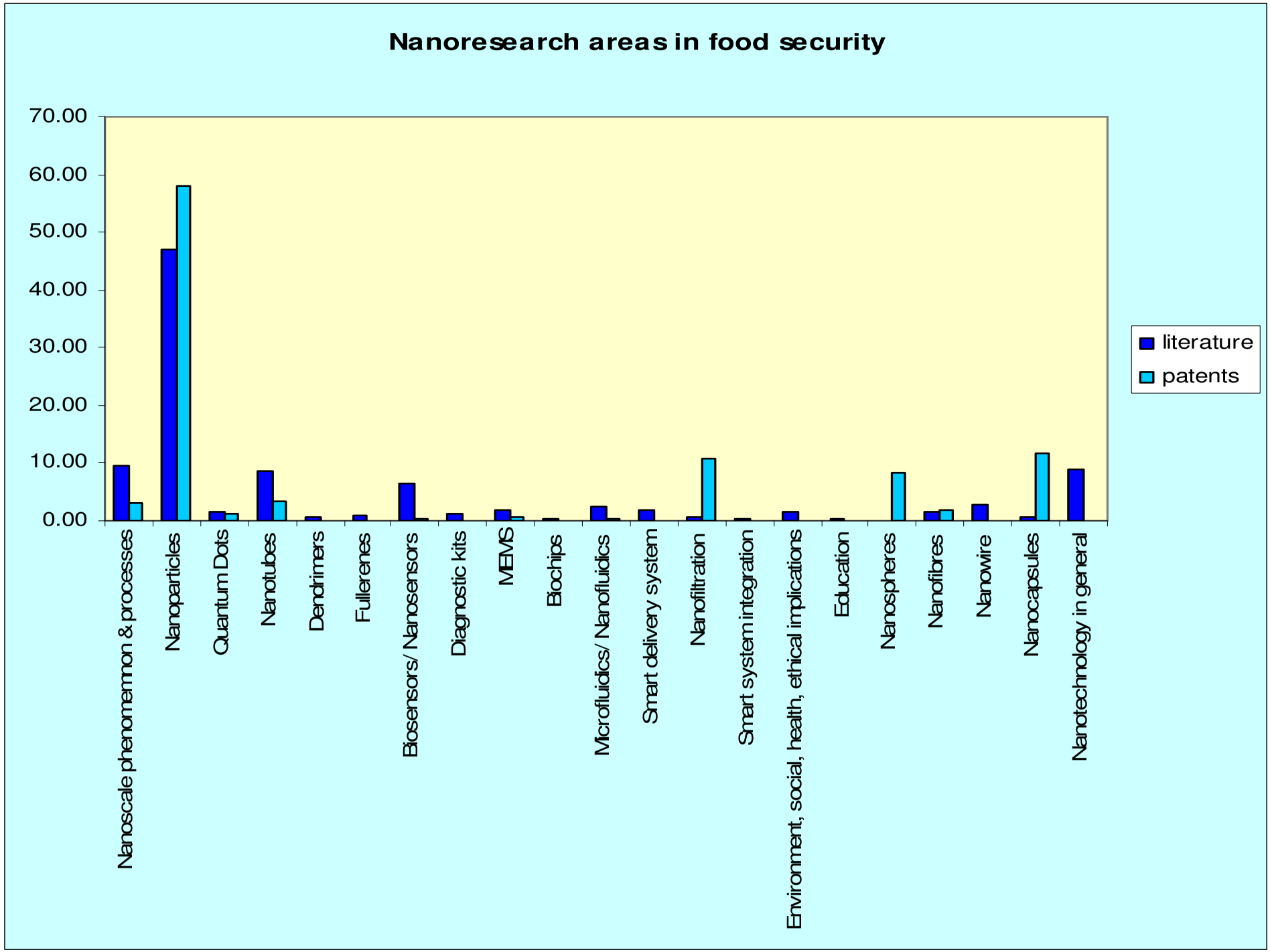
Integration of Food Security Determinants to Nanoresearch Areas and Agriculture



Results

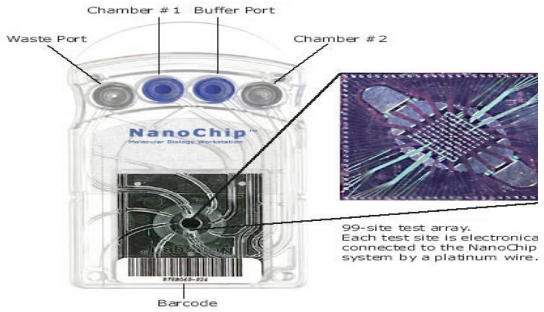
- >60 % records from both the databases
  - on R &D efforts
  - to enhance plant/animal productivity
  - food processing and food packaging areas
- In terms of food security this indicates research using nanotechnologies to address two areas
  - food availability and food use and stability

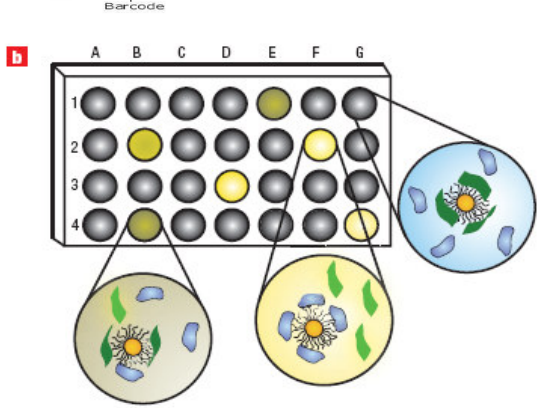


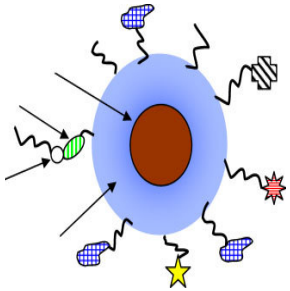

Nanoresearch areas in food security
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
literature
patents
Nanoscale phenomemnon & processes
Nanoparticles
Quantum Dots
Nanotubes
Dendrimers
Fullerenes
Biosensors/ Nanosensors
Diagnostic kits
MEMS
Biochips
Microfluidics/ Nanofluidics
Smart delivery system
Nanofiltration
Smart system integration
Environment, social, health, ethical implications
Education
Nanospheres
Nanofibres
Nanowire
Nanocapsules
Nanotechnology in general

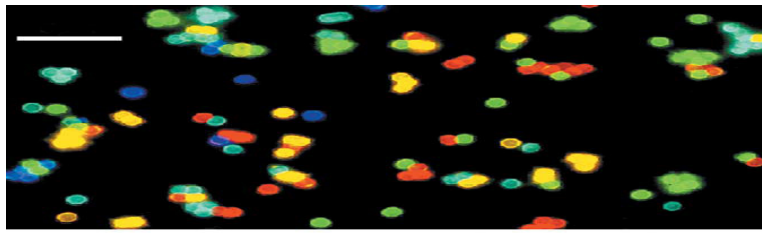
1.Plant/Animal Disease diagnostics

- Nanobarcodes as ID tags for multiplexed analysis for gene expression and intracellular histopathology
- QDs- fluorescence marker coupled with immunomagnetic separation for detection of *E.Coli*
- Label-free sensor chip assembled from peptide nanotubes-for electrical detection of low detection limit viruses
- Sensor array containing 6 non-covalent gold nanoparticles for detection and quantification of protein targets

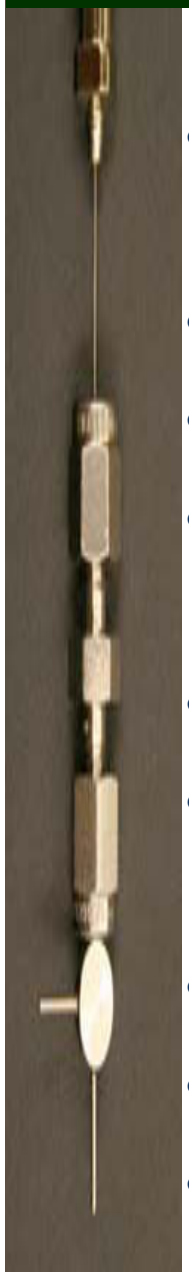








2. Delivery Mechanisms in Plant, Soil and Animal Systems



- Mesoporous silica nanoparticles for delivery of DNA and chemicals into plants
- Smart magnetic silica core for specific targeting, cell sorting and bioimaging
- Nanocontainers for delivery of drugs to organs or tissues
- Silica nanoparticles as DNA carriers, for gene delivery and promoters of transgene expression
- Carbon Nanofibres for gene therapy of plants
- Oligonucleotide-loaded nanoparticles for enhancing the expression of rice α-galactosidase gene in yeast cells
- Micro/Nanofluidic device- single-cell-based assay
- Carbon Nanotubes as molecular transporters
- Tin oxide nanowires for water vapor detection

3. Developing New Genetic types/breeds/cultivars and Crop Production Practices

- Atomically modified rice by drilling a nano-sized hole through the wall and membrane of a rice cell for inserting a nitrogen atom
- Functionalized Cow pea mosaic virus (CPMV) nanostructures for use in sensing applications
- Magnetic nanoparticles coated with tetramethylammonium hydroxide enhancing the growth of *Zea mays* plants in early ontogenetic stages
- Carbon nanotubes for experiments on artificial photosynthesis
- Blue shift of CdSe/ZnS nanocrystal-labels upon DNA-hybridization

4.Livestock Breeding and Livestock Management

- Veterinary medicines -composition of nanoparticles, nanocapsules and nanospheres
- Nanodevice implanted in an animal for detecting the presence of disease and notifying the farmer and veterinarian to activate a targeted treatment delivery system

5.Improving Soil Health

- Natural resource management- efficient use of soil resources
- Nanoparticles for soil *insitu* remediation
- Sorption and release of contaminants in the soil onto the surfaces of engineered nanoparticles.
- Nanoscale Iron particles for rapid destruction of chlorinated hydrocarbons in soil and groundwater
- Nanosensors for continuous monitoring of heavy metals

6.NRM- Efficient Use of Water Resources

- Nanotechnology for Desalination and water purification
- Nanoporous membranes for filtration of viruses
- Nano-sponges to absorbs toxic metals
- Ozone nano-bubbles to sterilize water
- Nanowire immunosensors array-for detection of microbial pathogens
- Ultrasensitive pathogen quantification in drinking water using high piezoelectric PMN-PT microcantilevers

7. Food Processing & Packaging

- Bioconjugated nanomaterials, biosensor, Nanocantilevers, CNTs, nanowires, BioMEMS for detection
- Nanosensors for enhancing flavors and taste
- Biofortification
- Edible nanosensors for detection of bacterial contamination in the packaged foods

- Natural biopolymer-based nanocomposite films for food packaging
- Nanoscale titanium dioxide particles as blocking agent of UV light in plastic packaging

Results Indicate

- Enhancing of four determinants
- Catalyze the process for enhancing food security for India
- Several projects using nanotechnology are under progress
  - Strategies to mitigate arsenic problem in food chain
  - Better pesticide delivery system
  - Developing efficient biodegrable polymers
  - Delivery systems for higher utilization of phosphorus in arid soils, and use of biosensors for quality agri-products and effective management of animal husbandry
- Progress in these is expected
  - To percolate to several strata of agricultural value chain
  - Consortia-based approach of the project
  - Involvement of several actors in public–private partnership mode conceived in unique model unlike the earlier approaches for R&D in the Indian NARS

Distribution of Patents based on IPC Classification

IPC codes	Description	%
A01H	New plants or processes for obtaining them; plant reproduction by tissue culture techniques	3
A01K	Animal husbandry	6
A01N	Preservation of bodies of humans or animals or plants or parts thereof; biocides, e.g. as disinfectants, as pesticides or as herbicides; pest repellants or attractants; plant growth regulators	6
A61K	Preparations for medical, dental, or toilet purposes	10
A61P	Therapeutic activity of chemical compounds or medicinal preparations	4
A23	Foods or foodstuffs; their treatment, not covered by other classes	5
B01D	Separation	6
C02F	Treatment of water, waste water, sewage, or sludge	2
CO7D	Heterocyclic compounds	2
C12N	Micro-organisms or enzymes;	35
C12Q	Measuring or testing processes involving enzymes or micro-organisms;	3
G01N	Measuring; testing	3

Indicates

- Intense patent filing activity for technologies
  - which have applications extendable to the agriculture value chain
- IP litigation can expected to emerge
- Complexities seen earlier in agricultural biotechnologies may assume even a higher level in this field
- Transfer processes of NT in this sector against the patent portfolios may need to be well understood and *policies developed before* the commercialization cycles are put in

Suggest

- Complex technology transfer would need sound governance policies to address the expected and unexpected complications
- Developing open access models or encouraging use of propriety ownerships on humanitarian licensing models
- To minimize the complications on technologies contributing for food security through stakeholder discussions from early-stage levels

Risk Assessment of Nanotechnology

Risk Assessment	Percent of records	
	Yes	No
Environmental risks	9.97	90.03
Social risks	2.99	97.01
Health risks	10.96	89.04

- Involving the stakeholders right from the early stages of technology development essential in the Indian context
- For a better understanding and acceptance of the products coming from the research
- Catalyse the life cycle of technology development in more positive way

Environmental, Social and Ethical Issues

- Environment and health risks
  - small size and large surface allow easy dispersion and bonding in environment and with human tissues
- Risks to farmers
  - handling of nanofertilizers and pesticides by millions of small farmers can lead to health risks
- Soil and water pollution
  - fertilizers and pesticides enhanced with nanomaterials can disperse into soil, water and atmosphere; nanoparticles can also bond more strongly with pollutants and transport them through soil and water
- Social risk
  - impacts on livelihoods of high cost technologies; access to technologies as most research is in private sector

Summarizing

- Food security is a primary concern for India
- Has engaged immediate attention by NARS
- NT has greater canvas and higher potential to address as compared to GR and biotechnologies adopted in Indian agriculture
- Significant enabling character of this technology
  - Allows it to be extended across the agri-value chain (from farm to plate)
  - Necessary if the three facets of food security - food availability, access and nutritional security are to be addressed

Summarizing

- Trends substantiate the current trend
  - In increasing investments and interest from several players
  - Applications across sectors so as to capture its applied potential
- The study also indicated
  - Need for more science-based evidence on possible risks on the environment, health and the social structure considering the broad areas it can affect
  - Public opinion/involvement for better market success
- The framework developed in this study also provides for a more participatory and consensual process of scientific policy-making

Policy Intervention

- Use of simple, effective technologies afforded by NT could ensure that Indian agriculture system
  - Can produce food not only to feed its massive population but also elevate the country as major food producer at the global level
- Ongoing Developmental Initiatives at national levels
- Nanotechnology- Policy Interface
  - Which could then be the representing arm of the country in the on-going attempts at international fora to develop a model for governance of nanotechnology at the global level
- The framework presented in this study provides a basis for engaging in such deliberations

Thank you
R.Kalpana Sastry
kalpana@naarm.ernet.in