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Agricultural Epidemiology and Environmental Toxicity: Some Statistical Perspectives

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SUMMARY

Environmental toxicity has significant impact on agricultural system and ecology, and consequently, on human being. The population explosion, particularly, in the Indian sub-continent and China, and to boost production and combat wastage of agricultural products, fertilizers and pesticides have been used, more extensively in the past six decades. There is a countless number of environmental stressors, some man made and not all working reconcilably, whose composite impact on agricultural system, plants and all living creatures has been disasterous. A statistical appraisal of environmental toxicology in relation to human health and agricultural epidemiology is made. Routine data mining approaches may be quite misleading in this venture.

Keywords: Animal husbandry, Arsenic contamination, Bacteria, Chemical dumping, Cold-storage contamination, Contamination of food and drinks, Data mining, De-forestation, E-coli, E-waste, Ecology, Epidemiology, Environmental health sciences, Farmentation, Genetics and genomics, Green house effects, Ground water, Horticulture, Human waste, Irrigation, Pesticides, Plant toxins, Pollution, Risk-analysis, Saline water effect, Sanitary landfill, Statistical assessment, Sub-soil contamination, Tsunami, Urbanization.

1. INTRODUCTION

We take a broader view of agriculture including animal husbandry, plant breeding, horticulture, nursery, poultry and cattle ranching, fruits, fish hatchery, jute, cotton, tobaco, tea and coffee cultivation, sugar cane, cinchona, plum and rubber plantation, flora and fungus, dairy and related farming. Indigenous medicinal herbs and herbal drug ingredients are naturally included in this spectrum. This also includes the basic agricultural practice in a traditional sense, its transition during the *green revolution* a few decades earlier, and the recent rampage of the on going (bio-)informatics evolution. The impact of environmental pollution and toxic contamination is escalating at an alarming rate. Some impacts are directly through industrialization and careless attitude toward our living environment while some are perceived through the infested agriculture system, as it is clear from agricultural epidemiology, ecology and (global) human health perspectives. Overwhelmingly, human involvement is an integral part of this bio-environment, deserving immidiate and critical assessment. Some of these salient features are listed below:

- The innovation of agriculture as a sustainable source of human food and energy, development of agricultural tools, irrigation system, use of fertilizers and other means to boost the agricultural output in a renewable way.
- Chrological development of agricultural science and technology.
- Agricultural labor, their socio-economic features over the passage of time.

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- Deputizing animals and machines to support the system (from *bullock and horse to modern tractors and water pumps*).
- Development of management and distribution protocols.
- Careless handling of our bioenvironment and thereby escalating the risk of food and drink contamination, some in serious chronic modes.
- Due to inadequate sanitary safeguards generating environmental toxins, transmitting deadly virus and other harmful ingredients to invade human system through their uptake through ingestion, inhalation and absorption mode.
- Creation of an increasingly artificial life style to pace with the advents of *information technology*, leading to excessive consumption and wastage of energy, affecting the ecosystem on our mother planet, and thereby promoting deleterios health effects.
- Human malpractice, including slavary of agricultural labor, use of child labor, money-lending, brokerage and other underground activities, promoting hoarding of agricultural and derived products for excessive profit and black-marketing.
- Conversion of agricultural products in to secondary energy products (e.g., gasohol or ethanol from corn or sugar cane).
- Escalating industrialization, and disposition (dumping) of radiation and chemical waste in subsoil or ground water.
- Environmental pollution and ambient toxins affecting agricultural products as well as all living creatures directly.
- Foothill deforestation and erosion of agricultural land due to land (mud-) slide and avalance.
- Urbanization and its impact on agricultural system and human health.
- Subsoil arsenite and impact on agriculture system and human health.
- Agricultural evolution and *quality of life* (QoL).
- Human contribution to the *green house effect* and its impact on the agricultural system and human survival.

It is possible to list a thousand and one such clauses. In this study, however, we shall mainly focus on agricultural epidemiology and the impact of environmental toxicolgy, both being man-made to a greater extent, and both affecting the life of all creatures on earth. In Section 2, the environmental impacts on agricultural system are outlined. Section 3 deals with agricultural practice and socioeconomic impacts. Agricultural epidemiologogical aspects are presented in Section 4. Section 5 is devoted to statistical perspectives. Bioinformatics and some biotechnological impacts are discussed in Section 6. Some concluding remarkes are appended in Section 7.

2. ENVIRONMENTAL IMPACTS

Respirable air, drinkable water, untainted, edible food, and renewable, affordable energy are the basic ingredients for human prosperity and survival on earth. Environmental pollution and toxicity have serious impact on each of these life sustaining sources. In a greater part of the Indian subcontinent, particularly in the rural areas, for cooking (and heating in some parts, in winter season), the primary source of fuel used to be woods (trees and plants). The use of coal, gas and electricity is on the rise at a pace but at a considerable environmental cost. With the explosion of human population, the demand for these wood clippings (and timber for furnitures and house construction) compelled the deforestation to a greater extent. This change in the rural topography has introduced serious climatic as well as ecological changes. On the other hand, rapid urbanization has its toll too. On top of that, in the foothills of Himalayas, the so called, *Tarai* area, this deforestation has led to serious land erosion along the slopes, inviting more frequent land or mud slides and avalances. This has led to more arid land (with reduced subsoil moisture) for agricultural use, thus resulting in deminishing the productivity of the land. In such less fertile lands, more fertilizers and more moistures (sub-soil waters) are needed to cultivate agricultural crops and vegetables, or related cattle foods. On the foot-hills, usually rain water slides along the slope and does not lead to enough absorption to have adequate sub-soil moisture to make the land cultivable. Traces of water in stagnant pockets are the ideal places for mosquitos to lay their eggs, thus spreading malaria and other related infected diseases. As such, there is increased need for pesticides to control weeds and insects. Further, along with the landslides and avalances, the harmful bacteria invade the ground soil and water inlets, and not only cattles are having toxin foods and drinks but also human being is getting exposed to more toxins through ingestion and absorption, as well as from contaminated milk and derived products. Contamination of ground water and cow milk has been well documented in the agricultural science literature in the West but may not be to that extent in the orient.

Due to irrigation canals and dams on the upper sector of main rivers, resulting in at least partial blockage of the main stream and reduced flow of water in the lower basin, the river beds are usually dry excepting for the monsoon season. These not only promote sedimentation of inorganic and organic (including human and animal) waste material, but also the accumulation of drainage outlets of municipal and industrial waste along the banks of the rivers add more to the environmental distress. Further, at the very first rampage of monsoon, these waste elements are carried away in the down-stream, invading the sub-soil and ground water levels on their banks. Flooding, very common in the north-east part of the Continent and coastal areas, under torrential rain, causes further ecological damage by spreading the contaminated sedimentation all around. Sanitary and waste land-fills adjacent to big cities and industrial sites are most noteworthy sources of subsoil and ground-water contamination. Dead and shelter-less animals for whom nobody cares, often victims of flooding, add more to such contamination. Out-break of dengue is often linked to such contamination.

Although Tsunami is not very common in the Indian sub-continent, virulent tornados, cyclones (in the coastal area) and dust storms (*Andhi* or *Lu*) in the great planes are more frequently encountered, and these are not totally human-made; the change in climate due to human industrial endeavors and deforestation (to compensate loss of agricultural land to make way for more urbanization to suit the population explosion) might have created imbalance in the higher atmospheric pressure and contribute to such natural calamities. *Wetland management and flood-water control* measures have not been developed to the adequate extent in the Indian sub-continent, and to the contrary, some of the dams and hydro-electric projects have led to further deterioration in this respect. This deficiency, in turn, has induced some ecological imbalance to disaster. Every year in the north-eastern part of India and adjacent Bangladesh, flooding is well anticipated, but the awareness and capability of the mass population to protect themselves from the devastation that follows are not perceptible. They rely solely on the mercy of god. The aftermath of such natural calamities can be severe loss of agricultural products, cattle lives and in some cases some loss of human lives too. Further, the waste, spread around, impounds insects, bacteria and virus of all kinds, which in turn can cause rampage of epidemic scale disease and disaster; outbreak of cholera and other diarrheal diseases is still unabated.

Due to industrial wastes, mining and other explorations, inorganic arsenite compounds have anchored their realm in a greater part of the coastal area, more noticably, the entire southern part of Bangladesh, coastal areas in West Bengal, Orissa and some other states virtually float on arsenic beds. In Bangladesh, in addition, the burial practice of wrapping the corpse in white clothing and placing it in shallow graves which are in the monsoon time sub-soil water level, thus creating more scope for decomposition and contamination of organic arsenties and other bacteria especially in the rainy season and low-land areas; the burden of population adds more to this distress. There is utter indifierence of all governments to probe in to this serious environmental disaster, and even the collection of relevant data on the impact of the arsenic toxicity is practically non-existent and most unreliable (Sen 1994).

A major source of environmental toxicity is the compounded environmental smoking and gaseous pollution comprising (i) industrial chimney and other modes of exhausts of gaseous waste and fumes, (ii) open area burning of waste products, (iii) bio-diesel exhausts from automobiles and small power plants, (iv) outside cooking on conventional coal furnaces, (v) traditional thermal power plants consuming mostly coal and other minerals, (vi) automobile exhausts, particularly, diesels and leaded gasolines, (vii) cigaretts and other tobaco products, (viii) locomobiles using coal or diesel run engines, (ix) atmospheric exhausts from airplanes as well as ships, (x) coastline oil spills and underwater oil lickage due to faulty operation (e.g., Mexican Gulf coast 2010, Alaska oil spillage a number of years ago), affecting marine biology significantly and contaminating human food items acquired from sea-water, and (xi) volcanic erruptions of fumes and molten lava, among others. Burning of oil fields in Kuwait some twenty years ago has still perceptable impact, aggravated by the winds and other powers of nature.

The toxic exhausts from chemical (industrial) plants have a different mode of penetration in to eco-system through direct inhalation, wind circulation in to adjacent areas impacting vegetation as well as living creatures, including notably the farmers, and with areal precipitation creating water contamination. Among the pollution caused by gaseous substances, the most noteworthy are the hydrogen-sulfide, ammonia, various chlorine, ethanol and carbon mono and di-oxides. Nuclear power plants exhausts have additional risk from low level radiation; further, lickage of radioactive gases or fluids, as was the case in the Kiev disaster in 1986, and Tsunami type disaster can have catastrophic radiation effect, as witnessed in the east coast of Japan in 2011. Forest fire on a large scale, as is common in certain parts of USA (and Australia too), and the use of chemicals to bring it under control can have compounded smoking and chemical toxicity impacts. There are many other environmental stressors.

There are other natural environmental disasters like earthquake which are not man-made but the human habitation, often without any due consideration of their bio-environment, has often made the impact even more catastrophic. Rupture of underground utility lines, unexpected fire breakouts and other catastrophic calamities are perceptable. Thinning of ozone layer, mostly due to aerosol and other industrial operations, causing the so called *green-house effects* is being identified as a prime source of environmental toxicity. The green-house effect is not only confined to human exposure to ultra-violet rays but also pertains to atmosphere as well as ground water and soil. Manmade green house effect and related climate change have led to the emergence of bacteria which can cause GI tract diseases in northeren Europe. It is anticipated that similar harmful bacteria have infested the rising and warming oceans water levels in the subtropical areas too, impacting the coastal area agriculture system. Also, during the past 15 years, old computers from the West with little renovation are being given away to the Indian sub-continent and West Africa, resulting in their dumping in landfills within a short period of time. This dumping of e-waste, ranging from consumed nuclear fuel rods or containers underground disposition (high level of radioactivity) to throwing away of dead computers, television sets, cell phones and all modern electronic gadgets (low level of radiation).

3. AGRICULTURAL PRACTICE AND SOCIO-ECONOMIC IMPACTS

From time immemorial, agricutural system has been dynamically changing, and it will continue to do so forever. The necessity of water and cultivable land have led to the development of human civilization mostly around major water ways. The innovation of irrigation is quite ancient, and yet, the use of fertilizers has not been so much ancestral. There has always been epidemiological impacts of human agricultural endeavours, but their outbreak has been dynamically escalating with the advent of modern technology. Further, the nature of evolution of this agricultural system and associated service manipulations in a socio-economic perspective, in the present time, have contributed to more significant risk, intricately mingled with environmental and epidemiological disasters. In the Indian sub-continent, small agricultural holdings with family level labor composition used to be common until a few decades ago. The farmers used to be either landless people or at best holders of small plots (*do bigha jamin*), barely enough to pay back their dues to the landlord (or money-lenders) and to have minimum provisions for their own (growing) families, often, failing to treasure even the essential sowing seeds for the next harvest season. These farmers were, mostly, little educated and not very conversant with the (mostly, unwritten) laws which were in favor of the money-lenders, and at the end, used to give up even that small land for failing to pay-back their debt, magnified by the huge (compounded) interest charged on their meager principal amounts. The agricultural labor system evolved with the whole family as a team for the farming, thus leading to the evolution of child labor set-ups; this miserable plight is still unabated to a greater extent in the Indian subcontinent. Growing of vegetables were also run by family and their sale were mostly confined to local markets without much profit; unsold (perishable) items used to be bounced, often in poor condition, for family consumption, leaving not much leverage to barter for other items for living which they could not produce. Road connections were mostly poor, thus preventing a smoother transportation of agricultural products to far away places. The middle-man or brokers role was much less predominant than the unscrupulous local money-lenders (often the landlords themselves). The fishermen used to have their (catch) collection from local rivers and ponds, and the sale of their perishable product used to be mostly confined to local areas. A greater part of the subcontinent population being vegetarian, the prospects for livelihood of the fishermen rested only with the non-vegetarian sector. Not only the rural-urban demographic pattern used to support the system but also, in that way, epidemiological impacts were mostly local. It is mostly left to guessing how many of agricultural farmers were doomed to have sun-stroke due to their long working on the field in the prime part of the day, not having much nurishment but drinking water from nearby sources, knowing well that they were not safe for drinking or even washing their face and feet. So much exposure to sun was also responsible for all sort of skin-diseases, including skin cancer. Their (bare) feet used to be the perfect gateway for countless bacteria and hook worms, and their sole dependence on rice (or wheat) in heavy consumption with some vegetables but with little provision of protein used to be the right environment for the propagation of diabetes, intensified by heredity factors - a perfect scenario of the *gene-environment interaction*. Long hours of bending for sowing the seeds on the wet agricultural fields, especially for the under nurished not so young persons, used to be a common cause for their posture and back pain syndroms, and their naked eyes exposed to the bright sun for a longer time used to be catalytic for early onslaught of eye diseases. Who knows what was their *life expectation* compared to other cohorts of industrial labors and residents in urban areas. Clinical or medical facilities were a minimum in rural areas, leaving the essential task to the so called herbal medicinal doctors, homeopaths and hakims. Pregnancies in the agriculture sector were no less in prevalence; after all, they had not much affordable recreation after their heavy toll of work; inadequate provisions for (mostly kerosene) lamps or lights, in the evening or night, used to leave them without other after-work recreation and the heavy toll of outdoor work during sun-rise to sunset were possibly impact factors in their growing families. There used to be a natural expectation: a new member of the family, especially a boy, in a few years would join the family team and relieve the seniors. The work load of the female members were even more: to feed the family, carry out all domestic work, to store the harvest in a suitable place at home and to break the kernels and get the final product from the grains. Many had scanty time to look for raising their own (mostly under-nurished) children. Generally, there are two to three harvest season a year for the crops, and that used to make the life of agricultural sector people busy year around. Vegetables were more in production during the monsoon period and in winter, but keeping away the rodents and other animals from these fields used to be a big problem. Even, in their meger storage of grains for their annual consumption, rodents and other insects were a major concernit would be quite appropriate to say that at least about 30 per cent of the food grains used to be lost due to insects and moisture. Moreover, infant mortality and maternal death rates were exceptionally high, especially among the childbirths at home with underage mothers; often the village level assistant (dhatri) at the delivery time did not have sufficient safeguards against infection, and the mother and the delivered child(ren) were susceptable to such septic fatal factors. Because of overwork, the pregnant women used to have miscarrage in greater numbers, and often, sex bias led to more infantile deaths. Reporting of vital records were very incomplete to give any real impression of the life and death of these people. After all, they were the Hari-jan left to the mercy of god. No doubt, the plight of the agricultural labor and farmers used to be miserable, more than what is perceived now.

The tea plantation in the Indian subcontinent has been mostly due to the British rulers, and the slopes of the lofty hills in the north and some in the south were ideal places for these plantation. The development of tea (and coffee) cultivation, in one hand, make them number one export item (mostly controlled by the British tea merchants) and, on the other hand, needed an enormous number of labors from adjacent provinces. Because of the development of tea industry in India (but some prime part being in England with exported and partly processed leafs), technical and managerial staffs used to have better housing and other living facilities. To the contrary, the life of the countless labors (both men and women) to cut the *two leafs and a bud* at the right time and sowing the seeds at an earlier stage used to be miserable. These labors were mostly from the poorest part of the continent, illiterate and without any social recognition. Their daily social life was gloomy with very little cultural activity; especially, the plight of the female labors was unimanigable. Sexual abuse and sexual harassments and social crimes, mostly committed by their co-workers and supervisors (often, all the way to the top level) were so common that these unfortunates led to the so called destitudes of the society. The worst is that after independence when most of the tea estates were taken over by the native companies, the labor problems became more acute and many of the farms were locked out, leaving a huge class of labors in measurable condition without any provision. The quality of tea drastically deteriorated and the quality tea production was taken over by other countries (e.g., Sri Lanka, South Africa). Herbal tea produced in the Far East and Europe is gaining popularity. No wonder, India is no longer the prime tea producing and exporting country. But *what about the epidemiological and environmental impact of this collapsed enterprise?*

In the post-independence era, in the Indian sub-continent, the influx of population, accompanied by a drastic change in life-style and outlook on life, have indeed impacted significantly the agricultural practice and management patterns. Big agricultural farms have taken away the small plots from the farmers, eliminating many of the interplot raised divisors to have more cultivable land, used better irrigation system (often, lowering the ground water levels by using deep water tubewells), replacing the traditional manures by high-potent fertilizers, and using machines (e.g., tractors) to improve the sowing system and crop collection at the harvest. Improved roadway connections and energy provisions have also been beneficial. This led to the so called green revolution, albeit in the process of storage of grains, use of pesticides have led to contamination, and the rodent infested grains still creates a major crisis. The procurement of food grains, their storage and transportation to markets have created a big class of brokers and moneylenders, sharing a major part of the profit, often by hoarding and other manipulations. The use of fertilizers have led to significant increase in the size of vegetables and their yield, albeit with compromise on their natural flavor, and use of preservatives have added another layer of contamination.

In the past, given the social environment and inequality of lifestyles of different classes of people, the farmers and agricultural labors had comparatively poor socio-economic status, often deprived of many facilities to which the upper strata of the society were entitled. No matter how much discontent they were, generally, they tended to accept the imposed economic poverty but their sober outlook on life created a manageable situation. One of the most noticable feature of the modern society across the globe is the greater access to communication and information for people in all walks of the society. Certain things, once deemed as luxury, have become necessary at all levels. Television and electricity have reached even the remote corners of rural areas, and cell phones are possibly more in number than their users. Education in the public sector is increasingly reaching out all strata of the society, and thereby, the traditional agricultural labor families are having greater access to modern education, resulting in quite different outlooks on life. With more and more small agriculture holdings succumbing to bigger cooperative farming with better machine equipments, more and more undeserving socio-economic and geo-political problems are cropping up in rapid pace. In the US, for example, agricultural labor is mostly composed of Hispanic workers many of whom may not be legal residents or immigrants; thus the provision for thefir health, (mostly, children's) education and welfare is probably not even at the minimal level. In the Indian sub-continent, in the industrial part, the former agricultural labors are mostly in industry, making way for migrants from less developed regions (including even some illegal migrants from adjacent countries) and thereby creating more disparities and social problems. Also, more and more agricultural land is either taken over for industrial developments or urban planning, thus enforcing more and more use of fertilizers and pesticides to produce more from available land for cultivation and combat loss from cold storage or infestation by rodents and other insects. The human addiction for modern life-style is in the root of a big social unrest which is likely to disrupt not only the agriculture system but also interactively other sectors.

4. AGRICULTURAL EPIDEMIOLOGY

We conceive of a bigger picture of agrucultural epidemiology wherein the health hazards as well as socio-economic disparity and disruptions in the agriculture sector along with their epidemic-impact are to be appraised objectively. It may be gathered from the preceding two sections that environmental toxicity and pollution, as well as, the built-in basic socio-economic malfunctionning are needed to be critically appraised in relation to their synergic impact on the entire agronomic sphere. In USA, the Department of Agriculture (USDA) and Food and Drug Administration (FDA), in close association with the network of health research and monitoring organizations under the umbrella of the National Institutes of Health (NIH), Environmental Protection Agency (EPA) and its dual unit: National Institute of Environmental Health Sciences (NIEHS), monitor the regulation of agricultural system as well as major drugs and any health hazard or risk due to food and water contamination or environmental pollution or disaster. This intricate network of surveillance has helped in reducing health risk to a certain extent, and also, by prescribing suitable precautionary measures, minimizing the extent of damage due to an identified or anticipated cause of health hazards.

Natural disasters like forest fires, hurricanes or tornados, havoc flooding and earth-quakes are not unlikely to take place in some regions of the vast country. Hog farming and poultry, particularly in low land areas accesible to waterways, when affected by flooding may lead to heavy fatality of these animals (and birds) with their decomposed bodies swept away to adjacent water outlets, thus contaminating not only the water but also the marine biology as well as the agricultural fields that are fed by the water ways for irrigation and other necessities. In one such flooding in eastern North Carolina (due to a hurricane) several years ago, more than 250 thousand chickens and some thousands of pigs, mostly caged or placed in closed compounds, were washed away to the main waterways and inlets; their dead bodies created a massive contamination problem with drinking water collected from the water ways, mass death of fish and other marine objects, and loss of agricultural products on a vast area of cultivable lands inundated by the flood. A more serious impact was observed with the burning of the oil in the Gulf of Mexico due to a fire in an underwater (BP Oil) rigging platform, the loss of marine fish and other birds and sea foods due to contamination not only had serious ecological impacts but also scores of people who used to live on marine products were out of work for a while, and the catch from the contaminated Gulf waters practically came to a halt, creating not only a shortage of supply to other parts of the country but also induced serious economic woes in the entire country. By contrast, in Nigeria the oil industry, mostly controlled by the multinational companies, systematically, over several decades, clogged the river delta with immensurable spillage and contamination due to toxic chemicals, not only destroying the marine biology but also the vegetation on both sides as well as the agricultural prospect. The problem is very severe due to the fact that in most african countries the climate is not agriculture-friendly and cultivable lands are really scanty. The worst situation has been with the Tsunami disaster in the east coast of Japan, and in spite of the strong determination of the Japanese people, the devastating effects have affected agriculture, marine biology and the energy or power supply on which the Japanese econmy is very much dependent.

It will not be an exaggeration to say that in the Indian sub-continent excessive environmental and ecological damages due to cyclone or monsoon storms and flooding or land (and mud)-slides take place more often than in the West, and the loss of human as well as animal lives may often be of much higher number than in the West. Yet, has there been any systematic accounting of (i) the erosion and loss of cultivable lands due to such natural disasters? (ii) What is the level of contamination or toxicity induced by such disasters with respect to marine products and consequent human health too? (iii) How in the coastal region, such contamination is carried away upstream in the high tides and induce more contamination in those areas? Food poisioning and even death are common in such flood infested areas. For example, due to economic reasons (mainly low labor cost), dry docks for ship repairing and tarpainting of their lower hull, the toxins are carried away by high tides upstream in adjoining rivers and other outlets, thus contaminating not only the water ways (and the marine biology) but also the subsoil moisture on both sides of the rivers. Outbreak of cholera and other gastrointestinal diseases is quite common. Has there been any systematic accounting of this disease etiology and ecological disaster?

Lack of proper sanitary waste surveillance standard and due to the fact that in the coastal area the drainage of waste products (including the feces) is in the main water stream, pretending that they will be washed away to the bay (or sea) by the low tides, it is quite conceivable that some deadli bacteria invade the subsoil moisture level, making their way to agricultural plots and infecting the crops and vegetables in massive and often fatal ways. E-Coli and hookworms are especially noticable in this respect. In a similar way, feeding of cattles with bacteria infested foods may cause *salmonella* type contamination which can affect the human health due to milk and or meat consumption. In USA, this contamination has been detected from time to time; however, due to an organized surveillance system in USA, a tab on the spread of these diseases is held without much delay. In the Indian subcontinent there may not be as yet an organized network of surveillance to monitor such contamination vigorously, and the outbreak of related deadly diseases in an epidemic level is not that uncommon. Part of the success of such monitoring activity is due to extensive epidemiological studies by not only the academic public health institutions but also the State board of healths and federal health agencies. In the Indian subcontinent, not only the public health awareness (for disease prevention and health promotion) is a minmum but also the government agencies have not come out of the age to meet the challenge imposed by the modern complex world. An essential requirement of this development of public health awareness is the grass-root education at the village to rural level with strong emphasis on agriculture and environmental ecology and epidemiology.

In the interior part of the subcontinent a significant area is arid to desert with severe water scarcity and impacted lifestyles. Not only agriculture is severely affected but also vegetation is impacted to some special types which are compatible in that environment. The population explotion has made the living conditions in this area quite unfriendly to the environment and ecology too. Human waste left in the open area, left at the mercy of the sun god, is often a major threat to public health. The deserts of Rajasthan (India) or south-east of Pakistan are resounding echos of this acute epidemiological problem. The creation of canals to import water from major rivers has elevated the prospect of cultivation to a greater extent but this has also invited the agricultural epidemiology to a driver's seat to join forces with the environmental toxicity and pollution creating impasses for the advancement of healthy environment. Urban pockets with more modern living facilities are consuming more energy, which in turn are pouring more environmental pollution and toxicity. The construction of huge reservors (e.g., Narmada Sagar) have taken away a vast area of cultivable land, disrupted the soil ecology and created an acute ecological imbalance, where again the primary focus needs to be on the agricultural epidemiology.

A vast area, particularly in the coastal planes, is so much infested by (sub-soil) inorganic as well as organic arsenic concentration that it has be come a nightmare not only from agricultural epidemiological perspectives but also from major public health issues. Skin diseases, especially among the working class people who use the contaminated water for all daily necessities but also for drinking and growing vegetables for their survival. Not much has been done to reduce the contamination to a safe threshold level and there has been practically no objective study of the epidemiolocal impact of this arsenic toxicity on our environment and health. This contamination has penetrated human and animals through absorption as well as ingestion modes, thereby calling for more advanced studies of health hazards due to such environmental toxicity.

The demand of more energy for modern life-style has resulted in an exponentially increasing use of traditional coal mining leading to the inhalation toxicity of coal dusts; black lung diseases and lung cancer are on the rise. Secondary sources of fuel/energy such as bio-gas made from sugar-cane have impacted the agricultural system and epidemiology. Traditionally, dried cowdung in conjunction with coal dusts (small particles) and mud were used for making combustable fuels for domestic brick or mud ovens, thus allowing the recycling of cow dung in a natural way. Modern efforts to produce (*gomay*) biofuels have not left out the cow dung! The sun is the ultimate source of energy and it remains to see how that would change the ecology and agricultural epidemiology in the sun-belt countries in the Indian sub-continent.

5. STATISTICAL PERSPECTIVES

In India, development of agricultural research facilities was initiated more than eight decades ago. In the (Pusha) Institute of Agricultural Reseach the prime emphasis has been on the production of more crops using modern scientific methods, and animal husbandry and plant genetics were all incorporated in this effort.

Statistics had a special role in this evolution. Back in the 1930s and 1940s, Professor P.C. Mahalanobis in Calcutta started catering for novel statistical tools for estimating the area under specific crop and their annual yield, while the Panse-Sukhatme team (Indian Agricultural Statistics Research Institute) in Delhi had pioneering efforts in developing sample survey methodology with especial emphasis on agriculture and animal husbandry. A prime boosting came from the blueprint of India's *First Five-Year* Plan in 1950 when Professaor Mahalanobis laid down a concrete statistical master-plan for the urgent growth of agriculture sector (production and economy), thus initiating the 'green revolution' in India in course of the subsequent five-year plans. The creation of National Sample Survey (NSS) Unit, formally under the Indian Statistical Institute, and later on as a separate entity under the central government (of India) has been a milestone in the advent of statistics in agricultural as well as industrial sectors. State Statistical Bureaus were set up in almost all the States of India, and the Central Statistical Organization (CSO) has been designated as the nucleus of all statistical activities to oversee all other State and related organizations. This is indeed a big achievement but there remains a lot more to encounter the uphill task of appraising and coping with the current complexities engulfing agriculture, environment and health sectors.

Formally, the census (count of human population) used to be at regular intervals of ten years. It was felt that in between the census years the figures should be updated, and statistical methods in conjunction with the sample survey tools were evolved to have the projections for the intermediate years. Gradually, more and more items have been added in the census questionnaire to get additional demographic and socio-economic information. I have the feeling that this ramification of census has been adopted to a certain extent in all the countries in the Indian sub-continent. A few natural queries are the following:

1. *How far these tools have been adapted for the census of live-stocks not only including the cattles, sheeps, goats, poultry farms and other domestic animals but also the pets such as cats and dogs?*
2. *Has there been any systematic statistical study of the growth of (non-domestic) rodents over the decades?*
3. *How about the (wild or not) animals without any shelter?* In India, monkeys and other related species, though ecologically helpful, are socially unmanageable, and it may be essential to have some sort of their head count.
4. *How about the distribution of domestic and shelterless animals over different regions?*
5. *What about the consumption of grains and related products to support the live stocks, including poultry?*
6. *What percentage of agricultural products (including vegetables and fruits) are lost at the harvest time by the rampage of non-domestic animals and birds?*
7. *What about the loss of agriculture products due to inadequate transportation facility from the field to suitable storage?*
8. *How much is the rampage of corporated farming over individual or family-wise farming?*
9. *What is the extent of use of modern equipments for cultivation, storage and transportation of agricultural products to markets?*
10. *What statistical picture is available about the retention of agricultural product by the farmers for their family use?*
11. *What is the typical agricultural family composition and the child-labor factor?*
12. *What is the relative poverty picture of agricultural labor compared to industrial labor?*
13. *What is the pattern of transition from agricultural to industrial labors? Is it one way or both? Typically, the landless agricultural labors migrate to industrial jobs, albeit often without any training, and thus ending as the most unskilled ones.*
14. *Is there any chronological pattern in the composition and distraction of agricultural labor over the past 65 years?*
15. *What about the money-lending practice and its role in the modern agriculture system?*
16. *How the contaminated or infected agricultural products are disposed of? Is it possible that a*

greater portion of that is sold in the market in unscrupulous ways? Even it is disposed outside in open trash collection areas, is it not accessable to the street animals and human beggers alike?

17. *How much is the e-waste dumped in open sites which are invaded by metal collectors, mostly children under 15, and systematically despatched to suitable underground brokers (without realizing that they may be subject to radiation toxicity?*

I could proceed in this way with a thousand one queries asking for some clarification and statistical resolutions. However, from statistical perspectives, it may be better to work in cooperation with the government agencies and academic institutions to fathom out a mutually agreeable way to import statistical reasoning in depicting this complex picture and to promote suitable way out for some adaptable resolutions. I know that IASRI and other institutions have developed a bulk of statistical methodology with emphasis on design of experiments and sampling techniques to understand the basis of statistical undercurrents in agriculture. Mathematical (or economic) models for these impacts are useful only when they are capable of producing a synergetic impact picture and are validly adaptable in this macro-agriculture context. However, in this rapidly changing world, we need to be more dynamic, more cooperative with data miners, and more critical of inappropriate routine analysis, especially, in this highly complex macro-system. This is elaborated in the next section.

6. BIO-INFORMATICS EVOLUTION AND AGRICULTURAL STATISTICS

The past two decades have witnessed a phenomenal growth of bio-technology and genomic science, nurtured by the ongoing *information technology* (IT) evolution. The agriculture sector is not outside the domain of the IT evolution. In fact, environmental and epidemiological undercurrents in agricultural science and practice have forced us to think seriously: *Wither statistics in bio-agronomics?* Many a things done in the name of *data mining*, however glittering they may be, often, may not have the full statistical support. It is our responsibility to claim a berth in the IT train by our positively interacting with environmental, epidemiological and genomic studies.

6.1 Mathematical Modeling and Statistical Validity.

Classical modes of planning of agricultural experiments put the prime emphasis on comparative studies with two or more treatments (fertilizers) in relation to their efficacy of production and maintenance of quality. Modern storage facilities of agricultural products demand suitable preservatives to arrest the process of deterioration of edibility and quality. Similarly, the use of pestcides is to protect from infestation of rodents and other insects. Yet the effective impact of preservatives (pesticides) has a life time of their own. This *expiration time* has to balance between the length of life of the product and preservation of food-value or quality. Increasing the preservative or pesticides doses may generally magnify the toxicity (*side-effects*) and cause epidemiological aftermaths. Thus, on one hand, we have the dose versus freshness duration while, on the other hand, we have a different picture of dose versus side-effects. For a statistical modeling, a balance between these to trends is needed for better serving the purpose. A comparatively new element in this arena is the likely *carcinogeneity* of many preservatives and pesticides. Further, these carcinogens are often not easily recognized and their impact may some times be a very slow process but affecting a bigger population served by the affected agricultural system. Recent advances in genomics have shed further lights on the underlying molecular biological activities of such agricultural toxins. Taking in to account the full genomic implications is yet to be accomplished satisfactorily is a challenging task not only for statistics but also for the entire bio-informatics, though the field is flooded with countless number of algorithms, pumping quantitative results by spectacular IT advancements.

A (bio-)mathematical modeling needs to take in to account various explanatory variables and allow stochastics to illustrate the variation in the light of such hidden factors. The dose response relations are hardly linear, even after suitable transformations, while the stochastic errors are not generally normally distributed. Conventional linear models are generally not adaptable, and nonlinear (often heteroscdastic) regression models are used for which nonparametric or robust methods are more appealing (Carroll 1982, Lim *et al.* 2010, 2012). Often, some *stochastic partial differential equations* (SPDE) are advocated, albeit the Gaussian error assumption may not be generally tenable. Much of the environmental toxicology with hidden carcinogeneity can not be studied in conventional agricultural fields and experimentations, as the contamination can escalate in the environment and affect the impacted population. As such, *animal studies* on rodents or other subhuman primates are made on an *accelerated life testing* scheme for assessing carcinogeneity. However, transmitting the findings to agricultural systems with human exposure in very diverse ways brings additional layer of uncertainty in the assessment. In USA, the HIEHS and NIH scientists are carrying out many animal studies for environmental carcinogeneity, and these findings will be helpful for agricultural sciences too. It will be nice to have more information on such animal studies in the context of agricultural systems in the Indian sub-continent. Possibly, very little is known about this, though in the IT sector there is a lot of breakthrough work there.

6.2 Agricultural Epidemiology and Epidemic Models

With modern storage facility and transportation system, toxicity problems are no longer confined to the specific location(s); some contamination due to some deadly virus in some location may cause a crisis at the epidemic level in the entire region. For example, in USA, an E-coli contamination in California was to result in havoc illness across the whole country, but the USDA/FDA surveillance network promptly reduced the epidemic prospect. In UK, the mad-cow disease was identified as a potential epidemic; the contamination was mainly due to the cattles having some deadly virus from their foods and fields where they were located. The government managed to execute a large number of cattles and burn them to control the spread. In the Indian sub-continent, is there any such network which can monitor the origin and spread of any such contamination very effectively? More than that, due to lack of sanitary and hygiene standards of agricultural labors and environmental toxicity affecting storage and distributional facilities, health crisis due to such contamination are not rare. As such, the Western blue print of an epidemic model may be grossly inappropriate in the Indian sub-continent. Intestinal and GI-tract diseases are more prevalent in the Indian sub-continent, and a major part of the contamination is due to the agricultural and water management systems.

6.3 Irrigation and Contamination Modeling

The shortage of rainfall and deforestation have made it necessary to rely more on irrigation. In some case, deep tubewells were used to have more underground water for both domestic consumption and agricultural use. However, gradually the sub-soil water level had shrunken to such a deeper level that not only thode tubewells became unusable but also whatever water was applied to the surface rapidly made their way through the dry porous strata and the subsoil moisture became unsuitable for any agricultural venture. Has there been any sucg study in the Indian subcontinent on the changing topography due to urbinization and their impact on existing agricultural system? Secondly, putting dams in the upstream sides of major rivers, irrigation canals have developed a network of moisturing agricultural fields. on the down-stream side, the river beds have become increasingly dry for a major part of the year, and are perfect breeding grounds for harmful bacteria, compounded by industrial and domestic wastes along the sides of the rivers. Has there been any study in the Indian subcontinent how the dams and canals have built-up big contamination forces not only affecting agricultural system but also human life?

6.4 Plant Breeding and Genetically Engineered Agricultural Products

It is a growing research field to boost production and to eliminate certain undeserving features by genetic engineering. Animal and plant cross-breeding science has been in the focus for a long-time. The genetics and genomics undercurrents, being more and more revealed by the IT evolution, are putting statistics and computer science in a challenging situation in coping with the massive data sets which are generated at an astounding pace and in incredible details. Conventional statistical analysis and modeling tools are often untenable in this *high-dimensional low sample size* (HDLSS) models. Data mining can produce ready-made quatitative answers for agricultural scientists. However, that needs to be statistically validated. In order to do it, statisticians must have adequate background to be engaged in collaborative research with agricultural scientists, and agricultural scientists must be open to the basic understanding of statistical rationaity in their fields of research. Conventional design of experiments may not meet the tenability criterion in such HDLSS setups. This needs to be introduced in academic institutions in conjunction with the need of agricultural science, so that with proper background, more effective collaborative research can be implemented in both academic institution and agricultural research centers. *What is the current standing of interaction of academic institutions and agencies in the Indian sub-continent in this vital respect?* Any reliable data sets which would elaborate this aspect? What about the quality of data collection and standard of data monitoring and data management in the Indian sub-continent? Data collection often rests with multi-level personnel with the basic task mostly left to semi-technical staff, thus creating impasses for valid statistical modeling and analysis.

6.5 Environmental Xenobiotic Impacts

Traditional wisdom used to guide us for assessing the environmental pollution and toxicity effects on agricultural system by bio-chemical perspectives. *Toxicogenomics* and *pharmacogenomics* have changed this outlook con-siderably. For example, in *inflamatory bowel disease* (IBD), contrary to the belief that excessively hot (exotic) spicey food is the carrier of the IBD virus and hot weather is the acceletor, it has been claimed by US and French scientists (Nature May 31, 2001) that a mutation of a gene in chromosome number 16 increases the susceptibility of IBD by 25 per cent. Of course, that finding did not reveal whether or not that particular gene acted alone or there is a group of *disease genes* with possibly that gene as the primary one. Moreover, how that mutation is influenced by the environment and agricultural system? Is it possible that certain agricultural product (*e.g*., certain species of green chili) in conjunction with soil condition and atmospheric climate may be associated with such a mutation? Can it be studied solely epidemiologically? How to supplement such genomic finding with statistical reasoning? It is better if in the Indian subcontinent agricultural epidemiology and biostatistics combine forves to gather a valid and effective picture of the gene-environment interaction.

6.6 Diarrheal Diseases

In some of the coastal areas in India and Pakistan and more noticably in Bangladesh, diarrheal diseses (like cholera, hepatitis, dysentry) are prevalent in specific seasons. The contamination of such deadly virus is mostly due to water ways and agricultural produces. Poor sanitary system also adds to this epidemic. In Bangladesh, there is an international diarrheal diseases center devoted to epidemiological research in this field. In India too there are research centers dealing with diarrheal and GI-tract diseases. In this respect, biostatistics is indispensible in any quantitative study of the rampage of such epidemics and their impact on agricultural system as well as human being. The use of saline vaccine has found to be of help in combatting with the spread of cholera. However, it has also been observed that new strains of the microbes are coming up with mutation of ealier ones, and they are quite resistant to some of the treatments. Naturally, it will be better to incorporate microbiology in conjunction with agriculture sciences to gather more statistical interpretation, consistent with epidemiological anticipations.

6.7 Arsenic Contamination

In the coastal areas of India and Bangladesh, arsenic contamination of ground-water and subsoil moisture is so severe that not only agriculture system is affected but also human life is endangered with absorption and ingestion toxins (Sen 2001a,b,c). For this challenging problem, the government support for a resolution is at best a minimum. Some crude (and cheap) water treatment filters have been introduced in a mini-scale; they simply try to lower the level of contamination in the tubewell water to a so called safe threshold. Even if that were available for the entire affected population it would not have made a satisfactory resolution. First, the treated water is at most adequate for drinking and cooking purposes, leaving all other urgent use of water from other conventional water souces which are contaminated to a greater extent. This contaminated water is escalating the presence of arsenite in agricultural produces, and that in turn is leading to toxic ingestion. Absorption toxicity is due to taking bath, cleaning other items, washing clothes etc. leading to mesothalioma to skin cancer. There has to be a serious scientific study of the extent of impact of arsenic toxicity on agricultural system and human life; statistical considerations are indispensible in this respect.

6.8 Aging Septic Tanks : Sewage Disasters

Septic tank systems are common in vast areas outside metropolitan cities. These tanks, typically, placed 3 to 4 feet underground, separate waste water from solid waste which is stored and broken down by bacteria. The partially treated water exits through perforated pipes and is absorbed and filtered by the soil. The sludge remaining in the tank needs to be pumped out every three to four years. Cheaper septic systems and poor maintenance, as very common in the Indian subcontinent, may fail even earlier, causing untreated water to leak to the surface soil, or even flooding. This can spread viruses and pathogenic bacteria which are carriers of diarrhea, hepatitis, dysentry, and even kidney failure (Sen 2002, ch.1). Overflow to water ways and thereby to agricultural plots and fields, especially during the monsoon season, can be disasterous; no wonder, septic tank failures have been termed *health-hazard time bomb*.

Although, there are many other major issues, it is not possible to enlist or discuss all of them here. Rather, as our main contention, in the next section, we would like to summarize the main line of our thinking in agricultural statistics.

7. SOME CONCLUDING REMARKS

It could be concluded from the discussion in the preceding sections that statistical considerations are most essential to bridge the gap between environmental and epidemiological impact on agricultural practice and science. Unlike laboratory experiments, agricultural system is much less controlled by hypothetical guidelines, and this certainly brings statistics in the basic formulation of the multifactor environmental, epidemiological and socio-economic stressors affecting not only the agriculture system but also human health and quality of life. A mathematical model is not at all tenable, and similarly, an epidemiological assessment may not be consistent with the statistical rationality and interpretation. In the West, many research agencies and universities have been developing statistical models and valid analysis procedures in this complex setup. At the same time, the IT and genomic evolution has tempted the scientists in this interdisciplinary field to surrender to the rampage of data mining. Of course, for handling huge data sets arising in modern interdisciplinary research, one must use advanced computing facility, and data mining is the naturial custodian of this arena. The basic problem is to develop data collection procedures with specific objectives, allow data monitoring and data quality control, so that data mining can lead to at least some reasonable resolution. In the Indian subcontinent, in my estimation, the basic problem is the lack of quality and objective consistent data sets. This needs to be fixed at par with the West and only then one can import their findings and validate that in the Indian subcontinent.

Essentially, our first and foremost task is to have an inventory of the principal environmental (including geo-political and socio-economic) stressors for agricultural system in the Indian subcontinent. Secondly, we need to appraise the impact of these stressors on agricultural epidemiology. Finally, given the network of agricultural environment and epidemiology, with proper emphasis on reliable and objective data collection, statistical modeling of this intricate network, its goodness (or lack) of fit on collected data sets and its scope of applicability are all to be explored. Interaction among the environmental scientists, epidemiologists, agricultural scientists, IT specialists and of course, statisticians at large is obligatory in this context. It is our hope that such an approach is explored more dedicatedly in the Indian subcontinent for their own benefit.

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Discussion of 'Agricultural Epidemiology and Environmental Toxicity: Some Statistical Perspectives' by Pranab K. Sen

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1. INTRODUCTION

The paper deals with environmental toxicology in relation to agricultural epidemiology and human health. After introduction, it covers environmental impacts on agricultural systems, agricultural practices and socio-economic impacts, agricultural epidemiology aspects, statistical perspectives and bioinformatics/ biotechnological impacts. It is commendable in that probably for the first time, particularly in the Indian context, epidemiological problems from the agricultural point of view have been given due attention leading to the emergence of the inter-disciplinary field of 'agricultural epidemiology'. The article raises one thousand and one queries that I feel myself neither competent nor knowledgeable to respond. Nevertheless I am able to see how they seem to have come about at the global level since industrial revolution and while developed countries like USA, Britain, Europe etc., have adequately addressed them to remedy the situation, third-world countries like those in the Indian sub-continent have lagged behind.

In India the issues are basically taken from the point of view of public health domain and agricultural context is rarely addressed. Rural development is no doubt the prime concern of the Central as well as State Governments and innumerable schemes and projects have been undertaken and continue to be on their agenda in which public health figures adequately. For example, Integrated Rural Development (IRDP) project was launched years ago by the Central Government in this context. It is a different matter however that the benefits therefrom have not percolated to the lowest ones in the society i.e. those below the poverty line. Very recently the Government of India has launched National Rural Health Mission (NRHM) to address all problems of health in the country and will shortly extend it to urban areas. On the other hand there has been a mushroom growth of non-government organizations (NGOs) throughout the country who have been taking up public health and hygiene problems as well as other problems of farmers in rural areas to remedy the situation. Some of them like Kheda Milk Cooperatives in Gujarat have made great names in the dairy sector. It would not be possible for me to enumerate all of them but I will take up a few of them. I will thus address in my Discussion several issues emanating from Dr. Sen's paper in sections entitled industrial revolution, green revolution, dialectical approach, environmental toxins and NGOs.

2. INDUSTRIAL REVOLUTION

The central theme running through the paper is the concern due to environmental stresses of various kinds and toxicity introduced due to either ignorance or lack of civic sense or else due to chance. Environmental pollution is an age-old phenomenon first introduced over 200 hundred years ago during the industrial revolution in England. In a recent show at London Olympics it was interesting to see how 'man' was replaced by 'machine' over time because of this revolution. It led to enormous development at several fronts and improved quality of life (QOL) but at a tremendous cost that we are still paying. An example where the revolution impacted the environment at the population level and was corrected by nature itself is the famous phenomena of *industrial melanism* of the peppered moth that I have described elsewhere and in a different context (Narain 2000). Tree trunks covered with lichens occurred all over Britain before the industrial revolution. The typical light–colored peppered moth (*Biston betularia*) when resting on such a trunk or bough by day was almost invisible to birds and thereby got protected whereas the melanic form *carbonaria* was extremely conspicuous and got rapidly eliminated. Since the industrial revolution, the atmosphere of many areas in Britain got progressively polluted by smoke. This resulted in the disappearance of visible lichens from the trunks and boughs of trees and their darkening due to deposition of soot. The light-colored moth when resting on such trees became now extremely conspicuous and was therefore rapidly eliminated by birds but the melanic form *carbonaria* now got protected in the dark background. Natural selection had thus begun to favor it in the new environment instead of the light-colored moths that were previously favored. Such adjustments however do not occur everywhere in different environmental stresses. But the fact remains that environmental pollution is a man-made menace and requires serious consideration at all times.

Another important factor as a fall out of this revolution is the erosion of diversity of life. With growing population and rapid modernization involving land degradation, forest cutting, coastal development and various kinds of other environmental stresses the biodiversity is fast depleting leading to large-scale extinction of some species and declining populations of many of them. To address such problems, an Earth Summit held in June 1992 at Rio de Janerio, Brazil adopted a Biodiversity Convention signed by 154 countries of the world to make sustained efforts to conserve the biological diversity, to use its components on sustainable basis and to attribute value to the biological resources particularly of the developing countries. The first Agricultural Science Congress of the then newly formed National Academy of Agricultural Sciences held at New Delhi debated this Convention wherein some leading scientists of the world participated (Narain 1993). The 20th anniversary of the first Earth Summit was held at Rio de Janerio recently during June 20-22, 2012 wherein heads of state from nearly 200 countries as well as 50,000 activists came to Brazil for the Rio+20 United Nations Conference on Sustainable Development. They released an outcome document entitled 'The Future We Want' with a view to reduce carbon, increase clean energy and address food and water shortages. The world demand of food as well as energy is accelerating at a fast rate with increasing population. .

3. GREEN REVOLUTION

Much more recent is another example of the famous *green revolution* that brought India from a deficit state in grain production to a surplus one. It is a different matter however that in spite of increased crop and milk production, people in rural country-side are poor and hungry. The success story of this revolution is worth discussing in this context. Dr. Norman Borlaug, the Nobel Peace Prize winner in 1970, sent a new plant type (semi-dwarf plant stature) of wheat to India in 1963 that led to varieties like *Lerma Rojo-64A* and *Sonora 64*. When grown with good agronomy, it gave about 5 tons of wheat per hectare in contrast to 1 to 2 tons of yield of the then existing tall varieties. Due to the efforts of Dr. M.S. Swaminathan in initiating National Demonstration Trials at several locations in North India and full support of Union Agriculture Minister Shri C. Subramaniam, India achieved quantum jump in wheat production (Swaminathan 2009). Similar success was reported in rice as well.

Hard-working farmers in states like Punjab, Haryana, and western parts of Uttar Pradesh were so enamored with the new high yielding varieties that they went on applying more and more inorganic fertilizers, particularly nitrogen, in irrigated conditions to obtain still higher yields. This went on for some time but at the cost of deteriorating the health of soils. Thereafter as a consequence, farmers required two to threefold or even more quantity of fertilizer to achieve the same level of yield which they had obtained earlier. This increased the cost of production and recurring loss to them. It is significant to note that the dwarf varieties put more of their energy into grains instead of vegetative parts of the plant increasing thereby the yield but also making it easier for weeds to outgrow them requiring the herbicide treatment necessary. Their reduced root growth makes the plant more sensitive to shortage of water. So while the age old problem of 'lodging of plants' with tall varieties was solved with the advent of dwarf varieties, it created simultaneously problems of soil health and ecosystem due to mandatory application of high-nitrogen fertilizer, irrigation and pest management. The strategy became, over time, environment non-friendly and led to an ecologically unstable system. Moreover, in view of the in-built capital-intensive nature of the green revolution strategy, that is though scale-neutral but not resources-neutral, it led to agricultural growth with non-equity, there being increased disparity between rich and poor farmers (Narain and Sharma 1987).

4. DIALECTICAL APPROACH

To overcome the un-sustainability in such a scenario, I advocated a *dialectical approach* in which the grain production process is looked upon as a two-way process wherein along with studying the effect of the inputs like fertilizer etc., on the yield, it is also required to look into how the production process affects the soil fertility and the ecosystem surrounding the plant - a sort of feedback of the output on the input (Narain 1992; 1997; 2008).

This dialectical view could also be useful for crop residues management. In the traditional agriculture practiced by our farmers over the ages, various forms of fertilization to maintain soil enrichment was a common thing. The soil fertility was maintained by leaving plant residues in the agricultural fields so as to be broken down by decomposition or in some cases burning the plant matter to release the nutrients back into the soil, i.e. burning rice straw in the patties. Plant residues were also used as fodder for livestock and the manure produced by the rural animals was used as a fertilizer. Organic waste materials were either actively composted and/or returned to the agricultural land for decomposition. The organic soil maintenance practices replenish nutrients and retain the microbial diversity needed for sustainable produce yields used by the farmer and the rural community. This simplified rural model reinforces a sustainable metabolic structure resulting in rural ecological balance. In the modern agriculture now adopted by the farmers this aspect of maintenance of soil fertility and health is not given as much attention as needed. This has led to a dialectic metabolic rift between plant produce and soil when the two taken together are regarded as a system in the production process. The two, being biological entities, evolve together in response to their individual needs and the system imparts properties to them as being parts of the system and not as individual parts. By extracting nutrients from the soil and not returning it back to soil in some form, the plant produce creates a metabolic rift in the system that is needed to be broken down to restore the rural ecological balance. Proper crop residues management can be of great help in this direction. Apart from economic considerations moral aspects need not be lost sight off. Increased yields at the cost of such a rift could become a source of un-sustainability that conservation agriculture is attempting to mend.

5. ENVIRONMENTAL TOXINS

The paper mentions, among other things, the lack of appropriate safeguards for controlling environmental toxins from getting into human systems particularly in India. It mentions rightly the surveillance network of organizations in USA like USDA, FDA, NIH and EPA etc. to prevent and control health hazards like the one of *salmonella* type that get into the human system on eating meat and drinking milk from cattle fed with bacteria infested foods. However the most catastrophic agricultural disaster in US history unfolded in the heart of Michigan about four decades ago when cows got sick due to eating PBB (*polybrominated biphenyl*) - a dangerous toxin belonging to the class of endocrine disrupting chemicals that wreak havoc on the system responsible for sending hormones regulating growth, development, tissue function and metabolism - and forced destruction of tens of thousands of cattle contaminated with PBB and allowed the toxin to slip onto the dinner plates and into the drinking glasses of 9 out of 10 Michiganders. Apart from untimely deaths, those surviving are still suffering from various ailments because of long term effect of PBB. The environmental epidemiological research on this issue is going on at Emroy University with no clues as yet. The event was a consequence of a shipping error that occurred in 1973 when 10 to 20 bags of PBB went wrongly into the cattle feed supplement (Red 2012).

6. NGOS

6.1 Indira Community Kitchen

After returning from FAO and establishing himself at the Maharashtra Association for the Cultivation of Science (MACS) at Pune, Prof. P.V. Sukhatme actively worked on nutritional concepts and data analysis to develop a *process view of nutrition* to indicate how the body interacts with the environment provided by food intake, slowing down metabolism on some days and speeding it up on others as occasion demands but always in a manner which enables it to maintain homeostasis. He stressed the importance of intra-individual variability in protein requirement and showed that it has a genetic component (Sukhatme 1982a; Sukhatme and Narain 1982). He also experimented on the question of how the poor can help the poor by organizing themselves in the form of small communities like the model of Indira Community Kitchen (NGO) that he along with others established at Pune.

This model illustrated how a band of 300 employees drawn from the poorest section of the population prepared traditional food articles (chapatti, rice, bhakhari, dal, vegetables, sweets) in the Kitchen, hygienically maintained, and sold them through as many as 10 centers at half the market price. The Kitchen illustrated how labor intensive technology could be used in offering guaranteed employment at market wage rate of Rs. 14 to 15 per day, on an average, keeping the marginal productivity sufficiently positive. Besides, the selling price included a margin of profit of 1 to 2 per cent set aside for future investment for further growth and for expanding the services to meet the needs of poor. The Kitchen was self sufficient and did not ask for any monetary aid or donation or even subsidies from the Government. This NGO demonstrated convincingly how development of Sukhatme's newer concepts in nutrition could be helpful to generate the philosophy that it is only poor who can help themselves.

6.2 An Approach to Rural Development

Prof. Sukhatme further experimented with a view to improve the living conditions of the villages by setting up *balwadis* in few villages where children were shown under the microscope how polluted a sample of drinking water could be. They in turn told it to their parents who got convinced to take action for getting the ponds/wells cleaned. Manual latrine pits were set up to show the way how hygienically the surroundings could be made. His approach to rural development was to aim at appropriate social transformation of rural people who constantly interact with their surroundings to develop a way of life of their own rather than limiting it to providing amenities in the rural areas (Sukhatme 1982b).

6.3 Gujarat Cooperative Milk Marketing Federation (GCMMF)

A very successful enterprise that changed for good the dairying sector of India was the organization of dairy farmers in Kheda district of Gujarat as a cooperative for getting remunerative price of milk thus removing the middle man. It was led by Dr. Verghese Kurien who is regarded as the father of white revolution in India and who passed away very recently at the age of 90. This movement culminated into Gujarat Cooperative Milk Marketing Federation (GCMMF) which today covers all the major milk producing areas of the state with a turn-over of about $2.5 billion. Its brand *Amul* has achieved nation-wide acceptance and use. The Cooperatives not only offer better prices but ensures regular income in the hands of those who tend the cattle viz. the women. It provides veterinary care for the animals as well as heath care of the members of the cooperatives at their doorstep. The Indian Agricultural Statistics Research Institute (IASRI), New Delhi conducted a series of sample surveys to assess the impact of milk producers' cooperatives on milk production and their income (Narain *et al.* 1979) and found that the removal of middle man had improved their status. Dr. Kurien, former Chairman of National Dairy Development Board also established Institute of Rural Management (IRMA) at Anand in Gujarat which is reckoned among the premier professional institutions of the country. The Kurien's model of milk cooperatives has also been replicated in other states like Rajasthan, Uttar Pradesh etc. but not with that much of success.

6.4 Ashoka Trust for Research in Ecology and the Environment (ATREE) at Bangalore - An Approach toward Sustainable Urban Solid Waste Management

Ashoka Trust for Research in Ecology and Environment (ATREE) was founded in 1996 by three professors of the University of Agricultural Sciences, Bangalore and Boston University, USA who had common concern for the fast erosion of India's rich diversity (ATREE 2004). Overtime it grew and started addressing problems of poverty and environmental degradation, climate change and poor government and ineffective policies. The increasing population and development had produced increasing volumes of waste to be managed by the current systems in place but the local solid waste management had not met the excess demand for proper waste disposal creating a backlog of wastes that accumulated within the urban environment. The deterioration of the urban environment reinforced incorrect disposal habits as people did not see their individual impact on such an environment. The concerns of several members of the ATREE research staff living within Sahakaranagar Layout about this growing level of mismanaged solid waste within the layout prompted an Integrated Urban Environment Initiative, Sahakaranagar Layout (IUEISL) in 2006 to build better solid waste management system in a sustainable manner.

The IUEISL aimed to create an improved community based solid waste management program through conducting community awareness and education programs, improving the existing solid waste management program with the construction of a composting/dry waste segregation facility and providing education and sanitary working conditions for employees of the solid waste management program. The goal of IUEISL was to produce high quality urban compost at the new compost and segregation site and sell it back either to the community if there was a market in the layout for it or it could be sold to farmers in the peri-urban environment surrounding Bangalore. By returning some of the nutrients consumed in the urban center to rural agricultural land, the rift in the ecological balance between town and country could be mended. The IUEISL thus tended to correct such a metabolic rift.

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Discussion of 'Agricultural Epidemiology and Environmental Toxicity: Some Statistical Perspectives' by Pranab K. Sen

Discussant : **Shyamal D. Peddada,** NIEHS, North Carolina, USA (peddada@niehs.nih.gov)

1. INTRODUCTION

I congratulate Professor Sen on covering a very broad range of topics that relate either directly or indirectly to agricultural environmental epidemiology. Issues and concerns put forth by Professor Sen are very thought provoking and could potentially impact public health management and policy.

The green revolution that began in the 1960's was timely and forward looking for a developing nation with a fast growing population. With it came several modern agricultural practices, such as, novel farming techniques, the use of genetically engineered crops, increased use of fertilizers and pesticides, etc. Professor Sen described several unintended consequences of such agricultural practices on the environment and public health. Recently, Sarkar *et al*. (2012) conducted a comprehensive study of the impact of modern agricultural practices on ecology and the environment in India. These authors share some of Professor Sen's concerns. Numerous other articles have been published in the literature along these lines (*e.g*. Mancini *et al*. 2009). Some of the issues raised by Professor Sen are not limited to India but are potentially global. Epidemiologists have linked a variety of cancers and other adverse health outcomes to the use of pesticides (*e.g*. Blair and Zahm 1995, Koutros *et al*. 2010). Some examples of diseases that are associated with pesticides include, asthma (*e.g*. Hoppin *et al*. 2009), lung cancer (Alavanja *et al*. 2004), non-Hodgkin's lymphoma (*e.g*. Blair *et al*. 1998), prostate cancer (*e.g.* Van Maele-Fabry and Willems 2004, Meyer *et al*. 2007), Parkinsons's disease (*e.g.* Kamel *et al*. 2007).

Complementing population based epidemiological studies, where it is often hard to control for all the confounders, toxicologists conduct laboratory based controlled studies on cell lines, tissues, and animals (such as zebra fish and rodents) to evaluate toxicity and carcinogenicity of various chemicals, including pesticides. For example, in the 1970's the US Congress established the National Toxicology Program (NTP) to evaluate toxicity and carcinogenicity of chemicals to which the humans are exposed. The NTP developed a cancer bioassay where rats and mice of both sexes are exposed to a chemical for 2 years (the approximate life span) and various tissues within each animal are examined for tumors. This cancer bioassay is regarded as the "gold standard" among industries and regulatory agencies worldwide. While such "low throughput" bioassays are very thorough, they tend to be slow and expensive. For example, a typical inhalation study may cost several million dollars. Not all chemicals to which we are exposed are likely to be toxic or carcinogenic. Hence it may not be time and cost effective to evaluate every chemical using low throughput assays. Only a subset of chemicals may need to be evaluated using the low throughput bioassays. To screen thousands of chemicals in a time and cost effective manner, in its 21st century roadmap the NTP launched quantitative medium and high throughput screening (qMTS and qHTS) assays to prioritize chemicals that would require further evaluation. Experimental units in such assays are typically cell lines, tissues or lower order organisms such as the nematode *C. elegans* rather than the rodents that are used in the NTP's 2-year cancer bioassay. The qMTS and qHTS assays provide dose-response profiles of thousands of chemicals which can then potentially be used to understand biological activity of a chemical at various doses (Inglese *et al*. 2006).

As Professor Sen alluded, there are numerous statistical challenges when evaluating the impact of modern agricultural practices on the environment and public health. It is practically impossible to discuss all the issues raised by Professor Sen. Hence in this article I shall limit my discussion to the statistical issues that arise in the design and analysis of qMTS and qHTS assays and present several open research problems for statisticians to consider.

2. DESIGN AND ANALYSIS OF QUANTITATIVE HIGH THROUGHPUT SCREENING ASSAYS

A high throughput screening assay typically consists of (k+4) plates where each plate contains a total of W wells (*e.g*. 96 or 384 wells). Within each plate, each well corresponds to a test chemical or a vehicle control. Plates are processed sequentially 1 through k+4 with the first two and the last two plates containing cells (or other experimental units) treated by the vehicle control and the intermediate plates, numbered 3 through $k+2$, contain the various test chemicals where dose increases with plate number. For a more detailed description one may refer to Parham *et al*. (2009). The placement of the chemicals on a given plate is largely motivated by the convenience of robotics. Given that the plates are processed in a sequential order 1 through k+4 (which confounds order with dose) and that the location of a chemical on a plate is fixed across all dose groups, there is a potential for spatio-temporal effects on the observed response. Even though the theory of statistical experimental designs is well developed for classical problems, with the exception of Qu (2010), there does not exist any literature on optimal designs for qHTS and qMTS assays. Although Qu (2010) introduced an important row-column design for such high dimensional assays, the objective of his design was to make comparisons among thousands of chemicals, which is not often the goal in toxicological and pharmacological studies. As noted in Lim *et al*. (2012b), a goal of qHTS (and qMTS) assays is to obtain dose-response curves for each chemical and to screen chemicals on the basis of the parameters of the fitted curves. Thus the objectives used in Qu (2010) may not be appropriate for the present purpose and there is a critical need for developing efficient designs that are feasible in the robotic/high-throughput context and "near-optimal" in some sense for a wide region of the parameter space. Multi-stage or designs with some sequential components may be helpful. In the coming years, these assays are expected to be ramped up to process over ten thousand chemicals.

Typically, the expected shape of dose response curve for a chemical in a qHTS (and qMTS) assay is a sigmoidal curve with response plateauing at high doses. Commonly the Hill function, with various alternative representations such as the following, is used for describing a non-increasing dose response relationship:

$$f(x,\theta) = \theta_0 + \theta_1 \frac{\theta_3^{\theta_2}}{\theta_3^{\theta_2} + x_3^{\theta_2}}, \qquad (1)$$

where θ_0 represents the minimum response (*i.e*. as dose $x \to \infty$), $\theta_0 + \theta_1$ denotes the maximum response (*i.e*. at dose $x = 0$), θ_2 is known as the slope parameter and θ_3 is the ED50, *i.e*. the dose corresponding to 50% of the maximum change from baseline. The above model can easily be reparametrized to denote situations where the response is monotonically increasing with dose.

As noted by several authors, such as Williams *et al*. (2007) and Lim *et al*. (2011 *a*, *b*, 2012, 2013 *a*, *b*), nonlinear dose-response models such as (1) present numerical as well as statistical challenges. Note that, unlike linear models, the information matrix in a nonlinear model is a function of the unknown model parameter vector θ. Consequently, a poor solution to the nonlinear least squares problem not only results in a poor point estimate for θ but could also potentially result in poor estimates of their standard errors. For this reason, when performing nonlinear least squares (or maximum likelihood) estimation one needs to solve the optimization problem by taking a very large grid of initial guesses. Of course this makes it computationally challenging in the qHTS assay setting where several thousands of models need to be fitted. A second problem is the reliance on asymptotic theory. Typically qHTS assays are based on small to moderate sample sizes (*e.g*. Parham *et al*. 2009, Xia *et al*. 2008). It is well acknowledged in the statistical literature (*e.g*. Lim *et al*. 2012b) that most asymptotic critical values are generally accurate for moderate tail probabilities but accuracy decreases in the far tails of the distribution which correspond to small levels of significance. Unfortunately, when dealing with high dimensional data (such as qHTS) statistical tests are typically performed at very low levels of significance. Hence standard false discovery controlling procedures such as the Benjamini-Hochberg method (Benjamini and Hochberg 1995) may not perform well in controlling the false discovery rate (see Lim *et al*. 2013a). Although it may be tempting to use a resampling based methodology, such as the bootstrap, to improve the accuracy of the p-values, as described in Lim *et al*. (2013a), it is computationally not feasible.

In addition to performing statistical tests on the model, toxicologists are typically interested in estimating parameters of the Hill model which help them to understand the toxicity of a chemical. Unfortunately, if doses are not properly spaced then it is likely that some of important features of the Hill function may not be properly estimated. The condition number of the information matrix can blow up as seen in the appendix of Lim *et al*. (2013a). This brings us back to the issue of optimal designs for qHTS assays. There is a need for developing optimal design theory that not only takes into account the spatio-temporal biases described earlier in this discussion, but also dose spacing. Unlike standard optimal design theory where a single linear or nonlinear model is fitted, in the present situation we need to fit several thousand of them. As noted in Lim *et al*. (2013a) it may be more natural to explore Bayesian optimal designs in the present context.

3. CONCLUDING REMARKS

Although in this discussion I focused on a very small piece of the big puzzle described by Professor Sen, many such little pieces are probably necessary to understand the big picture. In addition to the computational and statistical challenges described above, there are several other related problems that need to be addressed as we move to the big picture. For example, humans are not exposed to a single toxin (such as a single pesticide) in isolation but are potentially exposed to a mixture or a cocktail of several toxins. At the population level, described by Professor Sen, this is a very complex problem. For example, it is not always easy to identify active components of the cocktail and how different components work together synergistically or additively. Despite considerable literature in this area, researchers are still developing methods to test hypotheses regarding additive and synergistic effects of a mixture of chemicals. As a first step towards such inferences, toxicologists developed concepts such as *relative potency* of a candidate chemical relative to a reference chemical. For a pair of chemicals *A* and *B*, toxicologists often assume that the dose response curve of *A* is simply a translation (along the dose axis) of the dose response curve of *B*. Recently Dinse and Umbach (2011, 2012) discussed the deficiency of such assumptions and hence that of the notion of *relative potency* currently used by toxicologists. Study of mixtures of compounds is a complex problem not only from a statistical analysis point of view but more fundamentally from a statistical design point of view when conducting experiments. This is an active area of research that is generating considerable interest among epidemiologists as well as toxicologists. There are numerous other challenges that need to be addressed along the way as we try to understand our environment and how it impacts our health. For example, as stated by Professor Sen, relating exposure data to genomic data to understand gene by environment interaction is one of the pivotal pieces of the puzzle.

I congratulate Professor Sen for bringing this complex and extremely important topic to the attention of the readership of this journal. I am sure his paper will stimulate considerable interest among researchers interested in the environment and public health. I thank the editor-in-chief Professor V.K. Gupta for inviting me to serve as a discussant.

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Discussion of 'Agricultural Epidemiology and Environmental Toxicity: Some Statistical Perspectives' by Pranab K. Sen

Discussant : **S. Pyne** (spyne@broad.mit.edu)

The essay, 'Agricultural Environmental Epidemiology: Some Statistical Perspectives' by Prof. Pranab K. Sen, makes for fascinating and insightful reading. The author has covered quite a wide range of areas that could be addressed under the rubric of agricultural aspects of epidemiological studies.

My own view on the topic would perhaps begin at a point of reference that is common to many such aspects – to complex, interacting biosystems that surround us – such that in order to plan with a focus on most of the major scientific challenges of the 21st century, a deeper understanding of these biosystems may, I would claim, hold the key. Major problems, both of global and Indian origin, will increasingly revolve around detailed systemic understanding to facilitate planning, allocation and delivery of key and costly resources such as useful information and education, safe and nutritious foods, affordable and well-planned public health, clean energy, and optimally-used natural resources like land, air, and water. Biology and information would jointly cover every aspect of this network of inter-connected systems, a fact which must, therefore, naturally be at the core of designing of epidemiological studies.

A systemic characterization of many of the environmental problems, which are often inter-connected, underscores the multifaceted nature of such challenges. For example, a problem such as arsenic exposure could, and in my opinion, should be viewed not just from an environmental standpoint, but also using perspectives of agriculture, economics, energy, public health and policy. While arsenic ingestion through drinking of groundwater may primarily affect populations belonging to certain regions or socio-economic backgrounds, when the same metalloid starts to appear, say, in rice, for reasons of usage of groundwater for irrigation that might be linked to local politics and economics, then the effects spread fast through the system leading to a much wider and more unsuspecting range of exposure among the human and animal populations.

Similarly, systems biomedicine is an emerging approach of biomedical research that is capable of addressing issues of complexity and heterogeneity of health patterns which may be observed in terms of interactions between people and their environments. It seeks to understand diseases as states that result from the perturbation of biosystems, often modeled as multi-level networks that can propagate effects from single molecules to entire mechanisms and species, caused by different pathological factors such as an environmental carcinogen. Thus we can test the effects of lower level or early stage modulation of developmental and pathological processes in terms of outcomes that are measurable higher up or at later stage in the system. In other words, while a system-level understanding is more painstaking, and may call for dealing with the noise and complexity that are inherent in most systems, it could also facilitate designing of more robust and effective solutions.

When it comes to rationally accounting for noise, complexity and stochastic variations in the observations of any real-life system, it is primarily the statisticians, along with engineers and information theorists, who may have the adequate experience and expertise that are, at least in this respect, lacking among most other disciplines which traditionally tended to view noise, etc., as somewhat of a nuisance. This provides the statisticians with a unique advantage to assume more visionary and exploratory roles in designing new and robust methods for systems-level experimentation and analysis. Such advances can aid in gaining key insights into different mechanisms of stresses that the complex biosystems are subjected to, and use models that can capture precisely how specific effects of the stresses are propagated, thus leading to potentially more effective solutions.

I would therefore welcome statistical perspectives on the systems-level understanding of the environmental problems mentioned in the assay. The advantages of such an approach lie in the facts that (i) many interacting systems may share similar features and characteristics, and thus new methodology developed for one system may be relatively easily re-fashioned for application to several others, (ii) the systems-level solutions are more likely to be robust and sustainable, (iii) it can provide frameworks for modeling the course of evolution, i.e. the dynamics, of the problems that appear in the systems, and finally (iv) new technological and analytical advances are now supporting the means for detailed observation of and experimentation with different states of complex biosystems.

Let me end with touching upon some of the advances in technological platforms that may be used towards such investigations. Microbiome studies are gaining in popularity not only for providing novel insights into entire microbial communities that are present in humans, animals and plants but also shedding new light on the composition of the environments that surround them and how such interactions affect immunity and health in general. Similarly metabolomic studies are being increasingly used for unbiased identification of hundreds of small biochemical compounds, e.g. xenobiotics, phytochemicals, etc., in a wide range of studies for biomarker detection, agriculture, nutrition and food safety, and general profiling of health conditions in many natural biosystems.

While technological advances continue to enrich the field of genomics, studies of the epigenome, which records a variety of dietary, lifestyle, behavioral, and social cues, are emerging to provide a major interface between the environment and the genome. Epigenetic variation, whether genetically or environmentally determined, could contribute to key inter-individual variations in gene expression and thus to variation in the risks of common complex diseases. Thus epigenetic epidemiology studies are being conducted worldwide to investigate the developmental origins of health and disease. India, which leads the world with its burden of Type 2 Diabetes and metabolic syndrome, alongside its high prevalence of chronic malnutrition, rapidly changing lifestyles and a variety of dietary and environmental exposures, must pursue projects involving large cohorts, e.g. prospective studies, such that public health policy may be determined accordingly. In this regard, one might also emphasize on modernization of rural, semi-urban and urban planning, food and water distribution systems, and waste management.

Finally, the essay does not prominently mention about the need for informatics systems that can be key to providing the backbone for statistical analysis and optimal decision-making. Sophisticated monitoring and surveillance of biosystems could benefit not only from established geographical information systems but also involve such new platforms as remote sensing, mobile telephony, and social networks. The recent infrastructure of National Knowledge Network of India could be used to integrate information from many diverse but related perspectives – ecology, climate, health, agriculture and economics. By developing rigorous analytical methods for integrative analyses of multiple sources of information, we can hope to gain useful understanding of many of the complex problems that we face in the 21st century as listed in the essay.

Discussion of 'Agricultural Epidemiology and Environmental Toxicity: Some Statistical Perspectives' by Pranab K. Sen

Discussant: **BK Sinha,** ISI, Kolkata
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This draft paper by Professor PK Sen is written in a lucid style and it brings attention of the readers to the current state of affairs in environmental epidemiology arising out of scenarios caused by changing agricultural practices in the Indian subcontinent.

As regards environmental situation in the Indian subcontinent, it has been reported by the World Bank that prior to 1995, documentation and monitoring was at its worse; however, between 1995-2005 there has been fastest progress in addressing environmental issues and improving environmental quality.

Professor Sen has rightly pointed out that in the agricultural sectors, economic development [by dint of effective utilization of modern techniques and technologies] and pressure of growing population have caused major environmental issues such as: Forest & Agri. Degradation of Land / Resource Depletion [water/ mineral/forest/sand/rocks]/ Environmental Degradation

/ Loss of Biodiversity / Loss of Resilience in Eco–Systems / Fuel Adulteration / Solid Waste Pollution / Noise Pollution / Land Pollution /……

According to Professor Sen, the reasons are not far to reach out: Rampant Burning of Fuel-wood & Biomass / Lack of organized waste and garbage removal services / Poor management operations /Lack of Sewage Treatment Operations / Lack of Flood Control & Monsoon Water Drainage System / Diversion of Consumer Waste into Rivers / Cremation Practices near Major Rivers / Operation of High Emission Plants /Polluting Old Public Transports / Cyclones / Annual Monsoon Floods / ……

The following points may be noted in the form of supplementary information.

(a) As a follow-up of the World Summit in Rio-de-Janeiro, Indian Law took a serious note of Environmental Issues and the Central Pollution Control Board was established.

On the other hand, as regards Forestry and Forestry Products, Indian Forest Act was made effective. Prior to 1980, forest identification was 'Forest-in-name-only'. Based on Space Satellite / Remote Sensing of Real Forest Cover, Major Classification was made possible: Forest Cover/ Very Dense Forest/Moderately Dense Forest / Open Forest / Mangrove Cover/Non-Forest Land Further, Scrub Cover / Tree Cover / Trees outside Forest were also classified.

(b) It may be noted that the First Satellite Recorded Forest Cover Data for India was available in1987 though Landsat MSS [US Cooperation] data was made available in 2001. It is interesting to note that Indian Forest Census Data has been made available in 2007.

(c) It has been quite some time back that Ministry of Environment & Forests was established in 1985. National Forest Policy came into effect in the 1990's while National Forest Commission was formally established in 2003.

(d) It is encouraging to note that a number of NGOs are operating in India for assessing Environmental Pollution.

(i) Bombay Natural History Society [BNHS] has the Mission: To disseminate knowledge of flora & fauna / To study wildlife related problems / To recommend management plans for conservation of wildlife and its habitat.

(ii) Centre for Environmental Education [CEE] has the primary mission: To create environmental awareness

(iii) Centre for Science & Environment [CSE]: Deals with pollution/forest/wildlife/land & water use

(iv) CP Ramaswami Environmental Centre: promotes environmental awareness

(v) Development Alternatives : Pollution monitoring & control/waste recycling management/wasteland development

(vi) Friendicoes: Society for the eradication of cruelty to animals : Rescue/feed/medicate all injured/abused/ownerless animals; promote adoption programs for animals/sterilization of stray dogs/running mobile clinics in slum areas

(vii) Green Future Foundation: Environmental protection/energy & ecological conservation/ pollution control

(e) Besides, there are Indian Association for Environmental Management / Madras Naturalists Foundation / Narmada Bachao Andalon / Nilgiri Wildlife & Environment Association / The Energy & Resources Institute [TERI]. TERI has a provision forWorld Wide Fund for Nature Study

(f) As regards schools, we have School of Env. Science / School of Env. Studies / Centre for Water Resources Development & Management

(g) Again, there are a number of Research Labs. : Indian Institute of Petroleum [IIP] / Central Fuel Research Institute [CFRI] / Nat'l Env. Engg. Research Instt. [NEERI] / Unistar : Env. Research Lab – Recognized by MoEF [Vapi, Gujarat] / Mc D Built Env. Research Lab., Bangalore / Env. Testing Laboratories / Span Hydrotech Pvt. Ltd. Pune / Geo Enviro Solutions, Chennai

(h) As regards Government initiative, the Ministry of Environment & Forests [MOEF] looks after: Planning/Promoting/Coordinating/Overseeing and Implementation of Environmental & Forestry Programmes; Conservation & Survey of Flora & Fauna/Forests/Wilderness Areas; Prevention & Control of Pollution/Deforestation/Land Degradation.

All said and done, the need of the Day…..

(i) Co-ordination among Central & Line Ministries, Labs, Research Institutions, NGOs;

(ii) Establishment of a Forum for Cross Validation & Cross Checking of data gathered through different governmental and private initiatives.

Discussion of 'Agricultural Epidemiology and Environmental Toxicity: Some Statistical Perspectives' by Pranab K. Sen

Discussant: **Ratan Dasgupta,** ISI, Kolkata (ratandasgupta@gmail.com)

Agriculture and environment are interconnected topics having an impact on socio-economic system. This review paper touched a number of major concerns; let us discuss some of the important issues.

'Plant trees for better tomorrows' is a popular slogan we are hearing for years, although the ultimate result is not very encouraging in India till now; some recent works on arsenic mapping of underground water is already in progress. Rain water harvesting, solar energy, Ganga river action plans etc. is not unheard of these days, and these are creating some level of awareness regarding the environment around us. Sometimes for the sake of rapid development and immediate requirement of human need, adjustment of natural processes has to be made, be it East or West; the question is to what extent such diversions are advisable. This can be decided by an alert administration in consultation with experts, after analyzing the risk of changing the concerned natural processes, in the light of past experiences. In this scenario we the statisticians have a role to play in analysing relevant data in a balanced manner without any tilt. Such analysis should not only reveal the present picture, but also shed light on possible alternatives available and their adequacy to fulfil the present and future requirements.

Many important issues related to environment pollution has found place in Professor Sen's erudite article, the topic of plastic pollution is however missing, and this pollution can now be traced even to deep sea water. Indiscriminate disposal of polythene bags, rather than recycling, is one of the main reasons to clog underground rain water drainage pipes, and this nuisance is a health hazard. Disposal of plastics into the marine environment kills many sea creatures every year. A major portion of trash dumped in ocean is plastic. Plastic takes many years to decompose and continues to pollute the environment for a long time.

Fission based nuclear energy is associated with radiation risk. Research on alternative fusion based nuclear energy free from radiation hazard, is of immense importance.

Generation wise suffering amongst a poor segment of society is seen for addiction to country liquor; toxicology of this is often fatal. How predominant is this menace amongst workers in agriculture and other sectors, may require a survey to find. Education and a sense of awareness to the young mind from primary school level may tilt the balance for a better social scenario.

Black fume pollution from iron extraction factories from ores paints the plant leaves in nearby forests into black, covering these by carbon dust e.g., in and around the industrial area of Giridih, Jharkhand; among others, only in rainy season the natural green leaves are seen. To what extent this iron factories exhaust pollution affects the quality of agricultural products in nearby the industrial belt remains to be seen.

Some of the environment perils are manmade like unplanned deforestation, and some are nature induced, like flood devastation subsequent to heavy rain, earthquake, tsunami, forest fires etc. Proper planning with infrastructure to encounter the latter devastation, over which we have little or no control, may minimise the suffering. This also includes the former for which human responsibility is major.

High yielding and improved varieties of crops are welcome to meet higher demand, but domestic varieties need not be wiped out the altogether. These may go side by side. Even today the curly shaped sour variety *desi* tomato is in high demand in local markets in Kolkata even at a higher price from willing consumers. It is possible (to be checked by researchers) that the *desi* variety of tomato contains more vitamin C compared to relatively tasteless variety. Cultivations of paddy and fish were simultaneous in submersible low land of Bengal and other states before rampant use of chemical pesticides. Development of alternative potent herbal pesticides that will adapt to the environment is required. Minimising adverse effect of chemical insecticide / fertilizer should be further researched upon, as such adverse effect on land and environment may get accumulated over time.

Some flood resistant varieties of paddy are still cultivated in submersible low land in eastern region of Indian subcontinent. Height of paddy plant would increase, along with raise in flood water level within a limit; plant top still remaining above water. The Assam Agricultural University has developed two varieties of paddy named as *Jalashree* and *Jalkuwari*, which can withstand complete submergence for more than a week. Some indigenous rice varieties like *Neriguli* of Varada basin of Karnataka is reported to be highly flood resistant, these can stay submerged in water for weeks up to months; the grass blades rot and the stalks sprout once again when the water level recedes. Further research in these flood resistance and high yielding varieties would benefit a lot of farmers.

Dieticians are of the opinion that rice and dal (made into *khitchri*, a vegetarian hotchpotch) is nearly balanced diet for vegetarians. Those who do visit the interiors of Indian villages in eastern part know that small fish from local water bodies used to constitute a part of their daily meal. It may not be out of place to share an admission from an interior village-lad years back. When asked what, his meal was for the day, he replied 'rice, small fish fry, and small fish curry'. 'Anything else', asked the gentleman from city; 'well, a sour dish made of tamarind and small fish' was the reply. Slightly astonished, the gentleman asked, 'Didn't you take dal today? The little boy answered 'we are not *babu* (rich man)'. The costs of pulses are high compared to small fishes available in interior villages; poor persons still go for fishing in local water bodies for supporting daily meal. Organised pisciculture with government support will greatly benefit the poor on ownership basis.

Absence of healthy look may not always be an indication of lack of proper food; it may also be due to lack of healthcare: ignorance to combat infection from giardia, worm, amebiosis etc. A majority of giardia infections is usually associated with poor hygiene, sanitation, and ingestion of contaminated water. Good food, if not properly assimilated in the body in absence of healthy habits, is of no use. Proper health education and its implementation is important, otherwise balanced food and other supporting materials are essentially wasted, propagation of that awareness may be done by educating the little kids from primary school level onward, those who can insist up on other family members at home. Such education to kids is seen to be effective in 'no smoking zone' implementation in public places, and even at home, offenders shy away in front of informed kids.

Soybean is cheap and protein enriched food for midday meal program in schools; a jolt in school kitchen seems to be in view due to proposed price hike of cooking gas. This requires immediate attention.

A popular backyard tree with medicinal value in many homes is Drumstick; its flowers, sticks, leaves are rich in protein, vitamins, minerals. Curry preparation of this is tasty and good for expecting mothers. Villagers may be encouraged to plant and utilise the products from this tree to eradicate protein deficiency.

Reluctance to family control in villagers is mainly due to ignorance. Living standard and family size are associated. The housemaids travelling daily from distant villages by morning trains to help in domestic work for the rich category of the society in cities do not prefer a large family, taking the clue from their employers in city. Central Drug Research Institute has developed world's first non steroidal *'Saheli'* oral birth control pill to be taken twice a week on fixed days for the first three months, followed by one pill in a week thereafter. *Saheli* does not have the short term side effects like nausea, vomiting, and weight gain etc., which are commonly reported with the other oral contraceptive pills. The only side effects reported with *Saheli* (Centchroman) is the delay in the menstrual cycles in around 8% of the cases. *Saheli* is priced at Rs.16/- for a cycle of 8 pills. So, cost is about Rs.8/- per month, from fourth month onward for a reversible and effective birth control. Among so many environmental stressors, exponential growth of population is the main, feeding so many mouths causes drastic scarcity of the available resources. Awareness of these affordable options of birth control among the mass is essential. Centron is another brand name of the oral pill containing centchroman.

Forced and extreme birth control may not go well in a democracy like India and may cause untold suffering to old generation among others; there is nobody to look after an aged person in case of a family mishap, as seen in our neighbour China.

Development and exploitation are associated with education. There are many primary schools in the interior areas these days, but the teacher student ratio is sometimes alarmingly low, especially in disturbed areas inhabited by poor segment of society. Sometimes a single teacher has to run the entire primary school, including office work. One may then imagine the standard of education rendered. This part needs to be looked into. There is almost always some clash of interest between the native and migrated population, problems of this type is imminent in several regions in India. Scarcity of resources and opportunities are the main causes for conflict of interest.

Agriculture and industry may not always have a clash of interest, a meeting point may not be that allusive if the concerned parties are sincere for a solution; a big corporate sector is now exploiting the possibility of land requirement from adjacent state of Jharkhand (where land is not that fertile for agriculture and may be spared for industry), after a dispute over land with West Bengal government.

Educating the mass to combat on excessive environmental and ecological damages is essential, so as to have their participation in damage control. Such efforts are not uncommon, but surely scanty compared to requirement. School and college student with government experts from city may conduct regular program, after taking appropriate precaution and training, to make their counterpart in villages aware in these important issues. Such environment management participation of students is common in a number of countries including USA, Canada, and Tanzania.

Environment contamination via harmful chemical has reached such a level that the vultures are now almost extinct in Kolkata city. Even several years back a number of them could be seen nested on the tall tree tops near Victoria Memorial.

Public awareness has a positive impact on environment and ecological issues; in section 5 the author has recorded 17 such queries. A survey may first be undertaken to investigate the level of public awareness on environment, ecology and agricultural issues for shaping remedial measures by policy makers, at the base level. Participation by local club members to propagate latest development in agriculture, environment and related areas may enhance the awareness. Popular discussions on T.V. channels may play an important role to create such awareness.

Several years back bird flu disease affecting ducks and chicken propagated like an epidemic in eastern India. However, it has not reappeared very recently. Suitability of modelling these via epidemic process may be studied.

In most of the agricultural land in rural India the farms are divided into small plots, as a result the land used in boundary demarcation is wasted. This part may be compared over different states for appropriate ranking. The other side of the study being, sometimes field boundary act as refugia for grassland plant species diversity, protecting environment balance. An appropriate assessment of this in Indian context may be of interest.

Discussion of 'Agricultural Epidemiology and Environmental Toxicity: Some Statistical Perspectives' by Pranab K. Sen

Discussant: **GVS Murthy,** IIPH, Hyderabad (murthy.gvs@iiph.org)

It is nice to read the paper entitled "Agricultural Environmental Epidemiology: Some Statistical Perspectives." It is indeed good that the author addresses an important problem in the context of Indian agriculture. However, too wide a scope would tend to equate agriculture as defined by the author with ecology. After carefully reading the article, it seems that it could be better titled as 'Effect/Impact of Environmental Epidemiology on Agriculture'.

For increasing the scope and impact of this important article, it would have been better to look at what statistical techniques would be most useful to study in the impact of environmental epidemiology on agriculture. And for the sake of completeness, it would also be of importance to mention about the data requirements for making the statistical tools applicable. Though arsenic is an extremely important soil pollutant it is not clear why only arsenic has been highlighted. It would be useful to mention that arsenic is being showcased as an example.

Environmental Impacts

It has been mentioned that dengue results from water contamination. This would sound erroneous to readers as the only role that water has in dengue epidemiology is that the Aedes mosquito breeding is facilitated by stagnation of water in containers/ water bodies. Otherwise, there is no relation of contamination to dengue. At the most it could relate to environmental sanitation with respect to disposal of cans and allowing water to stagnate in artificial containers including air-coolers, etc.

A classic disease which is related to soil erosion in the foothills of the Himalayas is Iodine-Deficiency Disorders which has wide ranging consequences on pregnancy outcomes and intellectual output. Advocating consumption of Iodised salt in India has, therefore, gained significance for many reasons. Further amongst the gases mentioned, sulfur dioxide is important and needs to be included.

Agricultural Practices

Author should have used the term ‘illiterate’ in preference to the term used ‘little educated.’ In the past in India, the harvest cycles were limited to only 1 or 2 crops a year and that only in the river basins and Gangetic plains as there were no facilities for irrigation and the entire agricultural produce was dependent on rainfall. Moreover, the needs of the population from the agricultural basins were limited to agriculture providing food for sustenance and, therefore, the quantum of produce was limited. It is only from the 19^{th} century that the number of crops has increased.

The high fertility rate should also be linked to the fact that each extra hand at home was a helping hand as families tilled their own land and there was no mechanization. Also because of high mortality rates, families tended to produce more children as a ‘safety net’. The high fertility rate should not be dismissed as being the consequence of the ‘only form of entertainment at night’ but should be more importantly viewed from the economic perspective.

Agricultural Epidemiology

It will be important to mention mass destruction of crops due to infestation – Examples of potato blight, etc. Here is an excellent opportunity to dwell on the economic perspective of agricultural epidemiology by linking the effect of natural disasters and crop failures and debt to farmer suicides. What statistical methods would be useful in these circumstances would be very useful.

There is a significant body of evidence today of the causative role of arsenic in gall bladder cancers in the Gangetic plains. This fact should find a place in the article.

When agriculture is being viewed in a wider context, other health conditions like anthrax, bovine tuberculosis on the one hand and ‘mad-cow disease,’ avian flu and swine flu on the other merit attention. The mass culling of birds and pigs which are grown in pens for food consumption would have significant impact on agriculture related economy.

There has been a transition of disease because of environmental pollution of waters used for agriculture. A classic example is tape worm which should not be seen in vegetarians who do not ingest animal meat from which tapeworm originates. However, many vegetarians in Delhi are diagnosed with cysticercosis.

Statistical Perspectives

This section is of critical importance. The section should highlight some of the following issues:

What is the role of descriptive statistics in environmental epidemiology related to agriculture? How should data on environmental pollution be presented statistically – Which statistic is more important – for example mean levels or median levels? What additional information should the Census collect? What statistical tools including modeling techniques will be more useful for agricultural epidemiology?

Finally, the manuscript would provide an excellent resource if referenced as the readers would have an opportunity to look at cross references to further their knowledge.

Rejoinder

Pranab K. Sen

I am overwhelmed with the critical, constructive and most useful comments and in depth discussions of Professor Prem Narain, Dr. Shyamal D Peddada, Professor Bikas K. Sinha, Professor Ratan Dasgupta, Professor GVS Murthy and Dr. S. Pyne. Indeed the epidemiological and environmental aspects of agricultural systems (including practice) are so intricate and so much infected with lack of proper quantification, especially in the Indian sub-continent and China, that a thorough statistical appraisal is more than necessary. It is impossible to go into more mathematical gymnastics at this stage; rather, raising the basic issues and inviting the experts' views on them were my primary objectives. *If winter is here can spring be far away!*

I confess that my observations are from a broader perspective and viewed from a global stand-point. I am delighted to know the developments in India regarding the environmental and epidemiological perspectives, and it would be nice to bridge the gap between such ventures and the vast domain of statistical science. I love to have some feedback from experts in Pakistan, Bangladesh, Nepal, Sri Lanka and Myanmar on these issues. Being primarily in the area of statistical science and raising the flags on such nonstandard statistical perspectives in this broad domain of agricultural statistics, I thought that connecting the epidemiological and environmental impacts on agricultural systems would perhaps pave the way for more interacting statistical quantification of this complex setup. My task was to draw this composite picture without being digressed too far into the woods of public health in other connected areas, such as nutrition, public health practice, health administration, disease prevention and health promotion, which are also intricately related to agricultural systems, particularly in this part of our mother planet. Whatever statistical thoughts which could be imparted at this stage may appear to be perplexing and controversial at best, but it is in this venture a more interactive approach might come out - that's my hope and heartfelt desire.

As such, in response to Dr. Murthy's detailed comments, I would only touch the statistical aspects, leaving the major task of public health practice aspects with the recently established Public Health Foundation of India and its daughter institutes. Incidentally, the All India Institute of Hygiene and Public Health, the oldest one in India, appraised some of these public health practice aspects over the past 60 years. It is a classical example of how it combined epidemiology and biostatistics to start with so as to strengthen the role of quantitative objective studies in this highly interactive field of human health and environment. Time has come to assess how much it can be re-organized to come in the forefront of quantitative appraisal in India. Some of the faculty there in the 1950s and 1960s were already internationally reputed, but after their departure, the tradition did not last to its full impression. Regarding the iodine-deficiency disorder in the Himalayan footheels and its impact on child-birth (which comes under *maternal and child health* discipline) as well as *developmental biology* (which comes under biomedical and clinical science), I like to know more about such pictures not only in India (and Nepal) but also in surrounding (south and east Asian) countries. Has there been any thorough and scientifically objective investigation on the topographical diversity of this soil-erosion problem, its interaction with altitude and sub-soil moisture level, climatic diversity, and countless number of extraneous factors which could, when studied in synergy in a valid and robust statistical manner, provide useful information to combat this serious environmental problem affecting not only the agricultural system but also threatening the survival of all creatures on earth?

Let me go a few more steps in this direction: In the West, cutting down some particular trees (useful for paper and pulp industries and home building too) is done in a planned way. For example, if a particular tree takes about 20 years to grow to its full height and girth, then systematically and serially about five percent of the area is planned statistically for cutting down the fully grown trees, clearing the debris left behind, and planting their roots for attaining the full growth of the next generation. This way, the forest reserve is maintained at a more or less stationary level, without seriously uprooting the normal ecological balance. In this way, intrudors may not have the upper hand to halt the preservation process. On the other hand, I have a feeling that the sheer burden of population, poverty level, available land for cultivation and desparation for survival (cooking and heating fuel necessities) the deforestation is not planned nor the process of improving the system is given any priority. Take another classical example: Game fishing in river inlets in USA/ Canada. There is a strict rule that for each species, if a catch has some underaged ones, they should released immediately in to the waters so that they will acquire their full growth and also contribute to the growth of their respective school of species. Do we have a policy equally rational, enforced strictly? One of the reasons why the huge and regular shipments of fishes from Bangladesh and Myanmar to the West, in spite of deep freezing immediately after the catch, are often rejected by the consumers. The problem is that the water used in deep freezing may be so contaminated that harmful bacteria can make their way to the destination. I have a feeling shipments of seafood from China has the same basic problem - whereas the exodus of Chinese population can provide some commercial scope, the Western people with a difierent chemistry of immunity are voicing their concern more often than expected on chance grounds.

As regards Dr. Murthy's pertinent point on laying more emphasis on statistical perspectives, I whole-heartedly agree. This is the very basic reason mingled with my sincere hope that this appraisal with discussion may lead to more in depth statistical insight on other interacting aspects. Is it not expected that public health and environmental health institutions and agencies in these countries should bring these issues to the attention of statisticians, bring them in the arena to comprehend the underlying complexities, and work together to forsee a workable solution.

My understanding of this Journal (JISAS) is that it has been doing a commending developmental job on some statistical methodology along with genetic studies in relation to crop estimation, agricultural and horticultural suveys, design of such studies etc., in far greater mathematical and computational details. It's the time to expand this domain by the alignment of agricultural epidemiology and agricultural environmental perspective with due emphasis on toxicology and the ongoing evolution of toxico-genomics and pharmaco-genomics. If we could initiate such an interacting publication platform in JISAS, that would, in my estimation, be a solid step to align JISAS with the contemporary journals in the West.

I am grateful to Professor Prem Narain and Bikas Sinha for providing the detailed information on developing institutes and agencies in India to handle some of these issues. I am also aware of the International Diarrheal Disease Research Center in Dhaka, Bangladesh, which under an international consortium, has been carrying out a significant job in this sector with some inclusion of statistical appraisals. It has been observed that old treatment regimes are not of much utility in this fast changing environment, and cholera is intricately connected with water contamination and infection, thus being linked to agricultural system. My impression is that there is ample room to impart more statistical insights in this much needed task. Can we seperate water contamination, environmental pollution and agricultural dysfunction? Can we disregard the change in the microbe world even after the rise and fall of antibiotics over the past 70 years? This is where statistical appraisal is extremely important, and that's why the basic understanding of agricultural epidemiology and agricultural envionmental health science is a prerequisite for statisticians to work hand in hand with such interdisciplinary researchers. In the same way, such interdisciplinary researchers won't be able to fathom out the underlying statistical complexity and proper quantification without the cooperation of knowledgeable statisticians. I am happy with the provided list of institutes and agencies in India dealing with such applied aspects, and it will be nice to see how far statistical appraisal has been documented and developed in this context.

I am grateful to Dr. Pyne and Ratan Dasgupta for their dicussions. In fact, even in respect of durable agricultural foods, storage and preservative facilities are a must now. Do we have good statistical evaluation of toxicological perspectives in India where the climatic conditions, energy resources and water contamination may be quite different from the West. We need more statistical modelling, sampling design and analysis protocols. With respect to the impact of agricultural practice and food habits in India, diabetis has become a number one source of health disorder. Where is the statistical evaluation of the sampling design, clinical trials and environmental impacts of diabetes in the Indian sub-continent? Things are not that different in China? Do we need to pay adequate attention to this growing problem? Has there been any statistical investigation (clinical trial) on the age distribution of identified Type I diabets, their parents genetic effect, their diet pattern and living environment and their expectation of life picture? This interactive picture may tell us more on the agricultural epidemiological impact. The same features may pertain to type II diabetes - their detected diabetic starting age and living environment may have strong agricultural and epidemiological undercurrents. For diabets, at mature age, the condition can be more pathetic due to the fact that heart diseases, blindness and other disorders generally create a more complex chronic disorder with much less life expetation. Should it not be a general and primary public health issue and can it be scientifically investigated without the support of epidemiology and biostatistics?

Knowingly or not, we all have been trapped in the IT magic world under a false impression : All problems in every walk of life and science can be charted by using algorithms in abundance along with all fancy IT apparetus. We can boost agricultural outputs by genetic engineering, organic fertilizers and IT climatic manipulations. At the end of the day we will perhaps realise that we have been converted in to algoritms but recall that all creatures from living ones to mechanos have all limited life and in almost all of the cases, the length of life is stochastic. India and China have both remarcable strength in IT and that has boosted the economy in both the countries. On the other hand, the IT wonderworld has created serious social problems, disrupted traditional family life, created tremendous income inequality, and greater barriers for the agriculture sector. In this social environment the growth of agriculture economy will be highly impacted by the socio-economic disparities created by the darker face of IT. Agricultural products will be increasingly costlier, forcing the less afluent people to sacrifice some part of their quality of life. Agricultural environment will be increasingly polluted by the growing bipolar society and lack of affordability of possibly as high as 90 percent of the people. That may induce epidemiological disasters mingled with environmental health problems. They are coming up even in more afluent countries like USA, but there are some brakes in the West to combat that tug of war, only in short-term made-up resolutions. In the Indian sub-continent this is likely to be a greater problem - nobody likes to have a collapse of our gradually improving agriculture system mined to a certain extent by the strong epidemiological and environmental undercurrents. I think that it is the high time for agricultural scientist and epidemiology and environmental health sciences researchers and administrators to heed to meaningful and adaptable statistical rationality and technical tools to foster more valid data collection, data interpretation, data monitoring and data quality control. Only then statistical science can find its right place in this complex interdisciplinary field. JISAS has the obligation to take a driver’s seat in this reaspect and the State Statistical Bureaus be charged to update their data driven conclusions in a more rational and reliable manner. The designs for such studies may not follow the standard design of experiments of conventional agricultural studies, the acquired data set may not pertain to any standard model, and standard statistical methodology may need considerable ramification to suit valid statistical analysis of such complex survey data sets. Thus Statistics should be proactive in agricultural epidemiology and agricultural environmental studies.