Keynote Address

Agriculture for Greater Economic Growth

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The theme "*Agriculture for Greater Economic Growth*" reflects the following:

a) 44% of Sri Lanka land mass of 6.5 million hectares is suitable for agricultural production
b) 80% of Sri Lankan population is rural and 75% of this number is involved in agriculture
c) Agriculture provides employment to around 30% of the workforce.
d) The aquatic resource base includes a territorial sea of 21,500 km^2 and an exclusive economic zone of 517,000 km^2.

The above possibly creates the ambience that economic growth could be enhanced by these resources. Agriculture's share of GDP has been on a slide over a long period and currently stands at a mere 11%. The question then is can agriculture enhance its contribution and change its current trajectory. It is difficult to believe that this is possible but agriculture revenue and profits can certainly be increased substantially. Again agriculture would to a large extent depend on the area available for production and the efficient utilization of these resources.

Looking at the composition of agriculture it encompasses a wide range of crops, herbs and fruits that we harvest and in a wider sense includes forestry and fisheries, both fresh water and salt water. The fishing industry, the largest area available for utilization is really in the ocean and thus fisheries is the single largest source for enhancing economic growth. Sri Lankans are no doubt aware of the numerous conflicts that are going on within our economic zone, with poaching by fishing fleets from a number of countries. There was an old belief that fish around Sri Lanka died of old age. Is this really true? Have we enforced adequate safeguards to ensure that the spawning grounds of the fish around the island are safeguarded? The use of unauthorized net types and explosives - do they carry adequate penalties and strict enforcement? Are we conscious on the need to prevent pollution of the waters which would be a potential threat to the marine life? Thus in addition to providing boats, fishing gear and technology there remains a large number of issues which needs resolution in terms of sustainability. If these are addressed and investments facilitated for an aquaculture industry perhaps we could see a substantial improvement in the fishing subsector and hence agriculture's contribution to GDP. The Maldives has focused on the need to safeguard their fish resources which are worth emulating. They have -

- Adopted ecologically sustainable fisheries management measures based on best scientific evidence available, to ensure the attainment of maximum economic and social benefit from the sector while conserving resources for future generations.
- Formulated and implemented a Code of Conduct for responsible fisheries to ensure effective conservation, management and development of fishery resources, with due respect for ecosystem and biodiversity.
- Also established an effective technology-based system for Monitoring, Control and Surveillance (MCS) to ensure that all fishing activities are carried out in a manner consistent with national legislation and in conformity with international laws.
- Management responsibilities too have been vested at community level with the aim of Government Institutions and communities working together to develop conservation and management of the fisheries sector.

The 2.7 million hectares of agricultural and marginal land

In a recent presentation by Dr. Indrajith Coomaraswamy at the discussion on Economic Policy and the need for Reforms organized by the Liberal Party of Sri Lanka. He stated – I Quote "a major area of concern is our overall productivity. Agricultural productivity is just about half of that of Thailand. The government has recognized the sector's importance as it absorbs one third of the labour force but government must also register the fact that it only accounts for 11% of GDP. This means that the productivity in agriculture is only one third of the national average which is anyway very low" Unquote. This emphasizes the need to increase productivity.

When the government focuses on increasing production it is also need to focus on markets. It is a common theme in Sri Lanka where, for example, tomato farmers in the Matale area produce a surplus at a particular point of time which they are unable to sell. Will an increase in production exacerbate this situation? Similarly we have seen this has happened with vegetable farmers who have dumped large volumes of vegetables as they were unable to sell. In addressing this issue we need to take heed that globally food production needs to be increased by around 70% by the year 2030 and that the era of cheap food is said to be over. This is in the face of diminishing agricultural land as a result of conversion to urban utilization.

The above underscores the need for better planning and the availability of information to the farming community about market prices and projected market prices based on production after the collation of information of crops planted in different areas. This means that evaluation of the potential crops in different ecosystems be researched and farmers in each area kept abreast of what the farmers in other areas, both in the vicinity and in different Provinces are cultivating. Estimates of the time during which the produce would come to the market could be used to project the potential movement in prices. Some work in this area is being done by the University of Colombo in collaboration with Prof. Athula Ginige, Professor of Information Technology - School of Computing & Mathematics, University of Western Sydney, Australia. This kind of information will ultimately result in the most productive crop for an ecosystem being cultivated of course with the possibility that other areas may leverage early or late seasons where price advantages could be worked out. Information should be available to farmers on a commercial basis thus inculcating in their minds that these decisions are commercial and therefore, entirely theirs and no one is obliged to buy the entirety of their crop or guarantee prices. Certainly some safeguards would be useful but that should not be the reason why different crops are cultivated.

Looking back at agriculture up to the 19th century the cultivation process did not have constraints of land. Arable areas continued to be expanded to meet increasing demand for food. But with the population growth, increased trade in agricultural commodities and availability of new land suspect, the need for improvement in productivity became apparent. With this, agriculture changed in the first half of the 20th century propelled by the development of cheap fertilizer, access to plenty of water and chemicals to control both weeds and insects. Mendels Genetic theory was fine-tuned and contributed to the development of improved seed which in turn propelled productivity. These inputs enhanced agricultural productivity four or five fold by the end of the 20th century. Sri Lanka was no exception. The challenges today are entirely different. The arable land area is diminishing, water which was plentifully available is now in short supply, cheap fertilizer is no longer an option as the base raw material for fertilizer which is petroleum has recorded substantial increases in price. Further pesticides are under intense scrutiny by authorities. A major factor which drives the need for improvement of productivity is however, the increased demand for food and food security. Global warming which threatens food production however, projects the scourge of malnutrition and famine which could once again rear its ugly head.

Numerous studies and allegations leveled at the supply chain in the agricultural sector, sometimes unfairly with poorly collected and analyzed data lacking remedial measures and to approach these issues has been a huge problem. For example, the recent incident of attribution of the chronic kidney disease which was due to arsenic the finger was pointed at the pesticide industry. Similarly last week it was reported that the Sri Lankan rice have the second highest level of cadmium in a study of most rice producing countries and Bangladesh is said to be ahead of us. Over the last year there was an impact of climatic change in the paddy sector where the large farms have been operated. The seasons have witnessed minor shifts but this has impacted the paddy sector as the window for harvesting, which is normally a dry period has had inordinate rain. Then again excess rain has fallen on the crop at the time of planting submerging large tracts of paddy and destroying vegetables. The impact of these climatic change issues in addition to higher temperatures has had an adverse impact on production. Taking paddy as an example, overall production which was over 4 million tons in 2011 has dropped by 10-15% and surpluses for which we did not have adequate storage facility has mercifully been reduced.

There are several macro issues which need to be addressed in order to improve agriculture's contribution to economic growth. The first issue is land. The fragmentation of land has become a major problem. For example average landholding in the paddy sector is less than an acre. In an economy where per capita income is projected to be at US $ 4,000/- within the next five years, how will the farmer with such a small landholding make up his income? The cost of cultivation of an acre currently is marginally around Rs. 55,000/- and the fertilizer subsidy reduces this to around Rs. 45,000/-. Gross revenue assuming 100 bushels per acre which works out at a little over 5 tons per hectare would be Rs. 67,000/- leaving a margin to the farmer of Rs. 22,000/-. Our national average of paddy production is around 4.2 tons which differential would impact on revenue by nearly Rs. 10,000/-. Therefore, farmers income could be anything between Rs. 10,000 – 15,000/- per season, i.e. Rs. 30,000/- per year which is a mere US $ 240/- per annum. One needs to enhance this by a further US $ 350/- taking cognizance of the fact that cultivation costs includes labour wages. In this scenario will farmers continue to cultivate their land? Perhaps they would if they have no other option.

The second issue is the availability of labour flowing from potential earnings by the farmer. The availability of labour is a major issue. The shortage of labour needs to be addressed with continuing mechanization of repetitive backbreaking work. Mechanization is not possible with the current landholdings. All of these issues point in favour of consolidation of land for very little thought has been given. In fact the converse is true as even the available larger blocks of land continue to be fragmented.

In addressing each one of these concerns and in developing remedies the best option available would be to detail how we have addressed each of these issues in the farms that CIC manage. Firstly, look at the question of total revenue of the farm and also revenue per acre. Accordingly CIC have tried to optimize land utilization, by undertaking different activities in the highland area and focusing on seed paddy production in the lowlands which was our mandate. In the highland areas we applied rain water harvesting methodologies and converted the land mass in to different zones depending on soil condition as well as availability of water. CIC developed an integrated model of horticultural products, animal husbandry initiatives and also enhanced the growth of nitrogen fixing plants with sustainability in mind. With the optimization of land use we have different revenue streams from fruit, vegetables, milk, chicken, eggs, agro tourism and training.

In the paddy sector CIC undertook an accelerated programme for developing new hybrid rice varieties with export potential, keeping an eye on the high price realization by rice varieties such as basmati. We have developed a red basmati type rice which finds favour in export markets yielding a price of little over a dollar per kg. We have got a number of other rice varieties in the pipeline with improved fibre, mineral and glycemic indexes. We have also developed a 90 day variety with potential to yield over 10 tons per hectare. Currently we cultivate 1,500 acres of paddy per annum. Our average yields per hectare have varied but under good conditions we have produced 8.2 tons which is virtually double the national average and easily the highest yield in the region. As a seed producer we continue to grow varieties as required by the seed market and not necessarily the high yielding varieties. This has depressed overall yields. We have thus pursued both volume and price which has enhanced revenue.

The next issue is water management. In our highland crops we now focus on profit per litre of water. This methodology has helped us to improve water use. For example – CIC have cultivated around 50 acres of pineapple at Pelwehera, in the past. The crop was impacted by a drought as we were unable to put in adequate water. Consequently, fruit size dropped from 1300 gm to 700 gm which directly impacted on our sales and bottom line, as revenue from pineapple per acre is substantial in comparison to other crops. After numerous trials on water management we have now formalized the protocol wherein we could manage the pineapple with a little over 20% of the water that was required earlier. With this initiative we are once again ready to roll out a cultivation programme for pineapple in the dry zone. Dwelling into water management CIC group of companies were pioneers in the development of Sprinklers and Drip Irrigation methodologies having acquired knowhow from the success models operated by Israeli Farmers.

We have also been conscious that irrigated fields do not respond to water in the same way it responds to rainfall. If you are a gardener you will notice how plants rejuvenate themselves when a rain comes down. We have now developed an option to improve the absorbability of water by breaking down the lattice structure of delivered water to mimic natural spring water. The lattice structure in drip systems is said to have between 12-15 molecules whereas spring water would be 4-6 molecules. This perhaps explains the tea brewed in Nuwara Eliya would be different to the chorine packed water used for brewing in Colombo. Current experiments are with simple methodologies to improve the absorbability of water by disrupting the lattice structure. The higher temperatures will have an impact on the carbon availability of water which needs to be addressed in a different way. Scientists need to look at this matter. The efforts in water management in paddy has yielded around a 25% saving in water which is substantial considering it takes nearly 6 tons of water to produce one kilo of rice. Consequently, we have been able to cultivate near 60% of the land in each Yala season, contributing to enhanced surpluses.

The plants are dependent on non-mineral nutrients and mineral nutrients. The fertilizer subsidy is geared to the macronutrient component of mineral nutrients. The impression has been created in minds of the farming community that feeding plants with these macronutrients is the tool for improving productivity. The fertilizer utilization efficiency in this country is less than 30%, thus of the 210 kg of fertilizer we apply in an acre of paddy, only 70 kg is said to be used by the plants using a utilization model. The balance 140 kg goes waste polluting our waterways and rivers virtually poisoning drinking water. The nitrate content of ground water in some areas is reported to have reached near toxic levels. The fertilizer subsidy amounts to nearly 1% of our GDP and the continuous misuse does have an adverse reaction on the environment. In the paddy sector we have addressed this to some measure and continue numerous trials to reduce application of fertilizer, as we did not receive the benefit of subsidized fertilizer.

When we took over the Hingurakgoda farm the organic content in the fields was less than 1%. This is to be expected considering that we are a medium intensity ultraviolet light country, coupled with heavy rainfall, both of which tend to destroy and wash away organic matter. In the farms under our control organic matter is now a little over 3%. We have reaped the rewards in that our production as stated earlier is over 8 tons per hectare. In order to enhance the organic content in the soils we have developed a dairy herd. Initially our focus was only the cow dung from which we generated around 2,000 tons of compost per annum. Looking at the revenue potential we have now focused on milk production as well. Our average yield per buffalo when we started was a mere 2-3 litres, today our average yield is around 8.5 litres. We continued with a vigorous artificial insemination programme and have consequently improved the genetic makeup of our herd. Some of the new animals now yield 14 litres per day and we project that we would take our average milk yield to 12 litres per animal in the short term. We are focusing on a temperature management, nutrition management program and now to grow substantial areas of high quality feed material. The dairy will now be a major revenue stream for us in the future while contributing to better soil management.

Again in the rice area we have continued to carry out numerous trials to develop a different methodology for the delivery of fertilizer to the paddy. Here we have taken note of the Washington State University study where by increasing photosynthesis they were able to produce 35% more grain and the findings by the Michigan State University that foliar feed is 8-10 times more effective in terms of speed with which nutrients are utilized. The world has seen tremendous improvements in surfactant technology which has been applied to the Pesticide industry and unfortunately not the fertilizer industry because of the cost proposition. Scientists should look at the transfer of fertilizer via the leaves which improves fertilizer uptake.

Finally the very contentious area is the pesticides. The global pesticide industry has taken giant steps in the development of molecules which have very specific application focus, unlike the earlier generation of molecules which were wide spectrum, quantities applied too has seen dramatic reductions. Unrecommended use of pesticides by various individuals however, remains a huge problem. The industry continues to spend time and a lot of effort with education programmes on 'Dos and Don'ts and application methodologies. But these continue to be violated due to poor infrastructure such as monitoring services. Facilities for testing residual pesticides in food are either non-existent or ineffective. Consequently, some persons tend to spray Pesticides at inappropriate times violating recommendations even though harmful to the consumer. Sometimes diluted solutions, sometimes greater concentrations are used with adverse results. Modern agriculture is built on the management of pests as well. Therefore, pesticides are an important component. The improper use of pesticides needs greater inputs in addition to the excellent regulatory frame work now in place.

In our supervised fields and in the farmer outreach fields we continue to pursue minimum use of pesticides and consequently have developed a reputation as marketing vegetables and fruits of superior quality.

Another area that we have addressed is the export of rice. Coupled to this we are currently developing protocols for the cultivation of fruit. The development that we have finalized with regards pineapple similarly another two key fruit varieties need to cover are mango and banana and a host of other indigenous fruits. In this area we have leveraged the skills available in the tissue culture laboratory in developing methodologies promoting quicker generation of planting material as an option to grafting. We are in the process of cultivating experimental one acre plots of mango, guava and sour sup where we could manage the soil in which the plants are grown, the water and fertilizer inputs. We are also conscious of the need to reduce plant size and are experimenting with a closer planting methodology which will not only enhance the ease of picking of fruit but also improve production per acre by a minimum of two times. Banana is a further crop in which we have mastered the current global technology and now look to implement our learning into indigenous varieties. All of these initiatives are targeted at improving the gross revenue of the lands under our control while taking note of enhanced labour charges and the needed productivity.

Floriculture is another area in which we have excelled currently. Our tissue culture laboratory generates plants of wild flowers of Australia which we export back to that country. This is inaddition to foliage exports and a Joint Venture we are building in Dubai to access the Middle Eastern market using a wide range of plants available in this country. Basically we are contriving to leverage the potential of indigenous varieties which are less susceptible to pests and diseases. The indigenous plant population in this country is really our 'green gold'. We have leveraged on these varieties by investing in Science & Technology giving the pride of place to Ayurveda.

Samahan which we manufacture is a classic example. There is really no product of its class globally. It is a mix of herbs used for thousands of years, refined using modern methodologies of extraction blending and standardization. Similarly we manufacture Sudantha, a herbal toothpaste which is well on its way to be the leader globally in its class of herbal toothpaste.

These two examples are value added component to agricultural produce, available in the country which could contribute substantial revenue to agriculture. It is unfortunate that we have not developed the production requirements of our agri industry other than rice.

The final stage that we have to look at is storage, food processing and value addition. In the rice processing area we have installed a state-of-the-art Satake Rice Processing Mill which has enabled us to reach out to export markets. We are looking at expanding this processing facility thus adding substantial value to the paddy farmers and also to the overall economy. With these initiatives we have not only increased production and our own revenue. By providing farmers with good quality seed paddy we have enhanced their yields. We have computed the value of the increased yields at around 20 bushels per acre which considering the volume of seed we have supplied, works out to the addition of over One Billion Rupees to the rural farming community.

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Hazardous Pesticides in Agriculture and its impact on Human Health

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Man in the struggle for supremacy over other living beings has used his skills to assist him in his fight against pests, such as insects, which have a 200 million year evolutionary edge over him. Some of these pests destroy his food and transmit deadly diseases which include malaria and plague.

The value of chemical substances in their fight against pests was realized quite early by man. A papyrus of 1500 B.C. has recorded formulae for preparation of insecticides against lice, fleas and wasps.

However, the recent chemical pesticide use was started during the industrial and scientific revolution of the nineteenth century. In 1867, the farmers in the United States applied an arsenical poison "Paris Green" to protect potato farms from the Colorado beetle. In 1882, Millardet demonstrated the value of Bordeaux mixture as a fungicide. In 1897, the French vine-grower Bonnet applied copper sulphate to kill Charlock. The discovery of the insecticidal dichlorodiphenyltrichloroethane (DDT) by Paul Muller in 1939 has truly opened the chemical pesticide era.

In spite of using over 30 billion US dollars worth of pesticides, the Food and Agricultural Organization has estimated that one third of food supplies of the world is lost to pests and diseases. This amounts to as high as 35% for wheat, 24% for sugar beet and 40% for
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potatoes. Effective control of pests is therefore essential to provide adequate food for the increasing population.

A pesticide is defined as any substance or a mixture of substances intended for preventing, destroying or controlling of any pest including vectors of human or animal disease, unwanted species of plant or animals causing harm during or otherwise interfering with the production, processing, storage, transport or marketing of food, agricultural commodities, wood and wood products or animal foodstuffs or which may be administered to animals for the control of insects, arachnids or other pests in or on their bodies.

The term includes substances intended for use as a plant growth regulator, defoliant, desiccant or agent for thinning food or preventing the premature fall of fruit, and substances applied to crops either before or after harvest to protect the commodity from deterioration during storage and transport.

Pesticide poisoning is a global problem. The exact number of victims of pesticide poisoning is difficult to assess. In 1973, the World Health Organization (WHO) expert committee on "Safe use of pesticides" estimated worldwide there were as many as 500,000 cases of pesticide poisoning and about 5,000 deaths. In 1986, the WHO estimated that the number of unintentional acute pesticide poisoning victims globally was around one million resulting in 20,000 deaths.

A few years ago the Economic and Social Commission of Asia and the Pacific (ESCAP) indicated that the incidence of pesticide poisoning could be as high as two million a year resulting in forty thousand deaths. Every minute someone in an economically underdeveloped country is poisoned by a pesticide. Nearly 85% of the world pesticide production is consumed in the industrialized countries. Yet, the incidence of pesticide poisoning is 13 times higher in developing countries.

Pesticides have five main areas of use in Sri Lanka. They are widely used in public health programmes to kill vectors of malaria and filariasis. Secondly, pesticides are used for domestic and personal purposes for application to kill, for example; insects like cockroaches, or on the skin, to control scabies or head lice. Thirdly, they are used for fumigation of houses, ships and buildings. Fourthly, pesticides are used for the protection of material by incorporating in paint, timber, glue and leather to prevent or retard attacks by insects or fungi. Finally, in agricultural production, on garden crops, livestock and agricultural produce pesticides are widely used.

The usefulness of pesticide to man is proven beyond doubt. Even in early seventies it was claimed that DDT used against anopheline mosquito had already saved 15 million people from death due to malaria. Sri Lanka almost eradicated malaria with the help of DDT in early 1960s.

Although Sri Lanka has not yet achieved the goal of self sufficiency in food, in the seventies and eighties the paddy production has almost doubled. For example, the average yield of paddy which was 1.7 metric tons per hectare in 1965 was increased to 3.5 in 1985. Improved crop varieties, fertilizer and pesticides have all helped in this increased yield of paddy.

At present the world consumption of pesticides is approximately 2.5 billion kilos and it is estimated that as many as 25 million agricultural workers worldwide experience unintentional pesticide poisoning each year in spite of various pesticide regulation schemes in different countries.

Until 1962 there had been no regulation of pesticides import or use in Sri Lanka. At the time most of the pesticides were imported for malaria control and for the use in tea plantations. In 1963, the controller of imports and exports has limited the foreign exchange allowed for import of agrochemicals to Rs. 5.23 million. This decision has met with protest from importers and the government in response appointed a committee to look into the issue resulting in the preparation of a list of "Drugs, Chemicals and Proprietary preparations required for the agriculture" to avoid any effect on local agriculture production.

The introduction of more liberal economic policies after 1977 has demonstrated the urgent need for pesticide control legislation. With the change in economic policies the import of pesticides to the country increased dramatically by 237%, from 2166 tons in 1976 to 5144 tons in 1979, far exceeding the actual requirement of the country. Although the pesticide imports fell over the next few years one can imagine the potential problems, including opening doors for unscrupulous traders, brought about by open market policies with no regulations.

The Sri Lanka government introduced the Control of Pesticide Act No. 33 in 1980, one of the best legislations in Asia.

This Act provided for the appointment of a Registrar of Pesticides (ROP) to regulate the importation, formulation, packing, labeling storage, transportation, sale and use of pesticides. The act provided for the appointing of a ten-member pesticide formulary committee to advise the ROP. Although the pesticide control act was approved by the parliament in 1980, due to various logistical reasons it was only in 1983 the Registrar of Pesticides was appointed and pesticide regulation was initiated.

Since enactment of the Control of Pesticides act the Controller of Imports has referred import applications for pesticides to the Ministry of Agriculture.

The health effects of pesticides depend on the type of pesticide. Some, such as the organophosphates and carbamates, affect the nervous system. Others may irritate the skin or eyes. Others may affect the hormone or endocrine system in the body.

Acute exposure to pesticides can lead to death or serious illness. Chronic pesticide exposure is most often a problem in the occupational setting, particularly among poor rural populations where men, women, and children all work and live in close proximity to fields and orchards where chemicals are applied and stored.

Long-term exposure to pesticides can increase the risk of developmental and reproductive disorders, immune-system disruption, endocrine disruption, impaired nervous-system function, and development of certain cancers. Children are at higher risk from exposure than are adults.

Pesticides, when not judiciously used, may disrupt natural biological pest control mechanisms. More vigorous pest attacks may result, along with heavier chemical use, and increased health exposures. Pesticides, as well as fertilizers, can infiltrate water sources – contaminating drinking water and animal species, e.g. fish, upon which humans rely for nutrition. Such contamination can lead to a range of secondary public health impacts.

Pesticides may cause acute and delayed health effects in workers who are exposed. Pesticide exposure can cause a variety of adverse health effects, ranging from simple irritation of the skin and eyes to more severe effects such as affecting the nervous system, mimicking hormones causing reproductive problems, and also causing cancer.

A systematic review in 2007 found that "most studies on non-Hodgkin lymphoma and leukaemia showed positive associations with pesticide exposure" and thus concluded that cosmetic use of pesticides should be decreased. Strong evidence also exists for other negative outcomes from pesticide exposure including neurological, birth defects, fetal death and neurodevelopmental disorder.

The World Health Organization and the UN Environment Programme estimate that each year, 3 million workers in agriculture in the developing world experience severe poisoning from pesticides, about 18,000 of whom die. According to one study, as many as 25 million workers in developing countries may suffer mild pesticide poisoning yearly.

One study found pesticide self-poisoning the method of choice in one third of suicides worldwide, and recommended, among other things, more restrictions on the types of pesticides that are most harmful to humans.

A 2007 study by the California Department of Public Health found that women in the first eight weeks of pregnancy who live near farm fields sprayed with the organochlorine pesticides dicofol and endosulfan are several times more likely to give birth to children with autism.

Since chlorinated hydrocarbon pesticides dissolve in fats and are not excreted, organisms tend to retain them almost indefinitely. Biological magnification is the process whereby these chlorinated hydrocarbons (pesticides) are more concentrated at each level of the food chain. Among marine animals, pesticide concentrations are higher in carnivorous fishes, and even more so in the fish-eating birds and mammals at the top of the ecological pyramid.

Unintentional poisonings kill an estimated 355 000 people globally each year. In developing countries – where two thirds of these deaths occur – such poisonings are associated strongly with excessive exposure to, and inappropriate use of, toxic chemicals. In many such settings, toxic chemicals may be emitted directly into soil, air, and water – from industrial processes, pulp and paper plants, tanning operations, mining, and unsustainable forms of agriculture – at levels or rates well in excess of those tolerable to human health.

People are exposed to various potentially toxic agents and conditions in their natural and occupational environments. These agents may be physical or chemical, may enter the human body through oral, inhalational, or transdermal routes, and may exert effects on all organ systems. Several well-known as well as lesser known associations exist between chronic kidney disease (CKD) and both environmental agents and conditions, such as heavy metals, industrial chemicals, elevated ambient temperatures, and infections. The effects of these agents may be modulated by genetic susceptibility and other co-morbid conditions and may lead to the development of acute CKD.

Pesticide use raises a number of environmental concerns. Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species, including non-target species, air, water and soil. Pesticide drift occurs when pesticides suspended in the air as particles are carried by wind to other areas, potentially contaminating them. Pesticides are one of the causes of water pollution, and some pesticides are persistent organic pollutants and contribute to soil contamination.

In 1956, an unusual clustering of chronic tubulointerstitial kidney disease was observed in villages, families, and households in northwest Bulgaria. The disease was so focal that within an affected town, there would be individual households experiencing the disease next to households that were not. In addition, there was no racial, ethnic, or religious predilection for the disease. Another feature of the disease is its long incubation period. Affected individuals must live in the area for 15 to 20 years.

Therefore, it has neither been identified in children nor in adults who leave the area before reaching the age of 20 years. Finally, those with the disease were at a markedly increased risk of developing upper urinary tract tumors.

This disease was initially called "endemic Vratza nephritis," and was subsequently identified in Yugoslavia and discrete regions of Romania. Reflecting this wider geographic distribution, although still confined to the plains of the Danube Rivers, it was later renamed Balkan endemic nephropathy.

Balkan endemic nephropathy is a tubulointerstitial nephropathy with a slow progression after an insidious presentation.

The cause of Balkan endemic nephropathy remains subject to debate. One early hypothesis was contamination of food in endemic areas by ochratoxin A, a toxin produced by molds that belong to the Aspergillus or Penicilium fungal genera.

I mentioned Balkan endemic nephropathy because today there is a major debate as to what is the aetiolgy of the dreaded Chronic Kidney Disease of unknown origin (CKDu) spreading in some parts of Sri Lanka.

The last WHO report dated June 2011 discusses the relationship between Pesticides and Chronic Kidney Disease This report concluded that '*exposure to a combination of factors which are toxic to Kidney seems to cause this kidney disease. Toxic factors identified up to now include, nephrotoxic agrochemicals, arsenic and cadmium. It also recommends to control of the sale of agrochemicals which are known to be nephrotoxic e.g. Propanil, chlopyrifos and others*'.

However, in 2013 the Ministry of Health through the Ministry of Agriculture has submitted a detail report of the studies carried out by WHO in Sri Lanka on un identified Kidney disease. According to this report the Ministry of Health has informed the Cabinet of Ministers that they cannot be certain of the causal agent of CKDu from the WHO report.

The final WHO report states "*Nephrotoxic pesticides **may be aggravating** the progression of the disease* (page 45).

The report also states that pesticides contain minimum of 0.01 and maximum of 94.98 parts per billion (ppb) of Arsenic from 26 pesticide samples that they have analyzed from CKDu areas and 0.01-13.15 ppb of Arsenic from 26 samples analyzed from other areas. Since average or distribution of the data is not provided no inference can be made from these data. The amounts of arsenic found in pesticides are within the normal range found in other countries too.

WHO final report also indicate that pesticide residues have been found in people with CKDu as well as people from control areas. Some pesticide residues are found in urine of tested people but no link of pesticides with CKDu. In fact the presence of some residues of pesticides which are not even used in Sri Lanka make the validity of these data very doubtful in the context of kidney disease.

Following statement in the final report summarizes the findings of the WHO.

"*These finding may support the contention that chronic exposure to low levels of Cd may be playing a role in causation of CKDu in Sri Lanka. Co-exposure to As is likely to aggravate the effect Cd on the kidney making the changes More pronounced than exposure to Cd alone*".

Considering the above the Registrar of Pesticides in collaboration with the Pesticides Advisory Committee has decided that there is no conclusive scientific evidence linking CKDu and pesticides.

Arsenic in rice is a natural phenomenon. Arsenic is an abundant natural element found everywhere in the world. In Soil water, plant animals etc. Rice has a natural tendency to accumulate relative more arsenic as it grows in anaerobic conditions. Industrial Technology Institute and Kyoto University tested rice from all over the country and from CKDu endemic areas and found the arsenic levels in our rice is much lower than what is found in many other countries of the world.

Impurities of arsenic and other heavy metals are not unusual phenomena in pesticides. Literature shows pesticides in other countries too have similar levels of heavy metals. Internationally ppb levels of impurities are not tested in pesticides.

The Ministry of Health has informed the cabinet of ministers that they cannot conclude the cause of CKDu from the WHO report and hence the cause of CKDu is still uncertain.

According to senior nephrologist in the Kandy General Hospital the cause of CKDu is multifactorial.

No group has established a link between CKDu and pesticides. They all have mentioned pesticides as a potential suspect in addition to many other factors.

Local evidence by geologist suggests there is no difference in levels of arsenic in agricultural and non agricultural soils.

Recent ban on importing four pesticides (Carbofuran, Carbaryl, Chlorpyriphos and Propanil) is not due to any link with CKDu but they are high volume pesticides and crop research stations have found out better and low volume pesticides for the control of same pests.

Undoubtedly pesticides are harmful to humans if improperly used.

What should happen in future? Integrated Pest Management (IPM) strategies can reduce the use of agrochemicals, improve management, and optimize ecosystem mechanisms for pest control/soil enrichment – simultaneously protecting both farmers and the environment.

Future pesticide regulation scheme in Sri Lanka include more in house quality testing of pesticides, monitoring of pesticide residues in food and regulatory support for lowering of pesticide use in the country.

There should be policies to improve regulation and control of pesticide sale, distribution, and use. The health care systems should identify, treat, and monitor cases of pesticide poisonings. Educational/advocacy tools should be developed to inform the public as well as agriculture and health-care workers about health risks and best practice use of agrochemicals.

The global conventions on the management of highly toxic chemicals, including certain pesticides, from production to disposal stages should be implemented. These include: the Stockholm Convention on Persistent Organic Pollutants; the Rotterdam Convention on Prior Informed Consent Procedure for Certain Hazardous Chemicals in International Trade, and the Basel Convention on the Control of Transboundary Movements of Hazardous Waste and their Disposal.

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Safe Use of Genetic Engineering for Agricultural Production

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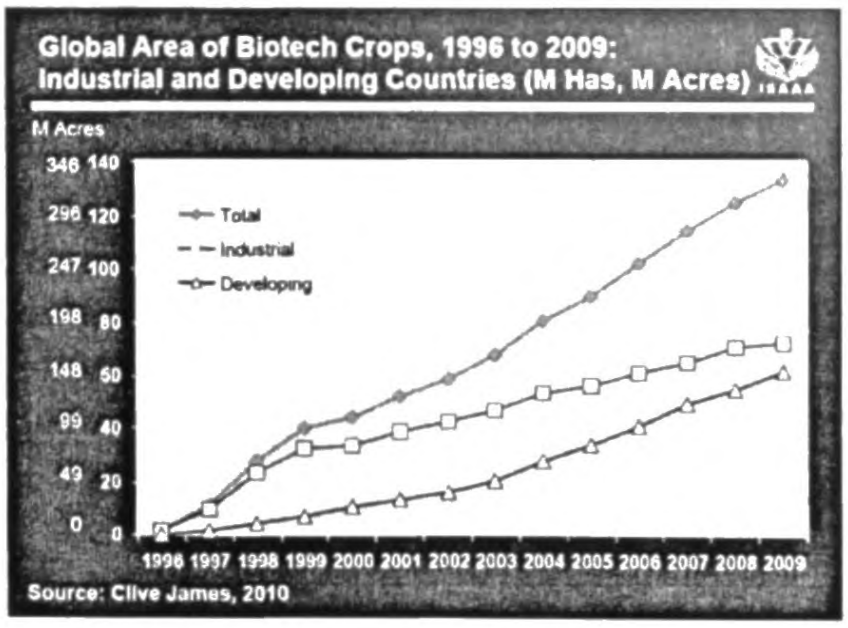
Introduction

Genetic engineering or recombinant DNA technology (rDNA) constitutes one of the techniques comprising modern biotechnology. It creates novel organisms (Genetically Modified Organisms: GMOs; also known as transgenic organisms) by transferring genes across species and even kingdoms. GMOs can be used to produce food (genetically modified food), feed (genetically modified feed) and processed products that include genetically modified ingredients, together known as GMO/FFPs (genetically modified organisms, food, feed and processed products). Transgenic organisms include plants, animals and microbes carrying foreign genes providing resistance to pests, herbicides, increased growth, better quality products, pharmaceuticals etc. However, as with any other technology, risks and concerns arising from the use of this technology have been identified by the scientific community that can affect human health and the environment in addition to other concerns such as gene theft, patents and socio-economic aspects. Notwithstanding these, the production of GMOs has expanded globally (see figures below) and the time has come for us to find out whether this technology can be used to contribute to agricultural production in Sri Lanka in a sustainable and safe manner.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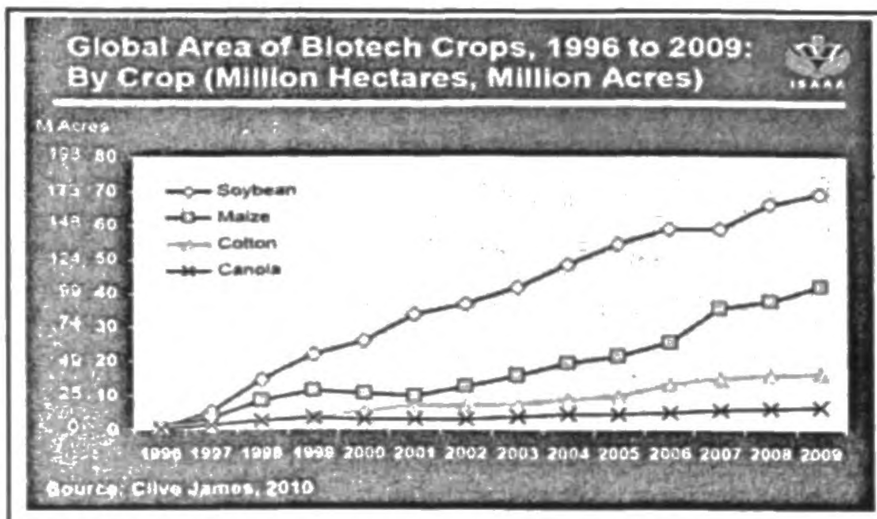
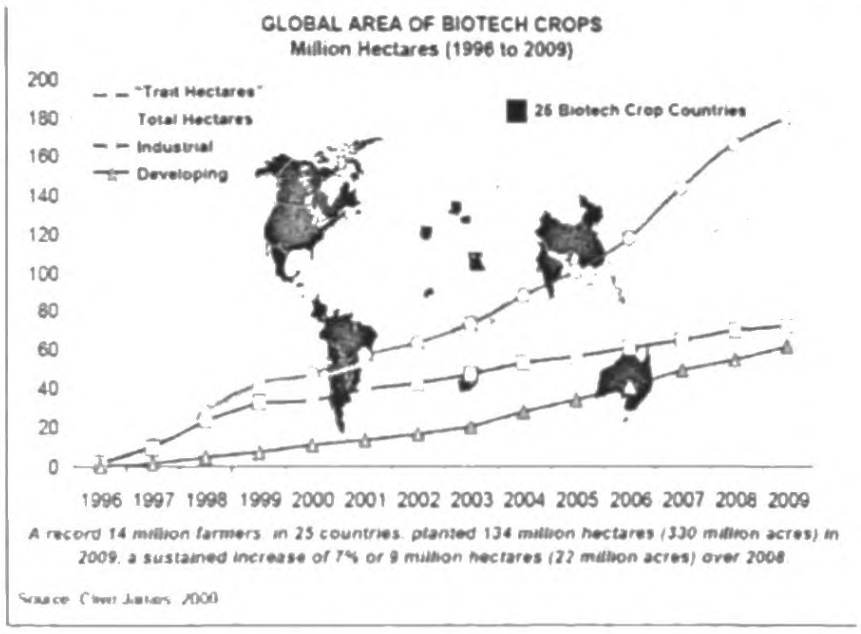




The global scenario

Today, the world population is around 7.2 billion for which about 25% of the habitable land and 90% of fresh water are used up for food production. Moreover, deforestation causes about 80% biodiversity loss and we experience around 30% greenhouse emissions. Confounding food production efforts is that there is about 1.3 billion tons of food wasted every year, with around 90 million tons wasted every year in Europe alone. In the developing world, >40% food losses are recorded; 1 in every 7 people goes to bed hungry and >20,000 children (< 5 years old) die every day due to hunger. The impact of food waste is both financial and environmental. In addition, there is wasteful use of chemicals and increase use of fuel. The emission of methane, the harmful greenhouse gas, is causing climate change, whilst the dumping of waste in landfills increase odour and attracts flies and vermin. Food is lost in the entire food chain from the farmer to the industry to retailers, caterers and consumers.

Going back in history, from the time of the Mayans to the Pharos and the Indus valley civilizations including our own 'granary of the east' period, to the present modern world, humans have gradually transformed their 'natural' world into a 'synthetic' world. Prior to the 1930s, synthetics were based on natural material such as alcohol, cellulose, corn, milk, starch etc. But thereafter, synthetics were produced from petroleum products, the excess hydrocarbons from the oil and gas industries from which new molecules were created by chemists to produce material that can be easily manipulated. These included lightweight, shatter-proof, flexible plastics, stretchy, water-repellent fabrics, detergents that get rid of dirt and grease, non-stick cookware, grease-resistant food packages, lining of food cans, flame retardants, antibacterial soaps, artificial fragrances, sunscreens, pesticides, preservatives, cosmetics and toys. These are found in the products that we wear, sit on and sleep with and hence rub into our skins. Traces of these molecules have been found in the food we eat, water we drink, the air we breathe. These molecules flow in our blood. They are found in our urine, breast milk, in the soil and in marine life. More than 400 million tons of such chemicals are produced every year. Humans are thus exposed to multiple chemicals simultaneously, while some can persist in the environment for years. Some fat-soluble chemicals can accumulate in plant and animal tissue and thus interfere with the natural chemistry of living cells which can eventually affect vital body systems, disrupt the balance of hormones, affect fertility, metabolism and cause behavioural problems and even cancers, through several generations.

So what can we do about these risks to the environment and human health due to the use of modern technology, including rDNA technology? Can we turn the clock back? If not, how then can we use this technology, the rDNA technology, to solve our agricultural problems in a safe and sustainable manner whilst protecting our rich culture and values? For this, we need to know what our problems in agriculture are, what resources we have and then how rDNA technology can contribute to solve them.

Our biological resources

Sri Lanka is a 'small' island nation situated next to a 'large' neighbor. Ours is a biodiversity 'hot spot' with a large amount of endemic species (Table 1).

Table 1. Some endemic species in Sri Lanka

Angiosperms –	3,154 species; 894 endemic
Pteridophytes –	336 species; 49 endemic
Fresh water fish –	91 species; 50 endemic
Fresh water crabs –	51 species; 50 endemic
Resident birds –	237 species; 33 endemic
Mammals –	124 species; 21 endemic

(National Red List of threatened fauna & flora, 2012)

National Biotechnology priorities

The National Biotechnology Policy of Sri Lanka

identifies the following 11 themes as priority areas for implementation.
Clean environment
Self reliance in food production
Well-being of the people through healthcare
Promotion of bioenergy
Sustainable use of biodiversity
Poverty reduction through bio-entrepreneurship
Bioprospecting of marine/ocean resources
Sustainable bioindustry
Positioning biotechnology in society
Human resource development to build capability in biotechnology
Government commitment for research and development and technology transfer (by establishing Centres of Excellence in the country and creating an Apex body to spearhead the development of Sri Lankan biotechnology sector).

Some 'burning' problems in agricultural production

The 'burning' problems in agricultural production in our country include, high cost of production: labour, chemicals, seeds; heavy use of chemicals that are imported causing a hazard to human health & environment; lack of appropriate local seeds which are easily available and tested in our ecosystems for tolerance to drought, flooding, salinity etc.; decreasing land for cultivation and hence coming into conflict with animals – elephants, monkeys; change of food habits of urban populations; wastage of food; loss of traditional varieties/biodiversity in many crops such as mangoes, bananas, tomatoes, chilli and the loss of traditional knowledge.

The technology

Recombinant DNA technology has been used to produce many novel GMO/FFPs including herbicide tolerant cotton, soybeans; Bt cotton, maize; TMV resistant tobacco; Flavr Savr tomato for improved quality; potatoes with high starch content; golden rice with increased vitamin A; improved canola oil; blue roses; carnations with increased vase life; drought, cold, salinity tolerant crops; plants producing pharmaceuticals; edible vaccines etc.

The technology involves the identification & isolation of a gene of interest, cloning it, transferring to a suitable vector such as *Agrobacterium* (or the use of a gene gun) for transforming cells of the crop of interest after which successfully transformed cells are developed into plants through the use of tissue culture techniques.

Current news

Currently, the apple genome has been mapped having 17 chromosomes, most of which are duplicates i.e. copies of parts of other chromosomes; the Christmas tree genome has been sequenced; the castor bean genome has been published; Wales want to remain GM free; France has enforced a national ban on MON 810 (Bt maize); China has slowed down GM research in order to investigate them more; the Philippines has enforced a court order to permanently stop all field trials of Bt egg plant; USA court has revoked the approval of GM sugarbeet - ~ 95% sugarbeets in US are Roundup Ready transgenic varieties – US court requires more stringent EIS report on how it will affect other plants; the Indian government has enforced a moratorium on Bt brinjal which took 8 years to produce; toxicological database on *B. thuringiensis* shows no mammalian health effects attributed to the delta-endotoxin (Cry proteins); studies on food & feed safety including toxicology & allergenicity tests carried out on rats, rabbits, fish, chicken, goats & cows; Austrian researchers proved Bt maize was harmful to mice; AquaAdvantage salmon, the 1st genetically engineered food animal has been produced - all are sterile females raised in land-based contained environments.

Risks to environment (agriculture)

Many GMOs are being produced in laboratories across the world and more than 160 countries have signed the Cartagena Protocol on Biosafety which allows nations to establish safety measures with regard to production, transport and use of GMO/FFPs considering the risks to the environment and human health.

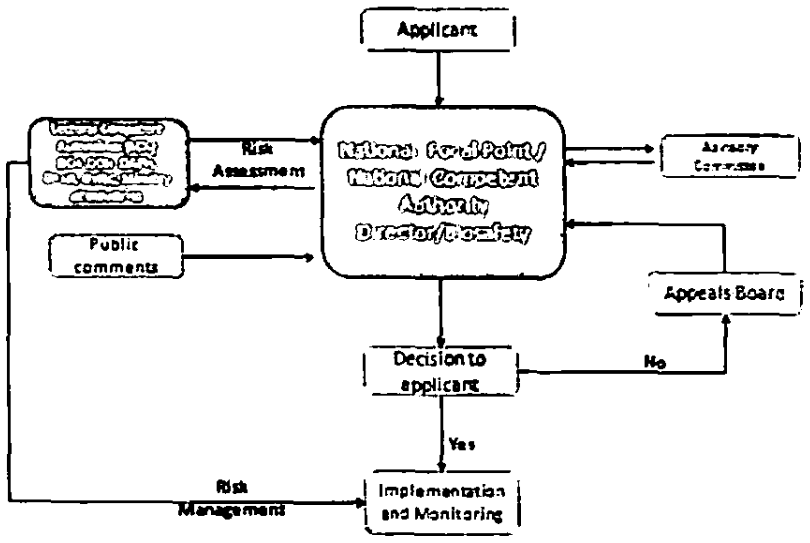
The risks to the environment include risks to Biodiversity due to the possible genetic erosion by aggressive/dominant GM crops e.g. traditional rice varieties; gene flow – contamination by GM pollen of traditional varieties, organic crops; transfer to weedy relatives; extinction of endangered varieties; marketability of non-GM products; effect on non-target organisms - butterflies, bees, moths, lady-bird beetles, lizards, frogs, crows, parrots & soil organisms; persistence of the transgene & its product.

Other risks include instability of the transgene through generations; evolution of resistance; weediness of GM crops; escape of salinity, drought, cold resistant crops; effect on soil ecology – functional composition & biodiversity; socio-economic issues such as the livelihood of farmers who grow non-GM crops; ethical & moral issues including patents, biotheft & biopiracy; owning 'life'; vegetarians; genes & products in pigs, cattle etc.

National regulations and the future

In order to regulate the GMO/FFPs (especially those imported), Sri Lanka as a signatory to the Cartagena Protocol has also ratified it. Progressing from there, Sri Lanka has established the National Biosafety Framework through which the National Biosafety Policy was also established. The Ministry of Health has included regulations regarding GM food in its Food Act with mandatory labeling. The Ministry of Environment, which is the National Focal Point for Biosafety, has now produced the final draft of the Biosafety Act of Sri Lanka which will be implemented as shown in figure below.

Biosafety Act: Administrative Structure



The stage is set for the decision makers to plan how to use this technology for improving agricultural production in Sri Lanka in a safe and sustainable manner, whilst remembering the words of wisdom of the Great Mahatma Ghandi:

"The world has enough for its needs but not enough for its greed"

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Managing Soils and Water in Sustainable Agriculture

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Reddish Brown Earth (RBE), Low Humic Gley (LHG), Non Calcic Brown (NCB), Immature Brown Loam (IBL), Red Latosol, Yellow Latosol, and Grumusols are major agricultural soils in the dry zone while Red Yellow Podzolic soils (Ultisols) being the modal soil in the wet zone. In the modern agriculture use of agrochemicals plays a significant role in achieving expected yield targets. Soils of Sri Lanka, in general, have low inherent fertility status, thus limiting crop growth and yields unless deficient nutrients are supplemented at adequate levels. Fertilizers and organic amendments contain many impurities leading to contaminate soils subsequently transferring to the humans through food chains. Out of the 17 plant nutrients, N and P reported of causing adverse effects to the ecosystems and environments when supplying more than necessary quantities. Trace metal pollution in soil is of a great concern because soil is a long-term sink for potentially toxic elements. Parent material and anthropogenic inputs such as fertilizers are found to be sources of heavy metals in soils. The solubility, mobility and bioavailability of trace metals in soils depend on the chemical species of trace metals which controlled by number of soil characteristics such as pH, organic matter, clay content and secondary minerals. Trace element studies, deals with trace amounts of interesting metals since the occurrence in soils is as such. Hence following quality control quality assurance steps is very important in trace element studies. Site specific fertilizer recommendations, strategies to increase fertilizer use efficiency, use of slow release fertilizers, and discourage of over-application of fertilizers are some of the measures that can be taken for sustainable agriculture.

Variability of Soils of Sri Lanka

Spatial variability of soils is very high, which is also true for Sri Lankan soils. Twelve soil orders have been identified by the Soil Taxonomy classification at the highest hierarchical level, where Sri Lanka is having six out of them, namely, Alfisols, Ultisols, Inceptisols, Entisols, Vertisols and Histosols. Great Soil Groups put forward by the de Alwis and Panabokke in 1972 used as the base for the modern soil classification done for wet zone (Mapa et al., 1999), Intermediate Zone (Mapa et al., 2004) and Dry Zone (Mapa et al., 2010) according to the Soil Taxonomy. Reddish Brown Earth (RBE), Low Humic Gley (LHG), Solodized Solonetz, Non Calcic Brown (NCB), Immature Brown Loam (IBL), Red Latosol, Yellow Latosol, Calcic Red Latosols, Solonchaks, and Grumusols are the major agricultural soils in the dry zone. RBE and LHG soils on undulating terrain covers the highest extent in the dry zone spreading from Anuradhapura, Monaragala, Vaunia, Polonnaruwa, Trincomalee, and Hambantota districts (de Alwis and Panabokke, 1972). Management of NCB is important in agriculture due to its sandy texture. NCB and LHG occur in undulating terrain covers districts of Ampara and Batticoloa. Red or Yellow Latosols occurring at flat to slightly undulating terrain covers the districts of Jaffna, Mannar, Puttalam and Vaunia. Latosols are deep soils and water holding capacity is very low requiring proper irrigation schemes for cultivation of crops. Grumusols occupies in flat terrain in the districts of Mannar and Jaffna where Gilgi micro-relief is the characteristic feature of the soils. Grumusols are highly productive soils with appropriate management practices to overcome poor soil physical properties. Alluvial soils and Regosols on Recent beach and dune sand are also use heavily on crop production with appropriate management practices. Sandy nature of the soil poses environmental threats, if fertilizer splitting and other management practices were not performed well.

Red Yellow Podzolic soils (Ultisols) are the modal soils of the wet zone of Sri Lanka both in the lowlands and in the central highlands. Low pH, low CEC and low base saturation are the main constraints in these soils. Addition of lime to correct pH and base saturation, addition of organic matter to increase CEC and application of fertilizers in several splits to reduce nutrient losses are the major management practices associated with this soil type. Reddish Brown Latosolic (RBL), Bog soils and Half-Bog soils are the other soil groups present in the wet zone. IBL (Inceptisols) soils occurs on steeply dissected, hilly and rolling terrain, are very susceptible for landslides and soil conservation measures need to apply when agriculture practices on this soil. Regosols and Alluvials are also agriculturally important soils found in the wet zone. Alluvials found in floodplains are relatively fertile soils. Poor water retention and fertility are some of the problems associated with Alluvials and Regosols on recent beach sands.

Soil Fertility and agricultural inputs

Soil fertility is the capacity of soil to supply plant nutrients in adequate amounts to facilitate optimum growth and obtain the yield potential of a crop. Fertilizers are applied to crop production to supply the essential plant nutrients. Of the 17 essential nutrients, C, H and O supplied naturally, through the air and water. Nitrogen, Phosphorus and Potassium were the macro nutrients while S, Ca and Mg were secondary nutrients and Cu, Fe, Mn, Zn, Mo, Cl, B and Ni are the micro nutrients where the classification was done based on the required quantities by the crops. In the modem agriculture use of agrochemicals plays a significant role in achieving expected yield targets. Soils of Sri Lanka, in general, have low inherent fertility status, thus limiting crop growth and yields unless deficient nutrients are supplemented at adequate levels (Indraratne, 2012). Soil properties that influence the availability of the essential soil nutrients are organic matter, texture, structure, cation exchange capacity, base saturation, soil temperature, topography, soil management factors and soil depth. Fertilizer import also increased significantly in the recent past.

Soil properties responsible for fate of inorganic pollutants added to the soils

Fertilizers and organic amendments contain many impurities leading to contaminate soils subsequently transferring to the humans through food chains. In Sri Lanka use of fertilizers and organic manures in more than recommended doses is a common practice in intensively cultivated vegetable growing soils. Out of the 17 plant nutrients, N and P reported of causing adverse effects to the ecosystems and environments when supplying more than necessary quantities. Further fertilizers are known of having potentially toxic heavy metals in small amounts. Long term fertilizer application could cause elevated heavy metal concentrations in soils. Hence, nitrates, phosphates and heavy metals could consider as inorganic pollutants receiving to the soils due to agricultural practices.

Inorganic as well as organic colloids present in soils are predominantly negatively charged creating an environment where the cationic substances are held tightly through electrostatic processes. Anions present in the soil environment retained with the colloid through non-specific adsorption and specific adsorption processes. Non-specific adsorption is similar to the cation adsorption, which is bound to the colloids through electrostatic attraction. Specific adsorption takes place between colloidal surface and ions present in the soil solution irrespective of the charge of the ion. Nitrates and phosphates are negatively charged anionic groups in soils with different retention mechanisms. Phosphate is held strongly through specific adsorption while nitrate is loosely held in soils by non-specific adsorption. Therefore, nitrates move freely through soil profile contaminating groundwater while phosphates adsorbed tightly with soil colloids. Phosphates could pollute surface waters through erosion and runoff. Nitrogen from fertilizers also can move directly into surface waters from runoff and erosion.

Cation exchange capacity of a soil determines by the factors such as clay % (texture), Clay mineralogy, OM content and pH. Electrostatic attraction for cations by negatively charged particles can be expressed using the Couloumbs Law; $F = K q_1q_2 / d^2$, where F is the attraction, K is the constant, **q1** and **q2** represent the charges of oppositely charged ions and **d** represent the distance between the two ions. When q1 increases, attraction between the ions increases indicating the affinity in the order of trivalent > divalent > monovalent. Similarly when ionic radius of the cation increases, d increases decreasing the attraction of the cation to the negatively charged soil surface. Accordingly high cation selectivity shows for trivalent cations and cations with smallest hydrated ionic radius by the soil surface. Hence multivalent trace elements added to the soils as impurities of agrochemicals could selectively bind to the soil surfaces.

The persistence and mobility of metals are determined by the sorption ability of solid phases. Adsorption of heavy metals by soil colloids is highly dependent on soil pH. Low pH results low adsorption of metals to the soil colloids. At low pH levels more heavy metals are present in the soil solution increasing the bioavailable fraction. Redox potential (Eh) is another important property that determines solubility of trace elements. Generally, trace elements solubility increases upon decreasing Eh. Outer sphere complexes and inner-sphere complexes are two main mechanisms responsible for adsorption of cationic metals. Electrostatic outer sphere complexes are weaker in its nature and exhibits cation exchange property. Trace elements are adsorbed to the colloids by inner-sphere or chemisorption process of which metals are adsorbed through covalent and hydrogen bonding. Precipitation and co-precipitation mechanisms are also responsible for retention of metals with soil colloids. Precipitation of trace elements is unlikely since a new solid phase will require some degree of supersaturation. Co-precipitation is more likely than precipitation in retention of trace element with soil colloids. A study on soil chemical properties on Cd and Pb sorption conducted by Appel and Ma, (2002) observed all soils sorbed more Pb than Cd, sorption depend on soil mineralogy, Cd sorption is more pH dependence than Pb, Cd was sorbed via electrostatic surface reactions and/or possible inner-sphere complexation at pH > 3.7 and Pb participates in inner-sphere surface reactions and sorbed more strongly than Cd.

Characterization of physicochemical properties of a soil enables predicting the behavior of nutrients and pollutants added to the soil. A study was conducted to characterize environmentally important physicochemical properties and processes of an Alfisol (RBE) collected from the dry zone of Sri Lanka (Sanjeevani et al., 2013a). Point of zero charge of the soil was recorded as 4.0 indicating net negative charges at the existing soil pH of 6.37. At the near neutral pH of the soil, the cation retention enhanced, subsequently reducing the mobility of metals.

Fate of inorganic pollutants added to the soil environment

When nutrients are applied to the soils as fertilizers it could be undergone many processes in the soil environment. Other than the plant uptake, the possible pathways are volatilization to air, runoff to surface water bodies, percolation to aquifers and bio-cycling. If the application rates do not match with the plant uptake rates, then the environmental pollution is unavoidable. Though there are 17 elements essential and supplied through fertilizers, so far the environmental pollution and or health hazards were reported by only two nutrients, i.e., N and P.

Most freshwaters biological productivity is limited by P. Agricultural activities are one of the major sources of P in surface waters. Eutrophic threshold for P is much lower than N and the value is 20 to 100 µg P/L (Essington, 2004). Ratio of N:P in water body is known as Redfild ratio and it is the indicator use to identify of which nutrient is limiting the eutrophication process. For an example if the Redfield ratio is > 16: 1; P is limiting and lower the ratio N is limiting the eutrophic conditions in a water body.

Soils that contain high levels of P from excessive fertilization increase the potential of P loss through runoff. The degree of phosphorus saturation (DPS) has been used in evaluating the risk of P loss from soil through runoff (Ige et al., 2005). The DPS is the percent ratio of P retained by soil to the total capacity of soil to retain P. It is based on the fact that although soils have capacity to retain applied P, this P retention capacity is finite; and as more P is added to the soil, the soil's capacity to retain P decreases and the risk of P loss increases. Thus, two soils with the same extractable P may not necessarily pose the same risk to the environment. Phosphorus adsorption capacities vary widely between 588 mg kg^{-1} to 5000 mg kg^{-1} in major soils of Sri Lanka (Indraratne et al., 2009). The degree of P saturation has been shown to be closely correlated with dissolved runoff P (Sharpley et al., 1996). Amarawansha and Indraratne, (2010) calculated DPS in intensively cultivated soils of Sri Lanka (Fig. 1) and identified that most of the intensively cultivating soils pose P loss to the adjoining water bodies.

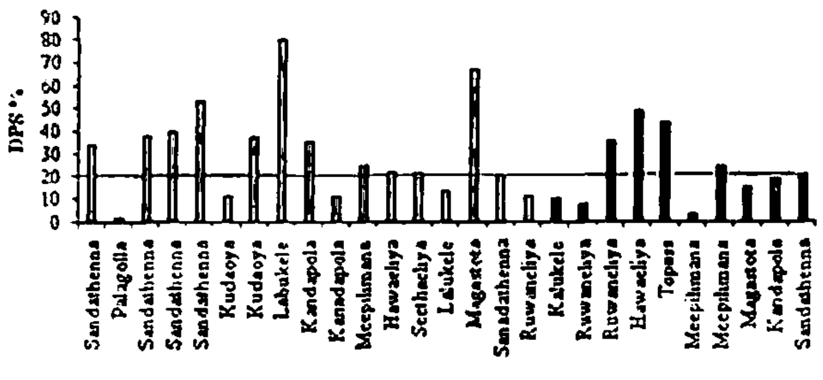

Fig. 1. Degree of Phosphorous Saturation in Intensively Cultivated Soils in Sri Lanka (Soils with more that 20% DPS are highly susceptible for run off P losses, Source: Amarawansha and Indraratne, 2010)

Many researchers paid special attention to intensive vegetable cultivation in Sri Lanka recently due to its possible negative environmental impacts (Rajapaksa and Raufa, 1999; Premarathne et al., 2011). Some features of intensive vegetable farming in Nuwara Eliya area are, continuous cultivation throughout the year cultivating 2-3 crops per year, use soil amendments (lime or dolomite), application of 3-4 times higher than recommended doses of fertilizers (Wijewardane, 1993), and use of higher doses of organic manures, foliar fertilizers and pesticides. More than 30% of Mid Country vegetable growing soils showed very high available P concentrations, i.e., >120 mg/kg (Fig. 2). This indicates very high risk of P losses from these fields to the adjacent water bodies.

Trace metal pollution in soil is of a great concern because soil is a long-term sink for potentially toxic elements. Parent material and anthropogenic inputs are found to be the main sources of heavy metals in soils. Common metal species found in soil are water soluble, exchangeable, organically bound, occluded in Fe and Mn oxides, definite compounds and structurally bound in silicates. Water soluble and exchangeable fractions are bioavailable of which would enter to the food chain, easily. A research carried out in the vegetable fields in some production areas of California showed that the concentrations of As, Cd, Pb and Zn had been shifted upward due to agricultural inputs (Chen et al., 2008).

Reactions of heavy metals with soil are important in determining metal fates in the environment. The solubility, mobility and bioavailability of trace metals in soils depend on the chemical species of trace metals which controlled by number of soil characteristics such as pH, organic matter, clay content and secondary minerals. Trace elements adsorbed to the soil colloids differently than the simple cation exchange mechanism. The mobility of the pollutant into the food chain is one of the issues of most concern. Mobile fractions of ions occur at a lower range of pH and at a lower redox potential. Hence, the concentration of trace elements is lower in soil solutions of alkaline and neutral soils found in the dry zone than in those of acidic soils in the wet zone. Therefore, type of soils play a major role in the accumulation, persistence and bioavailability of trace metals in soils. An experiment was conducted to study trace element concentrations in soils after using phosphate fertilizer at rates of 26, 39, and 52 kg P ha^{-1}) over a 40-yr period (Cakmac et al., 2010). Significant Cd increase was observed in phosphate application rates of 39, and 52 kg P ha^{-1} while phosphate rate at 26 kg P ha^{-1} (recommended P rate) showing no difference with control.

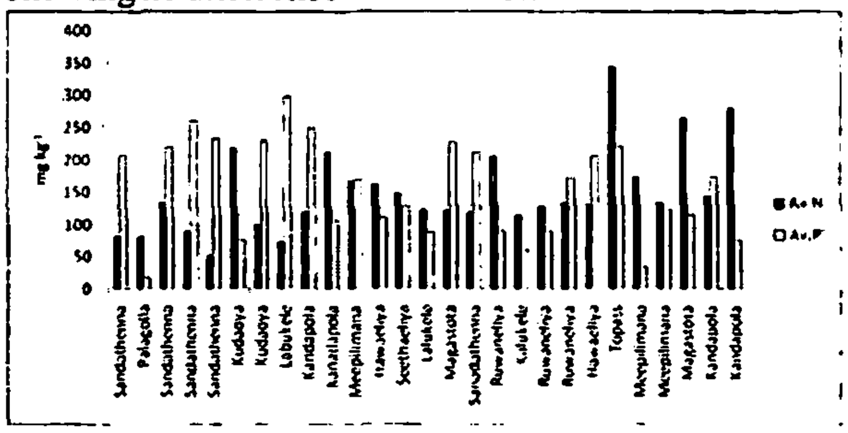

Fig. 2. High-input agricultural practices on available nutrients (Av N.= available nitrogen, Av. P= available P; Source: Pitumpe Arachchcige and Indraratne, 2011)

Surface horizons of 40 agricultural soils from low country and up country wet zone of Sri Lanka under vegetable crops were sampled to determine concentrations of Cd, Cu, Ni, Pb and Zn (Premarahne et al., 2011). Elevated levels of Cd, Cu, Ni, Pb and Zn than the uncultivated soils were observed in both up country and low country wet zone of Sri Lanka (Fig. 3). Measured mean values of Cd in few soils exceeded the maximum allowable limits imposed by the European standard; however, Cd concentrations in the vegetable crops were still below the standard levels. Authors observed the Cd to Zn ratio in studied soils indicated safer limits for Cd in more than 95% of the soils studied.

Establishment of baseline concentrations has been done in many parts of the world (Dudka, 1993).

Information on trace element baseline concentrations is not available in Sri Lanka. Therefore, Sanjeevani et al., (2013b) conducted a study to establish baseline concentrations of trace elements of surface soils in a selected soil map unit in dry zone of Sri Lanka (Table 1). This shows current background concentrations of the metals studied and will be helpful in future monitoring purposes.

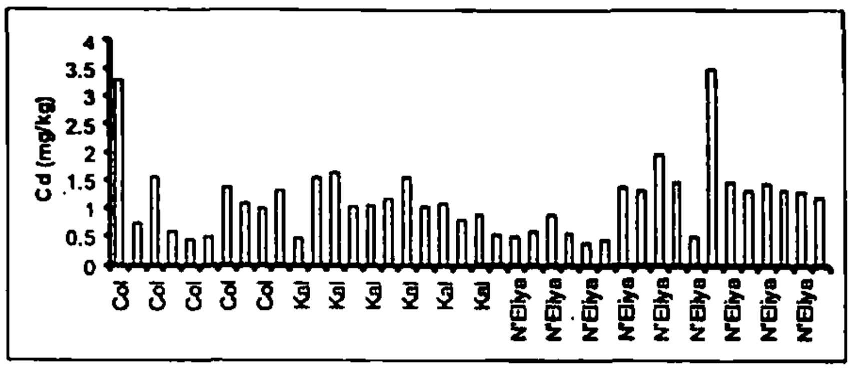

Fig. 3. Total Cd from intensively cultivated vegetable fields of Colombo (Col), Kalutara (Kal) and Nuwara Eliya (N'Eliya) districts (Source: Premarathne et al, 2011)

Table 1. Trace metal and Baseline concentrations (mg/kg) for Cu, Pb, Ni, Zn and Cd in a soil map unit of the dry zone of Sri Lanka (Sanjeevani et al., 2013b).

Trace metal	N*	Observed concentrations	Skewness	Baseline concentrations	GM	AM	Median
Cu	86	1.56 - 33.51	1.503	2.98-26.51	8.89	10.23	9.3
Pb	85	0.96 - 19.22	0.709	2.44-19.53	6.9	7.77	6.78
Ni	82	0.35 - 32.17	0.876	2.02-38.8	8.85	10.86	10.65
Zn	86	7.44 - 71.32	2.008	8.24-51.25	20.55	22.94	19.58
Cd	74	0.13 - 1.22	0.753	0.13-1.39	0.42	0.5	0.43

* Number of samples

Validity of generated soil pollution data

Sampling procedures should be strong enough to predict the spatial distribution. Soil analysis always included a dilution factor in soil analysis unless the whole sample is feeding to the machine. Choosing of extracting solution will depend on the purpose of the analysis. Available fractions are more important than totals for nutrients and heavy metals, if the objective is to know the sufficiency for plant or food chain transfers. Trace element studies, deals with trace amounts of interesting metals since the occurrence in soils is as such. Hence following quality control quality assurance steps are a necessity. Running known and unknown blanks and check with Standard Reference Materials (SRM) are some of them.

Management strategies to minimize pollution by fertilizers

Recovery of applied N to paddy soils in Sri Lanka is around 30% (Sirisena et al., 2003). Some of the improved N management techniques are split application, subsurface placement, use of slow release and coated urea fertilizers. Further N efficiency could be enhanced by the application of granular urea rather than prilled urea (Sirisena et al., 2003). Experiments conducted on adoption of leaf colour-based nitrogen application indicated 121 – 142 kg/ha can be saved when N is added based on leaf colour chart guidelines (Sirisena and Wanninayake, 2010).

Current researches on OM studies are trying to add high C: N ratio recalcitrant materials to the soils expecting to improve many soil conditions for crop growth (Mariaselvam et al., 2013). Biochar, produced by pyrolysis is one such recalcitrant organic material that can be used for soil improvements.

Site specific fertilizer recommendations reduce environment pollution and enhance the nutrient use efficiency by the crops. Many researchers reported that the new approach of fertilizer recommendation based on soil analysis, sorption studies, green house nutrient survey and field trials was successful (Amarasekara et al., 2007; Bandara et al., 2008; Kumaragamage and Indraratne, 2011).

Application of N fertilizers at the right time at correct doses is necessary to limit the buildup of nitrates during the periods at high leaching risks. This can be accomplished by applying nitrogen at the stage that crop can utilize it, using smaller and more frequent doses, and not applying excess amounts. Use of slow-release nitrogen fertilizers is another management practice that can prevent buildups of nitrates in soils. The rate of nitrogen release from fertilizers can be controlled by coatings or use of reduced solubility compounds.

Surface losses of nitrogen and phosphates can be minimized through application of soil conservation and water control practices. These practices include contour cropping, maintenance of adequate plant cover, returning crop residues to the soil, and use of forages and other close-growing crops on steeper lands. In the Sri Lankan context it is a must to discourage / prevention of over-application of fertilizers /manures in intensively cultivated areas, which has contributed significantly for the environment pollution in the recent past.

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