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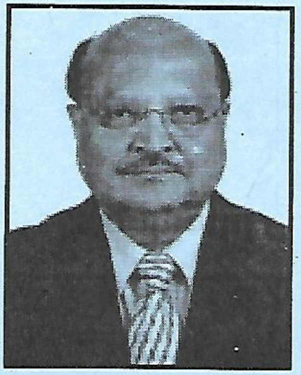
On

# Sustainability of Organic Agriculture in the Current Day Context




**Dr. C. L. Laxmipathi Gowda**
*Former Deputy Director General, ICRISAT, Hyderabad-502324,*
*and*
*Co-Founder, GRSV Consulting Services, Mysuru-570023, India.*



**Dr H R Arakeri Memorial Foundation**
**&**
**Institute for Studies on Agriculture and Rural Development, Dharwad - 580 008**

# SUSTAINABILITY OF ORGANIC AGRICULTURE IN THE CURRENT DAY CONTEXT*

**C L Laxmipathi Gowda**
Former Deputy Director General, ICRISAT, Hyderabad-502324, and
Co-Founder, GRSV Consulting Services, Mysuru-570023, India.

**Abstract**

Recent evidence suggests that organic agriculture (OA) is becoming unsustainable in many areas of the tropical countries. We need to realize that organic agriculture is not a panacea, and a cure for all ills of modern agriculture. There are important reasons why OA alone, in its present form, will not be sustainable. The current agriculture production (including food, feed, fibre and fodder) needs to be almost doubled to meet the demand for the projected ~9 billion population by 2050. Organic agriculture is suitable for some agro-ecologies, and there are niches where OA can be practised profitably and sustainably. One of the essentials of OA is to maintain good soil health, including soil fertility(organic carbon and essential macro and micronutrients), soil structure and soil moisture for good crop production. Most soils in the drylands of arid and semi-arid tropics of the world are low in soil fertility. A recent study from University of Western Australia has reported that it is not feasible to maintain organic matter in soils with less than 600 mm rainfall and daily average temperatures of >15C. Many smallholder farmers in developing countries cannot afford external inputs and hence follow traditional farming practices, and hence are organic-by-default. There is need to take a holistic view of soil health, and soil as a "bank of nutrients". Farmers need to replenish the nutrients taken-up by a crop every season, especially in the tropical and sub-tropical lands. Organic manures (FYM, compost, and other animal manures) contain small quantities of nutrients, and need to be applied in huge quantities. Additionally, the needed macro-and micro-nutrients should be supplemented based on soil test results. Using GIS for geo-referenced soil fertility mapping helps scientists to make appropriate recommendations of manures, bio-fertilizers, bio-enriched compost, fertilizers, and fertigation. We need to harness the synergies of integrating the valuable ancient knowledge and wisdom of organic agriculture with modern science-based technologies to meet the challenges of 21st century, through "Sustainable Agriculture Practices" (SAP). The researchers involved in agricultural research for development, policy makers, and the farmers need to join hands to develop a basket of technological options for SAP and empower the farmers to choose appropriate farming practices that are suitable for their farms, agro-ecologies and economic conditions for the sustainability of organic agriculture.

## Introduction

We had enough cultivable land, and sufficient food was being produced to feed the populationbefore the industrialization in the 19th century. Soils were fertile, and there was no need of chemical fertilizers. However, the agricultural scenario has changed tremendously over the last century. Cultivable land/capita is getting lesser, especially in Asia (about 0.6 ha per capita in India); soils are undergoing considerable erosion and depleted of major plant nutrients; rainfall is erratic and new species of pests, diseases and weeds have emerged. The situation is further complicated due to the effects of climate change.

The projected global population is likelyto be ~9 billion by 2050, from the current level of ~7.5 billion. It is projected that agriculture production(including food, feed, fodder, fibreand fuel), needs to be substantially increasedto meet the demand.According to IFPRI, the global food production needs to increase by ~60% by 2050.With increased incomes the food habitsof people will diversify,and the daily food needsare likely to increase resulting in the demand for meat, milk, and milk-based products. Considering that >54% of the children in South Asia (including India) are malnourished, improvednutrition will bean equally importantcomponent of food and nutrition security.This adds anotherdimension to the demand and supply of 'nutritious food' in sufficient quantities to meet the WHO recommended standards for better health and nutrition of human beings globally.

## The Context

Vriksh Ayurveda (VA) by Surapala (c 1000 CE) is one of the ancient Sanskrit treatises that deals with the art and science of managing horticulture and other agriculturally important crops. Although VA deals mostly with increasing the productivity of different horticulture species with appropriate crop husbandry practices, its principles are equally applicable to other field crops. Reading through the translated manuscript (Sadhale, 1996) of more than 300 Sanskrit verseswe can summarize the essence in to the following main principles of tree/crop husbandry: Appropriate management of soil, water, and nutrients with care and love; and proper control of weeds and plant disorders (physiological anomalies, diseases and pests).

**Broadly, the salient points in Vriksh Ayurveda can be summarized as follows:**

- Managing the quality of seed and planting materials (cuttings, bulbs, etc.), including their selection, proper maturing, harvest and post harvest practices, storage techniques(that include application of various treatments for longevity and breaking dormancy) suitable for sowing.
- Suitability of trees/crops to different kinds of lands and soils, based on physical parameters (sand, gravel, stones, etc.), colour of soil, chemical properties (acid, salty, sweet, etc.), and water holding capacity.
- Classification of lands based on availability of water-arid, ordinary, well-watered, marshy land, etc.
- Soil mulching practices to conserve moisture and managing weeds.
- Spacing for plantingbased on the height and spread of the trees (tall or medium trees or short trees and shrubs) to enhance the growth of roots to support the trees physically, and also to extract water and nutrients.
- Proper mineral nourishment of trees based on their nutrient requirements in time and space
- Application of organic manures (FYM, different animal dungs/ excreta, crop residues, oil cakes) and addition of ash (K) and crushed bones (Ca) and others.
- Application various liquid manures (such as Kunapa) that were of animal origin and fermented to ensure supply of many macro- and micro-nutrients over time.
- Integratedmanagementplantdisorders(physicalinjuriesphysiologica lanomalies, and those caused by microbes and insects) using various plant products (sprinkling of ash, leaf and bark powder, crushed seeds, oil and oil cakes,wine, etc.) and animal-based (cow urine, milk, ghee, curds, honey, etc.) materials.

It is evident that Surapala and others during his time spent lot of time and effort in deductive research to develop necessary tools and technologies to better manage the plants and trees to enhance productivity over time. This knowledge and technologies may not be fully relevant and sufficient to meet the demands of modern day agriculture, but Vriksh Ayurveda established a benchmark for future research. It is also evident that some of the practices (such as use of animal waste for Kunapa) are not practical in the current day agriculture. However, the location-specificity of crop husbandry practices was known even during Surapala's time, and the current-day agronomists are grappling with the same. It is therefore essential that we critically assess and understand the reasoning followed at that age, and fine-tune the crop husbandry practices with modern science-based technologies to suit the existing conditions. The current and future generations of scientists should build on what is known and available and refine the traditional crop management technologies and practices with current knowledge and science,and plan to achieve sustainable food and nutrition security for the present and in future years.This paper attempts to present a balanced approach regardingthe current thinking of national and international agricultural scientists to meet the challenge of increasing crop productivity per unit of land and water, and at the same time maintain and preserve the natural resource base to feed growing population in future years. It is understood that we need to harness the synergies of integrating the valuable ancient knowledge and wisdom with modern science-based technologies to meet the challenges of 21st century.

**Food Security and the Green Revolution**

The "Green Revolution" provided the much-needed food security to many countries, including India. India progressed from a "ship-to-mouth" condition in the mid-1960s to become a food self-sufficient country. However, concerns about the yields plateauing, reduction in total factor productivity, and the resultant negative environmental impactsof green revolution have been raised in many fora. These issues and concerns are valid, and we need to ensure that scientists make recommendations for agricultural practices that are context-specific, and environment-friendly as the generic (one-size-fits-all) recommendations of package of practices may lead to further deterioration of farming systems and agro-ecological conditions. Contemporary agriculture now faces the challenge of developing and mainstreaming agronomic practices that can make agriculture profitable to farmers, and at the same timeenhancefood production, while ensuring that the environmental impacts are sustainable and positive.

Many organic farmingproponents claim that organic agriculture (OA) is the only way for sustainability of future agriculture and feeding world population. However, we need to understand that organic agriculture is not a panacea, and a cure for all ills of modern agriculture. There are good reasons whyorganic agriculture alone, in its present form, will not be able to feed the future global population. Organic agriculture is suitable in some agro-ecologies for some of the farmers, and there areniches where OA can be practiced profitably and sustainably. There cannot be blanket recommendations or advisoriesconcerning organic agriculture for all the farmers and in all farming systems and situations in any given agro-ecology. Instead of the stand-alone "Organic Farming" approach, a more holistic approach by amalgamating the best practices of Vriksh Ayurveda and other traditional practices (that include current day Organic Farming practices) with modern-day science-based integrated soil, water, and nutrient management (SWNM) by adopting Sustainable Agriculture Practices (SAP) may be more appropriate for the current and future generations.

**Organic Farming**

As per ancient literature, agriculture originated in the hilly regions of Caspian basin of West Asia and the adjoining Iranian Plateau, dating back to 8000 BCE. It moved east towards India and China via the Harappan and Vedic civilizations. Agriculture was practised in India and China for many centuries, as far back as 5000 years. All of this agriculture must have been organic farming, which got lost when we entered the industrial revolution in the 19thcentury. Theneed to produce more food to meet the demands of increased population and high frequency of famines forced farmers to look for alternatives, including chemical fertilizers and pesticides that resulted in the advent of modern input-intensive agriculture. Revival of organic agriculture began in the early part of the twentieth century in Europe and later in the United States, and subsequently in other continents.

There are umpteen definitions of organic farming. Some people define organic agriculture as one that relies on use of farmyard manure, compost, and green manuring for adding nutrients to soil (that are eventually taken-up by plants) and use of biological control or bio-pesticides to manage pests and diseases. It is based on minimal use of off-farm inputs and management practices that restore, maintain and enhance ecological harmony. Organic farming practitioners avoid chemical fertilizers, herbicides, fungicides, pesticides and other chemicals such as plant growth promoters.

**As per literature reviews, organic agriculture has quite a few advantages:**

(i) Enhancing crop diversity: organic farming involves multiple cropping, and it provides insurance against risks associated with weather (rainfall) and pest attack, and provides a diversified food basket to the farming family. In addition, most organic farmers tend to cultivatelocal varieties and landraces thus enhancing crop varietaldiversity.

(ii) Maintaining soil health and fertility: Since organic farming involves addition of organic matter (green manure, compost, crop residues, etc.) the rhizosphere is rich in microbial activity and helps in sustained release of nutrients and managing soil-borne pests.

(iii) Managing weeds:Organic farming integrates agronomic management, and use of biological and mechanical interventions to manage pests (weeds, insect pests, and diseases).

(iv) Managing pests and diseases: Organic farming uses botanical pestcides (plant-based), andbio-pesticidessuch as those derived from bacteria and fungi to manage some of the plant pathogens. These are expected to be benign and do not adversely affect either the ecology or the human health

(v) Enhanced biodiversity:Naturally occurring biodiversity is reported to show improvement in organic farming, as a result of not applying herbicides and pesticides in organic agriculture systems.

**However, there are a few disadvantages with organic farming:**

(i) Crop productivity: One of the major limitations of organic farming is that the yield/ ha is low compared to traditional/ commercial agriculture. Many studies on the reduction in yield have been reported, but results are inconclusive. An FAO report in 2007 stressed that one could not feed the current population by organic farming, let alone the future projected increase in population.

(ii) Profitability: Profitability of organic agriculture (OA) is entirely depen dent on the price premiums offered to organically produced food.Since yield levels (at least in annual grain crops) in OA are up to 80% (of modern agriculture yields) in developed countries and up to 60% in developing countries, farmers will profit only if the price premiums are good. Marketing OA produce for individual farmer is difficult in developing countries, where certification and traceability issues are not properly addressed and implemented.

(iii) Labour requirements: Organic agriculture is bothlabour and knowledge-intensive system. The increased labour cost results in organic food becoming more expensive. Considering that labour is becoming expensive and scarce in India and other developing countries, OA will cease to be profitable, unless price premiums are commensurate. Many countries in Europe subsidize OA to support farmers who practice organic farming. If the subsidies are stopped, then profits disappear as well.

(iv) Environmental impacts:Although organic farming requires less energy, they need more land. There are reports that organic farming leads to higher nitrogen leaching, nitrous oxide and ammonia emissions, com pared to conventional farming.

**If one analyses the organic farming practicesglobally, the following can be summarized:**

(i) most of the certified organic agriculture is concentrated in the deveoped countries and very limited in the developing countries and countries in transition;

(ii) organic agriculture is feasible in countries where cultivable land is in plenty and farmers can follow the recommended fallows and coprottions;

(iii) much of the profitable organic farming is practiced in areas where soils are highly fertile and soil organic carbon content is very high;

(iv) organic farming is feasible and practical in perennial horticulture crops such as fruit orchards (apple, peach, orange, etc.), and plantations (coffee, tea, rubber, cocoa, coconut, etc.) that are commercial crops and profits are high;

(v) farmers in areas with good and reliable rainfall are able to practice oganic agriculture for annual crops such as staple food grains and pulses; and

(vi) farmers in arid and semi-arid regions (characterized by degraded soils and low and erratic rainfall) either cannot afford or risk applying externalinputs (chemical fertilizers, pesticides, etc.) due to the low-input, subsistence farming they practice normally.

**Are Organic foods safe and tasty?**

Globally, there is increased demand for "Organic food" that has led to further increase in area devoted to organic agriculture. The 2019 report of Organics International states that the area under organic farming in 2018was more 71.5 million hectares (out of the 870 million ha crop area). More than 130 developing countries together account for 11 million ha (25%), while about 45 developed countries in Europe, North America, Australia& New Zealand and South America (mostly Argentina and Brazil) have about 75% of land area for OA.But overall area under OA is <1.5 % of global cultivated area. The proportion of area devoted to "organic farming" in Asia is ~8% and Sub-Saharan Africa is less than 3% of the total area. Apart from Europe, North America, Australia& New Zealand, Argentina and Brazil where organic certification is well established, one is circumspect of what is sold as 'organic produce' in the markets in many developing countries, including India.

Claims of organic farming protagonists that that organic food tastes better is not fully supported by evidence. It is seems to be people's perception of taste rather than a fact that can actually be measured in well planned experiments or nutritional analysis. Nevertheless, truly organic foods have been shown to have very little chemical/toxic residues and thus may be considered safer than those produced with intensive use of fertilizers and chemicals. We do not know enough to say that organic food is better than the conventional foods.

**Certification and Marketing of Organic Produce**

Organic agriculture (OA) products are process certified and not product certified.. Process certification is an elaborate exercise beyond the reach of most smallholder farmers in the developing countries (~ Rs.25,000 per ha). Consumers are circumspect whether what they buy as "Organic produce" by paying a premium price is really worth the money? It is evident that more research is required to better define the product quality traits emanating from organic agriculture and on testing procedures for OA products during post-production stages including marketing channels; and there should be a shift from process quality testing to product quality testing for OA products in the near future.

**Is Organic Farming a Panacea?**

A recent article published in "The Hindu" newspaper (4 Oct 2016), the author (Mr. S Raghu Mokkapati) opines that "Organic farming promises a lot: it can reduce the detrimental effects of conventional farming while cutting input costs, fetch a premium price on produce, improve soil fertility, promote efficient use of water resources, and provide safe food for consumers. But having worked closely with 8,000 farmers, I know that the realities on the ground present a stark contrast to this Utopian picture". He further states that "organic farming is not an economically viable option for the smallholder farmers who make up 80 per cent of farmers in India; and pushing these methods on such farmers can actually do much more harm than good".

The Hindu article (above cited) suggested that "there is a lot we can do to improve organic farming and reduce the impact on the environment without going fully organic, by providing options to farmers about safe food that will allow the use of limited and specified agrochemicals within the safe levels specified by public health organizations".

From these analyses we can infer that organic agriculture is feasible and profitable for some farmers in some agro-ecologies and under certain farming situations and contexts; and there is need to make organic farming more profitable and sustainable usingmodern advances in science and technology, so that the farming community can produce enough food to feed the future world, in environment-friendly approach.

**The concept of "Soil as Bank of Plant Nutrients"**

In order to practice "Organic Agriculture" profitably and sustainably the farmers require good soil fertility (soil organic carbon and essential macro and micronutrients), appropriate soil structure and adequate soil moisture. Most of the drylands areas of the arid and semi-arid tropics of the world have degraded soils with low soil fertility, with high air and soil temperatures, coupled with low and erratic rainfall. In these areas, most of the resource-poor smallholder farmers follow 'organic-agriculture-by-default', since they can-not afford external inputs. Crop yields are low, and farmers also harvest the crop residues to feed their cattle, or the crop stubbles are grazed by stray cattle during the summer months. Hence, soil organic matter is low, and also degrades fast due to high soil temperatures.

A recent study from University of Western Australia has reported that it is not feasible to maintain organic matter in soils with less than 600 mm rainfall and daily average temperatures of >15C. It is suggested that instead of the stand-alone 'Organic Farming' approach, a more 'holistic approach' by empowering the smallholder farmers to improve the crop yields by adopting sustainable agriculture practices (choosing best practices from traditional farming and modern agriculture) as being more appropriate for maintaining and enhancing the soil fertility, during the current and future generations for feeding the world.

As mentioned above, we need to be pragmatic and holistic, and consider "Soils as Bank of Plant Nutrients". When crops are grown on a given land, large amount of nutrients are removed from the soil. For example, an average of one ton/ha of maize (corn) crop is estimated to remove ~161kg of Nitrogen, ~66 kg of P205 and ~48 kg of K20. (See Table 1)

| Table 1: Nutrient Removal Rates (Kg/Ton) of Two Grain Crops* | | | |
|---|---|---|---|
| Crop | N Removal Kg/Ton | P205 Removal Kg/Ton | K2O Removal Kg/Ton |
| Corn/ maize | 161 | 66 | 48 |
| Soybean | 63 | 13 | 23 |

**Source :** George Silva **(http://msue.anr.msu.edu/experts/george_silva),**

Michigan State University Extension, October 19, 2015

- Converted from Pounds/ Bushel to Kg/ Metric Ton (1000 Kg).
- Note: These are only indicative figures given for comparison purpose only.

These nutrients that are taken up by the crops (see Table 1) need to be replenished after every harvest to maintain a positive balance of nutrients in the soil. Organic manures, although essential to improve the soil physical and microbiological heath,contain small amounts of major nutrients such as nitrogen, phosphorus and potash(Table 2).

**Table 2: Content of major nutrients (%) in various manures and fertilizers***

| Manures/ Fertilizers | Farm yard Manure | Cattle Manure | Horse Manure | Sheep Manure | Chicken Manure | Urea | Single Super phosphate | Potassium Sulphate |
|---|---|---|---|---|---|---|---|---|
| Nitrogen | 0.5-1.5 | 0.6 | 0.70 | 0.70 | 1.1 | 45-46 | ---- | ---- |
| P2O5 | 0.4-0.8 | 0.15 | 0.30 | 0.30 | 0.80 | ---- | 16-22 | -- |
| K2O | 0.5-1.9 | 0.45 | 0.60 | 0.90 | 0.50 | -- | -- | 50-53 |

***-- Source:** Rodale's All-New Encyclopaedia of Organic Gardening, An Illustrated Guide to Organic Gardening, by Sunset Publishing, the Rodale Guide to Composting; and FAI: Fertilizer Statistics, 2013-14. The table is for comparison purpose only, and amalgamates information from different sources.

On an average, most organic manures (cattle manure, horse manure, sheep manure or farmyard manure) contain 0.5-0.7% nitrogen (N), 0.15-0.80%P2O5, and 0.45-0.90%K2O. It is evident that most commonly used organic manures (mostly cow and sheep dung and farmyard manures ) have less than 1% N compared to 45 % in Urea, < 1% P compared to 16% in Single Super Phosphate, and < 1% K compared to 50% in Potassium Sulphate. Farm Yard Manure will have slightly higher nutrient contents because of mixture of crop residue and manure.

Based on an average of 0.5% N in manure, farmers' need to add 9.2 tons of organic manure to get the equivalent of 100 kg of Urea containing 46% N. Hence, in order to maintain high yield level per unit of land,farmers need to add huge amounts of organic manures. Most farm families in the developing countries (with the exception of Sub-Saharan Africa) are not keepmany cattle (bullocks, cows, buffaloes and sheep) during the past 2-3 decades. Hence the issue is availability of huge quantities of organic manures to replenish the cultivated lands. It is also imperative that soils should get replenished with adequate amount of both macro- and micro-nutrients to sustain the soil health so that it can produce good crop yields over the years. Therefore, it is essential to supplement the nutrients (both macro and micronutrients) through the limited use of appropriate fertilizers to ensure that farmers are not over-mining the soils and make them barren over time. Hence, farmers should provide a combination ofappropriate amounts of both organic and other fertilizers to ensure improved soil health and sustainability of crop production.

**Organic farming vis-à-vis other farming methods**

Traditional farming practised by most of the resource-poor smallholder farmers in the developing countries is organic-by-default, as they cannot afford the use external inputs. As Organic Agriculture is contextual and depends largely on the price premiumsin the markets or governmental subsidies, and farmers can practice other sustainable and profitable farming methods that are suitable to their soils and agro-climatic conditions.

Conservation agriculture (CA) is an approach that advocates the concept of sustainable intensification of production by choosing the best possible options that farmers can practice. It involves: minimum soil disturbance or if possible, no tillage; permanent soil cover/ mulch using crop residues; and crop rotations or intercropping, and farmers choose what is best for them. Soil does not get disturbed with zero or minimum tillage, and carbon loss to the atmosphere is minimized leading to more soil organic carbon. It enhances rainwater infiltration, and reduces run-off and erosion. However, CA will need small farm machinery that can help farmers to sow seeds under no-tillage conditions, and also the use of non-persistent herbicides to manage weeds.

**Sustainable Agriculture Practices (SAP)**

A recent review paper by Kirchmann et al (2016) concluded that "cropping systems with lower intensity (e.g. organic systems) demand more land to produce the same amount of food. The key goal of intensified and sustainable agriculture is to increase yields with minimal environmental disturbances. This review provides evidence that systems based on scientifically verified best agronomic practices are superior over organic ones with respect to yield, nutrient leaching, greenhouse gas emissions and conservation of biodiversity". As mentioned above, the current and future generations of farmers will need a pragmatic approach of nutrient management based on soil analysis to ensure the nutrient requirements of crops to achieve certain optimum yield levels, by following **"Sustainable Agriculture Practices"**(SAP). This is an amalgamation of Resource Conserving Technologies (RCT), the principles of conservation agriculture, and science-based technologies of modern agriculture in a balanced way: (i) zero or minimum tillage, depending on the soil and climatic conditions;(ii) use of crop residues for soil cover (mulching) and as organic manure; (iii) soil-test based application of nutrients (both macro and micronutrients) as needed by the soil and cropping systems; (iv) manage weeds using safe herbicides as necessary; and (v) manage pests and diseases (using a combination of biological methods, biopesticides and minimal use of chemical pesticides) to ensure that crop is healthy and farmers do not incur crop loss.Since some of these practices are labour intensive, and farmers need to be educated or well informed, there is on-going debate on whether these practices can be widely adapted and adopted in the smallholder farming systems to help in meeting the future global food and nutrition requirements.

## Summary

Organic agriculture was practiced during ancient times. With burgeoning population globally, the demand for food was met by modern agriculture practices using external inputs (chemical fertilizers, pesticides, etc.). However, over-use of chemical fertilizers and pesticides resulted in ecological and environmental problems. This led to the Organic Agriculture movement in the US and European countries, and much later later in many other countries. While OA has many advantages with regard to environmental concerns, we are of the opinion that it alone cannot feed the increasing world population, with the impending climate change scenarios. The researchers involved in agricultural research for development, policy makers, and the farmers need to join hands to develop a basket of technological options for "sustainable agriculture practices"(SAP). SAP will include an amalgamation of resource conserving technologies, the principles of organic agriculture, and science-based technologies of modern agriculture in a balanced way. This holistic approach canempower the farmers to choose appropriate farming practices that are suitable for their farms, agro-ecologies and economic conditions.

**Way forward for Sustainability of Organic Agriculture**

Agriculture is location and crop specific, and there cannot be generic recommendations regarding the package of practices. Traditional farming was organic farming-by-default, and was relevant prior to the 19th century when soils were fertile, and crop rotations and land fallowing were followed to rejuvenate the soil to maintain good soil health. However, it is neither wise nor advisable to follow the past agronomic practices for the current day context of farming where soils have been depleted and impoverished by over-use or under-use of chemicals (fertilizers, pesticides, and other inputs). We need to take a holistic view of "soil as a bank of nutrients". Farmers should replenish the nutrients taken-up by a crop every season, especially in the tropical and sub-tropical lands. Organic manures (FYM, compost, and other animal manures) contain small quantities of nutrients, and will be needed in huge quantities. But these organic manures are not readily available in required amounts. Hence, the needed macro-and micro-nutrients need to be supplemented based on soil test results. For e.g., GIS-based soil fertility maps for a few states, developed by the Indian Institute of Soil Sciences (IISS, Bhopal, India) could help enhance productivity, sustainability and also prevent environmental degradation. Using GIS and geo-referenced soil fertility mapping helps scientists to make appropriate recommendations of manures, bio-fertilizers, bio-enriched composts, fertilizers, and fertigation.

Disruptive technologies have brought in revolutions in information technologies (IT), and IT is impacting several other fields, including agriculture. Farming is also undergoing transformation with the advent of precision farming, aided by cutting-edge technologies such as GIS, GPS, GNSS and LIDAR. There will be cheaper agricultural robots in the future, and farmers in developing countries can become managers of land instead of toiling in their fields. Agroponics technologies will help produce crops with much less water. Growing crops in the cities (Vertical farming), and in controlled growth chambers, without soil or natural light is already becoming popular. Alternative protein sources (such as from insects) will be available in the market in next 4-5 years.

We should harness the synergies of integrating the valuable ancient knowledge and wisdom of traditional agriculture with modern science-based technologies to meet the challenges of 21st century, through what we call **Sustainable Agriculture Practices (SAP).**

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