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Nutrients and their Role in Sustainable Agriculture

(*Yashvee[1], Vandana Verma[1], Sarita Verma[2] and Shikha Bhukal[1])
[1]Dep. of Ext. Education and Communication Management, CCSHAU, Hisar, 125004
[2]Department of Home Science, Constituent Government College, Bijnor, U.P., 246701
*Corresponding Author's email: yashveerathi1211@gmail.com

Sustainable agriculture is farming in sustainable ways meeting society's present food and textile needs, without compromising the ability for current or future generations to meet their needs. It can be based on an understanding of ecosystem services. There are many methods to increase the sustainability of agriculture. When developing agriculture within sustainable food systems, it is important to develop flexible business process and farming practices. Agriculture has an enormous environmental footprint, playing a significant role in causing climate change (food systems are responsible for one third of the anthropogenic GHG emissions),water scarcity, water pollution, land degradation, deforestation and other processes; it is simultaneously causing environmental changes and being impacted by these changes. Sustainable agriculture consists of environment friendly methods of farming that allow the production of crops or livestock without damage to human or natural systems. It involves preventing adverse effects to soil, water, biodiversity, surrounding or downstream resources—as well as to those working or living on the farm or in neighboring areas. Elements of sustainable agriculture can include perma culture, agroforestry, mixed farming, multiple cropping, and crop rotation.

Nutrients involved in sustainable agriculture

Nitrates: Possible sources of nitrates that would, in principle, be available indefinitely, include:

- recycling crop waste and livestock or treated human manure
- growing legume crops and forages such as peanuts or alfalfa that form symbioses with nitrogen-fixing bacteria called rhizobia
- industrial production of nitrogen by the Haber process uses hydrogen, which is currently derived from natural gas (but this hydrogen could instead be made by electrolysis of water using renewable electricity)
- genetically engineering (non-legume) crops to form nitrogen-fixing symbioses or fix nitrogen without microbial symbionts.

Phosphate: Fertilizer's main ingredient is phosphate. It is frequently a limiting factor and is the second-most crucial nutrient for plants after nitrogen. It is crucial for sustainable agriculture since it can increase crop yields and soil fertility. All of the main metabolic processes, such as photosynthesis, energy transfer, signal transduction, macromolecular biosynthesis, and respiration, involve phosphorus. It can improve disease resistance and is necessary for seed production, root ramification, and strength..

Both inorganic and organic forms of phosphorus can be found in the soil, and it accounts for around 0.05% of the biomass there. About 70%–80% of the phosphorus in cultivated soils is inorganic, and phosphorus fertilisers are the principal source of inorganic phosphorus for agricultural soils. People have turned to other sources because the prolonged use of phosphate-containing chemical fertilisers results in eutrophication and depletes soil microbial life.

Rock phosphate is used to make fertilisers using phosphorus. Peak phosphorus will happen over the next few hundred years, if not sooner, as rock phosphate is a non-renewable resource that is being mined for agricultural purposes.

Potassium: An essential component for plant growth, potassium is frequently sought after in fertilisers. This vitamin is crucial for agriculture since it enhances crop productivity, disease resistance, flavour, colour, and nutrient value. Grain, fruit, vegetable, rice, wheat, millets, sugar, corn, soybean, palm oil, and coffee are just a few of the crops that are frequently grown with it.

Potassium chloride (KCl) represents the most widely source of K used in agriculture, accounting for 90% of all potassium produced for agricultural use. The use of KCl leads to high concentrations of chloride (Cl^-) in soil harming its health due to the increase in soil salinity, imbalance in nutrient availability and this ion's biocidal effect for soil organisms. In consequences the development of plants and soil organisms is affected, putting at risk soil biodiversity and agricultural productivity. A sustainable option for replacing KCl are chloride-free fertilizers, its use should take into account plants' nutrition needs, and the promotion of soil health.

Soil

Walls built to avoid water run-off, Andhra Pradesh, India. Globally serious issue of land degradation is growing. The Intergovernmental Panel on Climate Change claims that: "Human activity has caused degradation on Earth's ice-free land to cover around 25% of the planet's surface (medium confidence). According to estimates with medium confidence, soil erosion from agricultural areas is currently 10–20 times (no tillage) to more than 100 times (conventional tillage) higher than the soil formation rate." Every year, southern Africa loses more than a billion tonnes of soil to erosion, which, if unchecked, will reduce crop production by half within thirty to fifty years. Growing enough food is threatened by improper soil management. Intensive farming lowers the amount of carbon in the soil, affecting soil quality, crop growth, and ecosystem health as well as hastening climate change.

Soil management techniques include no-till farming, keyline design and windbreaks to reduce wind erosion, reincorporation of organic matter into the soil, reducing soil salinization, and preventing water run-off.

As the global population increases and demand for food increases, there is pressure on land as a resource. In land-use planning and management, considering the impacts of land-use changes on factors such as soil erosion can support long-term agricultural sustainability, as shown by a study of Wadi Ziqlab, a dry area in the Middle East where farmers graze livestock and grow olives, vegetables, and grains.

Looking back over the 20th century shows that for people in poverty, following environmentally sound land practices has not always been a viable option due to many complex and challenging life circumstances. Currently, increased land degradation in developing countries may be connected with rural poverty among smallholder farmers when forced into unsustainable agricultural practices out of necessity.

Converting big parts of the land surface to agriculture have severe environmental and health consequences. For example, it leads to rise in zoonotic disease like the Coronavirus disease 2019, by degrading natural buffers between humans and animals, reducing biodiversity and creating big groups of genetically similar animals.

Energy

Energy is used in modern agriculture for food processing, storage, and transportation as well as on-farm mechanisation. As a result, it has been discovered that food and energy prices are strongly related. Oil is a component of agricultural chemicals as well. The depletion of fossil fuel resources will lead to rising prices for non-renewable energy sources, according to the International Energy Agency. Therefore, unless action is taken to "decouple" fossil fuel energy from food production and a shift toward "energy-smart" agricultural systems that include renewable energy, there may be a deterioration in the global food security. According to reports, Pakistan uses a closed system to power solar irrigation systems for irrigation of agricultural land. The environmental cost of transportation could be avoided if people use local products.

Water

In some areas sufficient rainfall is available for crop growth, but many other areas require irrigation. For irrigation systems to be sustainable, they require proper management (to avoid salinization) and must not use more water from their source than is naturally replenishable. Otherwise, the water source effectively becomes a non-renewable resource. Improvements in water well drilling technology and submersible pumps, combined with the development of drip irrigation and low-pressure pivots, have made it possible to regularly achieve high crop yields in areas where reliance on rainfall alone had previously made successful agriculture unpredictable. However, this progress has come at a price. In many areas, such as the Ogallala Aquifer, the water is being used faster than it can be replenished.
According to the UC Davis Agricultural Sustainability Institute, several steps must be taken to develop drought-resistant farming systems even in "normal" years with average rainfall. These measures include both policy and management actions:

- improving water conservation and storage measures
- providing incentives for selection of drought-tolerant crop species
- using reduced-volume irrigation systems
- managing crops to reduce water loss
- not planting crops at all.

Indicators for sustainable water resource development include the average annual flow of rivers from rainfall, flows from outside a country, the percentage of water coming from outside a country, and gross water withdrawal.

Key challenges

The current trajectory of agricultural production development is unsustainable due to its detrimental effects on the environment and natural resources. Up to 75% of crop genetic variety has been lost, one-third of farmland has been destroyed, and 22% of animal breeds are under danger. In the past ten years, almost 13 million hectares of forest per year have been converted to other land uses, and more than half of fish sources are fully utilised.

The primary issues at hand are the increasing scarcity and rapid deterioration of natural resources at a time when there is a rising demand for food, feed, fibre, and other products and services from agriculture (including crops, livestock, forests, fisheries, and aquaculture). In regions with a high rate of food insecurity and a reliance on agriculture, some of the biggest population growth is anticipated. Additional, intricately related elements exacerbate the predicament:

- Competition over natural resources will continue to intensify. This may come from urban expansion, competition among various agricultural sectors, expansion of agriculture at the expense of forests, industrial use of water, or recreational use of land. In many places this is leading to exclusion of traditional users from access to resources and markets;
- While agriculture is a major contributor to climate change, it is also a victim of its effects. Climate change reduces the resilience of production systems and contributes to natural resource degradation. Temperature increases, modified precipitation regimes and extreme weather events are expected to become significantly more severe in the future;

- Increasing movement of people and goods, environmental changes, and changes in production practices give rise to new threats from diseases (such as highly pathogenic avian influenza) or invasive species (such as tephritid fruit flies), which can affect food safety, human health and the effectiveness and sustainability of production systems. Threats are compounded by inadequate policies and technical capacities, which can put whole food chains at risk;
- The policy agenda and mechanisms for production and resource conservation are mostly disjointed. There is no clear integrated management of ecosystems and/or landscapes.

What needs to be done?

The difficulties mentioned above give birth to five fundamental principles that should direct the strategic creation of fresh ideas and the move toward sustainability:
Principle 1: Improving efficiency in the use of resources is crucial to sustainable agriculture;
Principle 2: Sustainability requires direct action to conserve, protect and enhance natural resources;
Principle 3: Agriculture that fails to protect and improve rural livelihoods and social well-being is unsustainable;
Principle 4: Sustainable agriculture must enhance the resilience of people, communities and ecosystems, especially to climate change and market volatility;
Principle 5: Good governance is essential for the sustainability of both the natural and human systems.
Sustainability needs to be viewed as a process rather than a clearly defined goal that must be attained in order to deal with the accelerated rate of change and growing unpredictability. In turn, this necessitates the creation of technological, policy, governance, and financial frameworks that aid resource managers and agricultural producers who are actively engaged in a dynamic innovation process. In particular:

- Policies and institutions are needed that provide incentives for the adoption of sustainable practices, to impose regulations and costs for actions that deplete or degrade natural resources, and to facilitate access to the knowledge and resources required;
- Sustainable agricultural practices must make full use of technology, research and development, though with much greater integration of local knowledge than in the past. This will require new and more robust partnerships between technical and investment oriented organizations;
- Evidence-based planning and management of the agricultural sectors requires suitable statistics, geospatial information and maps, qualitative information and knowledge. Analysis should focus on both production systems and the underlying natural and socio-economic resources;
- The challenges relating to stocks and utilization rates of natural resources often transcend national boundaries. International governance mechanisms and processes must support sustainable growth (and the equitable sharing of benefits) in all agriculture sectors, protecting natural resources and discouraging collateral damage.