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SUSTAINABLE AGRICULTURE

(A NAM S&T Centre Fact File for Dissemination of Information on Science, Technology and Innovation in NAM and Other Developing Countries)

FROM THE DG'S DESK

Warm Greetings to our Esteemed Readers! As we continue our eventful journey in the 21st Century, we face new challenges in life and try to find solutions through the application of Science, Technology and Innovation (STI). We also realise that STI is making tremendous progress with every passing day and the gap in scientific and technological development between the developing and developed world is widening. It is also recognised that new scientific areas are taking "Centre Stage" and it is extremely important for the developing nations and emerging economies to understand importance of these areas to help achieve "Sustainable Development Goals: 2030". In order to reduce this knowledge gap, the NAM S&T Centre plans to bring out concise information booklets (Fact Files) from time to time on emerging S&T topics of relevance to the developing world. This Fact File on "Sustainable Agriculture" is our first endeavour in this direction. I also take this opportunity to thank Dr. G. Ravindra Chary from India and Dr. Xavier Poshiwa from Zimbabwe for reviewing the contents presented in this Fact File and providing their valuable comments. We are thankful to Dr. Ranadhir Mukhopadhyay, Former Chief Scientist, CSIR-National Institute of Oceanography (CSIR-NIO), Goa, India for his contribution in bringing out this Fact File.

(Amitava Bandopadhyay)

Overview

Agriculture, the world's largest industry occupies around 50 per cent of the Earth's habitable land, employs more than one billion people, and generates over 1.3 trillion dollars (T$) worth of food annually. Demand for agricultural commodities is rising to feed the rapidly growing population of the world. Moreover, agriculture's profound connections to the environment, global economy, human societies and biodiversity makes it an important frontier for conservation. But over the centuries, unsustainable agricultural practices have seriously impacted people, dented food security and damaged the environment. No wonder the world, therefore, is slowly shifting to a more justifiable approach under the sustainable agriculture paradigm. In 2019, this growing industry had a global market size of 16.74 billion dollars (B$), which is estimated to reach 29.23 B$ by 2027. Future challenges for this paradigm shift in agriculture would involve spreading into arid, semi-arid and developing countries, maintaining crop diversity, harmonizing with local socio-economy and protecting massive data.

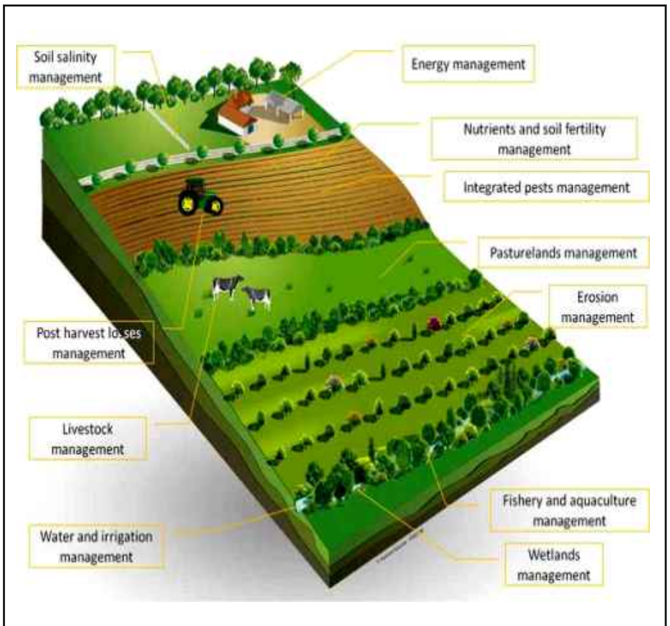

Fig.1. Components of Sustainable Agriculture [Image after https://www.pmfias.com]

Principles

Sustainable Agriculture (SA) integrates environmental health, economic profitability, social equity and constitutes a part of the UN's Sustainable Development Goals (SDG 14). This type of agricultural operation (Fig.1) can increase crop production, preserve and restore critical habitats, help protect watersheds, improve soil health, water quality and biodiversity, even in the face of erratic rain, drought, flood, and extreme natural events.

Sustainable Agriculture through justifiable resource management must meet society's present food needs, without compromising the ability of future generations to meet their requirements. This new approach would improve agricultural policies, management of livestock, and identify new and diversified income opportunities for producers while optimizing the manual workforce.

Difference to Traditional Agriculture

In contrast to conventional farming practices that involve land preparation, ploughing, watering, sowing, fertilizing, harvesting and marketing, the SA blends the traditional and advanced tools, techniques, methods and approaches. Besides offering a good yield, the SA also includes greenhouse automation, livestock management, and precision farming using drones, sensors, and artificial

Item	Traditional Agriculture	Sustainable Agriculture
Land	1 to 5 hectare	10 to 100 hectare
Main Goal	Best yield, high profit	Sustainable securing future
Tools used	Simple: axe, digging sticks, machete, hoe	Complex: tractors, threshers, harvesters
Animals	Several species (3-5)	Few species (1-2)
Labour/Energy	Manual, human and animal	Mechanical, diesel, electrical energy
Manure	Fallows, ash, organic	Inorganic & organic fertilizers, crop residue
Pest, Weed, disease	Control by manual, physical and cultural methods	Mechanical, chemicals (herbicides, insecticides), local knowledge
Harvesting	Manual, sun-dry, fire-dry	Mechanised + post-harvest refrigeration
Chemicals	Major use	No use of agrochemicals
Damage	High environmental	Low environmental
Crop and its management	Manual and traditional, Supports Mono-culture (same) crop, GM is used	Regulate defoliation, flowering, Supports Poly-culture crop, No use of GM crop
Yield	Low to moderate	Moderate to high
Diversity	Reduced biodiversity	High biodiversity
Soil	Erosion and reduced fertility	No erosion, high fertility
Debts	High debt to farmer	Low debt to farmer
Uphold	Better and easier to maintain	Difficult to maintain

Table 1. Difference between Traditional and Sustainable Agriculture 100 Hectare=1 km^2, [After Okigbo 1997]

intelligence (Table 1). The SA practices also addresses the issues of population growth, makes predictive analyses, and adopts end-to-end farm management techniques.

Benefits & Advantages

Every person involved in the food system, such as growers, food processors, distributors, retailers, consumers, waste managers, administrators and policy planners can play a role to ensure a sustainable agricultural system and generating employment. For example, crop growers may use scientific methods to conserve soil health, optimise the use of water and nutrients, enhance resilience to climate change, and minimize pollution levels. Food processors could employ advanced technology to produce value-based high-quality foods, while consumers and retailers could

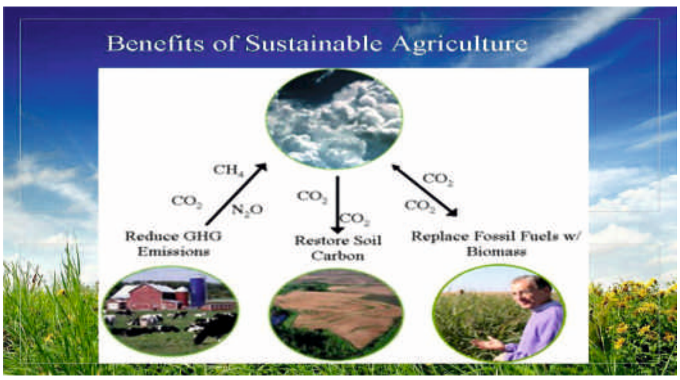

Fig. 2. Major Advantages of Sustainable Agriculture [Image courtesy http://visagsolutions.com]

demand only for those food items produced by adopting sustainable scientific and environment-friendly methods. Such intervention of science and technology could ensure food security and manage hunger. It would also help farmers get the maximum benefits and strengthen the local economy.

Besides these, SA has to remain a front-runner in controlling greenhouse gas dynamics (Fig.2). Not only does it reduce emissions of carbon, methane and nitrogen from soil/land to the atmosphere, but it also sequesters more carbon in soil and could even replace fossil fuel with biomass.

> Sustainable Agriculture is the future, as it combines science, arts and commerce to create an architecture that integrates environmental health, economic profitability and social equity

Methods and Practices

SA integrates multi-institutional and multi-disciplinary approaches, methods and practices, more specifically agriculture, society and economics. However, sustainable agriculture is more than a mere combination of practices. It needs deft handling of contesting situations among farmers, crop processing operators, market needs and economy.

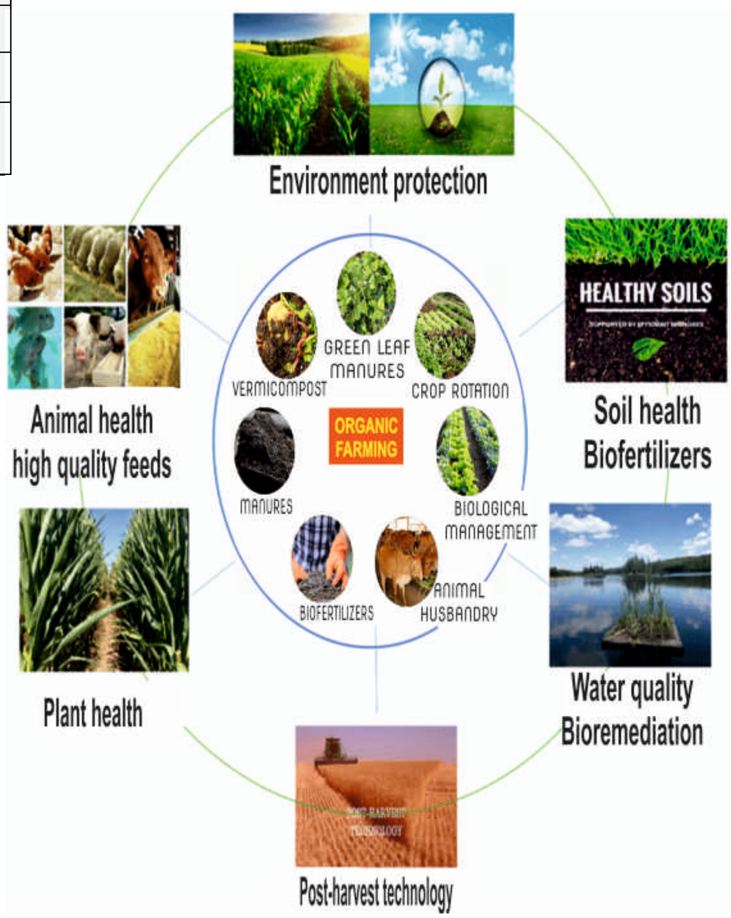

Fig. 3. Dimensions and Practices of Sustainable Agriculture [Image after Yu et al., 2020]

Sustainable agriculture practices incorporate natural mechanisms such as nutrient cycles, nitrogen fixation and pest-predator relationships. It encourages the genetic improvement of crops and animal species, enhancing the balance between cropping patterns and the productive potential while emphasising improved farm management and conservation of soil, water, energy and biological resources (Fig. 3) [Okigbo 1997, Yu et al. 2020].

Sustainable agriculture (also referred to as smart farming) refers to the usage of advanced tools like sensors, geospatial technologies, robots, drones, automation and artificial intelligence. It offers a comprehensive plan to manage all activities of the farm and bring a certain degree of predictability to the system. The cloud-based software would collect all data related to farming and process the same with regard to the weather, irrigation, water availability, crop yield, coupled with the trend and demand of the market. This system would also collect information about insurance, food processing, and export potential.

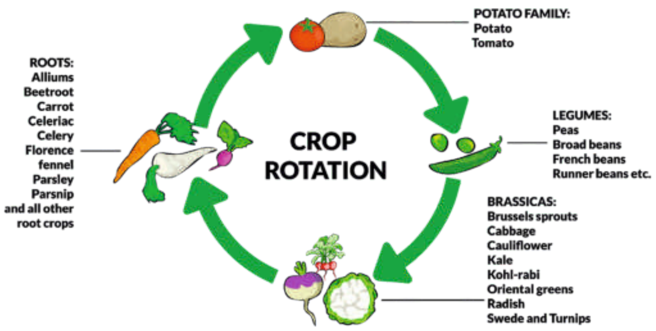

Fig. 4. Planting different crops sequentially on the same plot of land can improve soil health, optimize nutrients in the soil, and combat pest and weed pressure
[Image after PSCI, Princeton University, USA]

Besides conventional ways, SA also manifests by processes like permaculture, aquaponics, hydroponics and polycultures. Permaculture mimics the growth of vegetables and plants in natural ecosystems. Aquaponics involves the sustainable growth of fishes and plants together within the same environment, while hydroponics allows plants to grow without the use of soil. Polycultures include growing a multitude of different crops on a given expanse of land, either through crop rotation or planting rows of different crops side-by-side (Fig. 4). It uses nutrients, space, and energy in a balanced manner. Sometimes, planting trees in croplands could be advantageous. Besides providing direct benefits like timber, fodder, fuel-wood, fruits, herbal medicines, etc., the planted trees form wind-breaks, and crops can grow underneath these trees. This in turn improves the properties of soil and helps form a microclimate in favour of crop growth.

Sustainable Agriculture in the NAM Countries

Realising that growth in agriculture is two to three times more effective at reducing poverty than growth in other sectors, all countries are now focusing on strengthening their agriculture and allied sectors. Agriculture contributes about 25% of GDP in low-income countries and 80% in very poor nations. Globally as per the Food Sustainability Index (measured on three criteria - agricultural practices, nutritional measures, and food waste), the top eleven countries are France, Netherlands, Canada, Finland, Japan, Denmark, Czech Republic, Sweden, Austria, Hungary and Vietnam.

In this background, almost all the NAM countries are facing threats to their agricultural industry. Some of the critical are: how to (a) minimise soil degradation, (b) maintain and if possible enhance the farm productivity in the long term, (c) minimize residues from chemicals and inorganic fertilizers, (d) maximise the net social benefit from farming, (e) make farming systems sufficiently resilient to the vagaries of climate change and market fluctuations and (f) maintain agriculture as a gainful industry. A comparison of the cultivation types adopted by these nations suggests that sustainable agriculture produces maximum yield from the smallest extent of land.

In the 17th NAM Summit held in Venezuela in 2016, the leaders underlined the need to address the economic, social and environmental challenges to sustainable agriculture. It emphasized that achieving food security would require strengthening and revitalizing the agriculture sector in the developing countries. Such stimulation must empower the small and medium-scale local farmers and fishermen, develop appropriate technologies, provide technical and financial cooperation, offer access to and transfer of technology, strengthen weather-forecasting, and enhance investment in post-harvest technology and allied infrastructure development.

It is reported that some of the NAM nations facing acute undernourishment (768 million in 2020, Fig. 5) must recognise the importance of sustainable agriculture and the role it plays in ensuring food security. In this regard, SA is slowly taking a firm root in some NAM countries, viz., India, Nepal, Cameroon, Ethiopia, and Nigeria.

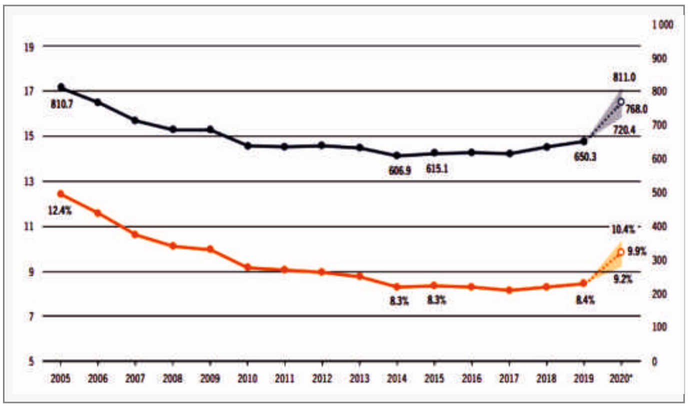

Fig. 5. Undernourished people (%, left axis, orange curve); Undernourished people (number in millions, right axis, blue curve). [Dotted lines for the year 2020. Source FAO 2020]

Sustainable Agriculture in Arid & Semi-Arid Countries

The arid and semi-arid countries are those that receive precipitation below potential evapotranspiration but fell short of becoming a desert. A large part of central to northern Africa, some parts within South Africa, northwest of the Indian subcontinent, and parts of West Asia fall in the arid / semi-arid category.

Farming systems in these areas (especially in northern Africa) involve a combination of crops and animals managed in line with their diverse cultural practices, amenable to different ecological and climatic zones. These systems have evolved through several millennia of traditional practices that were economically viable, ecologically sound and culturally acceptable under the then prevailing low population densities. However, population augmentation has considerably increased pressures on land, resulting in the intensification of farming. The transformation from traditional to modern agricultural practices, such as large-scale plantations, use of ranches, poultry farming and market gardening have eased such pressure considerably.

Sustainable farming could also impact the social structure in these countries by changing the approach from survival framing to profitable farming. It could change the marked division of labour between the genders and help remove unreliable financing systems. It could even bypass political instability and ethnic strife in some other countries (Okigbo 1997).

Business Model

The business climate for sustainable agriculture worldwide is improving. About 46% of the countries implemented 67 regulatory reforms over two years that are helping farmers to manage pest outbreaks, get quality seeds and access finance. In this regard, because sustainable agriculture cannot be achieved overnight, institution-building takes on added significance.

As, SA integrates three main goals – environmental health, economic profitability, and social equity (Fig. 6), such a paradigm would be more successful under a reformed strategy whereby instead of farming on a small stretch of land, a new concept of Community Cultivation (CC) could be taken up. This initiative would encompass contiguous agricultural land of say 500-5000 hectares (5-50 km^2) to start collective farming. Farming over such a large stretch of land in a scientific manner employing modern processes with the latest technology (sensors, drones, automation, and cloud software, etc.) would be both economically and socially viable.

Fig. 6. Sustainable Smart Farming Emerges from the Overlapped Areas of the Famous Three Circular Dimensions [Image courtesy http://visagsolutions.com]

Community cultivation involves that farmers would only lease out (not sell) their agricultural lands to the identified competent people's cooperative societies to undertake community cultivation. All existing farmers would continue to work in the CCs and would receive a fixed monthly salary. The responsibility of sowing, farming, storing and marketing of the crop in the local, regional, or global market may be decided and implemented by such self-financing peoples' cooperative societies. This will offer a basic financial income guarantee and financial stability to the farmers. This would also insulate the farmers from crop loss or financial bankruptcy and stop them from committing suicide (Mukhopadhyay et al. 2021).

Community Cultivation by self-financing Farmers' Cooperative Societies dealing with end-to-end (production to marketing) encryption employing an ethical version of SA practices are the best bet for the NAM and Other Developing Countries

Building a Common Ethical Vision

It is seen now that the intervention of Science and Technology could ensure food security and manage hunger i.e. a field-to-stomach cycle and an end to end solution. Given this, the NAM nations may explore the following 10-point guidelines in designing a common ethical vision for the SA system in their country through efficient Farmers' Cooperative Societies (FCC) or other such agencies:

1. Collate and process all data and information on climate, physiography, land, soil, irrigation facility, existing farming and cropping system, diseases, pests, and ecosystem of a given area.
2. Integrate crops, animals, livestock, forestry, and fisheries within a "comprehensive sustainable agriculture" production system.
3. Ensure marketing of crops and offer guaranteed financial benefits to farmers.
4. Choose the crop and varieties to be produced, and schedule the nature and sequence of operations.
5. Integrate traditional and sustainable agriculture technologies in clearing land (employ both manual and mechanical measures), land use planning, and watershed development. Further, integrate this knowledge with biological (nitrogen fixation) and chemical (fertilizers and nutrient cycling) processes, to control pests, disease and weeds.
6. Use biological and organic approaches and processes as much as possible, and reduce reliance on chemical and synthetic methods in maintaining soil fertility and pest management.
7. Undertake research and innovate new practices and technologies. Diversify production either through mixed cropping, intercropping, crop rotations or row cropping.
8. Bring clarity in post-harvest systematics, e.g. storage, processing, marketing, and re-planting. Ensure effective marketing and pricing systems for agricultural produce and build effective transportation and communication systems.
9. Form adequate educational and skill-development training facilities to roll out skilled farmer-technicians and experts in supporting services.
10. Integrate agricultural development as components of the overall economic development of the country.

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