PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol 9(sp3): 63–70
https://doi.org/10.14719/pst.1835

HORIZON
e-Publishing Group
HePG

REVIEW ARTICLE

Climate resilient agriculture practices - The future of farming

Jitendra Patel* & **G. Shiva Kumar**

Gitam School of Pharmacy, GITAM Deemed University, Rudraram, Sangareddy, Hyderabad – 502 329, India

*Email: jpatel@gitam.edu

OPEN ACCESS

ARTICLE HISTORY

Received: 15 April 2022
Accepted: 03 November 2022

Available online
Version 1.0 : 11 January 2023
Version 2.0 : 09 April 2023

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS etc.
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

CITE THIS ARTICLE

Patel J, Kumar G S. Climate resilient agriculture practices - The future of farming. Plant Science Today. 2022; 9(sp3): 63–70. https://doi.org/10.14719/pst.1835

Abstract

Climate-resilient agriculture (CRA) harnesses the intrinsic roots of agricultural and oxen production systems to generate increased long-term yields and farm income through sustainability. This review paper aims to draw attention to climate-resilient farming practices for medicinal plants and other cereal crops. There are several techniques and strategies that can be used to adapt to climate change, including yield-tolerant strains in poultry and cattle, Feed administration, irrigation, Agro-consulting and clay organic carbon. Governmental climate change adaptation programs such as the National Action Plan on Climate Change (NAPCC), the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), the Indian Council of Agricultural Research (ICAR), the Paramparagat Krishi Vikas Yojana and the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) continue to be implemented. Agriculture in India offers a living for the bulk of the populace and should never be disregarded. Increased demand for quantity, healthful food and diversity, as well as globalization effects and rising median income, would be revealed by India's growing population, globalization effects and increasing median income. Nutrient deficiencies in Indian soils, Imbalanced fertilizer application and Lack of Nitrogen-fixing crops have all caused significant climatic stress in India and the rest of the world. Various programs and policies, such as the Soil Health (Vitality) Card Scheme, are in place to improve fertilizer use efficiency. This cultivation practice pays attention to maintaining the environmental balance and bio-dynamization of agricultural systems so that ethical yield can be obtained.

Keywords

Climate change, Climate-resilient agriculture, Future forming, Governmental scheme

Introduction

Clime transformation is influencing agriculture all across the globe. However, nations like India are particularly accessible due to their large population, excessive reliance on natural origins, and lack of coping tools. Over the last 100 years, India's warming trend has shown a 0.60 °C increase. The predicted effects are likely to exacerbate field variability in many crops, posing a threat to food security. Increased heat, aqua stress and a reduction in the number of waterfall days have severely impacted wheat and paddy yields in parts of India.

Clime transformation is expected to have significant negative consequences, such as yield reductions of 4.5 to 9%, building upon the extent and dissemination of warming. Since cultivation accounts for around 15% of

India's Gross Domestic Products (GDP), a 4.5 to 9.0% reduction in generation suggests that the cost of clime transformation will be around 1.5 % of GDP yearly. Increasing agricultural yield is vital for guaranteeing diet and nutrient security for all, particularly resource-strapped minimal croppers who would be the most affected. Long-term clime transformation could severely affect the poor's livelihood security if adaptation is not planned.

Why India needs climate-resilient agriculture systems

According to worldwide populace figures, India's populace will grasp 1.38 billion in 2020, auditing 17.7% of the global crowd. There has been a 3.35 times increase in the country's population since independence. In 2027, it will surpass China as the world's most populous country. Despite this, India only occupies 2.4 % of the planet. According to the most recent agricultural census, the median size of a field grip per state is 1.08 ha. Most Indian states have minimal cultivators (those with less than 1 ha of land); the rest have small cultivators (1-2 ha). Most have faced significant challenges, including input supply, credit availability, proper transportation and market access. According to the Agricultural Census 2015-16, they produce about 60% of total food cereal production, including 49% rye, 40% gluten, 29% coarse corn, 27% pulses and more than half of the nation's fruits and comestibles.

For around 58 % of India's populace, agriculture is their primary source of income. Other natural-origin-based businesses are also crucial for the nation's commercial development. Field crops, arboriculture, oxen, fisheries and pullets are strongly linked to various United Nations Sustainable Development Goals (SDGs), including zero famine, nutriment and environmental activity (10).

As per estimates from the Union government, India's food productivity was 291.95 MT in 2019-20; the Union had set an object of 298.3 MT for 2020-21, up 2% over the previous year's output. Keeping up with the country's population, wealth and food production growth will require doubling food production by 2050. As a result, minimal farmers play a critical role in the nation's food care and achievement of the SDGs.

As per the State of Food Security and Nutrition in the World 2020 study, about 14% of India's populace (189.2 million) is still malnourished. India is ranked 94th out of 107 countries in the Global Famine Index 2020. Getting to "zero hunger" by 2030 is a huge undertaking that will require an integrated and multi-dimensional strategy for the country's entire sustainable agriculture and food systems. Clime transformation, especially its influence in extreme weather events, is one of the most severe threats to a country's food security. The expected temperature change of 1-2.5 degrees Celsius by another 8 years will likely impact product output significantly. High temperatures can shorten crop life, allow photosynthesis to fluctuate, increase crop gaseous exchange rates and influence the insect populace (10).

As a result of the climatic transformation, nutrient mineralization is accelerated, fertilizer use efficiency (FUE) is reduced and soil evapotranspiration is increased. Clime transformation has a direct or indirect impact on the crop, aqua and clay because it affects water scopes, changes the strength and frequency of droughts, affects the microbial populace, reduces clay organic matter, reduces yields and depletes soil fertility due to soil erosion, among other things. "Clime transformation may reduce yearly farm income in the range of 15% to 18% for irrigated areas and up to 20% to 25% for unirrigated areas," according to a 2017-18 economic survey. This results in food shortages and nutrient deficiencies in humans due to insufficient intake of good foods, making them vulnerable to health problems. South countries, from the Himalayas to the coasts, must be prepared to conflict with the effects of earth warming. As predicted, south Asian regions may have a heating effect of 2-6 °C in the twenty-first century (1). Carbon dioxide concentrations are enormous, up to 410 parts per million and are the primary cause of global warming (2).

Drought-prone states such as Western Rajasthan, Madhya Pradesh, Karnataka, Southern Gujarat, Andhra Pradesh, Haryana and Bihar are constantly experiencing dry spells (3). In Mumbai in 2005, over 20 million people were affected by the same problem. When the river Yamuna surged beyond the danger zone in 2008, it destroyed millions of dollars of property in Delhi and Haryana. Kerala was devastated by one of the most horrible floods of the year. In 1999, a superstorm hit Orissa, killing over a million people and causing massive property damage in coastal areas. During the Hud-Hud storm in 2014, Andhra Pradesh went through a similar scenario. In 2019, India and its neighboring nations were hit by a severe heatwave from mid-May to mid-June.

Agriculture sub-sectors and Clime transformation

Cultivation methods depend entirely on climate conditions. By the mid-20th century, Southasian countries have seen their crop output decline by 30%. In India, for example, a 1.5 °C increase in temperature and a 2 mm reduction in drizzle can reduce rye productivity by 3 to 15%. (4). Huge calefaction creates moisture stress in fruit trees, resulting in sunburn and cracking in apricot, apple and cherry trees. In litchi plantations, an increase in temperature during the ripening stage causes fruit to burn and shatter (5). Vegetable crop yields will be reduced by 5-15 % whenever ozone concentrations exceed 50 parts per billion per day. Increased cardiac rates (greater than 70 to 80 per min.), blood circulation and body heat (above 39.17 °C) are all effects of higher temperatures in animals. Heat stress is more common in dairy breeds than in meat types. Increased ingestion heat-production breeds are more susceptible to heat stress, whereas low dairy-producing animals are less susceptible (6).

Poultry is highly vulnerable to temperature-related issues, particularly heat stress. Due to heat stress, poultry feed consumption decreases (7), resulting in lower body weight and egg production and a reduction in meat quality. It lowers the eggshell density and increases egg breakage (8). Increasing environmental temperature may improve fish improvement and development over time.

However, it also increases the threats to the populace outside the thermal tolerance zone (9). With these issues in mind, the Government of India's Ministry of Agriculture and Farmers Welfare, as well as the Indian Council of Agricultural Research (ICAR), have developed several proactive initiatives at the village level. Clime transformation can potentially diminish agricultural income by 15% to 25%; it is past time to value and execute climate-resilient agriculture (CRA) more rigorously.

Climate resilient agriculture

A climate-resilient agriculture (CRA) strategy uses existing natural resources in agricultural and oxen production systems to improve productivity and lawn revenues in the face of climate change. In front of Clime's transformation, this strategy reduces famine and poverty for upcoming generations. CRA methods can change the current circumstance and sustain horticultural output on a provincial, regional and universal scale, particularly in a sustainable pattern.

Climate-resilient practices reveal improved access and use of technology, transparent trade regimes, extensive application of resource conservation methods and induced tolerance of environmental issues by agriculture and oxen. Although many nations have experienced natural disasters and combat in recent years, food security has been weakened by inadequate distribution, volatile food prices and high demand for agricultural ammunition (10).

Technologies and Strategies for Clime transformation adaptation

The different strategies are adopted by governmental organizations given in Fig. 1.

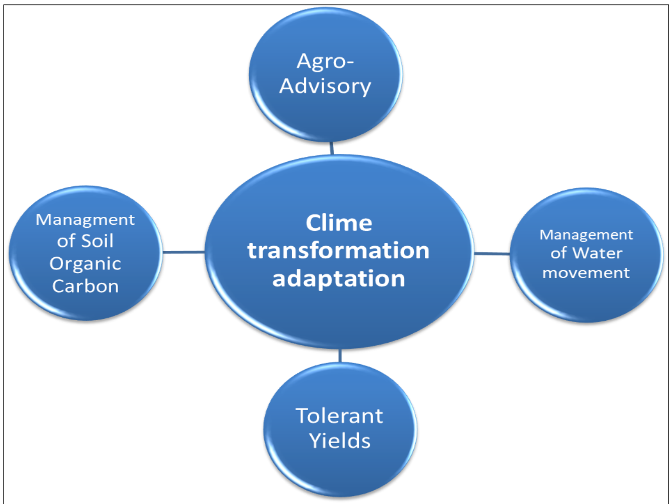

Fig. 1. Overview of the Technologies and Strategies for Clime transformation adaptation.

Tolerant yields

Drought patterns may necessitate a variety of flexible forms. Farmers in Maharashtra's Aurangabad area planted early-maturing and drought-tolerant cultivars of green gram, chickpea and fowl pea to achieve poor downpour conditions (rainfall of 645 mm). This resulted in a 20-25% increase in production over native varieties. Scarcity-tolerant, early-aging pigeon pea and sorghum cultivars were also introduced in the suburb of Maharashtra's Amravati region (rainfall 877 mm).

Tolerant breeds in poultry and livestock

Indigenous or Local varieties have the instinct to forage for food. The animals in nomadic systems reveal their owners when it's time to go in quest of new grasslands. Local breeds have distinct personalities that have evolved to fit into particular ecosystems worldwide. Drought resistance, thermoregulation, the ability to traverse long distances, mothering instincts and fertility, eating and digesting low-grade feed, and disease resistance are distinct characteristics. These cattle breeds aren't particularly productive regarding meat or dairy output. However, they are highly adaptable to unreliable nature and have small resource pathways (10).

Feed Administration

As a transformation measure, improving feeding systems can boost cattle production efficiency. Changing the frequency or feeding time, modifying the diet composition and integrating agroforestry breeds in the diet of animals. Some feeding approaches teach producers about the conservation and production of feed for varied agro-conservational zones. These strategies can lower the risk of Clime transformation by stimulating significant intake or insemination for inadequate meal ingestion, reducing massive temperature loads and reducing animal hunger and death (10).

Management of water movement

Furrow irrigated raised beds, rainwater gathering structures, micro-irrigation, cover the crop methods, greenhouses, laser land-levelling, restating of wastewater, shortfall watering and management of drainage are examples of water-smart technology that can help farmers reduce the impact of Clime transformation. Various technologies based on precise crop water requirement estimation; ground-water recharge techniques; endorsement of scientific water conservation techniques; changing fertilizer and irrigation plans; cultivating minimum water-consuming varieties; adjusting plantation dates; irrigation protocols; and accepting zero-tillage may assist cultivators in achieving satisfactory crop yields even in years with warmer temperatures and low rainfall. As a result, various international organizations, government research institutions, farmer organizations and private and non-profit agencies around the globe have been concentrating their attempts on the model and evolution of economics and environmentally favorable water-saving devices to improve water use efficiency (10).

Agro-advisory

Feedback farming is an integrated strategy; it may be described as farming with technocrat recommendations based on local meteorological data. Response farming's success, i.e., reduced danger and increased yields, has already been implemented in Tamil Nadu and various other states. Because Clime transformation is not a rapid event, response farming could be a viable alternative for Clime transformation adaptation measures. The key reason for response farming's effectiveness is due to time-specific technologies and location. It's time to spread the word about responsive farming's success to the rest of the farming community (10).

Soil organic carbon

A range of farm management practices can raise soil carbon reserves and promote soil functional stability. Providing a protective soil cover, conservational agriculture technology (reduced tillage, cover crops and crop rotations), conservation of soil practices (contour farming), and a nutriment recharge plan can replenish the soil's organic matter. For long-term soil health, integrated management of nutrients includes the use of inorganic and organic fertilizers, farm-yard manure, vermin compost, legumes in rotation and crop residue. The key to the long-term sustainability of Indian agriculture is to feed the soil rather than applying fertilizers to the crop without using organic inputs (10).

Governmental programs for Clime transformation adaptation

The Government of India has combined multiple policy programmes and sectoral strategies to guarantee efficacious and synergy use of live capital. The National Aim of Sustainable Agriculture was launched in 2010 as part of the National Action Plan on Climate change (NAPCC) to promote sensible resource administration. It was one of 8 missions under the NAPCC. The Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) was created in 2015 to solve water resource challenges and arrange a long-term solution that promotes each Drop More product by promoting drip watering for optimal water protection. In collaboration with the Indian Council of Agricultural Research (ICAR) and present governments, the Paramparagat Krishi Vikas Yojana mission was implemented to extensively utilize the adaption of climate-smart practices and technology. Green India Mission was started by the Government of India in 2014 under the auspices of the NAPCC with the primary goal of conserving, recovering, and increasing India's declining forest cover, thereby decreasing the negative consequences of Clime transformation. To maintain soil health, the Government of India has created the clay Health Card proposal, which aims to analyze cluster soil samples and advise farmers on their land virility condition.

In addition, Neem enclosed Urea was created to reduce the overuse of urea fertilizers, preserving soil strength and providing nitrogen to the plant. Programmes like the National Project on Organic Farming and the National Agroforestry Policy were implemented in 2004 and 2014 to incentivize cultivators with increased financial benefits and ecosystem conservation. These policies attempt to provide plant nutrients through organic revisions, boost clay carbon stock, and protect soil from corrosion. Several provinces, like Himachal Pradesh, Andhra Pradesh and Sikkim, have begun to embrace and promote organic farming practices on a larger scale.

Sikkim was recently designated as an organic state by the Government of India. For the past seven years, the ICAR has been executing agriculture contingency plans in around 650 districts across India through its chain investigation institutes, state agriculture institutions and other line departments to prepare for Clime transformation. The countries will use these models to adapt to Clime transformation consequences like floods, cyclones, scarcity, temperature waves and sea-water incursion. ICAR has built climate-resilient suburbs in more than hindered districts across India, which state governments are reproducing to create a carbon-positive suburb. The Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) was passed in 2005 with the goal of "improving employment prospects, as well as providing economic stability and environmental protection" (10).

Cultivation of Medicinal Plants

There are fifteen agro-climatic zones in India, with seventeen to eighteen thousand different blooming plants. Six to seven thousand are thought to have therapeutic properties. The usage of medicinal plants may be obtained from many Indian communities and is documented in Indian medical systems such as Ayurveda, Unani Siddha and Homeopathy. There are around 960 different types of medicinal plants in trade, with 178 other species having yearly consumption levels of more than 100 metric tonnes (37).

The future of Indian agriculture

Indian Agriculture provides a living for most inhabitants and should never be overlooked. Agricultural creation has increased, although its % of Gross Domestic Products has reduced below 20%. In contrast, other sectors' offerings have enlarged at a vast rate. This has enabled us to covert self-adequate and changed us from a food receptacle after freedom to a net distributor of cultivated and allied items. According to the 2nd advance projection for 2019-20, the entire food-grain output in the nation would reach a novel massive of 291.95 million tonnes. This is a good thing, but the Indian Council for Agricultural Research (ICAR) anticipates that the appeal for food grain will rise to 345 million tonnes (11).

Increased appeal for quantity, healthy food, quality and variety, would reveal India's growing populace, globalization effects and rising median income. While a reveal, the pressure to yield more types, quantities and food traits will continue to grow as accessible tillable land reduces. India is divided into a vast belt of productive land and disputed into 15 agro-climatic belts through the Indian Council of Agricultural Research (ICAR), which can collar various crops and weather conditions. India is the world's greatest erector of milk, tea, pulses, spices, jute, cashew, wheat, rice, oilseeds, fruits, comestibles, sugarcane and cotton. Despite these facts, the average predictability of various Indian crops is so poor.

The country's populace is assumed to grow to enrich the world's most significant in the coming decennary and alimentation them will be the primary concern. Cultivators are still incapable of making a modest living. Agriculture's future is a crucial issue for executives and all other NGOs. The government and other companies are efforting to project the critical censures of cultivation in India, such as minor farmer owning, primary and secondary handling, supply bond, a framework supporting good stock use, and marketing, to reduce market referees. Work on cost-effective technologies that shield the environment and conserve our natural resources is required. Privatization, liberalization and globalization changes influenced the input barter faster.

After 2003, agricultural marketing remedies changed how agricultural yields were sold by allowing privy finance in developing markets, agreement farming and prospects trading, among other things. These modifications to marketing acts have revealed some changes but at a lower rate. Along with this, India's information technology rebellion, new agricultural technologies, private investments, particularly in R&D and government endeavors to revitalize the coordinated campaigns to address the issues of smallholdings and small fruitage are all changing the face of cultivation in India. Many agricultural organizations started by highly enlightened adult people illustrate that they grasp the enormous capability of investing money and endeavors in this industry.

Over the next decade, the collective effects of technology will remodel the face of agriculture. All of the sets in agriculture make productivity and returns complex. However, India's agriculture sector still has a much-untapped capability. Many individuals, big companies, new start-ups and entrepreneurialism ventures are attracting much equity in innovations, inventiveness, research and development. Other aspects of pursuit due to optimum weather and soil conditions, high summon for food, untapped fortuities and various fiscal bonuses provided by the government for inputs, production framework, availability of shoddy credit facilities and marketing and send-out promotion. All agriculture issues are being converted into fortuities and this task is the future of agriculture (10).

Impacts of Clime transformation

South countries, from the Himalayas to the coasts, must be prepared to combat the results of universal warming. As predicted, south Asian regions may have a warming result of 2-6 °C in the 21^{st} century (12). Carbon dioxide concentrations are enormous, up to 410 parts each million and are the primary cause of global warming (13).

Fertiliser Use Scenario Trends in India and World

According to the World Fertilizer Magazine, India's food-grain production climbed by 3% annually from 175 Mt in 2002-03 to 296 Mt in 2019-20 (as anticipated), with just a minor increase in cultivated land. As a result, improving productivity is critical in this setting, as fertilizer accounts for at least half of crop yield. Arable land acreage is predicted to decline as urbanization and population pressure increase. Unless vertical agricultural expansion occurs, it will eventually influence the country's food production. Fertilizers must play a vital role in raising average crop yields per hectare and satisfying the world's and country's future food needs.

Nutrient Deficiencies in Indian Soils

For N, K, P, S, Zn, B, Fe Cu and Mn respectively the extent of nutrient shortages in Indian soils is 95, 94, 48, 25, 41, 20, 14, 8 and 6 %. The full expression/utilization of other nutrients is hampered by lower levels of some nutrients in the soil. In intensive agriculture systems, the current uneven and insufficient use of fertilizers, as well as the lack of organic manure addition, has resulted in the progressive rise of single or multiple nutritional shortages. Nitrogen insufficiency is common, although P and K deficiencies can be seen in rice-rice, rice-potatoes, rice-vegetables and other grain-producing cropping systems. Secondary nutrient deficiencies, such as Ca, Mg and S, have been widespread in sandy soils with low pH and organic matter (14, 15).

Emerging Nutrient Deficiencies

Seventy percent of the population in South Asian countries lives in villages, dependent on rains to cultivate their small plots of land. Crop development in these places is critical for regional self-sufficiency and global food security. South Asia produces over 31% of the world's rice and 18% of the world's wheat. In these places, irregular rainfall patterns, soil degradation, high temperatures, poor soil moisture content and numerous nutrient shortages contribute significantly to lower yields. Rainfed agriculture is confronted with significant difficulties in sustainable growth, such as natural resource conservation and land capacity expansion (16).

Management of Integrated Nutrients

The use of chemical fertilizers in conjunction with organic additions improves soil productivity and has a favorable relationship with soil C buildup (17, 18). Furthermore, incorporating root biomass C into the soil via crop residues balances the physico-chemical and biological environment, allowing for increased C sequestration rates (19).

Improving Soil Organic Carbon: Organic fertilizer supplementation during cultivation not only improves soil physical qualities, but also increases and maintains microbial activity, resulting in fast decomposition of organic matter in soils (20, 21).

Site-specific Nutrient Management

Site-specific nutrient management (SSNM) is a precise method of nutrient management in which nutrients are fed to the plant only when needed, resulting in precision agriculture; it can be used for any crop production. It essentially mixes nutrient requirements at each stage of crop development with soil nutrient supplying capacity based on an average field analysis. The SSNM technique proposes modifying fertilizer application rates to meet crop needs, resulting in increased production and profitability (22-24).

Balanced Fertilizer Application

All essential nutrients must be present in an appropriate form for maximum plant growth. Change is severely hampered if these nutrients are given in excessive amounts or in limited supply (25). As a result, it is critical to apply chemical fertilizers in a balanced manner to reap many benefits. It essentially entails the addition of a specified quantity of fertilizers to organic manures (26); balanced fertilization demonstrating rational use of fertilizer and organic amendments in agricultural production would ensure:

- The harvesting of synergistic interactions among seed, water, agrochemicals and other inputs in production;
- Efficient utilization of applied fertilizer, minimization of nutrient losses;
- Soil productivity;
- Least adverse environmental impact; and
- Sustenance of higher crop yields.

Nitrogen-fixing Crops

Biological nitrogen fixation is the conversion of atmospheric nitrogen (N2) into physiologically usable NH_3 by N-fixing rhizobia bacteria (Rhizobiaceae, Proteobacteria) in conjunction with plants. Using legumes in a given cropping sequence boosts biological nitrogen (N) fixation, which increases soil physical activity, reduces the need for excessive N fertilizers, and improves NUE. Legumes can fix 25-75 kg ha-1 yr-1 of nitrogen in a natural ecosystem. However, in a cropping system, they can fix several hundred pounds (27).

Intercrops

Crop failure is reduced, soil erosion is reduced and yield stability and cost-effectiveness are improved by intercropping (28). Growing non-leguminous crops with legumes has several advantages, including lowering disease attacks, weed management in the field and lessening the harmful effects of intense cereal farming on soil fertility and productivity. Furthermore, intercropping a legume with non-legume benefits the latter due to the former's nitrogen fixation. Likewise, two crops with different root systems, height, canopy, growth habits and adaptation will grow simultaneously with the least amount of competition for moisture and nutrients (29); higher yield sustainability across seasons; efficient use of available land resources; and better pest and disease control (30).

Customized Fertilizers

Customized fertilizers (CFs) provide a full spectrum of plant nutrients (multi-nutrient carriers) in the proper proportions to meet the crop's fundamental nutritional requirements at various stages of growth (31). These fertilizers are meant to contain all of the essential plant nutrients, such as macro (N, K, P), secondary (Mg, Ca, S) and micronutrients (Cu, Zn, B, Fe, Mn, etc.). They are created using a systematic granulation process.

Fertilizers with Water Solubility

Water-soluble fertilizers (WSFs) are a type of fertilizer that may be used in sprinkler/drip irrigation systems as well as foliar sprays to assist improve crop yields and quality in fruit and vegetable crops. These fertilizers have a low salt index so they won't damage plant tissues. They're also 100 % water-soluble, making them ideal for foliar application or fertigation. Water-soluble fertilizers are a mixture of all essential nutrients in various ratios to meet the matrix of crop type, water quality, soil fertility state and climatic circumstances (32).

Biofertilizers

Biofertilizers are an efficient chemical fertilizer substitute for sustainable agriculture (33); they are less expensive and more environmentally friendly, increasing farm output (34). Using biofertilizers is a potential method for reducing the consumption of conventional inorganic fertilizers. They can fix atmospheric nitrogen (N2), aid in soil phosphorus (P) access, boost plant health, and improve drought and salt tolerance (35). Azotobacter chrococcum is a free-living aerobic diazotrophic bacteria found in Indian soils.

Hydrogels

Hydrogels are semi-synthetic super-absorbent polymers (SAP) that can absorb 400 times their weight in water. They have demonstrated the ability to achieve higher yields with less water. When the surrounding environment dries up, it releases around 90% of the previously held water (36).

Agro-advisory-based Nutrient Management

Crop management strategies are rarely successful unless the meteorological conditions are ideal. Agro-advisory services can help farmers decide on their farms and advocate for them based on changing weather conditions. Besides wind direction, agro-advisory services (AAS) are helpful, and parameter forecasts satisfactorily match actual data. Agro-advisory Services regarding Clime transformation was provided in some villages of Marathwada as part of the project. All India Coordinated Project on Agrometeorology (AICRPAM) and National Initiative on Climate Resilient Agriculture (NICRA) revealed that AAS is an effective communication medium for technology transfer. AAS provides basic, timely and accurate pre-information about the weather conditions of various crops.

Slow Release Nitrogenous Fertilizers

The high solubility of nitrogen fertilizers facilitates leaching losses in upland areas and de-nitrification losses in low -lying places. Slow-release nitrogen fertilizers have taken much effort to develop. There are 2 types: urea-aldehyde products such as crotonaldehyde diarrhea (CDU), urea form (urea-formaldehyde) and isobutylidene diurea, which are naturally less soluble materials and urea-aldehyde products such as neem-coated urea, sulfur coated urea and polymer-coated urea (IBDU).

Programmes and Policies for Enhancing the Fertilizer Use Efficiency

Policies and programmes are essential to deploy proven technology at the farm level successfully. The importance of policy is demonstrated by neem-coated urea. Neem-coated urea technology has been around for decades. It was not widely adopted until the Indian government declared it essential to coat urea with neem oil to boost its effectiveness. As a party to the United Nations Paris Agreement, the country's commitment to reduce greenhouse gas (GHG) emissions reflected the policy's context (2015).

Soil Health (vitality) Card Scheme

India started the Soil Health Card (SHC) scheme in February 2015. This soil health card method provides information on soil type so that farmers can plant crops that are appropriate for the soil type. It encourages balanced and integrated plant nutrient use. As a result, the soil health card concept maintains soil productivity and improves FUE (16).

Waste to Wealth Programme

Waste to Wealth is another key programme launched by the Union Government. In truth, nothing should be considered waste, and the basic principle of this program is to reuse, recycle, or use it as a raw material to generate energy. India produces over 290 million tonnes of food grains, 320 million tonnes of horticulture produce, billions of eggs and several times the amount of meat produced in the United States. Large amounts of organic residue are produced in various food production systems and throughout the processing steps. These wastes from the food production system take vital nutrients with them. If we don't recycle these nutrients back into the soil, future agriculture will be unsustainable. As a result, the waste-to-wealth programme is critical for recycling plant nutrients.

Conclusion

Imbalanced and incorrect fertilizer nutrient management has severely harmed soil productivity levels. This act caused multi-nutrient deficits, groundwater pollution, poorer crop yields and ultimately, a danger to world food security. Agriculture is being impacted by climate change worldwide. However, India is especially vulnerable due to its large population, excessive reliance on natural resources and lack of coping methods. Climate Resilient Agricultural Practices are an emergency tool to be adopted. The National Action Plan on Climate Change (NAPCC), the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), the Indian Council of Agricultural Research (ICAR), the Paramparagat Krishi Vikas Yojana and the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) are all ongoing government climate change adaptation programs. These plans are to keep helping the cultivator restore the dynamic of the Agro system for medicinal plants and other food crops. In other country such as South Asia, Sri Lanka, Pakistan, Canada, Philippines etc. also adopting successfully different techniques and strategies like Agricultural Climate Solutions (ACS) programmes.

Acknowledgements

The author wants to acknowledge Dr. Vijay Kumar Patel, Associate Professor, Dr. C. V. Raman University Bilaspur, for providing the information and framing the articles. We also acknowledge Gitam School of Pharmacy, Gitam Deemed University, for providing necessary help during the tenure.

Authors contributions

Both authors contributed equally.

Compliance with ethical standards

Conflict of interest: The author declares that the provided information has no conflict of interest.

Ethical issues: None.

References

1. Ravindranath MJ. Environmental education in teacher education in India: Experiences and challenges in the United Nation's Decade of Education for Sustainable Development. Journal of Education for Teaching: International Research and Pedagogy. 2007;33(2):191-206. https://doi.org/10.1080/02607470701259481
2. Srinivasrao Ch. Programmes and policies for improving fertilizer use efficiency in agriculture, Indian Journal of Fertilisers. 2020;17(3):226-54.
3. Bhadwal S, Sharma G, Gorti G, Sen SM. Livelihoods, gender and climate change in the Eastern Himalayas. Environmental Development. 2019;31:68-77. https://doi.org/10.1016/j.envdev.2019.04.008
4. Ahluwalia VK and Sumita M, Environmental Science, New Delhi, Anne Books India; 2006.
5. Kumar JIN, Soni H, Kumar RN. Patterns of site-specific variation of waterbirds community, abundance and diversity in relation to seasons in Nal Lake Bird Sanctuary, Gujarat, India. International Journal of Bird Populations. 2007;8:1-20.
6. Dash S, Singh A, Upadhyay A, Singh M. Effect of heat stress on reproductive performances of dairy cattle and buffaloes: A review. Veterinary World. 2016;9(3):235-44. https://doi.org/10.14202/vetworld.2016.235-244
7. Deng Ye, Jiang Yi-Huei, Yang Yunfeng *et.al*. Molecular ecological network analyses. BMC Bioinformatics. 2012;13:113. https://doi.org/10.1186/1471-2105-13-113
8. Lin HV, Rogulja A, Cadigan KM. Wingless eliminates ommatidia from the edge of the developing eye through activation of apoptosis. Development. 2004; 131(10): 2409-18. https://doi.org/10.1242/dev.01104
9. Morgan JW, Walker RJ, Brandon AD and Horan MF. Siderophile elements in Earth's upper mantle and lunar breccias: data synthesis suggests manifestations of the same late influx. Meteoritics and Planetary Science. 2001;36:1257-75. https://doi.org/10.1111/j.1945-5100.2001.tb01959.x
10. Srinivasrao Ch**.** Climate resilient agriculture systems: The way ahead Down to Earth fortnightly magazine. New Delhi, India. Thursday 04 February 2021. https://www.downtoearth.org.in/
11. Shah J, Kahn M. The Future of Indian Agriculture & Food Systems: Vision 2030. Omnivore. 2020; 1-70.
12. Ravindranath MJ. Environmental education in teacher education in India: Experiences and challenges in the United Nation's Decade of Education for Sustainable Development. Journal of Education for Teaching: International Research and Pedagogy. 2007;33(2):191-206. https://doi.org/10.1080/02607470701259481
13. Srinivasrao Ch. Programmes and policies for improving fertilizer use efficiency in agriculture, Indian Journal of Fertilisers. 2020;17(3):226-54.
14. Srinivasarao Ch, Vittal KPR, Chary GR, Gajbhiye PN and Venkateswarlu B. Characterization of available major nutrients in dominant soils of rainfed crop production systems of India. Indian Journal of Dryland Agricultural Research and Development. 2006; 21(2):105-13.
15. Srinivasarao Ch, Vittal KPR, Gajbhiye PN, Sumanta K, Sharma KL. Distribution of micronutrients in soils in rainfed production

systems of India. Indian Journal of Dryland Agricultural Research and Development. 2008;23(1):29-35.

16. Srinivasarao Ch, Venkateswarlu B, Lal R, Singh AK, Kundu S. Sustainable management of soils of dryland ecosystems of India for enhancing agronomic productivity and sequestering carbon. Advances in Agronomy. 2013; 121:253-329. http://dx.doi.org/10.1016/B978-0-12-407685-3.00005-0

17. Srinivasarao Ch, Vittal KPR, Venkateswarlu B, Wani SP, Sahrawat KL, Marimuthu S, Kundu S. Carbon stocks in different soils under diverse rainfed production systems in tropical India. Communications in Soil Science and Plant Analysis. 2009;40:2338-56. http://dx.doi.org/10.1080/00103620903111277

18. Srinivasarao Ch, Satyanarayana T, Venkateswarlu B. Potassium mining in Indian agriculture: input and output balance. Karnataka Journal of Agricultural Sciences. 2011; 24:20-28.

19. Indoria AK, Sharma KL, Reddy SK, Srinivasarao Ch., Srinivas K, Balloli SS, Osman M, Pratibha G, Raju NS. Alternative sources of soil organic amendments for sustaining soil health and crop productivity in India - impacts, potential availability, constraints and future strategies. Current Science. 2018; 115: 2052-62. https://doi.org/10.18520/cs/v115/i11/2052-2062

20. Zou C, Li Y, Huang W, Zhao G, Pu G, Su J et al. Rotation and manure amendment increase soil macro-aggregates and associated carbon and nitrogen stocks in flue-cured tobacco production. Geoderma. 2018;325:49-58. https://doi.org/10.1016/j.geode rma.2018.03.017

21. Kuzyakov Y, Friedel JK, Stahr K. Review of mechanisms and quantifcation of priming efects. Soil Biology and Biochemistry. 2000;32:1485-98. https://doi.org/10.1016/S0038-0717(00)00084-5

22. Witt C, Dobermann A, Abdulrachman S, Gines HC, Guanghuo W, Nagarajan R et al. Internal nutrient efficiencies in irrigated lowland rice of tropical and subtropical Asia. Field Crops Research. 1999;63:113-38. https://doi.org/10.1016/S0378-4290(99)00031-3

23. Buresh RJ, Pampolino MF, Witt C. Fieldspecific potassium and phosphorus balances and fertilizer requirement for irrigated rice-based cropping systems. Plant and Soil. 2010;335:35-64. https://doi.org/10.1007/s11104-010-0441-z

24. Singh VK, Shukla AK, Singh MP, Majumdar K, Mishra RP, Rani M, Singh SK. Effect of site-specific nutrient management on yield, profit and apparent nutrient balance under pre-dominant cropping systems of Upper Gangetic plains. Indian Journal of Agricultural Sciences. 2015;85:335-43.

25. Kumar D, Shivay YS. Sustainable crop production and food security in India. Kurukshetra. 2007;59(11):11-16. https://doi.org/10.1371/journal.pone.0193766

26. Goswami NN. Concept of balanced fertilization – its relevance and practical limitations. Fertiliser News. 1997;42(4):15-19. https://doi.org/10.1007/978-1-4020-9875-8_8

27. Frankow-Lindberg BE, Dahlin AS. N2 fixation, N transfer and yield in grassland communities including a deep-rooted legume or nonlegume species. Plant and Soil. 2013;370:567-81. https://doi.org/10.007/s11104-012-1650-z

28. Chandra A, Kandari LS, Vikram S, Negi RK, Maikhuri, Rao KS. Role of intercropping on production and land use efficiency in the Central Himalaya, India. Environment and We: An International Journal of Science and Technology. 2013;8:105-13. https://doi.org/10.1007/978-981-13-0253-4_2

29. Bhatti IH, Ahmad R, Jabbar A, Nazir MS, Mahmood T. Competitive behaviour of component crops in different sesame-legume intercropping systems. International Journal of Agriculture and Biology. 2006;8:165-67.

30. Chu GX, Shen QR, Cao JL. Nitrogen fixation and N transfer from peanut to rice cultivated in aerobic soil in intercropping system and its effect on soil N-fertility. Plant and Soil. 2004;263:17-27. https://doi.org/10.1023/B:PLSO.0000047722.49160.9e

31. Rakshit R, Rakshit A, Das A. Customized fertilizers: marker in fertilizer revolution. International Journal of Agriculture Environment Biotechnology. 2012;5(1):67-75.

32. Malhotra SK. Water soluble fertilizers in horticultural crops - an appraisal. Indian Journal of Agricultural Sciences. 2016;86:1245-56.

33. Ebrahimpour F, Eidizadeh KH, Damghani AM. Sustainable nutrient management in maize with integrated application of biological and chemical fertilizers. International Journal of Agricultural Science. 2011;1:423-26.

34. Thavaprakaash N, Velayudham K, Muthukumar VB. Effect of crop geometry, intercropping systems and integrated nutrient management practices on productivity of baby corn (*Zea mays* L.)-based intercropping systems. Journal of Agriculture and Biological Sciences. 2005;1:295-302. https://scialert.net/abstract/?doi=ajar.2007.10.16

35. Arora NK. Plant Microbe Symbiosis: Fundamentals and Advances. N. K. Arora, Ed. Springer Science Business Media, Dordrecht. 2013. https://doi.org/10.1007/978-81-322-1287-4

36. Rakesh S, Ravinder J, Sinha AK. Hydrogel absorbents in farming: advanced way of conserving soil moisture. Indian Farmer. 2019;6(11):706-08. https://doi.org/10.1088/1757-899X/883/1/012074

37. India Brand Equity Foundation (IBEF) Blog, High demands for