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SUSTAINABLE AGRICULTURE: THE ONLY WAY FOR FUTURE FOOD SECURITY

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INTRODUCTION

Food is the most fundamental requirement for human survival, and agriculture remains central to food, nutrition, livelihoods and economic development. Modern agriculture has achieved remarkable productivity gains through improved varieties, irrigation, fertilizers, crop protection, mechanization and scientific management. However, intensive production has also contributed in many regions to soil degradation, nutrient imbalance, groundwater depletion, erosion, biodiversity loss and environmental pollution. Climate change is adding further uncertainty through increasing temperatures, irregular rainfall, droughts, floods and extreme weather events. The key question is therefore no longer only how to produce more food, but how to produce sufficient nutritious food without damaging the natural resources needed for future production. Sustainable agriculture addresses this challenge by integrating environmental, economic and social dimensions of agricultural development.

Future Food Security: The Global Challenge

Food security has four major dimensions: availability, access, utilization and stability. The 2025 FAO, IFAD, UNICEF, WFP and WHO report notes that the world remains off track for eliminating hunger and food insecurity by 2030 and highlights the effects of high food-price inflation on access to healthy diets, especially among vulnerable populations. Long-term food security therefore requires resilient agrifood systems, stable markets, better resource management and sustained investment. Sustainable agriculture is essential because it protects the productive capacity of land and water while supporting farmer livelihoods.

Climate Change and Agriculture

Climate change affects crop duration, photosynthesis, flowering, grain formation, evapotranspiration and pest dynamics. Heat stress during reproductive stages can sharply reduce yield, while rainfall variability can cause drought, waterlogging or delayed sowing. Climate-resilient agriculture should combine tolerant varieties with water conservation, soil-health management, diversification and improved nutrient efficiency. Sustainable systems must be designed for both adaptation and, where feasible, mitigation of greenhouse-gas emissions.

Soil Health: The Foundation of Sustainable Agriculture

Healthy soil contains adequate organic matter, balanced nutrients, active microorganisms, good structure and sufficient water-holding capacity. Soil degradation reduces productivity and increases dependence on external inputs. Sustainable soil management includes crop-residue recycling, compost, farmyard manure, green manuring, balanced fertilization, conservation tillage, cover crops and erosion control. Soil testing and regular soil-health monitoring should form the basis of nutrient decisions.

Integrated Nutrient Management

Integrated Nutrient Management combines mineral fertilizers with organic and biological nutrient sources such as compost, farmyard manure, crop residues, green manure and biofertilizers. The goal is balanced nutrition, higher nutrient-use efficiency and reduced losses. The principle of applying the right source, right rate, right time and right place can improve productivity while protecting soil and water. Site-specific nutrient management and soil testing can further improve efficiency.

Biofertilizers and Biological Inputs

Biofertilizers containing beneficial microorganisms such as Rhizobium, Azotobacter, Azospirillum, phosphate-solubilizing microorganisms and mycorrhizal fungi can support nutrient cycling and plant growth. They should be integrated appropriately with other nutrient sources rather than treated as a universal replacement for mineral fertilizers. Their effectiveness depends on crop, soil, climate, inoculant quality and management.

Water Conservation: More Crop per Drop

Water scarcity is becoming a major constraint to agricultural production. Sustainable water management emphasizes water productivity rather than simply increasing irrigation. Drip and sprinkler systems, rainwater harvesting, mulching, soil-moisture conservation and scientific irrigation scheduling can reduce losses. The objective should be to obtain more food and income from each unit of water.

Conservation Agriculture and Crop Diversification

Conservation agriculture is based on minimum soil disturbance, soil cover and crop diversification. Reduced tillage can reduce erosion and fuel consumption, while residue cover protects soil from evaporation and temperature extremes. Crop diversification through rotations, intercropping, pulses, oilseeds, vegetables and millets improves ecological and economic resilience and can interrupt pest and disease cycles.

Millets: Climate-Resilient Crops for Future Food Security

Millets including pearl millet, finger millet, sorghum and small millets are receiving renewed attention for climate resilience and nutrition. Pearl millet is particularly important in dry and semi-arid environments because of its adaptation to heat and water-limited conditions.

ICAR initiatives in 2026 continue to emphasize millet crop improvement, climate-resilient production technologies, seed systems, post-harvest management, value

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addition and farmer enterprises. Millets can therefore link sustainable agriculture, climate resilience and nutritional security.

Integrated Pest Management

Integrated Pest Management combines resistant varieties, crop rotation, cultural practices, biological control, monitoring and need-based chemical control. The objective is to maintain pest populations below economically damaging levels while minimizing unnecessary pesticide use and protecting beneficial organisms.

Agroforestry and Biodiversity

Agroforestry integrates trees with crops and/or livestock and can provide food, fodder, timber, shade, soil protection, carbon storage and additional income. Agricultural biodiversity, including crop, varietal and beneficial-organism diversity, strengthens ecosystem resilience and can reduce production risks.

Crop Residue Management and Circular Agriculture

Crop residues should be treated as resources rather than waste. They can be used for mulching, composting, biochar, biogas, bioenergy, mushroom production and appropriate livestock feeding. Circular agriculture seeks to convert wastes into useful inputs, reducing pollution and external input requirements. For example, animal manure can produce biogas and nutrient-rich bio-slurry, while crop residues can return carbon and nutrients to soil.

Precision Agriculture, AI and Digital Farming

Precision agriculture uses GPS, GIS, remote sensing, drones, sensors, satellite imagery and weather information to manage spatial and temporal variability. Artificial intelligence can support decisions on sowing, irrigation, nutrient application, pest detection and harvesting. These technologies can reduce input wastage and improve resource-use efficiency, but adoption must remain affordable and accessible to small and marginal farmers.

Climate-Smart Agriculture

Climate-smart agriculture aims to sustainably increase productivity, strengthen resilience and reduce agricultural greenhouse-gas emissions where feasible. Drought- and heat-tolerant varieties, efficient irrigation, conservation agriculture, agroforestry, integrated nutrient management and diversified cropping systems are important components.

Farmer Income and Economic Sustainability

Environmental sustainability cannot be separated from farm profitability. Farmers need adequate returns to invest in soil health, quality seed, irrigation and technology. Diversification, value addition, storage, processing, Farmer Producer Organizations and better market linkages can strengthen income and reduce dependence on a single crop or commodity.

Sustainable Agriculture in India

India has diverse agro-climatic conditions and millions of small and marginal farmers. Sustainable strategies must therefore be region-specific. Dryland regions can emphasize millets, pulses, rainwater harvesting and moisture conservation; irrigated regions can focus on efficient irrigation, nutrient management and diversification; flood-prone areas can emphasize drainage and tolerant varieties. Farmer-centered extension and locally adapted technologies are essential.

Role of Research, Policy and Farmers

Agricultural universities and research institutions should prioritize climate-resilient varieties, soil health, biofertilizers, integrated nutrient management, precision agriculture, water-use efficiency, sustainable mechanization and millet-based systems. Government policies should support soil and

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water conservation, diversification, sustainable mechanization, climate resilience, farmer training and market development. Farmers are central to implementation and should be active partners in technology development and evaluation.

Sustainable Intensification: The Way Forward

Sustainable intensification means increasing agricultural output without proportionally increasing environmental pressure. It focuses on higher nutrient- and water-use efficiency, improved soil health, reduced input losses, diversification and resilience. The future of agriculture should move from input-intensive farming toward knowledge-intensive and resource-efficient farming.

Ten-Point Roadmap for Future Food Security

- Protect soil through organic matter management and erosion control.
- Improve water-use efficiency and rainwater harvesting.
- Diversify crops, especially with pulses and millets.
- Apply balanced and site-specific nutrients.
- Promote biofertilizers and biological pest management.
- Develop and adopt climate-resilient varieties.
- Expand precision agriculture and digital advisory services.
- Recycle agricultural residues and develop circular systems.
- Improve farmer profitability through value addition and markets.
- Invest continuously in agricultural research, extension and farmer training.

KEY MESSAGE

Future food security depends not only on producing more food, but on protecting the soil, water, biodiversity and climate that make future production possible.

CONCLUSION

Sustainable agriculture is essential for ensuring that present food needs are met without compromising the ability of future generations to produce food. Soil-health management, balanced nutrient use, efficient water management, conservation agriculture, crop diversification, integrated pest management, agroforestry, biofertilizers, residue recycling, climate-resilient crops and precision technologies together provide a pathway toward resilient food systems. Millets, particularly pearl millet and other climate-resilient crops, can make an important contribution to nutritional and climate security. Sustainable agriculture should therefore be viewed not as a single technology or farming method but as an integrated philosophy of productive, profitable, resilient and resource-efficient farming. The future of food security depends not only on how much food we produce today, but also on whether we preserve the soil, water, biodiversity and climate that make tomorrow's food production possible.

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