

Climate Smart Agronomy for the 21st Century

Yaswanthi Vasamsetti¹, Makey Sri Chakra Naga Vardhan², Bunga Enosh², Kotla Likhitha²

¹Department of Agronomy, School of Agricultural Sciences, G H Raisoni University

²Department of Agronomy, School of Agriculture, Lovely Professional University, Phagwara

INTRODUCTION

21st century, climate and smart are the trending words of today's world which revolve around us where the climate change and agriculture are being reciprocal to each other which mean the smart agronomy leading the 21st century is and can be helpful for the farmers and growing produce. The changing patterns of rainfall raise in temperature, degradation of soil and deforestation which is affecting crop growth patterns and their adaptations is making agronomy to look after about crop production and soil management which will lead sustainability and food security. The mixture of traditional and modern innovations will help farmers and coming future farmers to increase productivity, building crop which will be resistant to the sudden climate shock. I belong from a place which is prone for cyclone and heavy winds which affect the crops in which traditional practices like conservation tillage, crop rotation, precision irrigation, organic amendments, and integrated pest management are the main with the modern transformation. Agriculture in the 21st century faces unprecedented challenges due to climate change, including rising temperatures, erratic rainfall, increased pest outbreaks, and extreme weather events such as droughts and floods. To ensure sustainable food production and resilient farming systems, climate-smart agriculture (CSA) provides a set of practices and technologies aimed at enhancing productivity, improving adaptation, and reducing greenhouse gas emissions. This expanded discussion highlights advanced agronomical practices across soil, water, crops, farm management, livestock, landscapes, and economic frameworks that can empower farmers to thrive in a changing climate.

1. Smart Soil Management

Healthy soil is the core of a climate-resilient agricultural system. Conservation agriculture, through minimum tillage, crop rotation, and permanent soil cover, improves soil organic matter, enhances water infiltration, and reduces land degradation. Reduced tillage minimizes CO₂ release from soil and supports carbon sequestration (FAO, 2021).

Organic amendments such as compost, vermicompost, biofertilizers, green manures, and biochar further enhance soil fertility. Biochar application has gained attention for its long-term carbon sequestration potential and ability to improve nutrient-use efficiency (Lehmann & Joseph, 2015). Precision nutrient management using soil testing kits, slow-release fertilizers, and nano-based nutrients ensures optimized nutrient supply while minimizing losses and environmental pollution. Integrated Nutrient Management (INM), combining organic and inorganic sources, allows for balanced feeding and long-term soil health restoration.

2. Smart Water Management

Water shortages and unpredictable rainfall are major climate-related challenges. Micro-irrigation systems especially drip and sprinkler irrigation improve water-use

efficiency and reduce wastage. Drip irrigation can reduce water use by nearly half while enhancing crop productivity (Kumar et al., 2020). Rainwater harvesting structures, such as check dams, recharge pits, farm ponds, and contour bunds, capture excess rainwater and improve groundwater recharge. Climate-adaptive irrigation scheduling using evapotranspiration (ET) data, soil-moisture sensors, and digital mobile apps enables farmers to irrigate based on crop needs rather than fixed schedules. This approach conserves water and prevents crop stress during heatwaves or rainfall delays.

3. Smart Crop Strategies

Climate-resilient crop varieties heat-tolerant wheat, drought-resistant maize, salinity-tolerant rice, and flood-resistant paddy like Swarna Sub1 allow farmers to cope with climate extremes (IRRI, 2018). Millets such as foxtail, pearl millet, and ragi offer natural resilience to drought and poor soils, making them ideal for climate-vulnerable regions. Diversification of cropping systems improves income stability and reduces risk. Including pulses, oilseeds, vegetables, and fruit trees ensures better resource utilization and provides nutritional security. Intercropping (e.g., maize

+ cowpea, mustard + chickpea) improves nitrogen fixation, reduces pest incidence, and stabilizes yields.

Protected cultivation using shade nets, polyhouses, and greenhouses helps regulate microclimate conditions. These structures reduce temperature extremes, enable off-season vegetable production, and protect crops from heavy rainfall and strong winds.

4. Smart Farm Management and Digital Solutions

Precision agriculture is transforming modern farming. Drones equipped with sensors can map fields, detect nutrient deficiencies, and apply inputs uniformly. Geographic Information Systems (GIS) and remote sensing support field-level decision-making by providing insights into soil moisture, crop health, and pest outbreaks.

Integrated Pest Management (IPM) reduces pesticide dependence through pheromone traps, light traps, beneficial microbes (*Trichoderma*, *Metarhizium*, *Beauveria*), and botanical pesticides. Weather-based pest forecasting models enable farmers to anticipate pest outbreaks linked to humidity, temperature, and rainfall, reducing crop losses.

Digital advisory platforms provide location-specific climate updates, early-warning systems for storms or heatwaves, and crop management recommendations. Such tools improve farmer preparedness and reduce climate-related risks.

5. Agroforestry and Landscape-Based Climate Solutions

Agroforestry integrating trees with crops and livestock offers multiple climate benefits. Trees sequester carbon, improve biodiversity, moderate microclimates, and prevent soil erosion. Systems like alley cropping, silvopasture, and boundary plantations increase productivity while enhancing landscape resilience (World Agroforestry Centre, 2019).

Trees such as neem, gliricidia, moringa, subabul, and eucalyptus help reduce wind damage, improve soil fertility, and provide additional income through timber, fodder, and fuelwood. Mangrove-based agroforestry in coastal regions further protects farmlands from cyclones and tidal surges.

6. Smart Livestock and Integrated Farming Systems

Livestock also plays a key role in climate-smart agriculture. Improved breeds that tolerate heat or disease reduce mortality during extreme events. Climate-controlled shelters, sprinkler systems, and shaded areas protect animals from heat stress.

Integrated farming systems combining crops, livestock, fisheries, and horticulture—promote resource recycling. Livestock manure becomes fertilizer; crop residues become animal feed; and pond systems provide fish along with irrigation water. Such circular systems reduce greenhouse gas emissions and increase farm profitability (FAO, 2021).

7. Climate-Resilient Supply Chains and Post-Harvest Management

Climate events often damage produce after harvest. Investments in solar dryers, cold storage, packhouses, and climate-controlled transport reduce losses and maintain food quality. Solar-powered cold rooms are emerging as an affordable, clean-energy solution for smallholder farmers.

Value addition processing grains, fruits, and vegetables into marketable products—reduces wastage and increases income. Climate-resilient market linkages through Farmer Producer Organisations (FPOs) improve bargaining power, reduce transportation risk, and promote collective marketing.

8. Smart Farm Economics and Policy Support

Carbon farming is gaining momentum as farmers adopt carbon-sequestering practices such as agroforestry, reduced tillage, improved grazing, and organic amendments. These practices generate carbon credits that farmers can sell in domestic or international carbon markets (World Bank, 2020).

Government schemes crop insurance programs like PMFBY, soil health cards, micro-irrigation subsidies, digital extension services, and renewable-energy incentives—support climate-smart transitions. Solar pumps and solar dryers reduce operational costs while mitigating emissions.

FPOs and cooperative models empower farmers to access credit, machinery, training, and improved markets making climate-smart transformations more affordable and sustainable.

Conclusion

Climate-smart agronomical practices provide a holistic framework that supports productivity, resilience, and environmental sustainability in the 21st century. From soil regeneration and water efficiency to climate-resilient crops, digital tools, agroforestry, integrated systems, and supportive economic mechanisms, these innovations offer farmers reliable pathways to thrive despite climate uncertainty. As climate change accelerates, the adoption of these practices becomes essential to ensure global food security, sustainable livelihoods, and ecological balance.

References

- FAO. (2021). *The state of food and agriculture: Climate change, agriculture and food security*. Food and Agriculture Organization of the United Nations.
- IRRI. (2018). *Climate-resilient rice varieties*. International Rice Research Institute.
- Kumar, M., Singh, R., & Patel, N. (2020). Water-use efficiency and crop productivity under micro-irrigation systems: A review. *Agricultural Water Management*, 242, 106394.

- Lehmann, J., & Joseph, S. (2015). *Biochar for environmental management: Science, technology and implementation*. Routledge.
- World Agroforestry Centre. (2019). *Agroforestry and climate resilience*. ICRAF Publications.
- World Bank. (2020). *Carbon farming and carbon markets: Opportunities for sustainable agriculture*. World Bank Group.

