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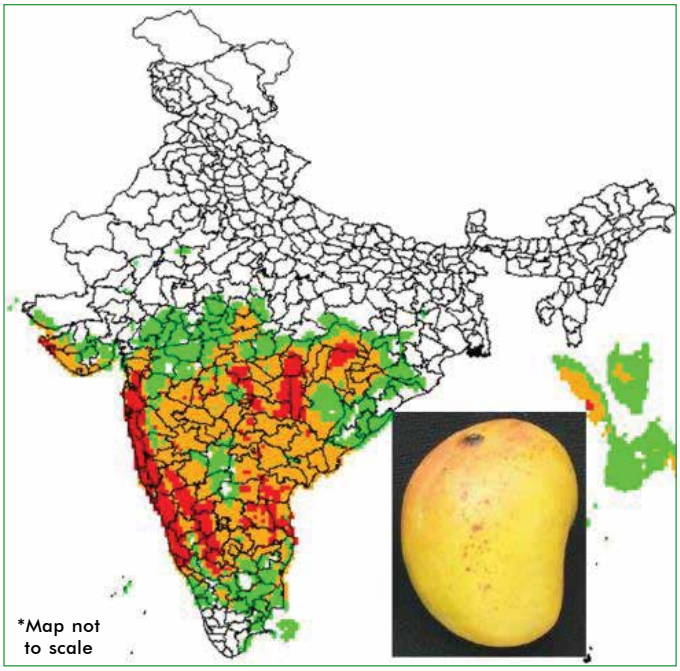
AI transforming horticulture: A glimpse into the future

The horticulture industry has witnessed transformative advancements, especially with the integration of artificial intelligence (AI), which is reshaping farming practices through data-driven precision agriculture. AI enables the collection and analysis of vast data volumes related to soil conditions, climate, and pest patterns, facilitating real-time, optimized decision-making for farmers. This approach enhances efficiency by tailoring pest control, fertilization, and irrigation schedules, which improves productivity, reduces resource waste, and increases sustainability. Key applications of AI in horticulture include niche modeling for crop diversification, variety selection based on regional adaptability, and the extension of crop cycles to previously unsuitable regions. Furthermore, AI aids in addressing climate change by projecting region-specific crop viability, thus allowing farmers to adapt proactively. Additional areas of impact include urban farming, yield prediction, quality control, and niche market targeting. AI also contributes to restoring degraded lands by analyzing soil health and environmental conditions to support suitable cropping strategies. As AI evolves, its applications will advance toward holistic environmental management, equipping farmers to mitigate climate change impacts and supporting sustainable agricultural growth.

HORTICULTURE is a complex industry that has gone through significant transformation over the years, and in particular, technology is given a larger role than it was before. Of these advancements, artificial intelligence (AI) is absolutely remarkable in every sense of the word. AI still has a large role to play in horticulture over the coming years, with more farmers leaping from conventional farming to data-driven precision farming. This is important because horticulture is one of the sub-sectors of the agricultural sector in India. AI can solve the problems that come with geographical location, climate and soil type. The ability to analyze large volumes of data, farmers will get analytics that make real-time farming strategy updates feasible. This may create higher revenues, improve use of resources, and, therefore, additional opportunities for sustainability.

Artificial intelligence has a key role in the development of horticulture by allowing more precise, more efficient and sustainable farming practices. Powerful AI-driven tools are able to ingest huge volumes of data associated with soil conditions, climate, pattern of pests and health of crops, thus giving farmers actionable insights to optimize the cultivation process. This enables the timing of pest control, fertilization, and irrigation treatments to be optimized as waste is minimized and productivity increases. On top of this, AI is used to pick the best crop variety for particular regions, thus resulting in higher yield and better resource use.

It is expected that AI applications will occupy a leading position in decision-making in the entire horticulture industry. Whether it is deciding which



Climate suitability for Alphonso mango based on maximum entropy model

crops would be appropriate to grow in certain climatic conditions, on a certain type of soil, and with a certain amount of water supply, or the best ways of producing crops, AI will give farmers valuable information. This will extend into managing value chains by being able to guess market demands, organize distribution means, and even improve off-season production through climate control and resource management technologies.

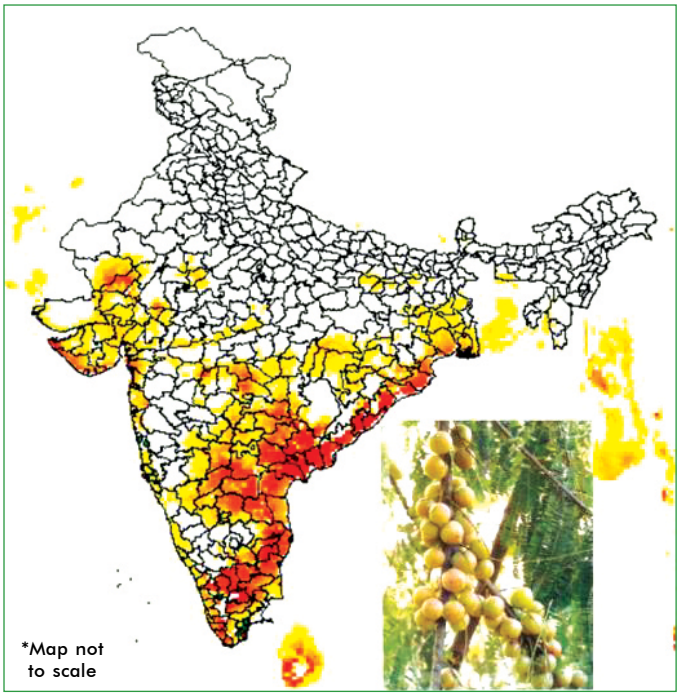
Applications of AI in horticulture

Niche modeling for diversification: AI-based tool that is said to revolutionize niche modeling is AI-powered crop growing decisions. Machine learning is very useful for generating information and helping farmers as researchers determine which areas are most favourable for producing certain crops and varieties. For example, it is possible to predict the best agro-climatic conditions for planting popular mango varieties such as Alphonso, *Dashehari*, or Kesar and their performance under climate change regimes. Applying AI techniques, it will be able to deliver patterns of weather changes to deliver necessary suggestions to the farmers so that they get higher crop yields, and threat of crop failure decreases.

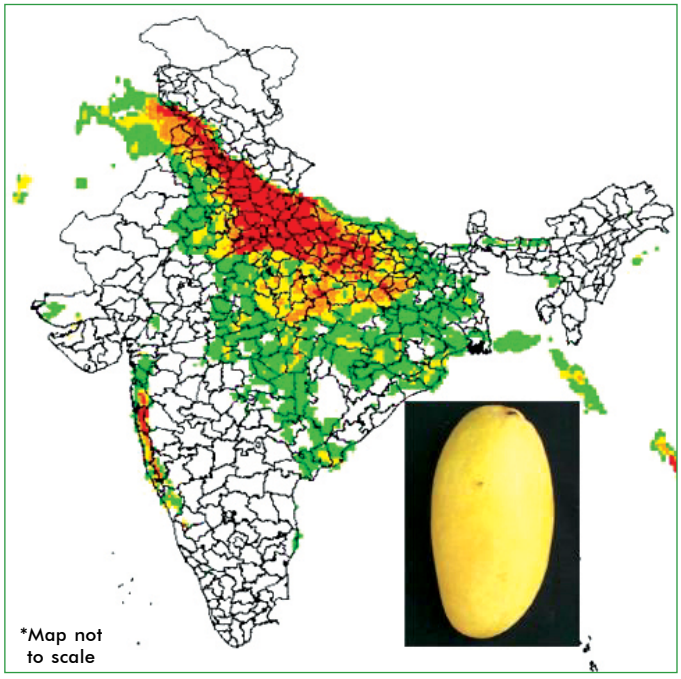
Variety selection: This is one area where farmers can make decisions just by selecting the right crop/variety for the region. In the future, AI will also be able to evaluate conditions and suggest, which varieties of the crops can be grown in a particular region. This is especially important given the climatic differences of the country. For instance, the red-pulp guava 'Lalit' can grow in some high-altitude regions as AI could identify more regions where it can grow and develops red colour on the peel also.

Exploring crop cycles and crop regions: In the future, as AI and automation continue to develop, there will be more chances to extend the crop period and bring cultivation to new and non-traditional regions. For example, AI could, for instance, indicate two cropping cycles of aonla for farmers so that they can optimize their growing seasons with higher profits due to off-season aonla production in specific areas of south India. It could also foster the determination of areas where high-demand fruits such as litchi can be grown off-season profitably in southern states. Such information will help farmers formulate ways to specialize in new plants, hence increasing other sources of income and enhancing horticultural production for the entire country.

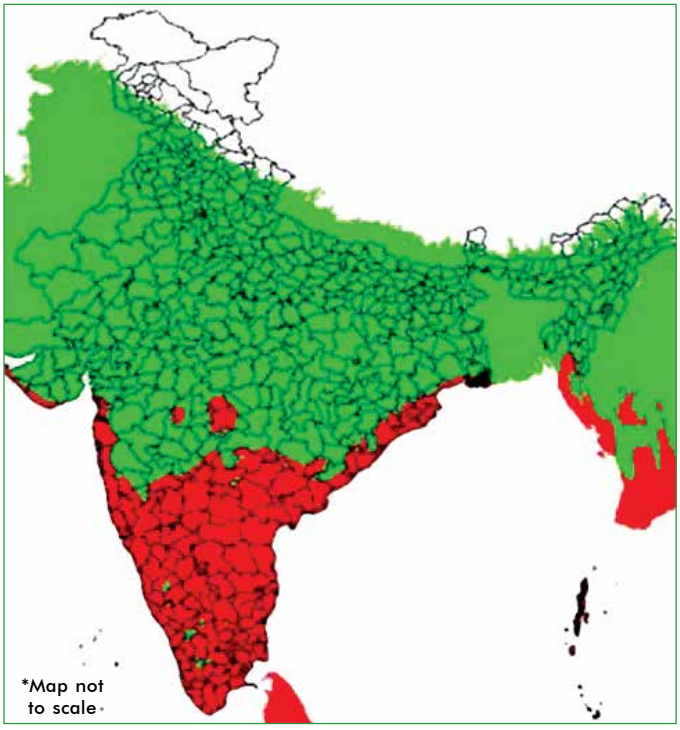
Climate change challenges: It is now well articulated that climate change may greatly affect horticulture crops



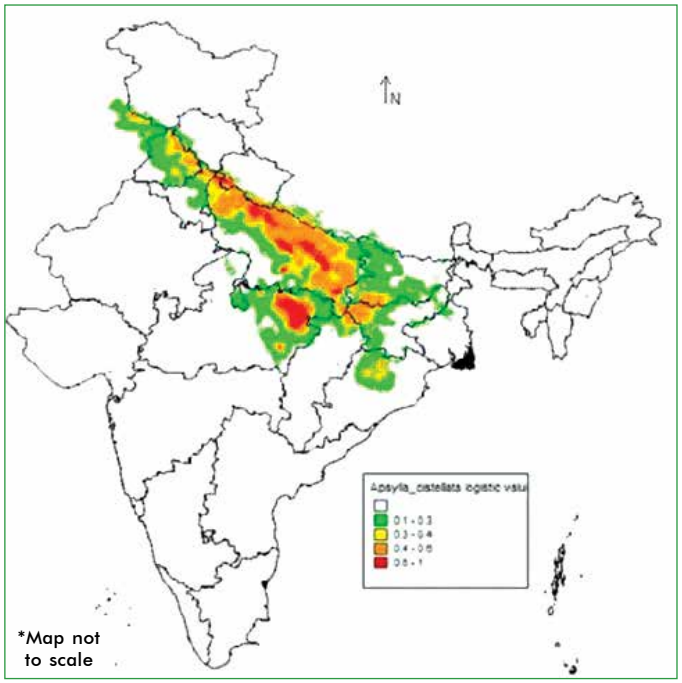
Possible areas suitable for producing two crops of aonla per year



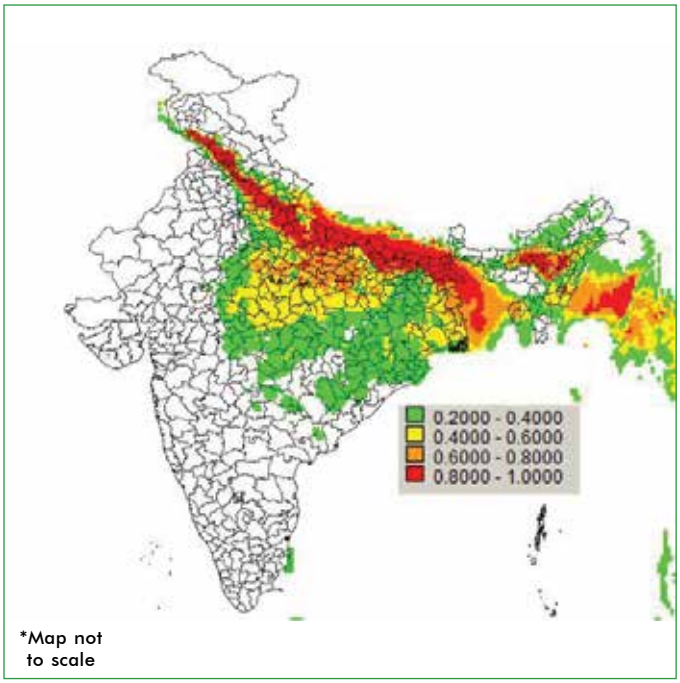
Areas with suitability climate for *Dashehari* mango production



Areas suitable for early flower induction in mango using paclobutrazol



Distribution of mango shoot gall psylla under different future climate change scenario by 2050 in India



Epidemic prediction for banana wilt caused by *Fusarium oxysporum* (Foc TR-4)

and, therefore, AI will be an important tool in assisting farmers with orchard planning in newer traditional and non-traditional areas, keeping future climate suitability. Subsequent AI architectures will create multiple climate scenarios for evaluating how various weather conditions will impact the quality of crops. For instance, AI will help Indian farmers understand which regions will be fit for cultivating fruits such as mangoes, apples, and guavas as well as varieties of other fruit crops as climate changes occur. This will aid them in changing their behaviour and continually adapting to changes in their environment.

Pest and disease management: Similarly, pest and disease management will be greatly assisted by AI early enough. Maps of pests and diseases will be produced by AI to provide farmers with warnings to prevent diseases from affecting their crops. For instance, AI has the potential to estimate pest infestation, such as the *Apsylla cistellata* that affects mangoes or diseases that affect mango plants, such as mango wilt. Real-time data make it easy for farmers to intervene at the right time, which in turn helps them to avoid using hazardous chemicals and embrace sustainable farming approaches. Areas at risk for banana wilt epidemics, specifically caused by the *Fusarium oxysporum* TR-4 strain, were forecasted. The predictions are based on current environmental conditions and disease spread models.

Urban horticulture: As more and more people shift their residences from rural areas, urban farming will be more important in food production. It is possible to suggest crops with the use of AI to be grown on rooftops and vertical farming within the context of urban farming based on the variability of sunlight and temperature. This will assist cities in upscaling the production of their foods, hence minimizing transportation, increasing soil cover and decreasing greenhouse gas emissions.

Yield prediction and quality control: AI will also become more important for estimating yields and quality. This reveals how assistance from AI in analyzing big data will enable farmers to effectively plan for planting and harvesting seasons in order to meet market needs. For example, AI could facilitate prediction of the yield of high-value crops, i.e., saffron and thus help farmers to decide on measures to increase income. For sustainable land use planning in horticulture, dependency on AI-driven models will be inevitable. What we are going to adopt over time and that is where AI will assist farmers in decision-making in terms of what crops should be grown in a certain piece of land with regard to output, soil quality and water retention.

Targeting niche markets: A form of modeling that can be used to explore and develop new product markets is called Niche market. AI will change completely the way farmers produce for niche marketing. Using AI, farmers can determine where exactly a new crop/variety is to be grown and where the farmers can reach out for the high-end market, such as the market for organic foods, off-season produce, high-value crops. This will enable the farmers to manage their crop production practices and seek other related income-generating ventures.

Restoring degraded lands: There are important functions of AI in the restoration of degraded lands, including the use of enhanced technologies in the collection of data, as well as the analysis of such data aimed at making relevant decisions. Satellite and GIS data can be processed using machine learning, which can determine wastelands and changes that occur in them over a given period. AI can be used to determine the soil health, water availability and level of desertification or salinity so that appropriate interventions such as afforestation, cropping system changes, or water management measures can be made. Few drought-tolerant fruits such as aonla, jamun, bael, dragon fruit, pomegranates or guava are

suitable for the soil conditions of the region they can survive and produce fruits even in extreme conditions and can also be planted for rehabilitation of wastelands. AI can make suitability maps of the environment for example, temperature, type of soil and water supply so that these crops are planted in the right area. By applying artificial neural networks, stakeholders can improve the outcomes of land restoration programme, identify areas that require further attention, and apply proper strategies for sustainable land utilization with increased biomass production and better perspectives for biodiversity. This can help generate employment in rural areas, build up rural infrastructure, and maintain ecological balance.

It is expected that the use of AI in agriculture will increase to the point where it is practically indistinguishable from precision farming. AI models will evolve from simple yes or no crop viability answers to comprehensive crop environment management. Facts gathered from satellite, drone, IoT, and weather models will be processed in real-time and made available to farmers as specific minute-by-minute recommendations for irrigation, fertilization, and pest control. Such real-time interaction will result in more concentrated resource utilization, greater efficiency, less waste, and increased sustainability. AI will also be able to handle more sophisticated environmental impacts as farmers deal with climate change. Improving models that show long-term changes in climate results will help farmers plan for climate change. Indeed, AI is expected to enable advances in biotechnology, resulting in the development of new smart crop varieties capable of dealing with adverse environmental conditions.

SUMMARY

Artificial intelligence has to become the key driver of the horticulture sector, which will provide precision agriculture and sustainable farming. From the arrangement of crop yields and the choice of the crops to be grown to the improvement of the use of resources and the fight against climate change, AI's inclusion will revolutionize the cultivation, management and marketing of crops. AI provides farmers with solutions based on real-time data and predictive, thus helping them make the right decisions and produce better crops while minimizing the effects they have on the environment. The future of horticulture will be characterized by better and more sustainable farming systems that can respond to challenges and produce food in the future.

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SUSTAINABLE DEVELOPMENT GOALS RELATED TO FRUITS AND VEGETABLES

SDGs 2 3

Health benefits of fruit and vegetables

Harness the goodness

Fruit and vegetables have multiple health benefits. They strengthen the immune system, combat malnutrition and help prevent non-communicable diseases.

SDGs 2 3

Diversified diet and a healthy lifestyle

Live by it, a diverse diet

Adequate amounts of fruit and vegetables should be consumed daily as part of a diversified and healthy diet.

SDGs 2 8 12 13 14 15

Food loss and waste

Respect food from farm to table

Fruit and vegetables are worth more than their price. Maintaining their quality and assuring their safety across the supply chain, from production to consumption, reduces losses and waste and increases their availability for consumption.

Innovate, cultivate, reduce food loss and waste

Innovation, improved technologies and infrastructure are critical to increase the efficiency and productivity within fruit and vegetable supply chains to reduce loss and waste.

SDGs 1 2 12 15

Sustainable value chains

Foster sustainability

Sustainable and inclusive value chains can help increase production, and help to enhance the availability, safety, affordability and equitable access to fruit and vegetables to foster economic, social, and environmental sustainability.

SDGs 1 2 3 4 5 8 11 12 15

Highlighting the role of family farmers

Growing prosperity

Cultivating fruit and vegetables contributes to a better quality of life for family farmers and their communities. It generates income, creates livelihoods, improves food security and nutrition, and enhances resilience through sustainably managed local resources and increased agrobiodiversity.

Source: *Fruit and vegetables – your dietary essentials, FAO background paper, FAO, Rome*