Advancing Climate-Smart Agriculture through India-Russia Collaboration

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Climate-smart agriculture (CSA) is emerging as a crucial global strategy to ensure food security while mitigating the impacts of climate change. Countries like India, which are highly vulnerable to erratic weather patterns and temperature shifts, are increasingly adopting CSA to build resilience in their agricultural systems. Similarly, in Russia, vast agricultural areas face rising climate-related risks, which has prompted the need for more adaptive and sustainable farming practices. One key area of innovation that supports CSA is envirotyping — a technique that uses environmental data to assess crop performance and develop strategies for adapting crops to changing conditions. Collaborative efforts between India and Russia in this field could unlock significant potential for both nations, leveraging their complementary strengths in environmental science, data analytics, and agricultural technology.

Integrating Process- and Data-Based Models for CSA

India's agricultural technologies and hydrological modelling expertise align well with Russia's remote sensing and satellite-based analytics strengths. For instance, my work at Skoltech in Russia focuses on integrating process- and data-based models to improve the efficiency and sustainability of agricultural systems through environmental process modelling. Collaborative research in CSA and envirotyping, which involves tracking how crops respond to environmental conditions such as soil health, water availability, and climate fluctuations, can help both India and Russia enhance their agricultural productivity in the face of climate uncertainties.

Existing bilateral frameworks, including joint research calls by the Russian Science Foundation (RSF) and India's Department of Science and Technology (DST), as well as multilateral initiatives like BRICS STI, provide a strong foundation for expanding collaboration in this space. The potential for collaboration between Indian and Russian scientists in Earth observation (EO), remote sensing, and agricultural modelling presents an exciting opportunity to address food security in a climate-uncertain world.

Process-based models, which simulate physical and biochemical processes, and data-based models, utilising machine learning (ML) and big data analytics, are both integral to CSA. Envirotyping, through its

holistic assessment of environmental conditions, such as soil moisture, temperature, and precipitation, empowers farmers and scientists to make informed, data-driven decisions to optimise crop performance while managing risks related to climate change. By integrating physics-based models and measurements of soil health, hydrology, plant growth, and climate change, among others, in conjunction with remote sensing technologies and ML algorithms, we can predict the impacts of environmental factors on crops and develop strategies to improve their resilience.

My collaboration with the Indian Institute of Science (IISc), Bangalore, employs hydrological models to assess how soil and water dynamics affect crop yield. This research is particularly relevant in semi-arid regions of India, such as Karnataka, Maharashtra and Rajasthan, where efficient water management is critical for ensuring agricultural sustainability. Parallel research with SRM Institute of Science and Technology (SRMIST), Kattankulathur, uses ML-based models to predict rainfall patterns, droughts, and crop yields based on climate data and satellite inputs. These tools are crucial for guiding farmers on optimal planting times, helping them mitigate risks associated with unpredictable weather. Such process- and data-based models are invaluable not only for Indian agriculture, where many smallholder farmers rely mainly on monsoons, but also for Russia's southern agricultural regions, which are increasingly affected by droughts and changing precipitation patterns.

Russia's satellite remote sensing expertise complements India's advancements in agricultural technologies. Joint efforts can significantly enhance their capacity to implement climate-resilient farming techniques, benefitting growers in both countries.

Strengthening Earth Observation and Analytics

India's legacy in Earth observation and remote sensing, driven by the Indian Space Research Organisation (ISRO), has significantly advanced agricultural monitoring. Satellite missions such as RISAT and Cartosat provide essential data for soil health assessment, drought monitoring, and crop yield forecasting. These satellite platforms, with their ability to capture high-resolution imagery, allow for precise tracking of changes in land use, water availability, and vegetation health.

Similarly, Russia's Resurs-P and Kanopus-V satellite series, managed by Roscosmos, provide high-resolution multispectral data for land use, crop health monitoring, and environmental management. These satellites are equivalent to India's Cartosat and RISAT missions. The Resurs-P series captures detailed imagery that can be used for precision farming, while the Kanopus-V series focuses on monitoring environmental changes, especially in agricultural landscapes, making it an ideal tool for CSA.

Russian companies like Sitronics and Sovzond offer geospatial services that process satellite data into actionable insights, enabling models that predict climate-induced impacts on agricultural productivity. Collaborating with Russia can also deepen bilateral ties in agriculture and environmental research in the private enterprise space. The rise of private Indian companies like Satyukt Analytics, which provides real-time satellite-based analytics for agriculture, further strengthens the technological infrastructure available for such collaborations. Satyukt's services include crop health monitoring, irrigation advisory, and weather forecasting, all of which align with the goals of climate-smart agriculture. Other companies, such as CropIn and Skymet, offer digital solutions integrating satellite data with AI-driven analytics to assist farmers and policymakers in making informed decisions.

Pathways for India-Russia Collaboration

India and Russia have a long history of scientific collaboration, and CSA presents new opportunities to deepen these ties. The BRICS STI Framework Programme and joint research calls by RSF and DST provide funding avenues to encourage cross-border research in areas such as drought resilience, water management, and climate forecasting. However, these areas must be emphasised in the funding calls to encourage joint proposals. For example, my proposed collaboration with IIT-Delhi focuses on developing models for agricultural drought forecasting, combining satellite-derived data with process-based environmental models to predict the onset of droughts and recommend preventive measures. This kind of collaboration can be expanded to include Russian scientists working in similar areas, particularly those focused on the southern steppes of Russia, which face drought risks identical to those in India, presenting a unique opportunity to co-develop technologies that will benefit both nations. Joint initiatives between Russia's Roscosmos and ISRO, such as data-sharing agreements, could improve the accuracy of satellite-based agricultural models. By integrating India's agricultural know-how with Russia's geospatial technologies, we could develop predictive models that help farmers make decisions that enhance crop yields and water efficiency.

Collaborative projects could include:

Joint Satellite Platforms: Developing a combined remote sensing platform that integrates data from Indian and Russian satellites to provide real-time agricultural monitoring••

Research Consortia: Establishing a bilateral consortium on climate resilience, bringing together Indian and Russian scientists in soil hydrology, crop modelling, and water resource management.

Private Sector Partnerships: Encouraging joint ventures between Indian and Russian private companies to co-develop tools for farm-level decision-making.

Additionally, joint initiatives like BRICS Research Centres could serve as innovation hubs, fostering knowledge exchange between Indian and Russian scientists working in climate resilience, soil hydrology, and AI-driven agriculture. These centres could focus on developing precision agriculture techniques, such as smart irrigation systems, that use real-time soil and weather data to optimise water use in agriculture.

India has established several platforms to facilitate collaboration between the Indian scientific diaspora and local institutions. The VAJRA (Visiting Advanced Joint Research) Faculty Scheme, the Vaishvik Bharatiya Vaigyanik (VAIBHAV) Fellowship, and the Global Initiative of Academic Networks (GIAN) are a few key initiatives that aim to bring diaspora scientists and international researchers to Indian institutions for joint research. While these programs successfully attracted talent from regions like the United States and Western Europe, their reach in countries such as Russia remains limited. Scientists based in Russia and other Eastern European countries often have fewer opportunities to engage with these programs due to a lack of visibility and promotion.

Expanding these initiatives to include greater participation from Indian diaspora scientists in Russia could significantly enhance bilateral collaboration in CSA and environmental science. Creating more accessible platforms promoting calls for joint research, fellowships, and innovation projects in non-Western countries would help bring Indian and Russian scientists together more effectively.

Conclusions

To fully realise the potential of CSA and envirotyping as areas of India-Russia collaboration, it is essential to

enhance the existing bilateral frameworks and make them more accessible to a broader range of researchers. Expanding the reach of programs like VAJRA, VAIBHAV, and GIAN while creating new, dedicated platforms for collaboration would help bridge the gap between the scientific communities of both nations. Additionally, stronger cooperation between the public and private sectors, particularly in leveraging emerging technologies like AI and satellite analytics, can further accelerate the adoption of climate-smart agricultural practices in both countries.

By fostering more robust partnerships and addressing regulatory challenges, India and Russia can together contribute to solving some of the world's most pressing agricultural challenges while setting an example for international collaboration in climate resilience.