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The Intersection of AI and Agriculture: Implications for Food Security and Environmental Sustainability in Pakistan

Muhammad Shakeel Ahmed Siddiqui (Corresponding Author)
HOD, Department of Political Science, Pakistan Studies and International Relations, Govt. Graduate College of Science Multan
Email: shakeelsiddiqui56@gmail.com
Dr. Qurat-ul-Ain
Assistant Professor of International Relations & Chairperson, Department of Media, Creative Arts and Global Political Studies, Emerson University Multan

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Abstract
Global warming & Climate change pose a significant threat to the agricultural sector worldwide. Artificial Intelligence (AI), as a recent advancement in computer sciences, seems to have the potential to solve the challenges with this new paradigm. This paper investigates crop production and food security in Pakistan and in entire region in pre and post Covid days in the face of a changing climate. Stressing the importance & appropriateness of AI in agricultural production as well as the food security could be critical in the quest for food and nutrition security. This study concentrates on AI applications in connection to four food security pillars. This evaluation is crucial because that provides decision makers and some other related authorities with a comprehensive assessment of climate impacts and mitigation strategies aimed at improving agricultural production and food security.

Introduction
The COVID-19 pandemic exacerbated global food scarcity in nearly every country by disrupting food supply chains and reducing income (Haque, 2020). The pandemic continues to have devastating effects on global starvation and poverty, especially among the most impoverished and vulnerable populations. In 2020, global starvation reached its zenith, with 2.3 billion individuals lacking year-round access to sufficient food, according to a July 2021 report from five United Nations agencies. Additionally, the

situation was exacerbated by the pandemic and climate disruptions, as over 155 million individuals were experiencing acute hunger as a consequence of conflict and insecurity. Furthermore, projections for the remainder of 2021 indicate that this trend will persist. The COVID-19 pandemic exacerbated global food insecurity in nearly every country by disrupting food supply chains and reducing income (Haque, 2020). The pandemic continues to have a catastrophic effect on global starvation and poverty, with the most vulnerable and impoverished populations being particularly affected. In 2020, global starvation reached its zenith, with 2.3 billion individuals lacking year-round access to sufficient food, according to a July 2021 report from five United Nations agencies. Additionally, the situation was exacerbated by the pandemic and climate disruptions, as over 155 million individuals were experiencing acute hunger as a consequence of conflict and insecurity. Furthermore, projections for the remainder of 2021 are consistent with this trend (Varshney et al., 2021).

An interconnectedness of challenges such as climate change, demographic change, energy infrastructure, and resource depletion are putting unprecedented strains on international food systems. Agricultural scientific progress must be directed toward finding solutions to the problems that are threatening global food security (Anik et al., 2017). New and emerging technologies, such as artificial photosynthesis, are in their infancy which may provide food and fuel solutions in the future. In an international and regulatory context, it is critical that emerging technologies be given the right environment in which to develop. The word technology refers to a wide range of techniques, skills, methods, and processes used in the manufacture of goods. The technology required to ensure food security varies by country. It is determined by factors such as the physical environment, infrastructure, climate, culture, literacy, economic conditions, and governance (Abdullahi, S., & Pradhan, 2018). Developing countries typically develop food security strategies along different paths and processes than developed countries. In developing countries, food security technologies include land preparation, soil and water management, seed production, weed management, pest and disease control, farm management, harvesting, and post-harvest practices such as storage, processing, packaging, marketing, and distribution. Based on effective government policies, technology can support improved economic growth and social well-being; effective harvest and post-harvest practices to minimize food loss; effective storage and conservation practices to increase the value of harvested products; identification of high value-added products to improve economic gains for processors and ensure long shelf-life; and enhanced marketing of available foodstuffs at competitive prices (Sultan, B., & Gaetani, 2016).

Pakistan has become a food surplus country and a major producer of wheat, which it distributes to needy populations through a variety of mechanisms, including the World Food Program, over the years (WFP). The country's recent food crisis has drawn widespread public attention, while policymakers have been chastised for failing to present a timely assessment of demand and supply (Rasul, 2021). This problem has been exacerbated by the recent food price crisis, which has reduced the purchasing power of those who are already living below the poverty line of less than $2 per day. According to the US Department of Agriculture's International Food Security Assessment, 38 percent of Pakistan's population will be food insecure in the next decade, from 2021-31. According to this assessment, Pakistan has the largest food gap in the region, with the highest level of food insecurity, even higher than Bangladesh It currently stands at 389, with Nepal at around 255. Furthermore, according to a recent World Food Program survey, approximately 82% of children in Pakistan have been denied a meal when they are in need, and the country has the second highest rate of malnutrition in the region. Approximately 18% of children under the age of five suffer from acute malnutrition, while 40% of the same age group suffers from stunted growth (PIDE, 2020). According to the Pakistan Bureau of Statistics, 16% of the population suffers from moderate or severe food insecurity. The incidence is twice as high in the rural population, at 20%, as it is in the urban population, at 9.2%. Furthermore, three out of every five households are food insecure (FAO, 2020b). The level of technological advancement is detrimental to productivity. Pakistani farmers continue to use hand tools and ancient methods to carry out agricultural activities, which not only results in underutilization of land resources but also in lower yields (Khan, F. H., Hasnin, N., Ohee, E. M. R., & Morshed, M. T, 2020).

Technological innovation and Agricultural production

Now with population of the world forecasted to hit 7.7 billion people till 2019, intensive agriculture is gaining prominence in the agrarian technologies industry (Reardon, T., Swinnen J. 2020). While Governments & international organizations have already stepped up their efforts in agriculture to achieve "self-sustaining intensity," adoption of Technological advancement which assistance in farming techniques, pest management, product testing, & interconnected disease prevention has become increasingly significant in the formation of more sustainable agricultural practices (Parkes, B., Sultan, B., & Ciais, 2018). Farmers have used artificial intelligence to grow higher quality crop production & obtain maximum food output per hectare. Leading technological developments are now being produced to encounter the world's increasing demands for food (Adedeji A.A., Ekramirad N., Rady A., Hamidisepehr A., Donohue K.D., Villanueva R. T., and Li M, 2020). The advancement of digital agriculture as well as its related technologies has created a slew of new data analysis possibilities. To enable the earlier detection of plant pathogens that can provide farm animals with prompt and effective nourishment, and also to achieve maximum agricultural returns & output based on supply and demand, AI augmented agriculture necessitates automation, decision making, & corrective action by artificial intelligence (Beans C. 2020).

For one in every seven humans on the earth experiencing food shortages, farmers are under increasing pressure to improve productivity, while also remaining environmentally and economically efficient (AgStat. (2019). Farmers are frequently forced to plant & harvest in a race against time, with very few hands-on decks, particularly due to the volatility of last several weather conditions. In this situation artificial intelligence can help. A technological advancement has resulted in new farming technologies which will alter orchard & farm management (Arif C., Mizoguchi M. and Setiawan B. I. 2013).

Over the last fifty years, agricultural development and policies have successfully shifted toward emphasizing external inputs to increase food production. This has resulted in an increase in global inorganic fertilizer consumption, as well as pesticide, animal feedstuff, and tractor and other machinery consumption (Butler D., Holloway L. and Bear C. 2012). These external inputs have supplanted natural resources and processes, making them less effective. Pesticides have largely replaced biological, cultural, and mechanical methods of pest, weed, and disease control. Inorganic fertilizers have taken the place of livestock manures, composts, and nitrogen-fixing crops. While underlying challenge for future agriculture is to achieve maximum use of these existing capabilities. These resources can be obtained by reducing the number of external inputs used and by more effectively regenerating internal resources. Evidence is accumulating that renewable & resource conserving methods and technologies can benefit farmers, communities, and nations in both environmental and economic ways (Ekanayake J. and Saputhanthri L. (2020).

Modern agriculture has been completely transformed by robotic systems, drones, & artificial intelligence software, tractors, Harvest automation, seeding & weeding, & drones are also widely used it on farms (Correa A.M., Teodoro P.E., Gonçalves M.C., Barroso L.M.A., Nascimento M., Santos A. and Torres F.E, 2016). Agricultural automation and robotics identify significant problems such as world's population, availability of labor on farms, & attempting to shift consumption patterns. Moreover, the world market for robotic systems is expected to reach 10.1 billion US Dollars till 2024 (Gadanidis G, 2017).

Conceptual Frameworks that Connect Technological Adoption to Agro-Ecosystems and Food Security

Conceptual models that interconnect food and nutrition security consequences to certain other constituents of agro-ecosystems are a good place to start when going to look into research gaps respectively food production process analysis and food and nutrition security outcomes (Nuwagaba, A., & Namateefu, L. K, 2013). There is a substantial and growing body of literature that hypothesizes and documents the connections between agriculture, nutrition, and health. Existing conceptual frameworks that link food security outcomes to other agricultural system components share a number of features and components (Schmidhuber, J., & Tubiello, F. N, 2007). Many frameworks recognize that food systems are complex and adaptive systems made up of:

Agricultural system operations include food production, processing, allocation, & utilization, as well as the capital allocated in such operations and indeed the consequences, which range from food and nutrition security to social & environmental welfare outcomes (Rao, K., Ndegwa, W. G., Kizito, K., & Oyoo, A, 2011). Those actors, institutions, and organisms whose decentralized behavior and interaction shape and modify food system activities and resource use, and whose behavior and interaction may change in response to food system outcomes (UNFCCC. 2015).

Just about all the methodologies recognize that somehow a variety of influences, not even just agriculture, influence global food security outcomes both for food production & nonagricultural families. The concepts of food environments and resilience are more recent additions to existing frameworks. Food environments are the physical, economic, political, and socio-cultural contexts in which consumers interact with the food system in order to acquire, prepare, and consume food ((Azeredo et al, 2016). Tendall et al. (2015) Resilience is defined as those of the food system and its ability provide the food and nutrition security placed above time or in the face of interruptions. When food systems are disturbed, there are three generic potential responses (Markus A. Meyer, 2020). Perseverance or durability: the behavior and attitude of the system remains constant. Stability is carried out in a manner that chooses to follow the same path it really would if there had been no disruption. Integration: Whenever a problem is detected, the behavior of the system changes, but still, it suddenly reappears to the behavior and attitude of a non-disturbed system (B. Walker, C.S. Holling, S.R. Carpenter, A. Kinzig, 2004). Conversion: implies that the current system deteriorates and therefore is replaced by a new framework with a different arrangement, relationship issues, & identities. This same proposed framework may or not yield good results as the old system (like food security). While a few deformations may be beneficial, managing risk is regularly genuinely worried with others who are not, as well as occurrences wherein the structure may perform poorly (J.M. Anderies, C. Folke, B. Walker, E. Ostrom, 2013).

Herrera (2017) develops a series of metrics that can be calculated with dynamic simulation models to assess stability or robustness, adaptation and transformation in social-ecological systems. The metrics help a) anticipating whether robustness, adaptation or transformation can be expected as a result of a given disturbance, b) identifying where the thresholds are between robustness, adaptation and transformation and c) understanding what the resources and drivers are that foster robustness, adaptation and transformation (H. Herrera, 2017),

Herrera discusses four main resilience metrics (2017) Hardness: The system's ability to withstand a disturbance without affecting the performance of the outcome function F(x) (the threshold value between robustness and adaptation) (ibid)

Recovery rapidity: The average rate at which the system returns to the outcome function's reference behavior (i.e., returns to the same steady state, pathway or regime). Elasticity: The system's ability to recover from a disturbance without switching to a different steady state or regime (the threshold value between adaptation and transformation). Index of resilience: The likelihood of maintaining the current steady state or regime (S. Carpenter, B. Walker, J.M. Anderies, N. Abel, 2001).

Since the emergence of the coronavirus pandemic, global food access, particularly in developing countries such as Pakistan, has become a major concern (i.e., COVID-19). It is dependent on the severity & shortage of entire supply chain of food as well as substantial loss of jobs. Minimal employment rates as a result of the lower income can have repercussions on status of the community and welfare, which is an essential designed to target set of criteria. Besides that, production & consumption of food are becoming a global priority and impact in terms of socioeconomic and climatic sustainable development. The four pillars of food security are divided into four categories based on four key dimensions: availability, access, utilization, and stability. For example, Nicholson et al. discussed the widely used measure of the food and nutrition security pillars and application in agricultural design methods.

Food security, as defined by scholars, is the "availability at every day of adequate global food & clean water to preserve a continuous growth of food consumption," this phrase coined first at the 1974 World Food Conference but has since evolved. The Food and Agriculture Organization (FAO) issued a declaration on global food security during the World Food Summit in Rome in 1996, defining it as "a sustainable condition in which every human, throughout time, access physically & financially to adequate, secure, & nutritious food which can meet their nutritional requirements to spend a healthy & active life." Besides, according to the FAO, environmentally aware food systems are "the accumulation of crops & entities, but also their consecutive synchronized value addition activities which produce desired agricultural raw materials & components" (Cumming and Peterson, 2017). These are then sequenced as specific food merchandise to ultimate customers & discarded after use with a way which is economically profitable worldwide, does have wider societal advantages, and therefore does not irrevocably deprive natural resources. The FAO revealed the worldwide Agricultural production & food Uncertainty that includes social access to healthy food as well as physical and financial availability, in its dimensions of food security. The method of obtaining sustenance in socially appropriate ways, including such purchasing at a supermarket instead of stealing, scrounging, or reliance on case of emergencies food supplies, is defined as social access to food ((FAO et al. 2018).

Scope of artificial intelligence in Pakistan

There are some tools for assessing operational processes & tracking results in order to reap advantages such as reduction agricultural waste, ensuring food security, reducing necessity chemical compounds on crops, including using funding more sustainably (Haque, A, 2020).

As per the Sustainable Development Policy Institutes of Pakistan research, the country can currently utilize three main AI applications. There are some tools for assessing operational processes & tracking results in order to reap advantages such as reduction agricultural waste, ensuring food security, reducing necessity chemical compounds on crops, including using funding more sustainably. As per the Sustainable Development Policy Institutes of Pakistan research, the country can currently utilize three main AI applications (Kamol, E, 2020).

To begin with, agricultural robots may have the potential to autonomously manage basic cultivation activities at a quicker speed with a larger quantity instead of humans. It also contains reliable techniques for farmers to safeguard crops from weed species without affecting the crop, including such computer vision. Second, it is revealed in many studies that modern technologies is helpful in track & evaluate statistics. This will address a variety of issues, including soil degradation, which is a significant component of food uncertainty and even has a harmful effect on the production. Deep learning algorithms could be used by computers to process & store data collected by drone technology, field sensors & GPS supported in tractors, among other things, about potential defects and nutrient deficiencies in the soil and crop. This information can also be used to monitor the condition & ability and willingness of agricultural crops in aspects of deficiencies & diseases. this will make Growers capable to take initiatives for their crop development which eventually lead to Country's food security (Shahzad, k, 2018).

Finally, predictive modeling has quite a part to play in precision farming & agriculture. Machine learning techniques is being used to monitor & predict external variables that influence production, including such temperature variations, wind speed, market shifts, rain fall & many others. For example, an established application in Pakistan by now offers climate alerts, and yet technological learning can lead this stage beyond by customizing forecasts to each client's particular requirements (Shahzadi, R, 2018).

Benefits of utilizing AI in Agriculture

- The aggrotech market in Pakistan is expected to experience substantial growth, with projections suggesting it may reach approximately $1 billion by the year 2025 (Rehman, 2021).
- Utilizing AI-driven predictive analytics has the potential to enhance the productivity of crops by 10-20%. Platforms that assess weather data, soil conditions, and crop health can provide farmers with informed guidance on optimal practices to enhance yield (World Bank, 2022).

- The irrigation field in Pakistan exhibits significant inefficiencies, with estimates indicating that over 50% of water utilized in agriculture is squandered. Smart irrigation systems powered by AI have the potential to decrease water usage by as much as 30% through the optimization of irrigation schedules informed by current information (Ahmad & Khan, 2022).
- Approximately 30-40% of prospective agricultural production in Pakistan is estimated to be lost as a result of pests and diseases. Applications of AI, including image recognition software, have the capability to identify diseases and pests at an early stage, which could lead to a substantial decrease in losses (FAO, 2021).
- AI platforms that link farmers directly to buyers have the potential to enhance the earnings of farmers by 20-30% through the removal of intermediaries and the provision of improved pricing data (Aziz, 2021).
- The growing recognition of AI for farming contrasts sharply with the low levels of actual adoption observed in the sector. A survey revealed that merely 15-20% of cultivators in Pakistan are utilizing any type of AI technology to their farming procedures (Rizvi et al., 2021).
- Improving farmers' digital competencies via training initiatives has the potential to boost AI adoption by approximately 25 percent (Ministry of IT & Telecom, 2021). Initiatives are underway to equip farmers with the essential competencies for the effective utilization of AI tools.
- The authorities in Pakistan have launched initiatives aimed at advancing aggrotech. The National Agricultural Research Centre (NARC) is currently focused on the integration of AI into agricultural research, aiming to improve both profitability and environmental sustainability (Pakistan Agricultural Research Council, 2022).
- Aggrotech companies in Pakistan that concentrate on AI solutions have experienced a rise in investment, accumulating over $30 million in 2021 (Shah, 2022). Prominent startups in the sector are Aggrotech, Crop-In or Smart-Agri.
- Pakistan is currently trailing behind nations such as India, which boasts a more developed aggrotech ecosystem valued at approximately twenty-four billion dollars (Singh, 2020). The prospective for AI in the country's farming industry is considerable.

Challenges to artificial intelligence in Pakistan

The following were some of the barriers to technology adoption: For starters, there is a scarcity of appropriate crop data needed for the implementation of such advanced technologies. To contest all of the factors & possibilities related to these factors, the system would require a wide range of different configurations of types of soil, climate predictions, grain variety, fertility, availability of water, period of time, and so forth (Taki, M., & Yildizhan, H, 2018). Second, such technology may be difficult to sell in regions under which agricultural technologies is not prevalent. Farm owners would almost obviously require additional support in incorporating it (Taki, M., Soheili-Fard, F., Rohani, A., Chen, G., & Yildizhan, H, 2018). Lastly, emerging innovations are widely recognized as puzzling & incredibly expensive because AgriTech companies come up short to explain clearly why their remedies are beneficial & how they're being incorporated to benefit the whole process (Shahzad, k, 2018).

Key Policy Recommendations about Artificial Intelligence and Future of Pakistan

To begin, the fundamental goal of the Pakistan's main AI strategy should be research & advancements in the field of Technologies such as AI. Pakistan is presently far behind other AI technologies, especially in the area of research and development and its application to food security and crop management. Even though some people are showing an interest & approaches, namely the Presidential Initiative for Artificial Intelligence & Computing and the National University of Science and Technology's National Centre of Artificial Intelligence, there really is no structured strategy or master plan for comprehensive and integrated research & innovation.

Decision makers should indeed contemplate & incorporate the acquisition of AI technologies from friendly nations such as China. Matter of fact, hardly a nation is willing to relinquish its advanced technologies, and this is where the art of safeguarding country's interests comes into play. Pakistan e should renegotiate with effectiveness of an intervention in this era of interconnectivity. The goals can actually be realized to a great extent if we perform our cards properly & tactically. This is important to note that this concentrating on constructing our AI technologies even while obtaining some AI technologies from allied nations would have a substantial effect on the economy and food security.

Pakistan's nuclear arsenal is its primary component of major national strength, making a significant contribution in the region and globally. These abilities are inadequate to satisfy significance in hegemonic politics and to satisfy needs of its own people by eliminating food insecurity because AI equipment is evolving the game rules, and one of essential criteria of this new power play is to become self-sufficient in AI. Throughout this anarchic international political system, the realistic lesson to be learnt is self-help & preservation. In this sense, the only alternative for self-help is to incorporate AI technologies and methods.

Conclusion

The immense potential of AI in agricultural production could only be realized by incorporating robust information processing deals into agriculture and agri sectors of the economy. Nowadays, segments, subsectors, & sections where AI is used illustrate greater growth specifications, production levels, efficiency, economic strength, reduced costs, and etc. Farm owners can utilize cognitive ideas to enhance agricultural output while also attempting to deal with highly flexible & changing circumstances in a sustainable fashion. By generating agricultural production on a large scale as well as enabling farmers to develop required farming techniques including such agricultural crops, cultivation, water management, or other agriculture techniques, preservation Ai applications can favorably reshape the agricultural industry of emerging economies into a modern industry.

Pakistan's rural & conventional farming communities may not be keen to accept those same innovative techs as yet. As a result, governmental & private interventions are needed to use novel strategies to enhance such techniques based on grower necessities, such as public-private-producer partnership systems, mutual architectures with all stake - holders, & grants and subsidies & funded assistance, in effort to force forth another this much-needed digital innovations.

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