

Nam Phuong Dao  
East Ridge High School  
Woodbury, MN, 55016  
India, Climate Volatility

## **How Climate Volatility Affects Indian Agriculture and Incentives to Mitigate These Harmful Effects**

### **Introduction**

As its population continues to grow, India struggles to provide adequate amounts of food for its population. A main contributor to the lack of food available is climate volatility. One aspect of climate volatility affecting food supply is droughts. Many crops depend on water to grow properly. However, India experiences severe droughts that greatly affect the production and consumption of many crops. Additionally, the increase in ozone (O<sub>3</sub>) surface pollution has negatively affected crop yield. These effects have caused India to lose a major portion of its food supply and income. To combat these effects, three solutions have been explored. First, is increased utilization of the rice-fallow system in India to increase crop yields. Second, more funding can be allocated to finding ways to cultivate O<sub>3</sub>-tolerant crops. Lastly, the cultivation of *Elaeagnus Latifolia* plants may help with diminishing the effects of air pollution and increasing the nutrient quality and density of the diet for the Indian population. This paper investigates climate volatility's effects on Indian agriculture and ways to diminish its effect on the food supply to preserve the nutrient supply for this growing population.

India is a South Asian country officially known as the Republic of India. With an approximate population of 1.308 billion people, which is estimated to increase by around 1 million each month, it is the second-most populous country in the world ("India", n.d.). Agriculture makes up more than half of India's labor economics, with its main food commodities being rice, wheat, cotton, sugar, horticulture, and dairy. Tree nuts and fresh fruit sectors have also increased within the last couple of years to fulfill increasing consumer demand ("India - Food and agriculture value chain", 2021). Sixty-five percent of India's population lives in rural areas, while 35 percent reside in urban areas (Kramer, 2021). Within these sectors, approximately 50.4 percent of food-insecure households live in rural areas and 46.1 percent live in urban areas (Bhuyan, Sahoo, & Suar, 2020). Though it may vary by region, a typical meal in India usually consists of a main starch such as rice, sorghum, or wheat; curried vegetables and/or meat; cured and dried vegetable dishes; thick lentil soups; condiments; and occasionally desserts (Srinivas, 2020). India has seen improvements within the economic and labor market sector, yet one-fourth of India's population continues to live below the poverty line; many are living on less than \$1.25 USD per day (McKay et al., 2020), exacerbating issues related to food access and availability. As a result, 37.9 percent of children under the age of five are stunted in India and 21 percent are wasted (International Institute for Population Sciences, 2015-16), which is concerningly high compared to the global percentage of 21.9 percent stunting and wasting at 9.9% (UNICEF, 2018). With India having over 200 million people experiencing food insecurity (McKay et al., 2020), it is imperative that action is taken to help those struggling to access healthy and nutritious food.

### **The Effects of Drought on Crop Production**

Droughts have been shown to decrease India's potential crop production. India suffers from severe drought every three years, with each drought lasting approximately three to six years in length (Mahapatra, 2022). Additionally, many Indian and American researchers have determined that Southeast India has received more than 40 percent less rainfall within the past three years (Jain, 2021). Not only does this lack of rainfall negatively affect India's water supply, but it also diminishes crop yield. As a result, many Indians are not receiving optimal nutrients from their diet. According to a survey conducted by New Delhi's National Survey Office, the presence of drought is accompanied by a decrease in the quantity, quality, and variety of foods consumed in India. It was found that when the annual rainfall is as little as 0.15 meters less than average, rice yield falls by 4 percent, pulses by 3.5 percent, potatoes by 1.5 percent, and urads by 1.4 percent (Carpena, 2018). While these numbers may seem insignificant at first glance, it is important to note that India's population is drastically increasing. It is crucial that there is enough food for the growing population. Any decrease in production will lead to negative effects on the population's diet and health. Additionally, foods most affected by drought are staples of the Indian diet, meaning there is high demand and cultural importance for these commodities. Droughts have also been accompanied by a decrease in consumption of processed foods, meat, fish, and dairy products. Moreover, households spend 0.7% less on fruits and vegetables (Carpena, 2018). This is concerning because it leads to lower consumption of calories, protein, and fat consumption as well as necessary micronutrients found in fruits and vegetables. Many turn to reliance on cereals instead of fruits, vegetables, pulses, and animal source foods (Carpena, 2018). As a consequence, Indians are consuming less nutrient-dense foods, achieving suboptimal nutrition status.

### **The Effects of Ozone Pollution on Crop Production**

Another contributing factor to the lack of crop yield in India is ozone pollution. Ozone pollution, which is caused by the increase in populations, urbanization, and industrialization, heavily reduces the crop yield and seed quality of all major Indian crops including: wheat, mustard, rice, and maize (Mukherjee et al., 2021). This reduction in yield is attributed to the presence of surface ozone pollution, which reduces the stomata of plants, compromising gas exchange and the plant's photosynthesis process ("Effect of Pollution on Plants", 2020). In 2005 alone, surface ozone pollution damaged 6 million metric tons of India's wheat, rice, soybeans, and cotton crops. This vast amount of lost food was enough to feed close to 94 million. With this agricultural damage, came economical damage. India faced a total economic loss of around \$1.29 billion, with \$1.16 billion stemming from the loss of rice and wheat crops alone ("Ozone Pollution in India", 2014). Not only did ozone pollution take away major sources of food and necessary nutrients from India's population, but it decreased their economic output too. Understand that in order to help those affected by food insecurity in India, it is crucial to focus on diminishing the harmful effects ozone pollution has on major crops.

### **Solutions to Mitigate the Effects of Drought**

Food production in India relies heavily on monsoon weather and is negatively affected by India's long drought seasons. It is important that farmers learn to plan and adapt their crop rotations based on the changing rainfall patterns. To combat the effects droughts have on Indian agriculture, efforts to expand India's use of the rice-fallow farming system should be increased. The rice-fallow system rotates the production of certain crops depending on the season. Rice is usually grown during the *Kharif* growing season, which occurs between June-October. Following the *Kharif* season is the *Rabi* growing season

which occurs between November-February (Gumma et al., 2016). During the *Rabi* season, the rice croplands are usually left fallow (or uncultivated). Instead of leaving this land uncultivated, the rice-fallow system utilizes this “off-season” to grow other crops. These crops include chickpeas, toria, lentils, field pea, garden pea, green gram, and maize (Yadav et al., 2017). It was found that cropping in this system provided the soil with more nitrogen, enhancing the nutrient value of the soil and increasing crop yield. Double cropping of rice-garden peas showed the highest rice yield while the rice-pea and rice-lentil cropping rotation required the least amount of energy and Global Warming Potential (GWP). This increase in nutritional legumes and rice crop yield provided the population with supplemental protein and nutrients (Yadav et al., 2017), which has the potential to fill gaps in nutritional deficiencies in India.

Although the rice-fallow system is already commonly utilized in India, it is estimated that about 11.695 m hectares of land still remain uncultivated during the fallow season in India (Singh N. et al., 2016). Meaning, there is a large amount of unused land that possesses the potential to grow more crops. The main problem, however, is that during the fallow season, this land is unmoisturized and difficult to cultivate many crops. Utilizing the rice-fallow double cropping system would bring moisture and extra nutrients back into the soil, creating a suitable environment for growing more crops. Additionally, farmers could focus on crops that require little moisture to grow such as lentils, chickpeas, lathyrus, mungbean, and urdbean (Singh N. et al., 2016). These crops are already staples of the Indian diet, so it would not be difficult for the population and/or health care providers to further incorporate these crops into the Indian’s existing diets. Additionally, these crops are high in fiber and antioxidants and would provide the population with more nutrients than rice alone would (Singh B. et al., 2016). Not only would increasing the use of the rice-fallow system increase the quantity and quality of food consumed, but it also provides struggling farmers with more crop yield, thus more income.

### **Solutions to Mitigate Effects of Ozone Pollution**

To combat the negative effects ozone pollution has on Indian crops, it would be beneficial to incentivize funding and research on producing O<sub>3</sub> tolerable plants. In addition to focusing on reducing ozone pollution as a whole, it will be substantial to promote the production and consumption of plants that can competently grow in the presence of O<sub>3</sub> pollution. Major focuses of these research projects should be to discover how to safely modify crops to adapt to O<sub>3</sub> pollution, discover nutritious foods that may already be naturally tolerant to O<sub>3</sub> pollution, and how to effectively incorporate these practices and new crops into the population’s diets. As populations boom, urbanization expands, and industrialization increases worldwide, the harmful effects of the ozone layer damage will only increase. It is important that we learn to adapt to these climate changes before it is too late.

Lastly, cultivating more *Elaeagnus Latifolia* (*e. latifolia*) trees can help mitigate the effects climate change has on Indian agriculture and provide a supply of food for the population. *e. latifolia*, commonly known as bastard oleaster, is a shrub grown in South India (“Plants for a Future”, n.d.). One major benefit of cultivating this plant is that it can fix the nitrogen levels in soil. This is a benefit because nitrogen fixation is an essential part of sustaining the environment and increasing food crop production. Planting more *e. latifolia* plants within the South Indian region would not only help farmers grow healthier plants, but it would help them grow more food for the population too. Moreover, the plants are also known to purify the air which may also help with reducing the amount of surface O<sub>3</sub> pollution. The *e. latifolia* plant is also

able to withstand intense Indian droughts and nutrient-deficient soil, making it a viable and cost-effective plant to reduce the burden of climate volatility.

Additionally, the *e. latifolia* plant produces an edible, nutrient-dense fruit, commonly known as the South Indian Olive. These reddish, olive-shaped berries are commonly eaten by those in the South Indian region and are often made into chutney, jams, jellies, and juices (Kumar & Pandharinath, 2018). It has been discovered that these wild berries contain high amounts of calories, protein, and calcium. In addition to these nutrients, the South Indian Olives also contain more iron, zinc, copper, manganese, and chromium per fruit than the average commercialized fruit (Seal, 2011). Meaning, South Indian Olives contain high amounts of various macronutrients, minerals, and antioxidants needed for the body to function properly. By cultivating more *e. latifolia* plants, more people would be able to gain access to an additional source of nutrients, coupling the positive benefits to the environment. This would help improve the nutrient value of Indian diets and promote health within the communities.

### **Process of Effective Implementation of Solutions**

In order for these solutions to be effectively implemented, proper awareness, management, and funding need to be allocated towards them. Oftentimes, the main barriers to preventing climate change are inadequate funding and resources. To overcome these barriers, it is important to establish strong partnerships with external organizations and to have those in power willing to make changes. To properly implement the recommended solutions in this paper, the main focus areas should be effective government intervention and education for the local population.

Government intervention can help incentivize Indian farmers to adopt successful farming practices by providing subsidies and increasing awareness of the negative effects of climate change. The government of India can introduce bills that incentivize the utilization of farming practices that take action against climate change and devise awareness campaigns on the subject. To further explain, the government of India could provide subsidies to farmers willing to adapt to these new farming practices. These subsidies would encourage farmers to utilize the rice-fallow system and grow more *e. latifolia* plants. This would provide Indian farmers with the necessary income to grow more crops and increase food supplies. Funding for these subsidies can be provided by external organizations such as the World Bank or the NABARD Bank. The World Bank is an international development organization owned by over 180 countries worldwide. Its mission is to lend money to the governments of poorer countries to help them improve their government and people's financial situation (International Monetary Fund, n.d.). The World Bank also has one of the world's largest developmental research centers specializing in areas such as health, education, nutrition, and the environment (World Bank Group, 2021). The World Bank is able to easily borrow money at low-interest rates from capital markets, work closely with the United Nations, and is solely focused on promoting the development and improvement of the economies of poorer countries (World Bank Group, 2012). Meaning, the purpose of these recommended solutions aligns with the World Bank's goals. Similar to the World Bank, the R&D Fund for Agricultural Institutes in India established by NABARD Bank aims to provide monetary funding to studies and development projects focused on solving agricultural and rural development problems in India (NABARD, n.d. and NGOBOX, 2016). These funds could be utilized to support research projects on cultivating  $O_3$  tolerable and *e. latifolia* plants in India.

Another area to focus on is education. In order for farmers and the local community to adapt to new agricultural practices, they must have the right knowledge to do so correctly. The goal of educating the local population should be to promote more awareness of issues related to climate change and to encourage them to become comfortable adapting to more sustainable agricultural practices. In India, there are established local non-profit organizations that aim to teach communities about sustainable agricultural practices such as Dilasa Sanstha and the Universal Versatile Society (UVS). Dilasa Sanstha helps tribal and small farming communities adapt to sustainable agricultural practices by educating them on low-cost technical solutions (GiveIndia, n.d.). Many of these solutions are focused on improving irrigation systems and mixed cropping (Dilasa, n.d.). By partnering with Dilasa Sanstha, we could educate local communities on how to utilize the rice-fallow system and its benefits. UVS also promotes development projects in India. They work to promote funds for community-based projects, many of which surround the environment and sustainable agriculture. They also implemented an education program that encourages local schools and colleges to teach the youth about tree plantation, waste management, and pollution control (UVSociety, n.d.). By partnering with UVS, we would have access to monetary funds to support the proposed solutions and the resources to educate the community on climate change, climate change's negative effects, and ways they can take part in diminishing these effects on the food supply.

### **Conclusion**

In closing, it is imperative that action be taken to diminish the effects climate volatility has on Indian agriculture, and subsequently, the nutrient quality and density of their diets. Droughts and ozone pollution were found to decrease the quantity, quality, and nutritional value of food. In order to reduce food loss through these occurrences, several recommendations have been presented. First, the incentivization of the rice-fallow double cropping system in India would utilize rice croplands more efficiently while providing a larger quantity and variety of crops to the population. Second, more funding allocated to researching plants that can withstand ozone pollution will be beneficial in helping to plan and adapt to the changing atmosphere. Lastly, the increasing growth of *Elaeagnus Latifolia* plants would increase nitrogen fixation in the soil and provide a nutrient-dense fruit source. To ensure that these incentives are implemented effectively, proper awareness, management, and funding through government intervention and education for India's local population must be devoted. With these incentives, we can help mitigate the food insecurity problem in India.

## References

- 10 banks that give grant support to Indian ngos/individuals*. NGOBOX. (n.d.). Retrieved August 8, 2022, from [https://ngobox.org/full-news\\_10-Banks-that-give-Grant-Support-to-Indian-NGOs-Individuals-NGOBOX\\_6945](https://ngobox.org/full-news_10-Banks-that-give-Grant-Support-to-Indian-NGOs-Individuals-NGOBOX_6945)
- About the World Bank*. World Bank. (n.d.). Retrieved April 11, 2022, from <https://www.worldbank.org/en/about#:~:text=The%20World%20Bank%20Group%20has,generati on%20and%20boost%20shared%20prosperity.&text=Mission-,The%20World%20Bank%20Grou p%20has%20two%20ambitious%20goals%3A,generation%20and%20boost%20shared%20prosp erity>.
- About Us*. UVSociety. (n.d.). Retrieved May 15, 2022, from <https://uvsociety.org/about/our-mission>
- Bhuyan, B., Sahoo, B. K., & Suar, D. (2020). Food Insecurity Dynamics in India: A synthetic panel approach. *Social Sciences & Humanities Open*, 2(1), 100029. <https://doi.org/10.1016/j.ssaho.2020.100029>
- Carpena, F. (2018). How Do Droughts Impact Household Food Consumption and Nutritional Intake? A Study of Rural India. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.3177818>
- Dilasa*. (n.d.). Retrieved May 15, 2022, from <http://www.dilasa.org/>
- Data Commons. (n.d.). *India*. India Demographics - Place Explorer - Data Commons. Retrieved April 8, 2022, from <https://datacommons.org/place/country/IND?category=Demographics>
- GiveIndia. (n.d.). *Giveindia - Dilasa Sanstha*. GiveIndia Fundraisers. Retrieved May 15, 2022, from <https://fundraisers.giveindia.org/nonprofits/dilasa>
- Gumma, M. K., Thenkabail, P. S., Teluguntla, P., Rao, M. N., Mohammed, I. A., & Whitbread, A. M. (2016). Mapping rice-fallow cropland areas for short-season grain legumes intensification in South Asia using MODIS 250 m time-series data. *International Journal of Digital Earth*, 9(10), 981–1003. <https://doi.org/10.1080/17538947.2016.1168489>
- India - Food and agriculture value chain*. (2021, October 22). International Trade Administration | Trade.gov. Retrieved April 11, 2022, from <https://www.trade.gov/country-commercial-guides/india-food-and-agriculture-value-chain>
- International Institute for Population Sciences (IIPS) and ICF. (2017). National Family Health Survey (NFHS-4), 2015-16: India. Mumbai: IIPS.
- International Monetary Fund. (n.d.). *The IMF and the World Bank*. IMF. Retrieved August 8, 2022, from <https://www.imf.org/en/About/Factsheets/Sheets/2022/IMF-World-Bank-New>
- Jain, N. (2021, May 20). *Southern India's 2016–2018 drought was the worst in 150 years*. Mongabay-India. Retrieved April 8, 2022, from

- <https://india.mongabay.com/2021/05/southern-indias-2016-2018-drought-was-the-worst-in-150-years/>.
- Kramer, S. (2021, September 21). *1. population growth and religious composition*. Pew Research Center's Religion & Public Life Project. Retrieved April 8, 2022, from <https://www.pewresearch.org/religion/2021/09/21/population-growth-and-religious-composition/>
- Kumar, V., & Pandharinath Said, P. (2018). Physico-chemical characterization elaeagnus latifolia from Sikkim Himalayas. *International Journal of Pure & Applied Bioscience*, 6(5), 361–366. <https://doi.org/10.18782/2320-7051.6386>
- Mahapatra, R. (2022, November 30). *Drought forever*. Down To Earth. Retrieved April 7, 2022, from <https://www.downtoearth.org.in/blog/drought-forever-44976#:~:text=On%20an%20average%2C%20India%27s%20rainfed,and%20negative%20impacts%20agricultural%20production>
- McKay, F. H., John, P., Sims, A., Kaur, G., & Kaushal, J. (2020). Documenting the food insecurity experiences and nutritional status of women in India: Study protocol. *International Journal of Environmental Research and Public Health*, 17(11), 3769. <https://doi.org/10.3390/ijerph17113769>
- Mukherjee, A., Yadav, D. S., Agrawal, S. B., & Agrawal, M. (2021). Ozone a persistent challenge to food security in India: Current status and policy implications. *Current Opinion in Environmental Science & Health*, 19, 100220. <https://doi.org/10.1016/j.coesh.2020.10.008>
- National Bank for Agriculture and Rural Development*. NABARD. (n.d.). Retrieved August 8, 2022, from <https://www.nabard.org/content1.aspx?id=519&catid=8&mid=8#:~:text=Established%20by%20the%20Bank%2C%20in,backed%20up%20by%20technical%20and>
- Ozone Pollution in India Kills Enough Crops to Feed 94 Million in Poverty*. (2014, September 4). Scripps Institution of Oceanography. Retrieved April 9, 2022, from <https://scripps.ucsd.edu/news/ozone-pollution-india-kills-enough-crops-feed-94-million-poverty#:~:text=The%20main%20component%20of%20smog,according%20to%20the%20new%20study>
- Pfaf Plant Search*. (n.d.). Plants for a Future. Retrieved April 10, 2022, from <https://pfaf.org/user/Plant.aspx?LatinName=Elaeagnus%2Blatifolia>
- R. (2020, October 13). *Effect of Pollution on Plants (And Do They Help Fight Pollution?)*. Conserve Energy Future. Retrieved April 6, 2022, from <https://www.conserve-energy-future.com/plant-pollution.php#:~:text=Stomata%20are%20the%20tiny%20pores,exchange%20is%20compromised%2C%20photosynthesis%20slows>
- Seal, T. (2011). Nutritional composition of wild edible fruits in Meghalaya state of India and their ethno-botanical importance. *Research Journal of Botany*, 6(2), 58–67. <https://doi.org/10.3923/rjb.2011.58.67>

- Singh, B., Singh, J. P., Shevkani, K., Singh, N., & Kaur, A. (2016). Bioactive constituents in pulses and their health benefits. *Journal of Food Science and Technology*, 54(4), 858–870. <https://doi.org/10.1007/s13197-016-2391-9>
- Singh, N. P., Praharaj, C. S., & Sandhu, J. S. (2016). Utilizing untapped potential of rice fallow of East and North-east India through pulse production. *Indian Journal of Genetics and Plant Breeding (The)*, 76(4), 388. <https://doi.org/10.5958/0975-6906.2016.00058.4>
- Srinivas, T. (2020, August 26). *Exploring Indian culture through food*. Association for Asian Studies. Retrieved April 10, 2022, from <https://www.asianstudies.org/publications/ea/archives/exploring-indian-culture-through-food/>
- UNICEF, World Health Organization & The World Bank. (2018, May 14). *Levels and trends in child malnutrition*. UNICEF / WHO / World Bank Group Joint Child Malnutrition Estimates Key findings of the 2018 edition. Retrieved from <http://data.unicef.org/wp-content/uploads/2018/05/JME-2018-brochure-.pdf>.
- World Bank Group. (2012, July 26). *Getting to know the World Bank*. World Bank. Retrieved August 8, 2022, from [https://www.worldbank.org/en/news/feature/2012/07/26/getting\\_to\\_know\\_theworldbank](https://www.worldbank.org/en/news/feature/2012/07/26/getting_to_know_theworldbank)
- World Bank Group. (2021, November 10). *World Bank Development Research Programs*. World Bank. Retrieved August 8, 2022, from <https://www.worldbank.org/en/research/brief/research-programs>
- Yadav, G. S., Lal, R., Meena, R. S., Datta, M., Babu, S., Das, A., Layek, J., & Saha, P. (2017). Energy budgeting for designing sustainable and environmentally clean/safer cropping systems for rainfed rice fallow lands in India. *Journal of Cleaner Production*, 158, 29–37. <https://doi.org/10.1016/j.jclepro.2017.04.170>