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How Improving The Water Scarcity Crisis in Punjab Can Help Increase The Food Security For The People of India

India is a vibrant and diverse nation with a rich cultural heritage and the largest population in the world, about 1.438 billion people. It is the seventh largest country by land area, 3.2 million square kilometers, and is known for its vast geographical diversity, ranging from the Himalayas to fertile plains, deserts, and coastal regions. The Indian economy is dominated by the services sector, at 54.71%, followed by the industrial sector, at 27.63%, and then the agriculture sector, at 17.66% (Statistics Times 2024). India's arable land is 154,447,948 hectares, the second largest amount of arable land in the world (MacroTrends 2021). The average land size for farmers in the nation is around 1.35 hectares or approximately 2.5 football fields (MacroTrends 2021). Most farmers sow grains and vegetables, and then they have some livestock which provide them with eggs, meat, dairy, and/or labor. The government of India is a parliamentary democracy with a bicameral legislature and is currently led by Prime Minister Narendra Modi from the Bharatiya Janata Party (BJP), which is aligned with right-wing politics. Under Modi's government, the Indian economy has risen 40% in the last eight years (United Nations 2024) and is expected to continue growing at a rate of 6.3% in the coming years (European Union 2024). However, despite its economic success and large amount of arable land, India is currently facing a major food insecurity crisis.

The average family size in India is around 4.44 people per family, and some jobs that an average person may work include government or private administrative jobs, labourers, or going into more advanced studies like the medical field, IT, or finance (Global Data 2021). Many young adults of India will often follow in their parents' footsteps as business owners or farmers, or occasionally both. The average wage for workers in India is around 384,000 INR per year or about $4,403/year. The diet for an average family differs from region to region. In North India, families will typically eat roti (tortilla-like bread), rice, dal (lentils), and/or sabzi (cooked vegetables). On the other hand, in South India, families will have dosa (a fermented crepe usually filled with vegetables), rice, sambar (vegetable stew), and/or idli (a puffy rice cake) on a normal day. These foods are some of the most nutritious as well. Although varyingly different in diets, both regions rely on grains as a major food source.

In India, around 13.9% of citizens are estimated to be malnourished. According to the Global Hunger Index (GHI), China, the second most populous country in the world, has less than 2.5% of citizens that are malnourished. India has about 5.56 times more undernourished citizens than China, a country with a similar population. Additionally, the GHI has stated that India ranks 105th out of 127 countries in terms of the level of hunger of citizens, with a score of 27.3, which indicates that India has a serious level of hunger. China, on the other hand, is one of 22 countries that has a GHI of less than 5 and its level of hunger has been deemed low (Global Hunger Index 2024). With relatively the same amount of population, one nation is extremely food insecure and the other is exceedingly food secure. The World Food Programme, an organization founded by the United Nations that aids in food insecurity, has said that China has marked a huge milestone in 2021 by announcing the eradication of extreme poverty in their

country. They have credited this accomplishment of China's food security to its ability to produce sufficient grain to feed its population of 1.4 billion people. Similarly, India has attempted to lessen their malnourished population by converting the agricultural industry of the state of Punjab into a mostly grain producing industry.

Panjab, the Land of Five (Panj) Rivers (Ab), is located in the northwestern part of the Indian subcontinent. Regionally, Panjab's designation extends from the Himalayas in the north, to the Thar desert in the south and its borders are shaped by the rivers of the Indus in the west and the Yamuna in the southeast. From the Indus River, five smaller rivers blossom across Panjab: Jhelum, Chenab, Ravi, Beas, and Sutlej. However, after the partition of British India in 1947, the rivers became split between Pakistan and India, creating two different regions which are East and West Panjab, respectively. The Jhelum, Chenab, and a majority of the Ravi rivers became a part of Pakistan, while the remaining parts of the Ravi, Beas, and Sutlej rivers went to India (Indian Independence Act 1947). To help with India's grain crisis in the 1960s, the Indian Government brought in American and European agricultural experts to assist Panjabi farmers with their farming methods and processes. These consultants established new policies and agricultural techniques in an effort to increase the production yields for grain crops. Since then, wheat and rice have become the most important crops for Panjab, and especially rice, as the state became a primary government mandated rice source for government grain reserves (Columbia Water Center 2024). Panjab produces approximately 20% of wheat for India and 12% of its rice while only having 1.5% of total land area in India. This strategy, nicknamed the Green Revolution, showed great promise when it was first introduced in the 1960s, however the potential of India's ability to reduce hunger quickly turned downhill when the issue of water came into play.

Water scarcity is a significant issue for farmers in Panjab. If there is no water for farmers to use to irrigate their crops then they can't harvest any viable produce, which means that India has less food to go around for all 1.4 billion of its citizens. One of the root causes for the water shortage for farmers is the lack of river water in Panjab. For thousands of years, Panjab has been the most fertile region in South Asia because of its rivers. Historically, Panjab's farmers have used their five rivers, and their canals and tributaries, to irrigate their crops. After the British partition, West Panjab, which is also called Punjab, India, could only use the water of the Sutlej, Beas, and a small part of the Ravi for all their water needs. Additionally, the Indian government started construction on the Sutlej Yamuna Canal (SYL) in February 2016, to divert water from the Sutlej river and into the Yamuna river, to help Haryana, another state in India. Because of this and because most of the Jhelum, Chenab, and Ravi waters being given to Pakistan means that the agricultural industry in Punjab now has less than 25% of the river water it had just seventy years prior (Sikh Teens 2024).

Another significant cause of water scarcity in Punjab is the dependency many Punjabi farmers have on groundwater because they do not have access to river water. Traditionally, in Punjabi agricultural practices, groundwater is only supposed to be used as a temporary substitute for irrigation. With only 25% of Punjab's river waters being set aside for the farmers of Punjab, many have had to rely on groundwater for the past couple decades. According to some Punjabi farmers, the groundwater was reachable at ~5 meters deep around seven to eight years ago. However, the groundwater levels are now found at ~21 meters (UN News Report 2023). The overuse of groundwater by many Punjabi farmers has caused the groundwater reservoirs to not have enough time to recharge their water supply. On October 25, 2023, a couple of Punjabi farmers talked to UN news reporter, Polina Schapova, and gave their own perspectives on the groundwater situation. Amandeep Singh, a landowner and farmer, said "We very much rely on groundwater, as we only have access to canal water once a week…Every year, we have to dig deeper to reach the groundwater…Reaching the groundwater is very expensive, but we landowners have no choice" (Schapova 2023). He also stated that ten years ago the level of groundwater was at 9-12 meters deep, while today it's at 18-21 meters deep. Harjeet Singh, another farmer interviewed, told Schapova that because of the declining water level, his income has been affected and he cannot afford to install a tool

such as a borewell which can get water from lower depths. Thousands of farmers across Punjab just like H. Singh and A. Singh are experiencing the same issues; if the water depth around their farms declines any more then they will not be able to irrigate their crops, causing a decrease in grain productivity for Punjab. In turn, if the demand set by India's population is not met for grain, then the country cannot feed its malnourished population.

The effect of water scarcity on farmers has already begun to be shown. VoxDev, a platform for people interested in discussing key policy issues, reported that in 2020 farmers whose wells had dried up from the declining water depth had their farm income significantly affected. Their incomes were about 25% lower than farmers whose wells were fully operational. Farmers who had these water problems cultivated less land with less profitable crops, and those crops usually were ones that needed more water. Moreover, their data showed no evidence that the affected farmers found ways to evolve their agricultural practices around the increasing water stress (VoxDev 2020). Another effect that has been increasing due to the lack of water are farmer suicide rates. According to the National Library of Medicine (NLM), suicide rates for farmers across India is now 47% higher than the national average. From 1995 to 2018, nearly 400,000 Indian farmers took their life, approximately 48 suicides a day. Although water scarcity in itself isn't the singular cause of these suicides, farmers will often take loans from the government to pay for extra river or groundwater and often aren't able to pay the loans back. As a result, the government officials will attempt to seize the farmers' lands. Many times, because of the failure of paying their debts, farmers feel a sense of hopelessness and humiliation and will then commit suicide as an attempt to resolve their heavy emotions (NLM 2021).

Many farmers from Punjab have been struggling to make ends meet for decades because of the major issues caused by water scarcity. However, there are three solutions that have helped farmers from different parts of the world overcome water scarcity. In Greece, for example, farmers have increased their efficiency of water usage by an estimated 95% gain compared to other irrigation methods. This was done through the technological improvements of their farms' conveyance efficiency, the proportion of water that is delivered to a specific field, as well as field application efficiency, which is the percentage of water actually being used by the crop in relation to the total amount of water delivered to that crop (European Environment Agency 2012). They did this by adding new and innovative irrigation networks which cost around ₹435,000 Indian Rupees per acre (INR), or $5,000. As stated above, the average land size is around 2.5 football fields for farmers in India, so the cost for an individual farmer to pay for these networks would come out to ₹1.08 million INR or around $12,000. For the thousands of farmers like Harjeet Singh who can barely afford to buy borewells, which cost approximately ₹260,000 INR or $3,000, this solution simply could not help because of the overbearing costs of the irrigation networks. Thus, this method is not a viable way to help reduce the water scarcity crisis in Punjab.

Two other solutions, though, could significantly improve the water scarcity crisis. The first one was used by people in Crete, an island of Greece, who found that water gains could be raised by advising farmers on how to properly irrigate crops via a resource called the Irrigation Advisory Service of Crete (IASC). This farmer-and-scientist-led service, established in 2005, informed farmers by phone of when and how to irrigate their fields based on approximate daily conditions that could affect crops. In its testing phase, using prototype fields, the information system that the service used calculated and recommended that the fields should be irrigated 9-20% less than what farmers had been doing in years prior. Moreover, after a few soil tests were conducted, the data showed that the crops were grown at the optimal soil water condition. Over the next two years, 2006 and 2007, the service began advising farmers on how to irrigate their fields. When this second phase began, the service showed great promise that it could help the Cretan farmers, and the number of farmers who were interested in the use of the system had also grown incredibly. Despite the successes of the system though, the service failed to gain traction among Cretan farmers primarily due to financial investment requirements and sociological impediments like culture and tradition (Chartzoulakis 2008). Similarly, Punjabis, culturally, do not like to change their ways and would

not want to invest high amounts of money into a service that would make them alter their traditional practices. However, if the service is spearheaded by farmers then it may be able to break through cultural barriers and become successful. It will take a lot of time for farmers to abandon tradition so there would need to be constant leadership on the part of both the farmers who would spearhead the service and the government, who would be overseeing the service.

The second solution that has worked in both the United States and Europe, that could help the water crisis in Punjab, is using regenerated water, otherwise known as cleaned wastewater, as an irrigation source. The cleaning and reuse of wastewater for irrigation has worked to help farmers in Gran Canaria who can no longer rely on groundwater or surface water being their primary sources of irrigation water. Gran Canaria is an island of 863,000 people with major water scarcity issues. Before the use of regenerated water was introduced, Gran Canaria relied on the small supply of groundwater reservoirs it had. However, over the years, Gran Canaria developed an unhealthy reliance on the groundwater reservoirs which started to threaten the water surplus it once had. By introducing reverse osmosis water treatment plants, which turn clean wastewater into usable irrigation water, Gran Canaria balanced out the overdependence on its limited groundwater reserves. The treatment itself is a combination of grates, sieves, and primary decantation which weeds out the larger sewage and debris while secondary decantation is used to further clean the water and get the smaller particles of bacteria via a biological treatment. After that, tertiary treatment, which is designed to remove any non-biodegradable or micro pollutants, is used to further prepare the water for irrigation reuse. The regenerated water is distributed to the Gran Canarian farmers' fields as a way to irrigate the crops without relying on the groundwater reservoirs that can then be primarily focused for the humans on the island (Reboso 2020).

Punjab could benefit from these two solutions, if applied in combination. The greatest benefit to reusing wastewater is that all of the water in the region can be cleaned. Punjab's rivers are already heavily polluted, the Punjabi rivers of Sutlej, Beas and tributary Kali Bein, and the intermittent Ghaggar river each have many large polluted regions of water along their courses. Many different industries' factories and buildings empty toxic waste into the rivers, resulting in water unfit for both human and agricultural use. Additionally, fluoride in Punjab's water has exceeded its safe limit and is starting to affect the health of humans, animals, and the environment across Punjab. The World Health Organization has a guideline of 1.5 mg/L F- being the absolute maximum amount of fluoride allowed in water for it to be regarded as safe for water usage. Punjab's fluoride crisis shows that around 9% of 28,648 wells contained greater than 1.5 mg/L F- (Khattak 2022), which means that there also may be serious health consequences like dental and skeletal fluorosis in store for many Punjabis in the future if the fluoride is not reduced. On top of that, wastewater production is at a peak in Punjab; many villages and cities across the state have overflowing sewage ponds and treatment plants that are not being treated properly. If Punjab starts to implement the cleaning and reuse of wastewater it could help create more irrigation supply for farmers while also cleaning the pollution in Punjab's waters. Furthermore, if water treatment plants are installed across Punjab, the fluoride amount can also be massively reduced which can help save humans and wildlife from horrifying health repercussions and, at the same time, improve the environmental damage of the water. Establishing a service like the one in Crete could also help many farmers conserve their irrigation usage more efficiently. A majority of farmers in Punjab do not have any education higher than a tenth grade level, so having a service that they can take advice from would be beneficial. Moreover, despite the cultural abandonment that farmers would have to undergo, if given time, the service would be helpful in developing advanced agricultural practices while also creating smarter farmers who can help make a flourishing future India. On top of that, these technologies are appropriate for India because they align with the economic, environmental, and societal conditions of the region of Punjab. Regenerated water use, specifically, is appropriate because it is available year round, especially in dry seasons, and using it reduces the environmental burden on groundwater sources. The advisory service is also appropriate because it can be delivered via phone, a technology that is already widespread in India, and it supports bottom-up development, empowering local farmers. The two technologies are also stronger together

because using regenerated water without proper knowledge can damage crops and soil health if not monitored and an advisory service alone cannot increase irrigation capacity without access to additional water sources. In combination, using treated wastewater will increase the available irrigation supply while the advisory service ensures its efficient, effective, and safe use. Simply put, both of these technologies are adaptable, sustainable, empowering, and scalable.

Alas, there is still an expense that would have to be paid for the creation of both of these solutions. According to the director of innovations, Gunnar Herber, at Salincx, a leading water treatment plant contractor, costs for building a plant in Asia would come to be around ₹10-16 million INR for a plant that handles 5 million gallons of water per day (Herber 2024). For Punjab to even have a decent enough capacity of treatment plants, there would have to be about 30 plants built across the state and the total cost for all of these plants would come out to be ₹420 million INR. For the advisory service, there would probably need to be around 10 call centers for every district of Punjab (23 districts). Assuming that 500 sq ft would be enough space for these centers, then an individual call center would be around ₹500,000 INR which would bring the total cost of all the centers to ₹115 million INR. So, for both of the proposed solutions, the costs would be approximately ₹535 million INR or around $6.1 million dollars. From the perspective of farmers, this cost is too expensive and any major investments from farmers would probably be deemed unattainable. However, a way to negate almost all of these expenses would be to have the solutions come as a cost to the Punjabi state government, as they could establish these solutions as government subsidies, so that the overall expenses would dramatically lessen instead of having these costs be at an individual farmer level, like the first method. The reason why the Punjabi government would do this is because they could improve the water crisis but then also gain a profit by selling the government services and therefore the expenses would become beneficial for the government. The total fees for the subsidies would come out to around ₹430 INR or around $5 per farmer and compared to the first solution where farmers would have to pay about ₹1.08 million INR or around $12,000, this proposed solution is beneficial to the farmers as well. Additionally, if needed, the central Indian government could aid in creating financial assistance for the Punjabi government. The Indian government would be incentivized to aid Punjab because, as mentioned before, Punjab produces approximately 20% of wheat for India and 12% of its rice. Punjab's agricultural industry is integral to India's success in reducing the food insecurity in the country, so, India should take the steps necessary to help the Punjabi government in their endeavors.

India has a significantly malnourished population that doesn't have sufficient food access. India, in realization of their predicament, has attempted to increase their grain surplus by delegating Punjab as a grain provider for India. However, one of the reasons for the failure of this strategy is the water scarcity crisis that is affecting farmers in Punjab; if farmers can't irrigate their crops, then they end up harvesting less grain, which then affects the overall grain supply for India. This crisis of water shortage is mainly caused by the depletion of groundwater resources and the decrease in access to river water in Punjab. Yet, there is a potential solution in increasing the technological aspect of farming. Unfortunately, this solution is too expensive for individual farmers. There are two solutions, the reuse of regenerated water and the establishment of an advisory service, that, if used in conjunction and implemented properly, could help Punjabi farmers increase their irrigation capacity and efficiency. These methods, though expensive, can be considered practical not just because they would solve the water crisis but also because they would help reduce the significant amount of pollution while aiding in creating more effective farming practices. Moreover, some farmer unions, organizations, and non-profit foundations that can help kickstart these solutions are the Young Farmers Association Punjab, Punjab Agricultural University, Department of Water Resources Punjab, India, and the Ambuja foundation. If India decides to put in the resources to reduce its malnourished people, my recommendation to do that would be to help the water crisis that is plaguing Punjabi farmers by introducing the reuse of wastewater for irrigation and an irrigation advisory service that gives farmers a seat at the table alongside scientists.

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