Hung Huynh
Portage Northern High School
Portage, MI
India, Water Scarcity

India's Water Crisis: The Fruits of Unsustainable Agriculture and Water Pollution

With agriculture as the backbone of stability for India, the collapse of this industry will spell chaos for its people and economy. As decades of unsustainable usage of groundwater for agriculture accumulates combined with the heavy pollution in its bodies of freshwater, the scarcity of clean water is a crisis in India. This crisis already threatens the water security of millions of people, bringing death and disease to many. If things don't change, India's food security will also be compromised as clean water runs out, furthering the suffering of its population in poverty and malnutrition. The compromisation of India's food security will destabilize its economy and government. If India does not take steps to address its water scarcity problem, it will be facing a very gloomy future ahead.

India's population of 1.37 billion people is second in the world while it is the 7th largest in landmass and economy, boasting the fastest growing economy at the rate of 7.3% (World Population Review, 2019; The Economic Times, 2018). Its parliamentary democratic republic rules its 3.29 million square kilometers of 6 major climates (Pariona, 2017; Mattyasovszky, 2015). Considering its diverse climates, 52% of India is arable land, allowing it to be the second largest in global agricultural production (Trading Economics, 2015; CATR, 2018). India's exports total to approximately $320 billion, $90 billion of which are mineral fuels/precious minerals and $38.2 billion in agricultural exports (Workman, 2019; India Brand Equity Foundation, 2017). Although agriculture is responsible for only 17% of the GDP, it provides jobs for more than half the population (Jain, 2018). India is the global leader in rice production, producing 43.2 millions of hectares as of 2017 (Cago, 2017). These impressive overall statistics are only due to India's large population and size since the average farm size is only about 1.1 hectares or 2.7 acres, approximately 2 football fields (Agri Business, 2018).

Average Indian families are about 4-5 people as they form the diverse hierarchical system where life varies according to location, ethnicity, and caste (Esri, 2018). With more than half the population making up the untraditional middle class of uneducated farmers and construction workers, they earn between $2-10 per day (Biswas, 2017). Those in air polluted urban areas can mostly afford to only live in slums while two-thirds of the population lives in rural villages, many in mud or brick houses with thatched or bamboo roofs (Oddizzi, 2014). Rural conditions often lack adequate sanitation and running water, with biomass such as wood and dung used for cooking the staple cereals and pulses diet (Irfan, 2018; Makanaka, 2013). Since electrification of villages remains a goal of Prime Minister Narendra Modi, more than 80% of people have access to electricity - although there are power surges due to lacking power plants (D'Cunha, 2018). Discrepancies between rural and urban India and varying wealth statuses across its states result in the least adequate and accessible healthcare in the most poor and remote regions (Envisage International, 2019). Assisted by over $2 billion from the World Bank, India's Education for All Program allows nearly 20 million children in India participate in primary education. However, only 44% complete their secondary education (The World Bank, 2015). Additionally, India remains high in the world in malnourished children as "a child under five is almost twice as likely to be chronically underweight in India as in sub-Saharan Africa," (Gautam, 2018). This leaves 1 in 4 children malnourished in India while 15% of the population is undernourished as a whole due to poverty (India FoodBanking Network, 2019).

The heavy reliance on agriculture forces farmers to depend on rain to water their crops, 75% of which falls during the 4-month monsoon period (Skymet Weather, 2017; Bhanja et al., 2017). However, shifting monsoonal patterns due to climate change can devastate crop growth if droughts, heavy downpours, or floods occur. (Stratfor, 2012; Turner, 2018). This impacts GDP and even leads to mass farmers suicides due to debt, crop prices, and famine (Dey, 2018). To address these inconsistencies, India turned to groundwater for irrigation and consumption. Annually extracting the 19.2 gigatons that makes up 25% of global groundwater usage, India leads the world in groundwater usage with more than the next 2 countries in China and the U.S. combined (Jain, 2018; Biswas & Hartley, 2017). Furthermore, the prevalence of flood irrigation results in much of the water ending up in the ocean, contributing to the global 10-30% of the annual rise in sea levels (Jain, 2018; James, 2015). The excessive extraction of groundwater causes land subsidence, an irreversible situation in which the porous sediment compacts, permanently reducing its storage capacity as wetlands are lost and building infrastructure is damaged (Sengupta, 2015). In addition, arsenic from the Himalayan rocks pollutes the groundwater as it is carried downstream and forced into the groundwater through land subsidence (Young, 2009).

With decades of untreated industrial waste dumped in water and on land, 70% of India's freshwater -- groundwater and surface water -- is polluted (Schneider, 2018; EAI, 2017). Hundreds of districts in India are impacted by water pollution from salinity, heavy metals, and other contaminants, contributing to severe health problems and an annual death rate of 200,000 (Banerji, 2018). Combined with saltwater intrusion and contaminated replenishment sources, these bleed into the groundwater as the water table, or level of groundwater, falls. The scarcity in clean water not only forces people to consume unclean water, it also forces them to use contaminated wastewater to irrigate their crops, making the crop toxic as contaminants are absorbed into the plants that feed millions (Möller-Gulland, Ganter, & Pope, 2019).

India's water scarcity problem is a web of interconnected challenges. As illustrated in Figure 1, these problems are not independently isolated. There are many problem types from the Youth Institute's list that play a critical role in regards to India's water scarcity problem because they are caused by multiple factors that serve as feedback loops for one another. Combining political and technological approaches in water management and sanitation is one step towards solving India's water scarcity problem.

Connections Between India's Agriculture Water Problem

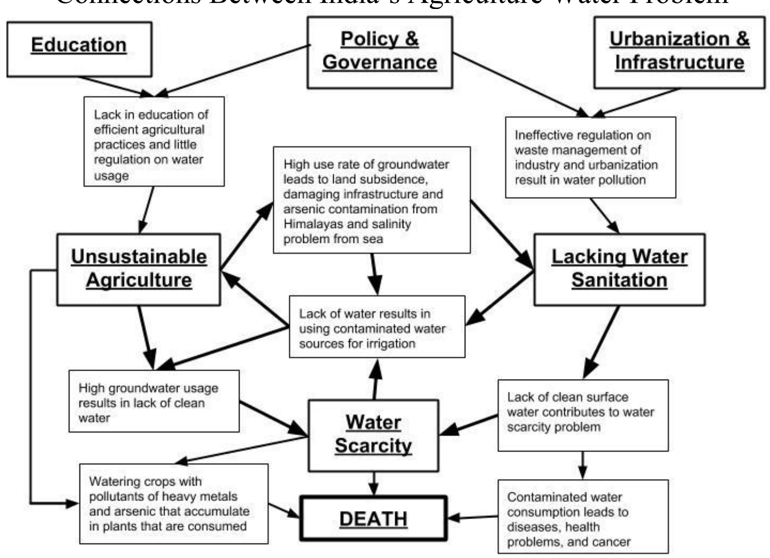

Figure 1: The interconnected web of India's problem and its feedback loop.

One approach to solving the water scarcity problem requires awareness in the importance of water management. Once farmers understand the context of India's water problem, they are more likely to cooperate with the policies created by the cooperation between India's federal and state governments to limit groundwater pumping. In thewestern Indian state of Gujarat, changes in policies seem to have a positive impact on groundwater replenishment, which can be seen in Figure 2. Utilizing data from NASA's Gravity Recovery and Climate Experiment (GRACE) twin satellites launched in 2002, the data was obtained as the satellites detected micro shifts in gravity resulted in mass changes to generate gravity anomaly maps (NASA, 2004). Through "Policies like restriction of subsidized electricity for irrigation, [and] separate electricity distribution for agricultural purpose[s]," the groundwater recovery map displays significant gains as Gujarat constructs an aquifer recharge system (Bhanja et al., 2017). The restrictions on electricity for irrigation is effective in helping recharge the aquifer by directly limiting the amount of time each day that farmers can pump water, thereby reducing their water extraction to allow for better aquifer recharge. When compared to regions of north and east India where these irrigation policies have yet to be effectively implemented, a continual decline in groundwater storage can be seen while Gujarat's high level of success can be seen as the darkest teal color to the west in Figure 2.

India's Groundwater Storage Trends

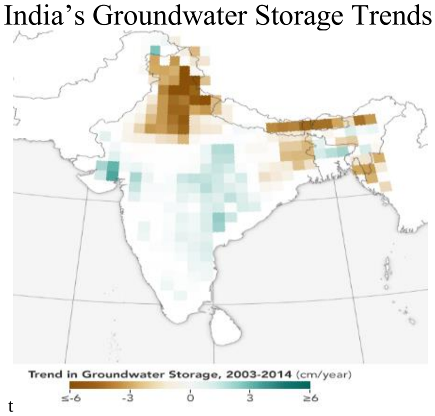

Figure 2: Gains and losses in groundwater storage trends (NASA, 2014).

With the majority of farmers utilizing the flood irrigation method using water from wells, much of the water is lost through runoff and evapotranspiration, resulting in low efficiency as the whole field is flooded with water (Dhawan, 2017). The excessive water causes waterlogging, resulting in aeration stress, which is the impairment of gas exchange between the soil, air, and plant roots (Jackson, 1983). Small optimizations to this method would be to use surge flooding where irrigation is done in bursts to allow for water to percolate and also use ditches to capture runoff to be reused (USGS, 2016). However, this cannot match the efficiency of a drip irrigation system where water is run through tubes with holes and drips on the roots near the plants, minimizing the water loss by a tremendous amount. This also produces a higher crop yield while also allowing for the use of saltier water without dramatically affecting crop productivity (Yadvinder-Singh, Kukal, Jat, & Sidhu, 2014). With the salt in India's groundwater, this will be good for the crops because they will experience less foliar salt accumulation in the leaves, which can damage the plant (Hanson & May, 2011). Overall, the use of drip irrigation holds great promise to helping resolve India's overconsumption of water because of its minimal water usage when compared to traditional flood irrigation, not to mention the potential increase in crop yield as it helps remediate the foliar salt accumulation when groundwater is sourced, which is now more salty due to saltwater intrusion.

The extra requirement with this method is that it requires some infrastructure setup with the tubing system, an option that not all farmers have access to and might not be able to afford. Similarly, a sprinkler system requires less infrastructure but still maintains higher efficiency than flood irrigation, although utilizing saltier water can affect plant growth as salt gets on the leaves. Utilizing these systems can save up to 50% water for rice and 70% for wheat, critical in the drier regions where these water consuming crops are grown (Sudhir-Yadav, Balwinder-Singh, Humphreys, & Kukal, 2013). The challenges of this system is similar to that of the traditional irrigation system: where to get the water. When tackling this obstacle, one can consider the two main types: surface water and groundwater. Although it can be expensive, India can look towards building desalination plants along its vast coastline, which would then lessen the stress on groundwater consumption as people are provided with an alternative option. In regions farther away from the coast, there are many rivers and bodies of freshwater that can be resorted to by using structures such as canals to divert water to the desired region. With its prominent monsoon season, much of that water in India is unused. If India starts building reservoirs, this surplus water can be stored and used at a later time. Undoubtedly, this water storing technique can be especially important for communities that live far away from a water source. Additionally, pipelines can also be built to bring water to communities distant from water sources.

To implement these systems, perhaps India's government can work with farmers who can't afford them to install the infrastructure. Since the more efficient drip irrigation produces higher crop yields, farmers can perhaps pay back with portions of their harvest over a period of time. These policy changes to water management and the use of more efficient irrigation systems should lessen the stress on groundwater sources. However, the potential problem with this is the funding and organization to get it started. A great start will be looking towards the $3 billion funding given to the National Mission for Clean Ganga (NMCG) to cleanup the holy Ganges river for 5 years up to 2020, of which only $205 Million had been spent (Wilkes, 2017). As the population and industrialization continues to grow, India must start looking at sources of irrigation beyond groundwater as its polluted surface water remains an imminent problem.

The contaminated surface water sources are options that India can explore to provide another solution to the water scarcity problem. Since 70% of its fresh water is polluted, India is home to the Ganges and the Yamuna river, 2 of the world's 10 most polluted rivers, a water pollution problem that is a costly $106 billion annually (Rinkesh, 2019; USAID, 2017). Additionally, India is home to Delhi, the most polluted city in the world, along with 12 others that make up 13 of the 20 most polluted cities worldwide (APF, 2014). With some of the water pollutants being heavy metals and spilled oil while the majority of air pollutants being black carbon particulate matter, the solution to both of these problems can be found in another one of India's problems: agricultural biomass waste and crop residue.

A study published in 2015 found that 611 million metric tons (MMTs) of biomass residue was produced annually in India, 158 MMTs (25%) of which was unused (Cardoen, Joshi, Sarma, & Pant, 2015). Large portions of that waste comes from plants such as sugarcane, rice, wheat, and bananas. With nowhere to place wastes such as the rice straw after harvest and the lack of access to technology to remove it, hundreds of thousands of farmers burn these crop residues to quickly plant their next crops, contributing heavy amounts of pollution to the air in the process (Green Car Congress, 2019). As a matter of fact, air pollution from crop burning is costing India $30 billion annually (Chatterji, 2019). Tractors such as the Happy Seeder were made in attempt to solve this problem. However, it remains unaffordable for many farmers (Gupta, 2016). In the state of Punjab, power plants have been built to utilize the straw, but their combined use consumes under 10% of the total waste (Anand 2016). The policies to ban crop burning remain ineffective as farmers have no incentive to follow them. But what if they were provided the tools to remove the straw while at the same time that waste is used to treat water pollution instead of contributing to air pollution?

Through the process of adsorption, biomass waste from farms and food processing can be repurposed as the answer to India's polluted waters. Fundamentally, adsorption utilizes the electrostatic forces and functional groups within the biomass to bond with ions of heavy metals. Traditional industrial treatment methods used such as chemical precipitation are inefficient, producing unusable waste sludge. With adsorption however, once the heavy metal ions are removed from water, desorption can strip the metal ions from the sorbents in a much more concentrated solution that can potentially be harvested, allowing for possible reuse of the sorbent filtrate (Gisi, Lofrano, Grassi, & Notarnicola, 2016). The efficiency of biomass such as rice straw can be enhanced using chemicals in its binding sites to assist in the bonding process (Khandanlou et al., 2015). Since different types of biomass are attracted to different types of substances, biowaste such as sugarcane bagasse can help remove oil contaminating India's water (Gorgulho, Guilharduci, & Martelli, 2018). Biomass modified by iron compounds was also found to be able to remove arsenic (Ansone-Bērtiņa, Klavins, Robalds, & Viksna, 2012). The abundance of biomass waste in India gives the industrial expansion of this method high potential for effectiveness.

Implementation of this method would require the intervention of India's government to heighten its policies on industrial pollution. Over the past years, the Ministry of Environment, Forest and Climate Change has been ineffective in its pollution regulation, lacking clear organizational structure and authority, with inconsistencies across regions and shortages on management staff (Dinesh, Kapoor, Kohli, Menon, & Venkatram, 2016). Once reformed, stricter management can properly regulate heavy penalization for industrial plants that violate pollution laws. This would incentivize them to start looking for cost-effective solutions to treat wastewater, which once pointed towards biosorbents, can also help farmers. With biowaste that once was burned, farmers can settle an agreement with the industry to sell it for a cheap price while the industry is able to provide machinery to remove and transport the waste, a likely prospect if they want a cheap cleaning solution. This will also work to promote the economy while also reduce the output of wastewater and crop burning that pollutes the environment. With enough treatment plants to treat only 30% of wastewater and a lack in public-private partnership, India can seek out cooperation in the private sector for help in building treatment plants (Delawala, 2017). In USAID's partnership with India, $5 million from the private sector has been raised for the Water Sanitation and Hygiene (WASH) program. If they are made aware of the potential of utilizing biosorbents in treating wastewater and reducing air pollution, this can be a game-changer if it can be implemented.

With the solutions proposed, their implementation will definitely lead to a better future in water security for India. Since states such as Gujarat have already successfully implemented policies to mitigate excessive water extraction through the limitation of electricity for pumps, positive trends for groundwater storage in its area could be seen. If water conservation can be furthered with much more efficient irrigation techniques such as drip irrigation instead of flood irrigation, not only will water be saved but crop yields will increase due to better growing conditions. With the potential of increased crop yields, India's government can set up a plan with farmers to set up the tubing infrastructure that they can later pay back for with portions from their crop harvest. The possible increase in crop yield will also likely contribute to the excess biomass waste and crop residue that contributes to air pollution if farmers burn them. However, if USAID continues its partnership with India in the Water Sanitation and Hygiene program, they can work with the private sector to build treatment plants while reforming regulations will encourage utilizing this biomass waste to treat pollutants in water. This will help reduce air pollution and treat water pollution, both of which are problems that total to cost India over $130 billion annually. The implementation of these solutions should help solve the water scarcity problem in India. With the benefits of solving India's water security issues, the side effects will also include increased food security and reduced pollution, all of which serve to provide security to the most valuable thing of all: human life.

Bibliography

AFP. (2014, May 08). India admits Delhi matches Beijing for air pollution threatening public health. Retrieved April 7, 2019, from https://www.theguardian.com/world/2014/may/08/india-admits-delhi-matches-beijing-air-polllution-world-health-organisation-cities

Agri Business. (2018, August 17). Average farm landholding size shrinks to 1.1 ha. Retrieved April 7, 2019, from https://www.thehindubusinessline.com/economy/agri-business/average-farm-landholding-size-shrinks-to-11-ha/article24719240.ece

Anand, G. (2016, November 02). Farmers' Unchecked Crop Burning Fuels India's Air Pollution. Retrieved April 7, 2019, from https://www.nytimes.com/2016/11/03/world/asia/farmers-unchecked-crop-burning-fuels-indias-air-pollution.html

Ansone-Bērtiņa, L., Klavins, M., Robalds, A., & Viksna, A. (2012). Use of Biomass for Removal of Arsenic Compounds. *Latvian Journal of Chemistry,51*(4). doi:10.2478/v10161-012-0018-7

Banerji, A. (2018, July 04). India's 'worst water crisis in history' leaves millions thirsty. Retrieved April 7, 2019, from https://www.reuters.com/article/us-india-water-crisis/indias-worst-water-crisis-in-history-leaves-millions-thirsty-idUSKBN1JV01G

Bhanja, S. N., Mukherjee, A., Rodell, M., Wada, Y., Chattopadhyay, S., Velicogna, I., . . . Famiglietti, J. S. (2017). Groundwater rejuvenation in parts of India influenced by water-policy change implementation. *Scientific Reports,7*. doi:10.3897/bdj.4.e7720.figure2f

Biswas, A. K., & Hartley, K. (2017, July 22). From Evidence to Policy in India's Groundwater Crisis. Retrieved April 7, 2019, from https://thediplomat.com/2017/07/from-evidence-to-policy-in-indias-groundwater-crisis/

Biswas, S. (2017, November 15). Is India's middle class actually poor? Retrieved April 7, 2019, from https://www.bbc.com/news/world-asia-india-41264072

Cago, L. (2017, April 25). 10 Largest Rice Producing Countries. Retrieved April 7, 2019, from https://www.worldatlas.com/articles/the-countries-producing-the-most-rice-in-the-world.html

Cardoen, D., Joshi, P., Sarma, P. M., & Pant, D. (2015). Agricultural biomass in India: Part 1. Estimation and characterization. *Resources, Conservation and Recycling,*39-48. doi:https://doi.org/10.1016/j.resconrec.2015.06.003

Chatterji, R. (2019, March 04). Air Pollution From Crop Burning Costs India $30 Billion A Year, Says Study. Retrieved April 7, 2019, from https://www.huffingtonpost.in/entry/air-pollution-from-crop-burning-costs-india-30-billion-a-year-says-study_in_5c7ce815e4b0e1f77653b196

CATR. (2018, December 31). Blog Details. Retrieved April 7, 2019, from http://www.tpci.in/blogs/analytical-study-of-indias-agricultural-exports-policy-2018/

D'Cunha, S. D. (2018, May 07). Modi Announces '100% Village Electrification', But 31 Million Indian Homes Are Still In The Dark. Retrieved April 7, 2019, from https://www.forbes.com/sites/suparnadutt/2018/05/07/modi-announces-100-village-electrification-but-31-million-homes-are-still-in-the-dark/#209fb1f63bae

Delawala, D. (2017, August 25). Why Wastewater Treatment In India Is No Longer Optional. Retrieved April 7, 2019, from https://www.wateronline.com/doc/why-wastewater-treatment-in-india-is-no-longer-optional-0001

Dey, A. (2018, June 08). India has not published data on farmer suicides for the last two years. Retrieved April 7, 2019, from https://scroll.in/article/881265/india-has-not-published-data-on-farmer-suicides-for-the-last-two-years

Dhawan, V. (2017). Water and Agriculture in India. Retrieved April 7, 2019, from https://www.oav.de/fileadmin/user_upload/5_Publikationen/5_Studien/170118_Study_Water_Agriculture_India.pdf.

Dinesh, K., Kapoor, M., Kohli, K., Menon, M., & Venkatram, P. S. (2016). HOW EFFECTIVE ARE ENVIRONMENTAL REGULATIONS TO ADDRESS IMPACTS OF INDUSTRIAL AND INFRASTRUCTURE PROJECTS IN INDIA. Retrieved April 7, 2019, from https://in.boell.org/sites/default/files/how_effective_are_environmental_regulations_to_address_impacts_of_industrial_and_infrastructure_projects_in_india.pdf

EAI. (2017). Industrial Waste Generation and Management in India. Retrieved April 7, 2019, from http://www.eai.in/ref/ae/wte/typ/clas/india_industrial_wastes.html

Envisage International. (2019). Healthcare System in India. Retrieved April 7, 2019, from https://www.internationalstudentinsurance.com/india-student-insurance/healthcare-system-in-india.php

Esri. (2018, September 19). Average Household Size in India. Retrieved April 7, 2019, from https://www.arcgis.com/home/item.html?id=6cf22970ea8c4b338a196879397a76e4

Gautam, S., & Mishra, P. K. (2018, September 28). How Do We Address the Alarmingly High Malnutrition Rate in India? Retrieved April 7, 2019, from https://fit.thequint.com/health-news/malnutrition-in-india

Gisi, S. D., Lofrano, G., Grassi, M., & Notarnicola, M. (2016). Characteristics and adsorption capacities of low-cost sorbents for wastewater treatment: A review. *Sustainable Materials and Technologies,9*, 10-40. doi:https://doi.org/10.1016/j.susmat.2016.06.002

Gorgulho, H. D., Guilharduci, V. V., & Martelli, P. B. (2018). Sugarcane Bagasse as Potentially Low-Cost Biosorbent. *Sugarcane - Technology and Research*. doi:10.5772/intechopen.72153

Green Car Congress. (2019, March 04). Study: India's crop residue burning pollution causes US$30B economic losses, health risks. Retrieved April 7, 2019, from https://www.greencarcongress.com/2019/03/20190304-india.html

Gupta, R. (2016, November 12). Happy Seeder: A solution to agricultural fires in north India. Retrieved April 7, 2019, from https://www.ideasforindia.in/topics/environment/happy-seeder-a-solution-to-agricultural-fires-in-north-india.html

Hanson, B., & May, D. (2011, June). Drip Irrigation Salinity Management for Row Crops. Retrieved April 7, 2019, from https://anrcatalog.ucanr.edu/pdf/8447.pdf

India Brand Equity Foundation. (2017, July 17). Analysis About Indian Agriculture Industry, Market Size, Export & Investment Opportunity. Retrieved April 7, 2019, from https://www.ibef.org/industry/agriculture-india.aspx

India FoodBanking Network. (2019). Hunger in India. Retrieved April 7, 2019, from https://www.indiafoodbanking.org/hunger

Irfan, U. (2018, October 31). Why India's air pollution is so horrendous. Retrieved April 7, 2019, from https://www.vox.com/2018/5/8/17316978/india-pollution-levels-air-delhi-health

Jackson, M. B. (1983). Approaches to relieving aeration stress in waterlogged plants. *Pesticide Science,14*(1), 25-32. doi:10.1002/ps.2780140105

Jain, N. (2018, June 07). India's groundwater crisis, fueled by intense pumping, needs urgent management. Retrieved April 7, 2019, from https://india.mongabay.com/2018/06/indias-groundwater-crisis-fueled-by-intense-pumping-needs-urgent-management/

James, I. (2015, December 19). Groundwater depletion adding to global sea-level rise. Retrieved April 7, 2019, from https://www.desertsun.com/story/news/environment/2015/12/19/groundwater-depletion-global-sea-level-rise/77587028/

Khandanlou, R., Ahmad, M. B., Masoumi, H. R., Shameli, K., Basri, M., & Kalantari, K. (2015). Rapid Adsorption of Copper(II) and Lead(II) by Rice Straw/Fe3O4 Nanocomposite: Optimization, Equilibrium Isotherms, and Adsorption Kinetics Study. *PLoS One,10*(3). doi:10.1371/journal.pone.0120264

Makanaka. (2013, July 29). What rural India does and doesn't eat. Retrieved April 7, 2019, from https://makanaka.wordpress.com/2013/07/29/what-rural-india-does-and-doesnt-eat/

Mattyasovszky, M. (2015, May 11). The Largest Countries in the World. Retrieved April 7, 2019, from https://www.worldatlas.com/articles/the-largest-countries-in-the-world-the-biggest-nations-as-determined-by-total-land-area.html

Möller-Gulland, J., Ganter, J. C., & Pope, C. T. (2019, March 26). Toxic Water, Toxic Crops: India's Public Health Time Bomb. Retrieved from https://www.circleofblue.org/2018/india/toxic-water-toxic-crops-indias-public-health-time-bomb/

NASA. (2014). Groundwater Gains in India. Retrieved April 7, 2019, from https://earthobservatory.nasa.gov/images/91008/groundwater-gains-in-india

NASA. (2004, March 30). Gravity Anomaly Maps and The Geoid. Retrieved April 7, 2019, from https://earthobservatory.nasa.gov/features/GRACE/page3.php

Oddizzi. (2014). LIVING IN INDIA | HOMES. Retrieved April 7, 2019, from https://www.oddizzi.com/teachers/explore-the-world/country-close-up/case-study-india/living-in-india/homes-2/

Pariona, A. (2017, June 22). What Type Of Government Does India Have? Retrieved April 7, 2019, from https://www.worldatlas.com/articles/what-type-of-government-does-india-have.html

Rinkesh. (2019, January 26). Top 11 Most Polluted Rivers in the World in 2019. Retrieved April 7, 2019, from https://www.conserve-energy-future.com/most-polluted-rivers-world.php

Schneider, K. (2018, December 4). Groundwater Scarcity, Pollution Set India on Perilous Course. Retrieved from https://www.circleofblue.org/2018/world/groundwater-scarcity-pollution-set-india-on-perilous-course/

Sengupta, S. (2015, July 04). Land subsidence is serious. Retrieved April 7, 2019, from https://www.downtoearth.org.in/interviews/land-subsidence-is-serious-46662

Skymet Weather. (2017, March 27). Dependency of Indian Agriculture on Monsoon. Retrieved April 7, 2019, from https://www.skymetweather.com/content/agriculture-and-economy/dependency-of-indian-agriculture-on-monsoon/

Stratfor. (2012, July 16). Effects of Monsoon Season on India (Dispatch). Retrieved April 7, 2019, from https://worldview.stratfor.com/article/effects-monsoon-season-india-dispatch

Sudhir-Yadav, Balwinder-Singh, Humphreys, E., & Kukal, S. S. (2013). Chapter 6 - Effective Management of Scarce Water Resources in North-West India. *Agricultural Sustainability,*103-125. doi:https://doi.org/10.1016/B978-0-12-404560-6.00006-X

The Economic Times. (2018, July 19). Ahead of China, India to remain fastest growing economy in FY19 & FY20: ADB. Retrieved April 7, 2019, from https://economictimes.indiatimes.com/news/economy/finance/india-fastest-growing-economy-in-asia-on-track-to-meet-fy18-target-adb/articleshow/65049353.cms

The World Bank. (2015, September 18). Educating India's Children. Retrieved April 7, 2019, from http://www.worldbank.org/en/country/india/brief/educating-india-children

Trading Economics. (2015). India - Arable land (% of land area). Retrieved April 7, 2019, from https://tradingeconomics.com/india/arable-land-percent-of-land-area-wb-data.html

Turner, A. (2018, August 16). Royal Meteorological Society. Retrieved April 7, 2019, from https://www.rmets.org/resource/indian-monsoon-changing-climate

USAID. (2017, November 24). Partnership for Water Sanitation and Hygiene (WASH) | India. Retrieved April 7, 2019, from https://www.usaid.gov/india/water-and-sanitation

USGS. (2016, December 02). Irrigation techniques. Retrieved April 7, 2019, from https://water.usgs.gov/edu/irmethods.html

Wilkes, T., & Kalra, A. (2017, April 07). EXCLUSIVE - India's Ganges clean-up in a shambles, Modi intervenes. Retrieved April 7, 2019, from https://www.reuters.com/article/india-ganges/exclusive-indias-ganges-clean-up-in-a-shambles-modi-intervenes-idUSKBN1780ZC

Workman, D. (2019, April 05). India's Top 10 Exports. Retrieved April 7, 2019, from http://www.worldstopexports.com/indias-top-10-exports/

World Population Review. (2019). Total Population by Country 2019. Retrieved April 7, 2019, from http://worldpopulationreview.com/countries/

Yadvinder-Singh, Kukal, S. S., Jat, M. L., & Sidhu, H. S. (2014). Chapter Four - Improving Water Productivity of Wheat-Based Cropping Systems in South Asia for Sustained Productivity. *Advances in Agronomy,127*, 157-258. doi:https://doi.org/10.1016/B978-0-12-800131-8.00004-2

Young, C. A. (2009, March 24). Scientists solve puzzle of arsenic-poisoning crisis in Asia. Retrieved April 7, 2019, from https://news.stanford.edu/news/2009/april1/fendorf-arsenic-water-poison-asia-040109.html