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Bangladesh: Minimizing Environmental Degradation for Food and Environmental Sustainability

In the midst of the exponentially increasing demand for food, farm owners throughout the world struggle to produce a sufficient amount of food to sate the growing population, often harming the environment in the process. Deforestation, erosion, and pollution are the ramifications of rampant exploitation of the earth's resources – for the sake of maximizing food production. A desecrated environment yields polluted water, contaminated soil, and destruction of biodiversity. Furthermore, environmental deterioration contributes to the prevalence of water-borne and vector-borne diseases such as cholera and malaria (Lean), and has a strong correlation with climate change that fosters devastating natural disasters. The 2011 Human Development Report from the UN Development Program warns that "development progress could be halted or even reversed because of environmental degradation" (Schlein). In the wake of a global food crisis, innovations to minimize environmental degradation must be foremost in pursuit of universal food security.

One nation where the need for environmental control is extremely dire is Bangladesh. It is the most densely populated country in the world, supporting an immense population of 160 million people in its small area of 140,000 square kilometers ("Bangladesh"). The United Nations Human Development Index ranks Bangladesh 146th out of 182 countries, and 31.5% of the population live under the poverty line of living with $1 per day ("Bangladesh"). Its poverty is in part due to the nation's infancy and the corruption in the government. In 1972, Bangladesh gained independence from Pakistan under the Prime Minister Mujib. Yet, economic struggles followed, and much to the public's discontent, Mujib declared a state of emergency, resulting in his assassination ("Bangladesh"). In the midst of the turmoil, General Rahman declared martial law, establishing military control over the government. Such disorder inhibited the establishment of industry and infrastructure to bolster the economy, culminating in the nation's GDP per capita of $554, 194th highest in the world.

82% percent of Bangladesh's population live in rural areas, a majority of them subsistence farmers often suffering from poverty. A typical rural family – known as *paribar* – consists of the extended family, with several generations living under one household ("Bangladeh-Rural Society"). Many peasant Bangladeshis do not receive adequate education and their meager diet consists of rice, with the addition of vegetables and seldom fish, the main source of protein ("Food"). However, the lack of food causes chronic malnutrition and energy deficiency, which result in stunted growth of children and low birth weight of infants. According to a report from FAO, "9.5 million children, more than 54%, are stunted" suffering from deficiencies of vital nutrients such as Vitamin A. In addition, lack of awareness on nutrition condones poor food preparation; over 40% of thiamine and niacin are lost as rice is washed (Bhattacharjee). Access to health care is a major crisis in Bangladesh, as 60% or approximately 80 million do not receive modern health care.

In Bangladesh, 55% of the total land is arable, but the wealthiest landlords own 50% of the land available ("Bangladesh"). Most peasant farms have one hectare of land or less, on which they grow rice and jute (Heitzman and Worden). Since Bangladesh experiences a tropical climate, several crops can be harvested on the same land each year. Thus, three major types of rice are cultivated seasonally in Bangladesh: *aman* (sown June-Aug), *aus* (March-May), and *boro* (Nov-Feb) ("Food Security"). Aside from food crops, Bangladeshis also cultivate industrial fiber crops such as jute, which is grown on the same land as rice through crop rotation techniques. Nonetheless, families spend "nearly 90% on food," because the small harvest yields only enough for one-fifth of the family's diet needs and frequent flooding devastates the crops (Bhattacharjee).

It is tragic that a country like Bangladesh blessed with fertile lands and immense agricultural potential fails to produce enough food for the citizens. Contributing factors may be the current impoverished state of most of the small-scale growers as they are unable to afford expensive fertilizers, which in turn stagnates input-to-output ratio and profitability. However, deteriorating environmental conditions impact agricultural productivity much more severely. Soil fertility has degraded substantially due to deforestation with increasing demand for land, use of chemicals, and nutrient depletion from repeated cultivation cycles ("Food Security"). Also, environmental degradation from misuse of agricultural practices increases the prevalence of natural disasters in this extremely vulnerable country, where flash floods and cyclones wreak havoc on crops and infrastructure. Bangladesh has the human resources and agricultural potential to achieve food security, but first it must stymie further environmental degradation.

"You can't eat potential," were the famous words of the Nobel Laureate Dr. Borlaug. In the mid-20th century, it was becoming evident that the world would not be able to feed itself if population continued to escalate. For instance, in 1960s, India was importing 10 to 15 million tons of grain at its nadir, until Dr. Borlaug's innovations of high-yield, rust-resistant wheat and modern fertilizers. Upon their introduction, wheat that used to grow sparsely in India's fields increased to "densely packed 6,000 lbs per acre" (Miller). Similarly in neighboring Bangladesh, technologies and innovations from the Green Revolution to improve yield and efficiency were crucial in increasing food production, as Bangladesh has relatively little land to support its enormous population. In the 1970s, before the intervention of the Green Revolution, Bangladesh produced 10 million tons of rice per year, whereas in 2010, production rose to 32.3 million tons (Leishman); although insufficient to eradicate poverty, it is a tremendous feat. However, annual growth rates in harvest have been slowing in recent years (Hazell). Amidst the benefits it incurred, the Green Revolution introduced a notion of 'chemical agriculture' or 'conventional farming' in which production relies excessively on fertilizers and pesticides that deteriorate the water and the soil.

One of the prominent reasons that farms fail to produce sufficient food is that soil quality has degraded. Between 1970 and 1995, fertilizer use increased from 15.7 kg / ha to 135.5 kg / ha, nearly ten-fold (Hazell), because the popular high-yield-variety of rice necessitates a higher dose of fertilizer than the low yield ones (Aziz 10). . The heavy reliance on inorganic, artificial fertilizer may prove to improve production at first, but prolonged use results in reduced water retention in the soil and an imbalance of pH, which inhibits the absorption of nutrients in the soil, thereby hindering production. With the commercialization of the Haber-Bosch process, synthetic nitrogen has become easily accessible and widespread as a fertilizer, prompting soil acidification.

As the Green Revolution invested heavily in increasing rice yields in Bangladesh, monocropping – planting the same crop each year – became the standard agricultural practice. While yielding abundant harvests, monocropping is prone to depleting the soil of some nutrients specifically essential to the crop and destroy the diversity of the soil. This cycle of cultivation has several consequences: growing only one type of crop increases vulnerability to harmful pests, and necessitates more fertilizers to supplement nutrients. Adding chemicals can acidify the soil and deplete its organic matter, and increased concentrations of nutrients in the ground encourage the formation of lush canopies that provide an ideal environment for more pests (Hazell). Conventional farming has become standard in Bangladesh and the use of chemicals escalates each year.

In order to stop this negative feedback cycle, Bangladesh farmers must invest in crop-rotation to replenish the soil each year and reduce the use of pesticides. Although such practices reduce specialization and may be more expensive to support, crop rotation improves soil diversity and productivity, and decreases environmental impact by reducing the amount of inorganic chemicals used. Crop rotation would inhibit the propagation of pests by interrupting their cycle of growth with new crops, thereby reducing insect damage and need for pesticides. The Bangladeshi government could potentially add legumes such as soybeans, peanuts, or alfalfa to the standard farm crops, as they are able to create increase the nitrogen content in the soil through atmospheric fixation and alleviate the overuse of fertilizer. Such measures

would help relieve poverty by augmenting food production and sustaining the environment simultaneously, because farmers would not be as dependent on harmful and often expensive fertilizers.

The Bangladeshi must minimize another environmental malpractice: deforestation. Without the trees, the once-moist soil is desiccated from overexposure to unaccustomed sunlight and forests "quickly become barren deserts" ("Deforestation"). Wind and rain can easily erode away the thin layer of rich topsoil, leaving behind poor subsoil inept for proper agriculture. In an attempt to escape from poverty, landless peasants resort to forested areas for farming, often practicing 'slash and burn' agriculture. Although this practice provides nutrient-rich ash, a lack of proper knowledge and skill can destroy forest cover rapidly and lose so much topsoil that agriculture does not yield enough harvest (Cornell).

Flooding is another major consequence of deforestation. Bangladesh is situated on a delta strewn with three large river systems: the Ganges, Meghna, and Brahmaputra, in addition to 300 other rivers and channels. The annual monsoons and the snow-melt from the Tibetan Plateau directly increase the discharge of floods. However, deforestation has increased run-off, and the sedimentation from topsoil erosion raises the river bed, thus reducing the capacity of the channel, increasing the likelihood of flooding (Munna). These floods displace millions of people and destroy existing crops. For instance, recent floods in June and July of 2012 killed 131 people and displaced 250,000 from their homes (Ahmed, Anis); a major flood in 2007 incurred the equivalent of $84 million USD damage to agriculture and farms, losing an estimated production of 420,000 tons of rice ("Bangladesh Flood Damage"); the 1998 flood covered 2/3 of the entire country ("World: South Asia").

The present dire conditions are exacerbating rapidly. Environmental degradation to the soil and forests accelerate erosion, and the soil's inability to retain water adds increased seepage into the river systems. By 2050, at the present rate of environmental decline, up to 70 million people could be impacted each year from flooding alone ("Current Condition"). Like other disasters, the rural poor have the most difficulty recovering. They rely almost solely on subsistence farming for food and income, and flooding not only disrupts the actual agricultural production, but also inhibits market access as natural calamities destroy infrastructure.

Aside from mitigating soil depletion and flooding, Bangladesh must regulate the deteriorating water quality. Samuel Coleridge's lines, "Water, water everywhere, nor any drop to drink," accurately describes the aggravating environmental concern: in this water abundant nation, pollution is a growing concern with rising levels of industrial effluents and agrochemicals. Up to 70% of the chemicals applied to crops are either released as greenhouse gases into the atmosphere or lost to runoff, the latter of which pollutes surface water ("Conservation Buffers"). Fertilizers with their high content of nitrogen and phosphorous cause eutrophication in the ocean, rivers, and lakes, and induce algal blooms that deplete oxygen from the water, destroying biodiversity. Such environmental dilapidation hinders the Bangladeshis' access to adequate nutrients as it obstructs the fishing industry, which serves as the population's main source of protein and fatty acids. Furthermore, fertilizer and chemical plants dump industrial effluents into the river systems, not only polluting the waters, but also rendering them inadequate for drinking or agricultural purposes. Hence, groundwater has become the primary source of irrigation and potable water in Bangladesh.

Groundwater is being extracted at an unfathomable rate of 53 billion cubic meters annually through 8.6 active wells in Bangladesh ("Bangladesh: Invisible Hazard"). The rate of discharge being greater than that of recharge, the water table level is receding rapidly, aerating the aquifer. Consequently, salt water seeps into the groundwater and the soil, killing flora and hindering agricultural production for the coastal farmers. Nevertheless, from the overuse of groundwater arose a more dire consequence: arsenic contamination.

Despite conscious efforts to prevent well contamination, 1.4 million shallow tubewells, around 16%, are contaminated with arsenic ("Arsenic Mitigation"). Although debates exist as to how arsenic originated in the ground, the contamination of the once-pristine aquifer is indisputably a result of human impact. One hypothesis regarding the presence of arsenic is that minerals such as pyrite and arsenopyrite began to oxidize due to aeration underground as the water level declined, yielding water-soluble arsenic ("Arsenic Contamination"). On the contrary, judging from irregular concentrations of arsenic in the delta, the oxidation may have occurred with man-made herbicides and pesticides containing arsenic. Regardless, arsenic contamination of groundwater is a major crisis, as the Bangladeshis primary source of drinking water is no longer safe and many impoverished have no choice but to continue consuming arsenic tainted water. The World Health Organization deems 10 micrograms per liter the maximum permissible arsenic level, yet water from many tubewells reported more than 50 micrograms per liter ("Arsenic Mitigation"). Exposure to arsenic also occurs through rice consumption. As groundwater seeps into the farmed soil or is used for irrigation, rice accumulates arsenic in the grains at a strikingly high of 1.7 milligrams per kg ("Rice in Bangladesh"). The Bangladeshis must be especially wary of exposure, because arsenic enters the body through mere contact, let alone consumption, causing arsenicosis, a potentially fatal poisoning. It is difficult to diagnose, especially in a developing nation without proper health care, until symptoms of melanosis (darkening of skin) and keratosis (hardening of hands and feet) appear ("Arsenic Contamination"). Currently, 70% of the population at direct risk of consumption or exposure to arsenic toxicity, but the crisis may exacerbate quickly, if aquifer aeration continues at the present rate.

Arsenic contamination disadvantages women particularly. According to a survey by the Bangladesh Arsenic Control Society, women afflicted with arsenic poisoning are socially discriminated, with girls turned away from school and wives divorced (Rabbani). Also, culturally the Bangladeshis judge a woman's beauty by her white complexion, which is difficult or even impossible for afflicted women ("Arsenic Mitigation"). Thus, many cannot marry, and because people believe that arsenicosis is either contagious or a curse, affected women face additional difficulties as jobs become difficult to find ("Arsenic Mitigation"). In a male-dominated society, these discriminated women are ostracized and often unable to support themselves.

Despite the efforts by international organizations and the Bangladesh government to deter the worsening contamination, the clean-up process and improvements have been slow. Bangladesh is one of the poorest nations in the world; both the government and the people do not have the means to adequately confront the issue. The purification process for arsenic is especially difficult, as mechanisms by which arsenic seepage occurs are not yet fully understood, unlike those of contaminants such as fertilizers or pesticides (Mergel). Resolving this crisis would relieve, above all, the health concerns from contaminated food and water. Social discrimination toward women would be alleviated, and economic development and poverty reduction could become reality in Bangladesh.

Climate change is a global concern that affects and is affected by environmental degradation. The elevating temperatures throughout the globe entail severe ramifications: global warming melts the polar ice caps and causes changes in weather patterns. Bangladesh has an average land elevation of 1 meter; hence, rising sea levels increase the danger of salt water intrusion and estuarine floods near the coast. In the island of Kutubdia on the southeastern coast of Bangladesh, rising sea levels sunk most of the island, reducing its area from 250 square km to 37 square km; likewise, if sea level rises at the present rate, Bangladesh may lose up to 18% of its land area ("Climate Change"). Additionally, global warming causes extreme weather patterns throughout the globe: heat waves, unusual precipitation, and increasingly frequent natural disasters. According to the International Panel on Climate Change, intense rains have become more common in the recent decades, which endanger millions of families in areas such as Bangladesh with the risk of flooding. Higher marine temperatures also encourage the formation of destructive tropical cyclones, which require water temperatures of 80 degrees Fahrenheit to form. Carbon dioxide emissions that cause global warming are absorbed by the oceans, where it forms carbonic acid,

acidifying the ocean and destroying marine life ("Climate Change Impacts"). On the other hand, environmental degradation directly exacerbates global warming and climate change. Deforestation eliminates the very factors able to reduce greenhouse gases by converting to oxygen through photosynthesis. Fertilizer and chemical factories emit greenhouse gases, and soil management produces high levels of nitrogen oxide, a more potent greenhouse gas, capable of trapping 300 times as much heat as carbon dioxide. As nitrification and denitrication occur in the soil, nitrous oxide is emitted at low levels naturally; however, the application of synthetic fertilizer with high nitrogen content intensifies emissions in Bangladesh ("Nitrous Oxide").

Chemical agriculture in Bangladesh has incurred much damage to the environment; however, the problems are not without cure. Soil nutrient depletion and acidification, as well as water pollution can be resolved with donor-financed aid from NGOs and community efforts by the rural poor and farmers. First, Bangladesh must invest in reducing chemical impact. Currently, fertilizers are not produced to accommodate for specific crops, although Bangladesh primarily grows rice. Hence, more precise matching of nutrients with the specific plant needs would minimize excess nutrients increasing nitrous oxide emissions or polluting the water supply. Furthermore, research into site-specific nutrient management or 'precision farming' would enable determination of soil needs, and nutrients could be applied at optimal rates and times (Hazell). The International Fertilizer Development Center has developed a project called 'urea deep placement' (UDP), which involves slow-release, compressed urea pellets placed deep in the soil. Because these environmentally friendly pellets are buried in the ground unlike other fertilizers, there is minimal loss due to rain or winds, which decreases run-off pollution. Currently, UDP has not yet gained popularity and is only used in a few regions. If UDP is scaled up to nationwide levels and Bangladesh fully exploits this alternative method, farmers will also save money while maintaining yield increase, as urea pellets are low-cost and only need to be applied once a year as opposed to conventional fertilizers that must be applied up to three times (Saadi). Less nitrogen used for fertilizer directly translates to a decrease in run-off and pollution, and conventional agriculture will become more sustainable. Fertilizer will cost less to acquire, and with extra money, Bangladesh peasants will be able to better support their families and reduce poverty.

In addition, deforestation and forest degradation must be restricted in order to prevent loss of biomass and preserve the environment. Primarily motivated by the dearth of available land and poverty, many Bangladeshis encroach to forested areas to profit from illegal logging and find farmland, a testament to the ineffectiveness of the forest management. Many people consider the current forest laws obsolete, largely because the extant regulations are rudimentary and "the Forest Act of 1927…is still the basic law governing forests in Bangladesh" (Ahmed, A. I. 22). To impede such malpractices, the government must prioritize introducing more stringent laws and regulations to safeguard against future environmental harm. Furthermore, the forest department (FD) ought to scrutinize its officials for corruptions. Several cases have been reported that some FD officials are aloof to the ongoing deforestation and taking bribes from opportunistic sawmills or timber businesses (Ahmed, A. I. 43) If Bangladesh stymies further deforestation, it will preserve the forests' unique biodiversity, maintain soil quality, and minimize soil loss which prevents run-off pollution.

Counteracting chemical detriments and deforestation is not enough; strategies to prevent water contamination must be considered. Most of the water pollution in Bangladesh occurs as a result of run-off and pollutant seepage into surface and groundwater, thus conservation buffers are optimal means of mitigation. Conservation buffers are essentially 'living filters,' capable of deterring and intercepting 50-100% of the pollutants from run-off before they reach surface water (Al-Kaisi). Although there are various types of conservation buffers, many of them involve growth of vegetation as physical barriers. The vegetation's' roots grow deep, creating air sacs within the soil and encouraging infiltration, which can minimize damage from flooding as water is spread out in the ground ("Conservation Buffers"). It also prevents erosion, as the roots hold the soil together, allowing the ground to retain its organic matter.

Among the many types of buffers, the Bangladesh government ought to invest in contour buffer strips, where small strips of perennial vegetation separate wider strips of agriculture, or field borders, as opposed to riparian forests or filter strips on floodplains, because Bangladesh has a huge population density and land remains extremely valuable to support the growing population. Creating buffer strips among or around cultivated fields will disperse pollutants and trap them before they contaminate an open water source. Conservation buffers do not directly influence food production; however, it will help regulate soil and water quality that ultimately allows food production to become sustainable, maintaining consistent high yields and providing enough food to eliminate malnourishment and poverty in Bangladesh.

Minimizing arsenic contamination in Bangladesh will benefit the entire population immensely. Shallow tubewells, the primary cause of extreme levels of irrigation and arsenic seepage in groundwater, were preferred over deep tubewells for their low cost (Hossain 27). However, to provide the population with clean water, deep tubewells that reach into pristine, confined aquifers must be installed in Bangladesh, prioritizing the areas with the highest reported levels of arsenic. In 2005, a major outbreak of diarrhea occurred in Bangladesh, the source traced to shallow tubewells (Escamilla). A study was conducted comparing incidence rate between those who drank from the newly installed deep tubewell versus the preexisting wells, and discovered that households using the former had 46% lower risk of illness (Escamilla). Hence, the installations of more deep tubewells could control arsenic exposure among the population and reduce health concerns especially for the rural poor who do not have adequate health care.

In order to restore the biosphere, Bangladesh needs cooperation of local organizations, government, and NGOs. After limiting environmental damage, small-scale farmers will enjoy consistent, increased harvests that lead to food security. Local efforts are being made to attain Millennium Development Goals like environmental sustainability. In Dhaka, Bangladesh Poribesh Andolon (BAPA), an independent local volunteer organization, has worked to stop and reverse the environmental degradation and create a civic movement to increase awareness of the crisis. BAPA's success is largely due to structuring its programs under specialized committees focused on specific environmental issues. These groups then organize public campaigns and seminars to reach out to nearby districts and exhort for activism. Its prominent projects were persuading the government to enforce a ban on polythene bags and a "river saving movement in Dhaka" by urging policymakers to control agricultural pollution and building proximity to water ("Bangladesh Poribesh"). The latter could be scaled to a nationwide level, as many of Bangladesh's rivers remain polluted. If organizations such as BAPA could work with policymakers to actively clean rivers, farmers would not have to rely solely on groundwater, allowing aquifers to replenish themselves. Another local organization is the Noakhali Rural Development Society (NRDS) which fights poverty and marginalization by providing aid and sustainable practices for farmers as well as increasing market access. One of its projects is the "Livelihood Initiatives for Vulnerability Eradication (LIVE)" directed to promote environmentally sound integrated farming to deprived coastal population of Noakhali.

However, improvements in environmental protection remain slow Bangladesh for two main reasons: poverty and lack of education. As evidenced by the low GDP per capita, neither the government nor the majority of the people have substantial potential to generate dramatic change. Concomitantly, it becomes difficult for Bangladeshi famers to adopt alternative practices such as crop rotation and conservation buffers. Furthermore, both crop rotation and conservation buffers entail prior knowledge. While crop rotation will surely improve nutritional standards and promote food security, it can only be optimized through a land-specific cropping pattern, since factors such as irrigation, soil fertility, and fallow must be considered (Hoque). Likewise, farmers have to be aware of the pros and cons of using various types of vegetative species as well as the methods to counter run-off pollution. Yet, these barriers are not insuperable. NGOs such as the United Nations ought to aid Bangladesh with monetary support in its pursuit of food and environmental sustainability. For instance, by investing into increasing market access for the rural population, farmers would gain a greater profit margin, which in turn could allow them to implement environmentally friendly practices. Fortunately, there are ongoing relief programs available

through which Bangladesh can restore the environment. The World Bank is currently investing $70 million for a project to increase safe water provision and expedite emergency responses to natural disasters in 125 locales ("Bangladesh Rural Water"), and UNICEF has sponsored the screening of 4 million tubewells for arsenic contamination ("Arsenic Mitigation").

Granted, monetary aid from NGOs is vital in supporting a developing nation like Bangladesh, but additional measures must be taken to empower and educate the Bangladeshis in order to perpetuate restoration. As population is expected to reach 250 million mid-century, without emphasizing sustainability of relief programs, future restoration will not only be extremely costly but also problematic. Therefore, in implementing solutions for environmental degradation, NGOs must consider providing education to natives. According to a study by the World Bank, 92% of the farmers do not take any protective measures when using agrochemicals, because most do not fully understand the health risks of chemical exposure, resulting in nearly 20,000 deaths each year ("Overusing Pesticides"). NGOs ought to sponsor programs to educate natives about environmental degradation who would in turn spread awareness to the villagers, creating lasting impact and minimizing ignorant malpractices. Such program is crucial for the perpetuity of Bangladesh's environmental repair, as it transforms individuals into knowledgeable leaders amidst the ongoing crisis.

Minimizing environmental degradation will contribute immensely to ensuring productivity and relieving hunger. With the Green Revolution came rapid modernization of agriculture and the introduction of "chemical" farming which improved crop yield dramatically, but damaged soil and water quality to the point of jeopardizing human lives. Profligate deforestation only contributed to erosion and exacerbated flooding, while excessive groundwater usage caused the water table to recede and introduced arsenic into the water. Thus, reduction in agrochemical usage, conservation of forests and water, and prevention of pollution will help heal the environment which then will alleviate the impoverished farmers from poor harvests and empower them to produce enough food to support themselves and even perhaps profit through commercialization. Nonetheless, Bangladesh's maturation into a secure, developed nation is still obstructed by several unresolved issues. Aside from environmental repair, Bangladesh must seek solutions in improving infrastructure and compromising socioeconomic differences among its population. First, enhanced infrastructure with more feeder roads would provide the rural poor with access to proper markets and an opportunity to commercialize. Additionally, those suffering from poverty ought to make use of micro-loans from Grameen Bank. Founded by Dr. Yunan, Grameen Bank conducts 'microfinances,' which consist of small loans given without collateral. It loans to 8.29 million penurious people and effectively fights poverty. Given the implementation of preventive measures and innovations to mitigate damage, Bangladesh can fully employ its potential to achieve environmental sustainability, food security, and the capacity to feed the world.

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