Edmund Sumpena
Westview High School
San Diego, CA,
U.S.A. Indonesia,
Flooding

Land Subsidence and Sea Level Rising in Indonesia

Introduction Flooding has become a major concern for island countries and coastal regions due to the rising sea level and progressing land subsidence. In Indonesia, unregulated drilling of industrial-scale wells used to obtain clean water from underground aquifers has accelerated the sinking of land. Groundwater under Indonesia is drying up. Jakarta, the capital city, is one of the "fastest sinking cities in the world", and the land is expected to dip below sea level by 2050 (*BBC News*). Rising sea levels, monsoons with more torrential rains, and little long-term government regulations exacerbate this problem. The devastating results of flooding are inundating people's homes with water and causing the agricultural sector to lose fertile land.

Background Indonesia is an archipelago with the total number of 13,466 islands, of which "922 are permanently inhabited" (*The World Factbook*). It is the world's largest islandic country, composed solely of small and large land masses sprawled along the equator from the Indian Ocean to the Pacific Ocean (*The World Factbook*). Indonesia is the world's fourth most populous nation with an estimated population of 270 million; 58% inhabit the island of Java (*World Population Review*). The government is a presidential and constitutional republic with Jakarta as its capital located on the northern coast of Java. There are three branches of government with the president as the head of the executive branch, the People's Consultative Assembly as the legislative branch, and the Supreme Court of Indonesia as the Judicial branch.

Indonesia has a GDP of $1.042 trillion (*The World Bank*), and 12.81% of the GDP is from agriculture, which occupies about 30% of its land ("Indonesia: Share of Economic Sectors in the Gross Domestic Product (GDP) from 2008 to 2018"). Located in the tropical region with an average annual rainfall of 320 cm to 610 cm (*Nations Encyclopedia*), the country's abundant rain, sunshine, and fertile soil enables agricultural success. As one of the world's major agricultural nations, Indonesia produces a wide diversity of tropical products and important agricultural commodities, including palm oil, natural rubber, cocoa, coffee, tea, cassava, rice, and tropical spices. Rice is a staple food in the Indonesian diet; however, because of Indonesia's large population, the rice produced is consumed internally (*Indonesia Investments*).

Geographically, Indonesia is one of the countries located on the Ring of Fire, an active series of

volcanoes along the Pacific Ocean, and "contains the most volcanoes of any country in the world" (*The World Factbook*). Subsequently, farming in the mountainous terrain is challenging, forcing many farmers to plant at lower elevations in coastal areas. The country also has a booming aquaculture industry due to its extensive coastline over 54,716 km long (*The World Factbook*), which enables farmers to set up over half a million hectares of aquaculture ponds. The industry is vital in maintaining the nation's supply of fish and shrimp, as well as a variety of other marine animals. Currently, aquaculture accounts for "21 percent of Indonesia's agricultural economy" and makes up "3% of national GDP" (*Food and Agriculture Organization of the United Nations*). The top aquaculture products exported include shrimp, fish and seaweed, and the total aquaculture production in Indonesia has been increasing at the rate of 21.47% since 2005. It produced more than 6 million tons of fish and shrimp in 2019 (*Food and Agriculture Organization of the United Nations*).

On average, the Indonesian family size is 4 per household with an average household income of $183/month. 45% of the labor force works in the agricultural and construction sector ("Indonesia Monthly

Earnings") and 10% of Indonesian residents are still living below the poverty line (*PRB*). Typically, Indonesian meals consist of richly flavored side dishes, meat/poultry, vegetables, soup, and steamed rice. The dishes are often supplemented by coconut milk, peanut sauce, and a variety of spices. To cook the food, traditional Indonesian kitchens employ a firewood-fueled kitchen stove, while modern Indonesian kitchens use a liquefied petroleum gas-fueled stove or an electric stove. However, low-income families typically lack access to nutritious food or modern cooking equipment. In rural areas, most dwellings are made of pounded earth, concrete, or raised wood, with bamboo-woven walls supported by wooden frames. In the city, floors are composed of cement or tile. Walls made of brick and plaster are supported by teak or meranti wood frames. Regardless of dwelling location, housing conditions are unsatisfactory and lack dependable potable water.

Challenges and Government Measures Many water sources in Indonesia are contaminated during floods, raw sewage and garbage clog the canal systems. Access to clean water is challenging and leaves local populations with no alternative other than to drill wells. With lack of regulations in groundwater extraction, underground aquifers are gradually depleted. The land then loses structural support and results in land subsidence or sinking land. With sea levels on the rise, Indonesian islands become subject to regular floods, which is worsened by torrential rain during the monsoon season.

Coastal city Jakarta, with a population of over 10 million people, sits on the naturally swampy ground. Depleted aquifers exacerbate land subsidence, causing the city to sink at an "average rate of 1 - 15 cm per year" ("Deep Dive: Rising Sea Levels Force Relocation of Indonesian Capital"). As of now, the city has sunk by four meters in the last 30 years and 40 percent of the land area is already below the sea level (*Harvard Political Review*). At the current rate of rising sea level and sinking foundations, areas of Jakarta will be "entirely submerged" within the next 30 years (*BBC News*). Disturbingly, Jakarta is not

the only place that will be submerged. Two small islands in South Sumatra have disappeared as a result of rising sea levels and four more islands are on the verge of vanishing (*The Jakarta Post*).

Consequently, low-income Indonesians, who struggle in poor living conditions, further suffer from the destructive effects of flooding. For example, monsoon flooding in March 2020 inflicted damage to over 11,000 hectares of agricultural land along the coast of Java by destroying crops, altering soil salinity, and polluting hundreds of aquaculture ponds. Java, with a population of over 100 million and the majority of inhabitants living in the northern coastal areas, is increasingly submerged due to rising sea levels (*Earth Journalism Network*). Coastal flooding is common, resulting in elevated soil salinity and ultimately devastating rice farms or other agriculture. The flooding destroys aquaculture ponds, carries diseases to marine animals including fish and shrimp, and negatively affects the food supply chain.

To combat land-subsidence and sea level rising, the Indonesian government has implemented an infrastructure project to build inner sea walls along the coast to control tidal movements (*BBC News*). However, these seawalls are largely ineffective at shielding the city from large ocean surges that typically arise during monsoon seasons or high tides as frequent flooding still persists. To overcome this challenge, Indonesia's government plans to build a massive 25 miles long and 80 feet high outer seawall or dike with 17 artificial islands off the coast of Java sea to help slow down Jakarta from sinking further. However, experts doubt whether the seawall and artificial islands can solve Jakarta's subsidence problem as "they will only buy Jakarta an extra 20-30 years to stop the long-term subsidence" (*BBC News*). The Indonesian government does not intend to wait for the eventuality, and is preparing to move its capital to Borneo where construction will start in 2021.

The government has also mandated farmers to actively participate in conducting a large scale of mangrove reforestation, and encourages coastal communities to aid the program. These resilient trees are good natural barriers against coastal flooding, and replenishing coastal mangrove forests will help

reinforce the coastlines (*Reforest Action*). However, since the coastline is already occupied by aquaculture ponds, there is not enough space for mangrove reforestation ("Mangrove Threats and Solutions").

Proposed Solutions So far, the measures taken by the Indonesian government to address flooding are not effective in the long run. Modern technology and alternate solutions are necessary to shield the effects of land subsidence and rising sea level.

A new technology, mobile barrier, is one of the solutions proven to effectively mitigate the effects of flooding. In particular, MOSE ("MOdulo Sperimentale Elettromeccanico" or *Experimental Electromechanical Module*) mobile barrier technology has shown to be effective in combating similar issues of sinking lands and rising sea levels which cause seasonal flooding in Venice, Italy. Similar to Venice's geographical landscape, Indonesia has swampy terrains which are appropriate and well-suitable

for the implementation of this technology. MOSE is a series of floodgates usually located at the entrance of a lagoon, which is filled with sea water to remain submerged during normal tide. This submergence allows invisibility from the surface of the water and prevents hazards to shipping lanes. Each floodgate resembles a metal box structure which is bound to its housing by hinges (*MOSE*). In the event of a high tide which can cause flooding, compressed air from the housing compartment is pushed inside the floodgate to empty the water. The floodgates will then rotate around the axis of the hinges, rise up to emerge from the surface, and block the flow of incoming tide into the lagoon. When the tide falls, the lagoon and the sea will have the same water level, allowing the floodgates to fill with water again to return to the original submerged position. Caissons, the housing compartments, are connected by underwater tunnels, allowing for convenient technical inspections and maintenance (*MOSE*). Caissons contain all the systems and buildings necessary for the operation of the floodgates. Their placement at the bottom of the lagoon are guided precisely by GPS, advanced topography, and computer algorithms. These mobile barriers are designed to provide protection from tides up to 3 meters high (*MOSE Venezia)*. This technology is environmentally friendly as it allows constant flow of sea water in and out of the lagoon during normal tides, minimizing ecological damage by preventing stagnant water.

MOSE is a multinational project; three Italian companies teamed up Enerpac (USA) and Strukton Immersion Project (Netherland). Foreign companies specialized in certain technologies and top international engineers were vital to the success of this project. Indonesia water authorities can adopt a technology similar to MOSE by building mobile barriers at the entrance of shipping channels to the Jakarta harbor. Jakarta port authority can add levies to the ships entering Jakarta harbor or port to help finance this expensive infrastructure project which costs US $6.5 billion (*CBS News*). With an annual revenue of US $750 million (*Indonesia Shipping Gazette*) and cargo volume of 7.64 million TEU (Twenty-foot Equivalent Unit - a unit for cargo capacity), Jakarta port authorities can acquire additional funding for the project by increasing the tax per cargo shipment (*World Shipping Council*). This project, similar to MOSE, will require Indonesia to collaborate with several nations. Major trade partners, such as Japan, China, Holland and the United States, can provide the necessary technology, expertise, and materials. With 140,169 annual engineering graduates in Indonesia, the 6th highest in the world, this massive project will create the much-needed high-income and sustainable construction jobs, as well as improve the economy (*Forbes*). This is an opportunity to train and expose Indonesian engineers to new modern technology - a novel skill that can benefit many future technologically-advancing projects. Though the initial investment for this project is large, the country will reap its benefits in the long run. In 2007, a storm surge inflicted “$500 million in damage” and left “half a million homeless” (*Harvard Political Review*). If this new technology were implemented, the Indonesian government would save an accumulation of billions of dollars on the next potential storms. With the flood-preventing innovation, coastal agricultural and aquacultural facilities will be able to thrive, increasing production yields, revenues, and hence, local people’s quality of life. Subsequently, Indonesia will become more self-sufficient and be able to effectively provide its population with adequate nourishment, which ultimately

ensures food security. These long-term benefits will far outweigh the cost of construction, once

the project is completed.

Another solution is to regulate the extraction of groundwater by balancing the level of pumping and recharging of aquifers. By enforcing this regulation, Indonesia can reduce over-extracting its groundwater and alleviate land subsidence. California's Sustainable Groundwater Management Act (SGMA) is an example of regulation that Indonesia can consider. San Joaquin Valley, CA has been facing similar challenges as Indonesia. As one of the most productive agricultural regions in the US, farmers have been over pumping groundwater since 1920 which resulted in land subsidence (*USGS*). To comply with SGMA, California uses its massive levee and dike networks to strategically divert water to designated agricultural lands or recharge basins to let water percolate and replenish the underground aquifers (*Water Education Foundation*).

To encourage adaptation and implementation of policy similar to California's SGMA, Non-Governmental Organizations (NGOs) such as Transnational Institute (TNI) and Wetlands International can collaborate with the Indonesian Ministry of Maritime Affairs. Through this regulation, Indonesia will be able to effectively manage and recharge drying groundwater in Jakarta and the northern coast of Java to alleviate its sinking land. During monsoon torrential rains, Indonesian Water Authority can realign the irrigation systems to strategically flood designated lands as recharge basins. This method will allow floodwater to infiltrate through the ground and into aquifers which will gradually slow land subsidence and reduce the destructive effects of floods. Meanwhile, agriculture and aquaculture can continue to operate along the coast with less risk of destructive flooding, which ultimately leads to better yield and profit. By adopting this program, the Indonesian government can collect more tax revenue from the increased profit of agriculture and aquaculture industries. The revenue can then be used to finance this flood management program. This serves as a great long-term solution, since groundwater replenishment can reduce flood risk and alleviate land subsidence.

The implementation of floating farms currently used in Bangladesh is also a solution to be considered by the Indonesian government. Although not an island, Bangladesh, which naturally has low elevation, faces similar flooding problems like Indonesia. Summer monsoons cause rivers to swell, devastating major agricultural fields and threatening food security of the nation of 156 million people. Floating farms, small-scale properties that float atop bodies of water, allow crops to "flourish in flood conditions" ("The Floating Gardens of Bangladesh"). In the case of floods, these unusual farms will simply float to the surface of the water, preventing a season's worth of crops from being destroyed. Typically, farms are made of a "8 meter long and 2 meter wide" floating raft base composed of "bamboo and water hyacinth", as well as a layer of soil, compost, and cow dung ("Floating Gardens in Bangladesh"). Rafts do not last indefinitely and often decay at the end of each growing season; therefore, new rafts are often constructed annually. To protect crops from ducks, rats, or other wild animals, fencing can be set up around rafts. Aside from growing crops, these floating farms also support animal farming, including duck and fish.

There are many advantages to this solution: the raw materials are cost-effective, construction time is short (2-3 weeks), effects on the surrounding ecosystem are minimal, and the solution is sustainable. For an average of $260 to build a "56 feet long and 16 feet wide" structure ("The Floating Gardens of

Bangladesh"), many farmers around the country can protect their crops from the negative effects of flooding. Farmers can form cooperatives to distribute the cost of construction. NGO relief organizations can also provide farmers with the initial capital. USAID, an agency that has dedicated $2 million in Indonesia to aid agricultural workers (*National Cooperative Business Association Clusa International*), can help train farmers to construct the farms. Another organization, IFAD, hands out funding in the form of microloans, or low value loans, allowing farmers to jumpstart their floating farms (*International Fund for Agricultural Development*). Ultimately the prospect of these flood-resistant farms makes the investment worthwhile. Most importantly, floating farms will remain an effective solution, as long as rafts

are replaced annually. No additional infrastructure is needed to accommodate floating farms. Over time, materials can be altered, additional features can be added, and designs can be upgraded to improve the robustness of floating farms. In summary, the solution addresses the problem of flooding on farms with great efficacy, due to low cost, low execution time, and high sustainability.

Conclusion The destructive nature of coastal flooding in Indonesia cannot be ignored. While not all risks can be prevented, alternative measures are necessary to better prepare coastal communities for floods, adjust to new conditions, and quickly rebound from disasters when they occur. Through the adaptation of modern technology and new regulations, the Indonesian government can mitigate land subsidence and sea level rising effects on agriculture and aquaculture. By exploring solutions in other nations and embracing change, Indonesia will be able to effectively preserve food security for all citizens.

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