Environmental Issues in East Asia

EA30e Spring 2021

May 15, 2021

Contents

Preface

Guiding Principles

Environmental issues in East Asia are not unique or particularly more prevasive than other parts of the world. However, the issues are borne from particular histories that may contrast with other parts of the world and other parts of the world may be able to learn from.

In this project, the students in EA030e (Spring 2021) have written a textbook that highlights examples of environmental processes. Each student contributed to one theme, composed of two examples that highlight environmental issues of East Asia.

Context and Positionality

As students in a college course located in Southern California, we approach the project with...

Our goal is not to call out environmental issues in East Asia, but to point to linkages of how a range of globalized economy contribute to these environmental problems.

In the end, it would be useful for us to acknowledge we have some capacity to address these how these global linkages could be modified to reduce these environmental issues.

We are not experts, but learning... if there are errors please let us know... We recommend that suggestions be submitted via a github pull request.

Goals

Processes across horizontal boundaries define many environmental patterns that frame human interactions with the environment. How do humans impact processes that cross these boundaries and how do humans influence these ecosystem interface?

Rationale

We hope to learn more about the how environmental issues are expressed in different parts of the world and to what extent can we learn from this work.

Activity

Each group will be composed of two students, that will become experts and teach their classmates on the topic.

East Asia and the World

Acknowledgments

Everyone in the world!

Permission for Continued Collaborations

Congratulations, you have done a steller job describing environmental issues in East Asia and create a valuable resources for others.

As a goal of the course, the content can continue to evolve and even improve with new research and contributions. Thus, the text you have written could be revised in the future, should you give permission. For example, I'd like to add a glossary and an index of topics – more than we had time to do. I should also fix citation issues at some point.

I have purposely given you the option after grades were submitted to ensure that how you proceed will have no bearing on the your course outcome.

However, you may appreciate others going over and possibly improving your text with time and adding their names as contributors or co-authors iftheWhether or not you decide to give permission has no bearing on your grade.

Form

I, ______________________________, give permission for other collaborators to edit my text to improve the clarity and add new information. Contributions should be explicitly documented in the chapter contributions section. Should the edits be substantial, additional co-authors may be added to the chapter as appropriate.

☐ I give permission for others to edit my chapter without contacting me.

☐ I give permission for others to edit my chapter after contacting me.

☐ I prefer to collaborate with others in the editing of the chapter.

Sign: ______________________________

Print Name: ______________________________

Chapter 1

The Political Ecology and Economy of Rice in Myanmar

Lucas Florsheim

1.1 Introduction

As climate change becomes an increasingly concerning threat to agriculture many countries throughout Southeast Asia are rushing to adopt new agricultural practices that subvert issues like flooding and rising temperatures. According to the IPCC, Southeast Asian food production could fall by up to 30% By 2050 If certain agricultural adaptations are not implemented (Wassmann et al., 2004).Although specific agricultural adaptations and solutions differ depending on climate and region, many scientists have outlined the general changes that will need to be implemented to sustain food production in the face of the climate crisis. «««< HEAD

======= »»»> 126dbbbd5b991bcc977adb9b87ef5faf2d9f4cb6

Adaptive options for confronting issues related to increasing temperatures and hydrological disruption include incorporating crops that are heat-resistant and less vulnerable to salinity stress, improving water management, and altering crop management practices. Other potential options are implementing resource-conserving technologies (RCTs), diversifying crops, improving pest management, and creating better weather forecasts. (Wassman et al., 2009). While evidence shows that these methods will indeed work to sustain agricultural production in countries throughout Southeast Asia, many of these adaptations may not be feasible implementations for developing countries with complex political structure and history.

«««< HEAD Myanmar certainly fits the bill of having a convoluted government and political history. Since its independence from Great Britain in 1948, the country has fallen victim to several coups and has been ruled by its military for most of the last 70 years. Leading up to the Green Revolution in the 1960s, Myanmar was one of the top rice exporters in the world (Naing et al., 2008) (Naing et. al, 2008). The deltaic regions of Myanmar had an advantage over other rice producing areas as lucrative deep-water or floating rice systems were routinely utilized. Following the Green Revolution, the countryâĂŹs military government was not initially invested in implementing new agricultural methods and thus fell behind other leading rice exporters. Just as lack of infrastructure and varying priorities caused Myanmar to lose its spot as the top rice exporter in the latter half of the 20th century, these factors now actively inhibit the country from performing the necessary implementations in response to the agricultural issues posed by the climate crisis.

Myanmar has made tremendous progress towards democracy in the last 20 years. This progress culminated in a democratically elected parliament being sworn in 2016, with the elections of 2015 being the first openly contested elections since 1990. A democratically elected government is necessary to execute the sweeping agricultural adaptions and to introduce the infrastructure needed to combat the effects of climate change. Military goverments prioritize controlling the economy, which often means maintaining the status quo, even in the face of climate change. Earlier this year the military of Myanmar, led by General Min Aung Hlaing declared a national emergency and seized control of the country in the form of a coup de'etat. The military is now in sole control of the county's operations and infrastructure and has spent the last several months attempting to qual both peaceful protests and armed civilian resistance (Goldman, 2021). The overwhelming majority of Burmese people are in opposition to military governance, resulting in daily protests since the coup took place. Since the military seized power on February 1st, over 600 civilians have died at the hands of the government, and thousands more have been injured and arrested (Goldman, 2021).

Combatting the effects of climate change and ensuring food security in Myanmar through sustainable rice production is only possible if the country is politically stable. A history of political unrest and conflict inhibiting proper infrastructure and development indicates that Myanmar will struggle to adopt the agricultural adaptations that experts recommend to mitigate the environmental problems of the coming century.

In this chapter we will examine the political economy and ecology of rice in Myanmar throughout history as well as the potential climate related threats to rice production. It is through this analysis that we will attempt to understand the implications of the history of rice production in Myanmar, as well as examine the current state of MyanmarâĂŹs government as it relates to the future of the country's rice production in the era of climate change.

======= Adaptive options for confronting issues related to increasing temperatures and hydrological disruption include incorporating crops that are heat-resistant and less vulnerable to salinity stress, improving water management, and altering crop management practices. Other potential options are implementing resource-conserving technologies (RCTs), diversifying crops, improving pest management, and creating better weather forecasts. (Wassman et al., 2009). While evidence shows that these methods will indeed work to sustain agricultural production in countries throughout Southeast Asia, many of these adaptations may not be feasible implementations for developing countries with complex political structure and history.

Myanmar certainly fits the bill of having a convoluted government and political history. Since its independence from Great Britain in 1948, the country has fallen victim to several coups and has been ruled by its military for most of the last 70 years. Leading up to the Green Revolution in the 1960s, Myanmar was one of the top rice exporters in the world (Naing et al., 2008) (Naing et. al, 2008). The deltaic regions of Myanmar had an advantage over other rice producing areas as lucrative deep-water or floating rice systems were routinely utilized. Following the Green Revolution, the countryâĂŹs military government was not initially invested in implementing new agricultural methods and thus fell behind other leading rice exporters. Just as lack of infrastructure and varying priorities caused Myanmar to lose its spot as the top rice exporter in the latter half of the 20th century, these factors now actively inhibit the country from performing the necessary implementations in response to the agricultural issues posed by the climate crisis.

Myanmar has made tremendous progress towards democracy in the last 20 years. This progress culminated in a democratically elected parliament being sworn in 2016, with the elections of 2015 being the first openly contested elections since 1990. A democratically elected government is necessary to execute the sweeping agricultural adaptions and to introduce the infrastructure needed to combat the effects of climate change. Military goverments prioritize controlling the economy, which

often means maintaining the status quo, even in the face of climate change. Earlier this year the military of Myanmar, led by General Min Aung Hlaing declared a national emergency and seized control of the country in the form of a coup de'etat. The military is now in sole control of the county's operations and infrastructure and has spent the last several months attempting to qual both peaceful protests and armed civilian resistance (Goldman, 2021). The overwhelming majority of Burmese people are in opposition to military governance, resulting in daily protests since the coup took place. Since the military seized power on February 1st, over 600 civilians have died at the hands of the government, and thousands more have been injured and arrested (Goldman, 2021).

Combatting the effects of climate change and ensuring food security in Myanmar through sustainable rice production is only possible if the country is politically stable. A history of political unrest and conflict inhibiting proper infrastructure and development indicates that Myanmar will struggle to adopt the agricultural adaptations that experts recommend to mitigate the environmental problems of the coming century.

In this chapter we will examine the political economy and ecology of rice in Myanmar throughout history as well as the potential climate related threats to rice production. It is through this analysis that we will attempt to understand the implications of the history of rice production in Myanmar, as well as examine the current state of MyanmarâĂŹs government as it relates to the future of the country's rice production in the era of climate change.

»»»> 126dbbbd5b991bcc977adb9b87ef5faf2d9f4cb6

1.2 Climate and Rice Production

Being one of the largest countries in Southeast Asia, Myanmar experiences several different climates, varying greatly based upon region. The most northern parts of the country feature a humid subtropical climate with hot and humid summers and mild winters. The Northeastern part of the country experiences a temperate oceanic climate meaning warm summers without significant seasonal differences in precipitation. The rain-fed rice producing regions in the south of the country are in either Tropical Savanna or Monsoon climate zones. Tropical Savannah climate classifications are defined by having distinct and differing wet and dry seasons. Monsoon climates are very similar to Tropical Savanna climates, but experience significantly heavier rainfall. Precipitation and minimum and maximum temperatures not only show substantial variation across the country but are also greatly impacted by monsoons.

Temperatures are generally lower in the mountainous regions to the North, whereas the southern portion of the country is much warmer and wetter and therefore more suitable for rice production (Naing et. al, 2008). Ayeyarwady, Yangon, and Bago are the three major rice growing divisions in Myanmar, all of which are in the Southern part of the country.

The Irrawaddy delta is responsible for 68% of Myanmar's rice production (Brackenridge et al., 2016). River basins and deltas are the most ideal for rice agriculture, as fertile sediment deposited by water, known as alluvial soil, is naturally provided, and monsoon rainfal is prevalent in these floodplains. (Naing et. al, 2008). Rice cultivation in Myanmar relies heavily on deep-water rice production, the flooding of paddy fields that results in increased growth and higher yields.

1.3 Agricultural Production and Food Insecurity

Jobs in food production make up over 80% of the workforce in Myanmar, 70% of these jobs are in rice production. Despite relying on an agricultural economy, Myanmar has historically struggled to feed its population. In 2019, the Myanmar Ministry of Health and Sports conducted a random

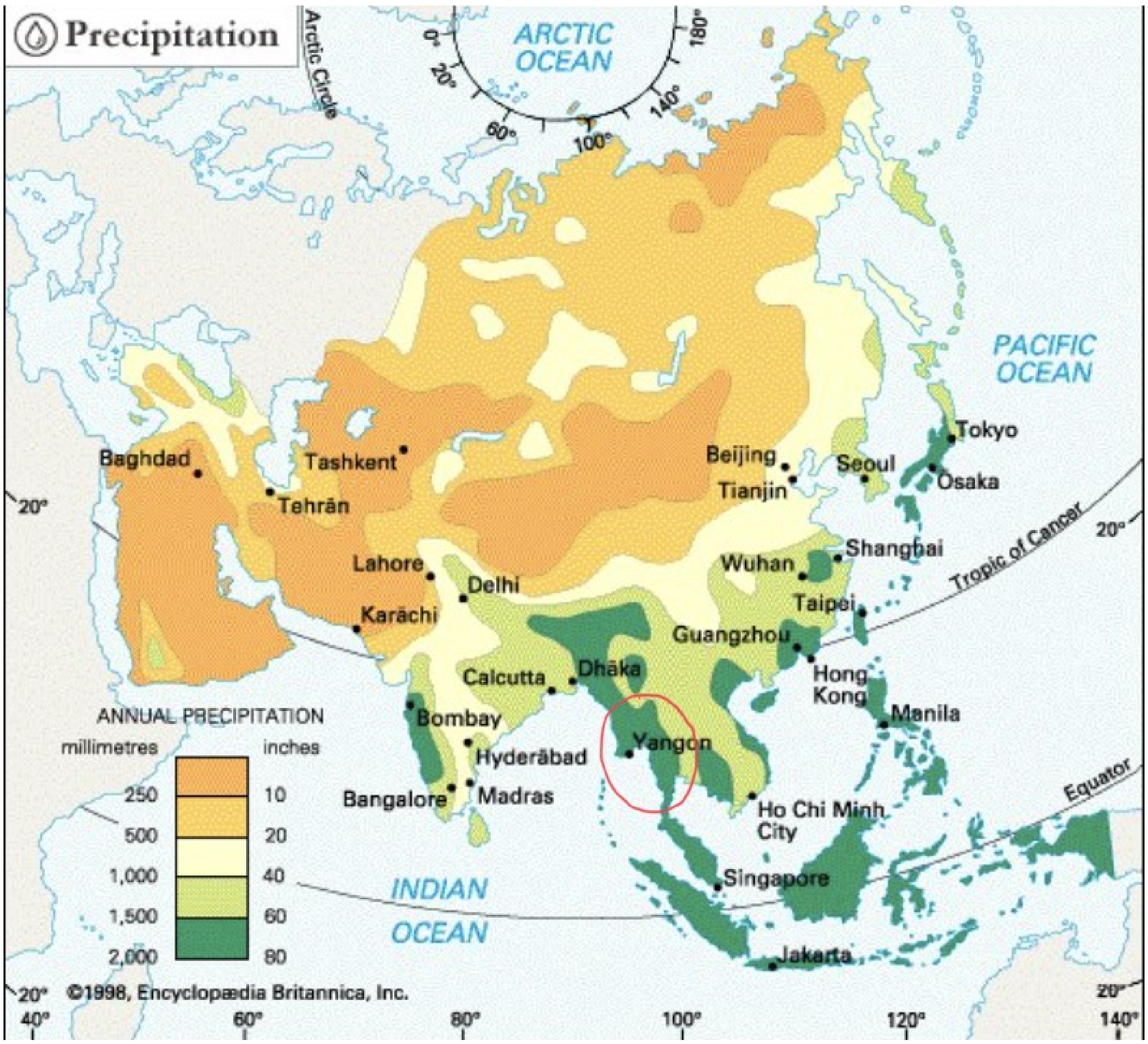


Figure 1.1: Average annual precipitation in Asia, the rainfed rice-producing region of Myanmar is circled in red.

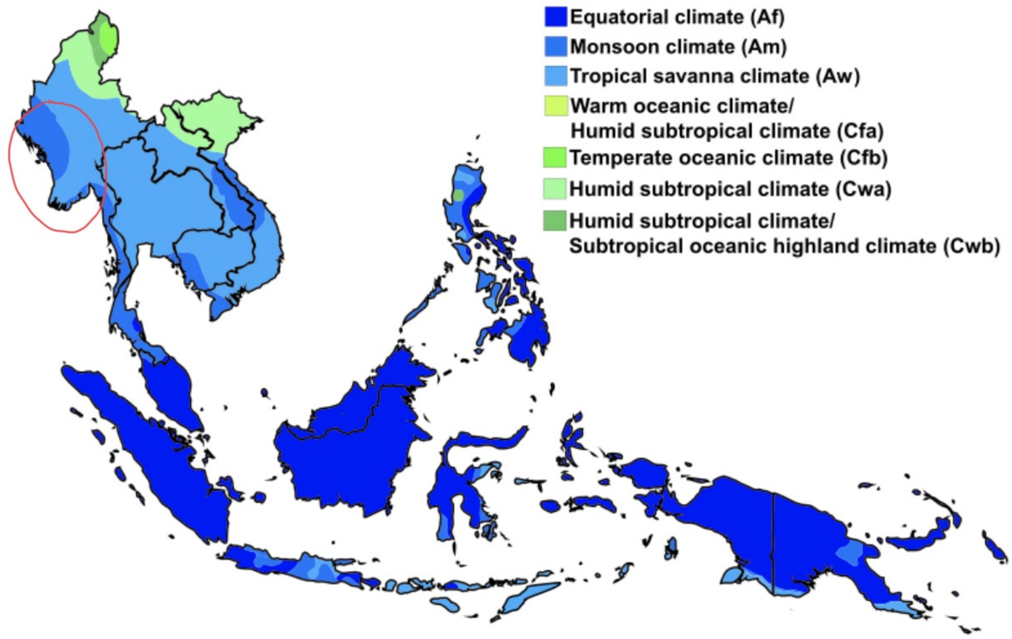


Figure 1.2: Climate Classifications of Southeast Asia, with the rice-producing region circled in red.

sampling survey that revealed that 1 in every 3 families in Myanmar is food insecure and is facing problems related to undernutrition (Hlaing et al., 2019). Because the majority of Burmese people work in agriculture, understanding the source of economic and food insecurties of these individuals is critical. In a survey that involved 22 NGOs in Myanmar, it was concluded that hunger in agricultural communities is heavily tied to farmer's limited access to markets, land tenure rights, and lagging and ineffective agricultural environments and technology (Elkharouf and Pritchard, 2019). Many farmers live in isolated communities connected by dilapidated roads and do not own cars or have access to public transportation.This being the case, it is extremely difficult for farmers to reach sellers or traders. In addition, complicated land tenure rules often lead to disputes over agricultural land and leave loopholes for the government to seize farmland. Furthermore, the government's reluctancy to subsidize the costs quality seeds and proper agricultural technology has been economically detrimental to many farming communities.

1.4 Implications of Climate Change on Rice Production

According to the Asian Development Bank (ADB), the effects of climate change are expected to result in a decrease in rice paddy yield across all Asian sub-regions of up to 20% by 2050 (Sinnarong et. al, 2019). A simulation using climate projections from Thailand's Development and Coordination Center for Global Warming and Climate Change, and the Southeast Asia START Regional Center, an environmental organization founded by the National Research Council of Thailand and Chulalongkorn University, created a regional climate modelling system that could be used to predict changes in precipitation and temperature and model the subsequent consequences on the economy. This simulation, which combined macroeconomic theory and crop modeling, revealed that the fluc-

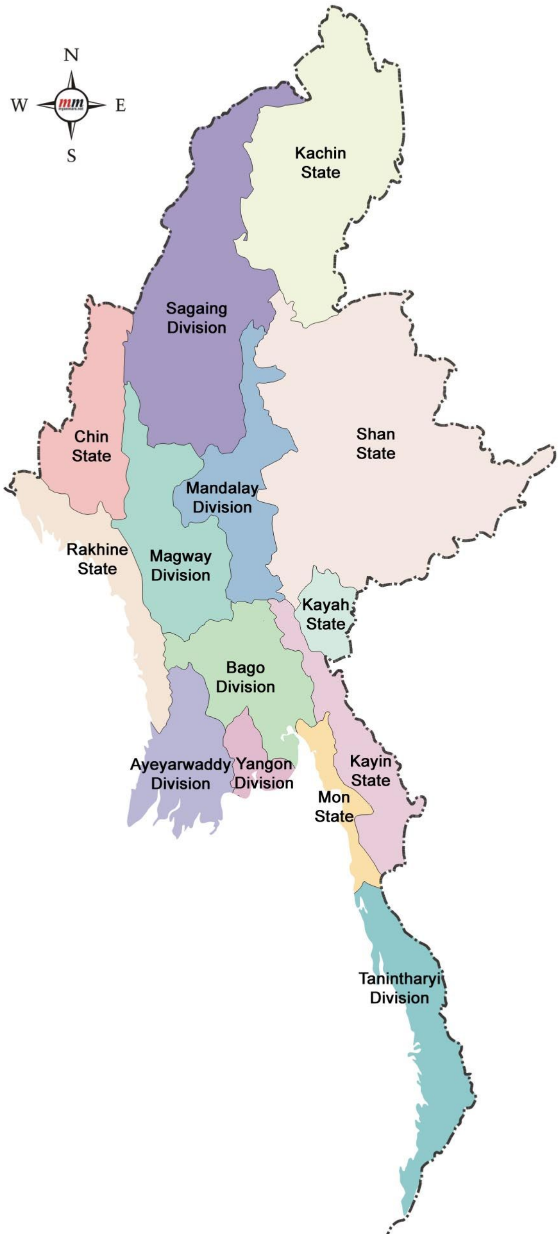


Figure 1.3: Map of regions in Myanmar

tuations in temperature and precipitation associated with the effects of climate change ultimately result in the instability of prices of rice and other crops across 73 provinces in Thailand (Sinnarong et. al, 2019). Although the model was specific to a 20 km x 20 km region in Thailand, its implications can certainly be applied to neighboring Myanmar. While the unpredictability of temperature and precipitation pose significant threats to Myanmar's agricultural economy, extreme weather and sea-level rise are also expected to have a negative effect on rice production in deltas such as the Irrawaddy River Basin (Furuya et. al, 2013). In the following sections the ways in which increasing temperatures, increasing variability in precipitation patterns, and other climate change related factors have been found to decrease average rice yield will be explored.

1.4.1 Increasing Temperatures

One effect of climate change that has a significant impact on rice production is increasing temperatures. In Myanmar, the warmest months occur directly before monsoon season, from March to June. During these months, the Southern coastal regions of the country experience temperatures well above 36°Celsius (C), which is beyond the critical limits of heat tolerance for rice ((Wassmann et al., 2004)). A study conducted by Dr. Shao-Bing Peng of Huazhong Agricultural University concluded that rice yield can decrease by up to 10% for each 1°(C) increase in minimum temperatures during the dry-season, which occurs from October to May in Myanmar (Peng et. al, 2004). Rising temperatures are more significant in the winter months, lasting from November to February, than in the summer as it is expected that there will be a more prominent increase in minimum temperatures than maximum temperatures annually ((Wassmann et al., 2004)).

High heat stresses rice crop during the most vulnerable periods of the plant's production cycle. The growth rate of rice increases linearly as temperatures increase from 22°C to 31°C, and then decreases significantly beyond that point ((Wassmann et al., 2004)). In the vegetative stage, the period of growth between germination and flowering, temperatures hotter than 35°C have an extremely negative affect on photosynthetic carbon fixation. At high temperatures kinetic energy increases and bonds within cellular membranes loosen which creates a reorganization of thylakoid stacks, or grana. (Karim et al., 1997), This heat-induced reaction can reduce photosynthesis by over 35% (Oh-e et al., 2007.

During the reproductive stage the meristem, the tissue on the tips of roots and shoots prodcues new cells, begins producing flowers. It is during this phase when rice plants experience spikelet sterility because of high temperatures (R. (Wassmann et al., 2004)). Spikelet sterility refers to reduced fertility in florets, in this case caused by reduced pollen production as a result of increased temperatures. Regarding the ripening period, also known as grain filling, high temperatures can greatly decrease grain weight and size because of excessive energy consumption that occurs to meet increased respiratory demands that are associated with warm temperatures (R. (Wassmann et al., 2004)). As a result of negative effects that occur at multiple different stages in the production cycle of rice, rice yield can decrease by as much as 39.6% if the crop experiences temperatures above 35°C (Xiong et al., 2017).

1.4.2 Sea Level Rise

According to the National Oceanic and Atmospheric Administration (NOAA) from 2018 to 2019 global sea level rise (SLR) was 6.1 mm. Over the last 100 years, the average SLR has been 1.8mm (Chen et al., 2009). SLR is projected to increase up to 5 m by 2100 as a result of melting glaciers, ice sheets, and ice caps (Dasgupta et al., 2009). While this melting does not usually occur in tropical regions, the implications of SLR are experienced throughout Southeast Asia. SLR is associated

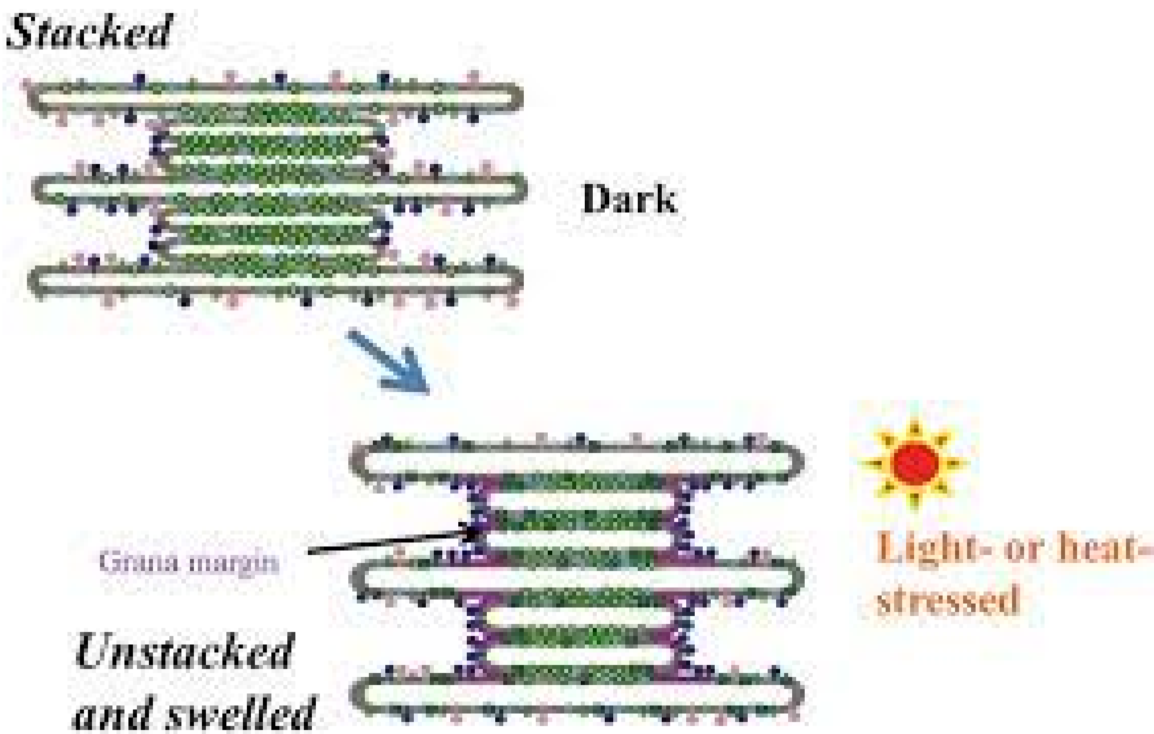


Figure 1.4: Comparison of an undisturbed (stacked) chloroplast and the swelling of the grana that is induced by heat [MLH: let's create a better image]

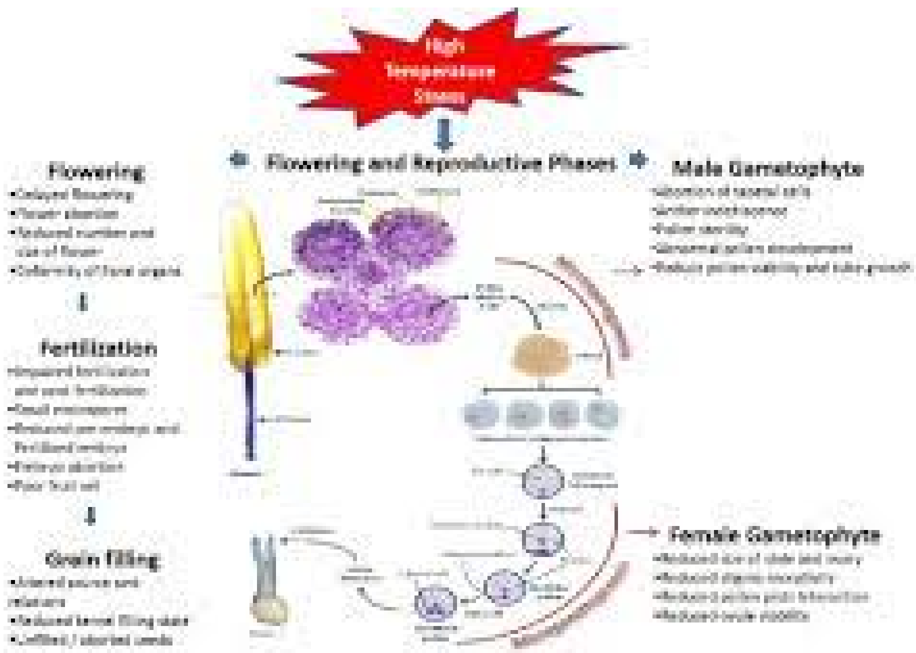


Figure 1.5: The effects of high temperature stress on male and female reproductive phases. Although high temperatures effects both male and female functions, studies show that high temperature predominantly reduces rice grain size by impairing the production of pollen–R.
(Wassmann et al., 2004).

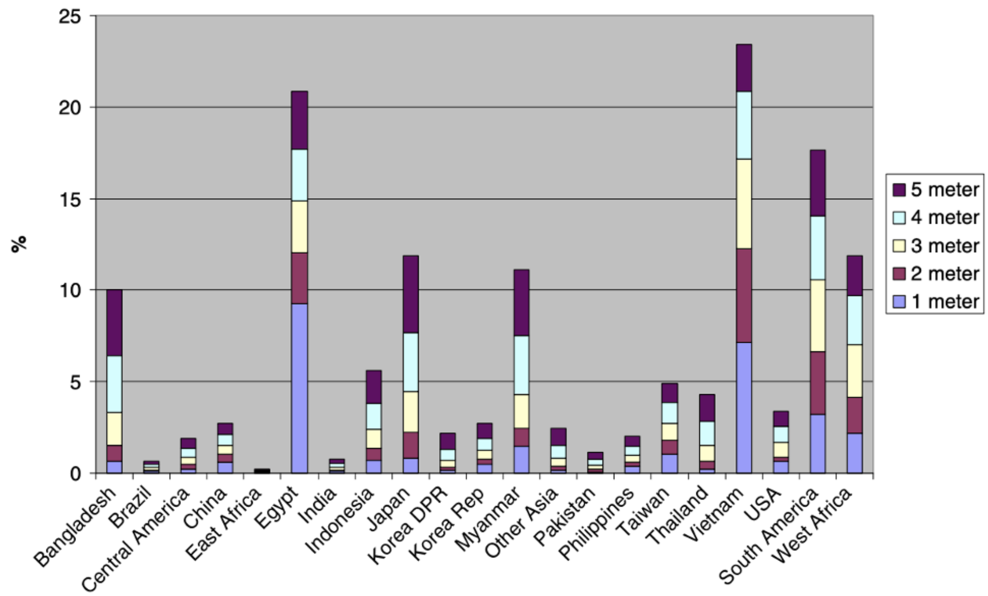


Figure 1.6: Percentage of agricultural land lost under projected SLR for a number of vulnerable countries –Chen et al., 2009.

with several environmental issues that are prevalent in Myanmar including coastal erosion, flooding, changes in groundwater quality and subsequent decreases in agricultural production (Chen et al., 2009).

For each meter of SLR, Myanmar is projected to lose 0.85% of its rice cropland (Chen et al., 2009). If long term estimations are correct, a 5-meter increase in sea level could result in a loss of over 6.5% of Myanmar's available rice cropland and up to a 10% decline in rice production (Chen et al., 2009). Under these circumstances the price of rice could jump by as much as 22%, which would have a massive impact on food security regionally in Myanmar, and worldwide (Chen et al., 2009). According to the World Bank Myanmar has a poverty-rate of 37% (The World Bank, 2021). Moreover, people in Myanmar spend 60% of their income on food (The World Bank, 2021) meaning the price of a staple food like rice rising could have disastrous implications for the average Burmese person.

1.4.3 Precipitation and flooding

Rice is predominantly grown in monsoon season in Myanmar, which lasts from May to October. Rice paddies require extremely large amounts of water and are often grown in rain-fed river deltas. Most years during monsoon season these rain-fed deltas produce as much rice as the dry-zones, mountainous and coastal regions combined (Myint et, al., 2018âĂŤwiki). Although monsoon rainfall is intergral to plentiful rice production, excess precipitation and flooding related to tropical storms can also be detrimental. For example, floods tied to monsson rainfall during a La NiÃśa episode in 2003 led toa 14% decline inrice exports the following year (Brackendridge t, al., 2009). While rice cannot be grown without adequate levels of rainfall, heavy precipitation and extreme weather result in flooding which has proven to be an increasingly prevalent problem for MyanmarâĂŹs rice farmers over the last 50 years.

There are two main types of flooding in Myanmar. The first type has to do with the way in which monsoons and tropical storms hit river deltas hard, triggering river plains to act as runoff generators (Kravtsova et al., 2009). This first type of flood occurs when extra-local runoff from wetter parts of the delta upstream flows downstream onto drier floodplains (Brackenridge et al., 2016). In addition to extra-local precipitation flowing downstream, a second type of flooding occurs when local rainfall concentrates on naturally wetter lowlands, which are often the sites of agricultural fields (Brackenridge et al., 2016). This is known as pluvial flooding. Pluvial flooding is often associated with large-scale rainfall events like monsoons, and other types of extreme weather as they are caused by high levels of precipitation on already saturated soil in floodplains (Brackenridge et al., 2016).

Myanmar's unique geomorphology greatly influences precipitation and flood patterns throughout the country. Most of the rivers in Myanmar are classified as anabranching (Furuchi et al., 2009). This means that the rivers are made up of multiple channels with divided flows as a result of sediment build-up. As sediment accumulates in riverbeds, the flow of rivers is often diverted into smaller channels (Brackenridge et al., 2016). Over the course of a year these small diversions can result in entire segments of rivers to migrate over 100 meters (Brackenridge et al., 2016). Accumulated sediment and diverted channels cause unpredictable river flow which can be a serious flooding hazard.

Throughout the 19th and 20th centuries river embankments and levees were constructed in an effort to protect agricultural land from river channel migration (Hajek and Edmons, 2014). In addition to levees and embankments, reservoirs and dams also influence flood hazards throughout the country. When dams and reservoirs were being constructed throughout the 20th century, flood control and mitigation were not considered. Most of these dams were designed to have a spillway feature, a system in which excess water can pass through the dam in a controlled manner when the reservoir is full (Brackenridge et al., 2016). This spillway design is extremely susceptible to flash floods when the mechanism fails. In addition to issues with spillway dams, large hydroelectric dams also pose flood hazards. (Gupta et al., 2009). These dams trap sediment during floods which in turn creates a sinking delta, a phenomenon that occurs when riverbeds erode due to a lack of delivery of sediment and sink, which increase the risk of flood hazards downstream (Syvitski et al., 2009). Innovations like levees and dams have had moderate levels of success, but when these structures are breached during massive floods, damage is worse than it would be otherwise (Brackenridge et al., 2016). These constructions do not allow for much local flood storage or local flood mitigation, so when these systems fail, they fail miserably.

While geomorphology and human construction certainly play prominent roles in causing flood hazards in Myanmar, factors such as deforestation, mangrove logging, delta subsidence and sea level rise have been identified as other main contributors to what scientists refer to as temporal flood trends (Brackenridge et al., 2016). In the past, flooding has been measured using stationary analysis, a type of flood analysis that relies on the assumption that variables other than time are nonfactors to streamflow (Nonstationarity of Hydrological records– Bayazit 2015). In the last decade, this type of analysis has come under increasing scrutiny as scientist begin to acknowledge the significance of variables that are influenced by climate change. In Myanmar, deforestation, especially of mangrove forests, has destabilized coast lines and made deltas more susceptible to storm surges (Brackenridge et al., 2016), which are small tsunamis of seawater that flood coastal land (Seekins, 2009). Subsidence, the rapid sinking of land as a result of human activity, has made both coastal land and deltaic agricultural flood plains more vulnerable to flooding (Brackenridge, et al., 2016). Futhermore, rising sea levels have increased the frequency of inundation. All of these factors influence flooding temporally, meaning they cause unprecedented stream-flow inflections and

Figure 1.7: Inundation along the upper Ayeyarwady river in the state of Kachin during normal winter flow (top), monsoon season flow (middle), and unusual floodingâĂŤusually tied to extreme weather– bottom

are greatly influenced by climate change.

La Nina, the cold phase of the El Nino-Southern Oscillation (ENSO) cycle, also heavily influences flooding in Myanmar. The wettest conditions and most extreme weather are often associated with La NiÃśa years in Myanmar. In addition to La Nina, other large-scale weather circulations, defined as tropical or global changes in atmospheric and oceanic patterns and weather, affect precipitation and flooding in Myanmar. The Madden-Julian Oscillation (MJO) is a 30-90 day weather pattern associated with anomalous and intense rainfall in Myanmar (Brackenridge et al., 2016). The Indian Ocean Dipole (IOD) has the opposite effect as it causes warm and wet conditions in the Western Indian Ocean but acts as an inhibiter to rainfall during monsoon season in Myanmar (Brackenridge et al., 2016). The Pacific Decadal Oscillation (PDO) is also important to consider as its cold phase induced nearly twice the number of tropical storms as its warm phase does (Brackenridge et al., 2016). Weather patterns and seasonal oscillations greatly influence rainfall, flooding, and agricultural planning. Preparing for and predicating these oscillations and relaying information to farmers throughout Myanmar has proven to be a difficult task. In the case of extreme weather events, lack of communication and infrastructure can prove to be economically detrimental and deadly.

1.5 Cyclone Nargis

Cyclone Nargis was a Category 3 tropical storm that struck Myanmar in May of 2008. Cyclones are low pressure storms that form in the Indian Ocean and are identical to the typhoons that occur in the western Pacific and the hurricanes that occur in the eastern Pacific and Atlantic (Seekins, 2009). The regions that were predominantly affected by Cyclone Nargis were the Ayeyarwady Delta, the Yangon region, and other parts of Southern Myanmar, which are all prominent rice producing regions in the country. Upwards of 140,000 people died, and buildings and croplands were devastated by a 4-meter-high storm surge, which is a temporary rise in sea level as a result of a tropical storm (Seekins, 2009).

Nargis is significant to this chapter not only because it had a monumental effect on rice production, but also because it is a prime example of the failures of Myanmar's military government to protect the lives and economic interests of its residents.

When Nargis first hit Myanmar, the storm surge flooded approximately 5,200 square km of coastal and low-lying land, contaminating thousands of rice fields with salt water. An estimated 404, 858 hectares of cropland were inundated by saline water (Seekins, 2009). The storm took over 24 hours to pass through and hit the country on the Western side first, before concentrating over the Southern deltaic region and moving North (Brackenridge et al., 2016). The nature of this storm path was a significant factor in the degree of destructiveness of the storm as the movement triggered a counterclockwise rotation along the shallow southern seabeds of the country, resulting in maximum winds up to 118 km/hour (Brackenridge et al., 2016).

Just like any other major flooding event, population growth, deforestation and human construction were identified as long-term causes of the damage inflicted by Cyclone Nargis (Brackenridge et al., 2016). Although these factors are significant, it is important to consider the role of the government of Myanmar in permitting unsustainable dam construction and deforestation to occur, but it is even more important to analyze the country's disaster response, and to hold the military

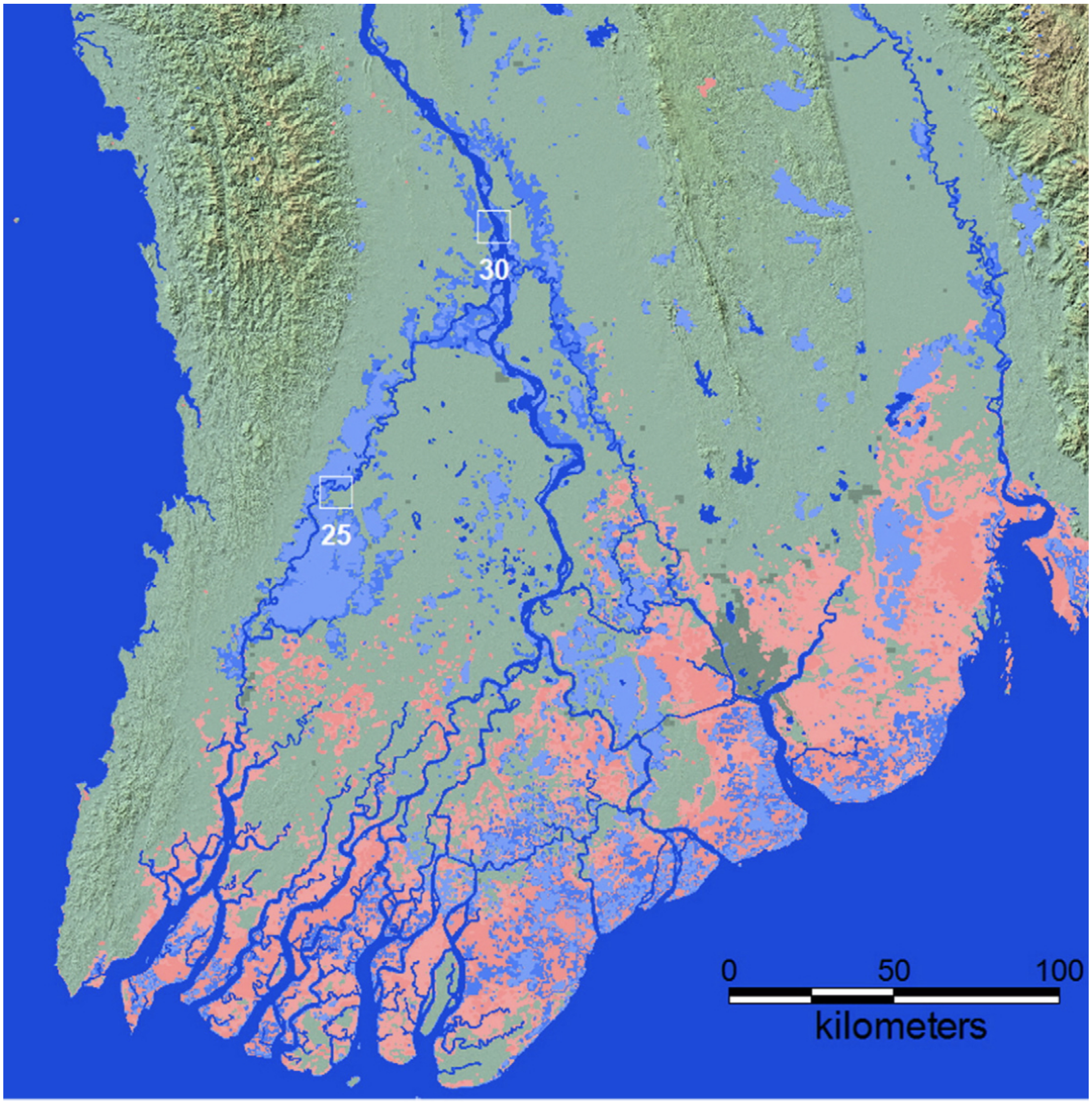


Figure 1.8: Inundation as a result of Nargis (red), compared to typical winter hydrology (dark blue) and average maximum monsoon flood events (medium blue).

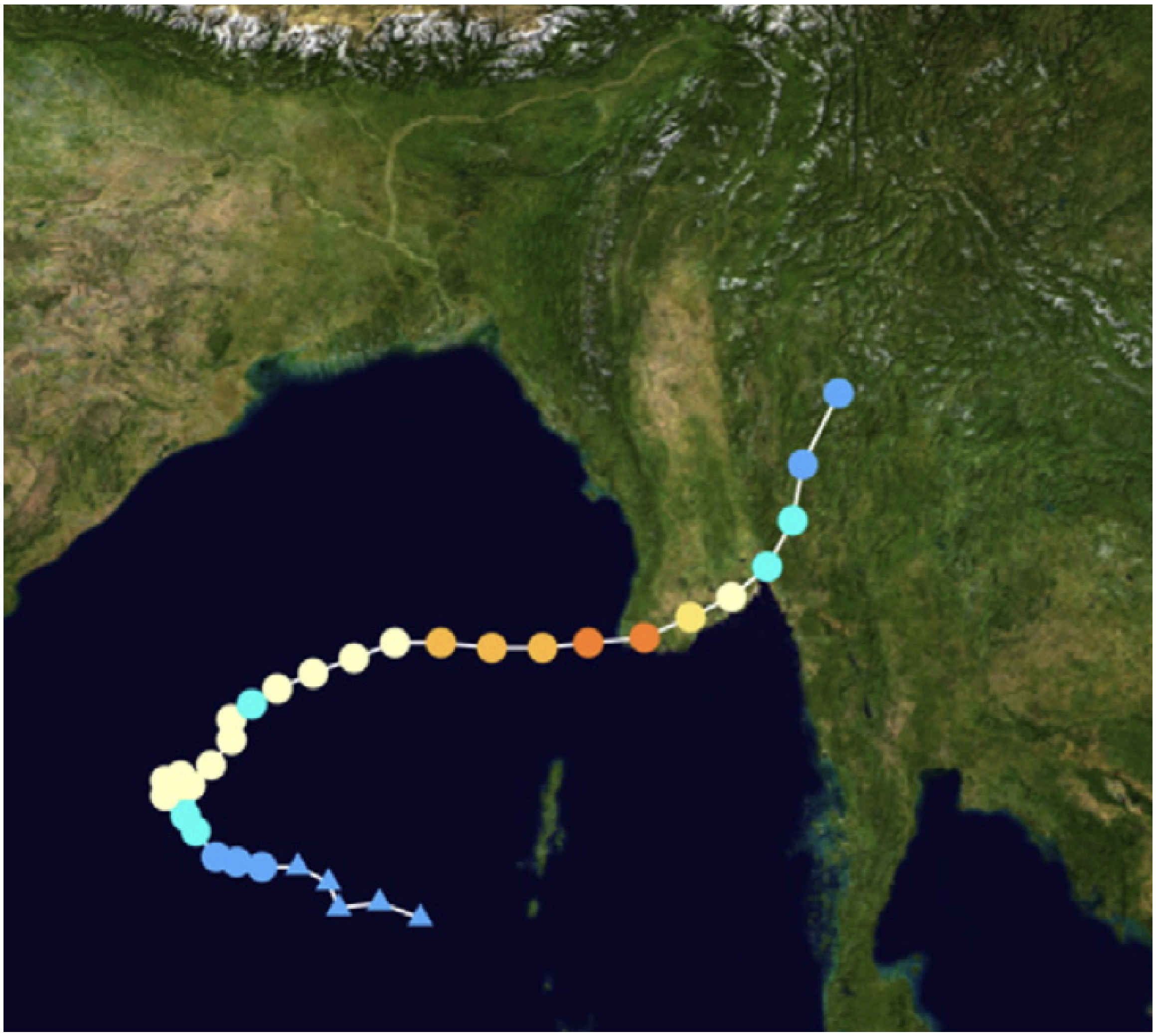


Figure 1.9: Storm path of Cyclone Nargis

government accountable for their failures to protect Burmese people.

In the days following May 3rd, so much chaos and death ensued that the government of Myanmar stopped counting deaths after the toll reached 138,000 (Brackenridge et al., 2016). Although government officials in Myanmar and weather experts worldwide could predict the areas in the projected path of storm, the government failed to communicate the severity of the storm or highlight evacuation routes to those living in the communities most affected in the coastal south (Brackenridge et al., 2016). Shortly after the cyclone touched down weak infrastructure was quickly overwhelmed. Storm shelters reached capacity and already damaged roads trapped residents in inundated villages (Brackenridge et al., 2016). Many of the deaths tied to Nargis occurred in the weeks following the storm as people in rural areas did not receive proper aid and experienced disease and starvation (Seekins, 2009).

Cyclone Nargis did not impact all the residents of Myanmar equally. Poor agricultural workers and other disenfranchised groups throughout the southern parts of the country bore the brunt of the damage. According to the Post-Nargis Assessment, a project conducted by the Special Association of Southeast Asia Nations (ASEAN), 61% percent of those who died due to Cyclone Nargis and its aftermath were women (Macan-Maker, 2008). Furthermore, thousands of impoverished children were orphaned and had to relocate to cities where they were referred to as âĂIJCyclone Kids.âĂİ (Seekins, 2009). Many of these children became subject to exploitation in new metropolitan environments. Young girls were frequently forced into prostitution and young boys were often recruited into the Tatmadaw, the Burmese armed forces.

In the aftermath of the cyclone, foreign aid and global responses to the disaster were met with hostility and ignorance by Myanmar's military government. When the United Nations called for over 187 million dollars in relief funds, the State Peace and Development Council (SPDC) responded that they would accept foreign aid but wanted absolute control over distributions of supplies and made it extremely difficult for relief organizations to get boots on the ground (**?**).(Seekins, 2009). As time went on Myanmar's government introduced stricter restrictions on the aid coming into the country. Charity and relief organizations frequently ran into roadblocks where military forces confiscated food and supplies (Seekins, 2009). The SPDC began facilitating propaganda to discourage organizations from interfering with their response to Nargis. The State-run newspaper âĂIJThe New Light of MyanmarâĂİ declared that the residents of Myanmar no longer needed help obtaining food and supplies because they could get vegetables from the fields and fish and frogs from the creeks (the Irrawaddy, 2008).

The corruption and overall inefficiencies that were prevalent in the process of delivering aid remained an issue for different relief efforts and government initiatives throughout the country. The SPDC assigned a government organization called the Union Solidarity and Development Association the task of cleaning up the physical damages to infrastructure in the effected regions. The association quickly devolved into a corrupt and harmful presence in many of the communities they were supposed to rebuild (Seekins, 2009). The task of removing debris and repairing structures was often left to be organized by community initiatives (Seekins, 2009). Over the following weeks the international spotlight on the crisis dwindled and food shortages and corruption continued. The Los Angeles Times reported that rice was continuing to be exported out of the country even as thousands of residents of Myanmar were starving domestically (Seekins, 2009)[MLH: get the original citation from the LATimes!]. The SPDC responded by saying the country was attempting to generate revenue while prices were up globally (Seekins, 2009).

At first glance the occurrence of Cyclone Nargis may seem like a rarity. Large tropical storms usually do not make landing in the Southern regions of Myanmar, especially compared to regions such as Rakhine, which was hit by severe tropical storms 6 times from 1980 to 2000 (Brackenridge, 2016). This being said, an event as severe as Nargis is projected to reoccur increasingly frequently as the climate crisis worsens (Brackenridge, 2016). Nargis was extremely damaging to agricultural production in Myanmar, and rice farms in particular were devastated by the event. Much of the agricultural infrastructure that was constructed throughout the 1980s in an effort to improve rice yield was severely damaged or destroyed by the storm. Construction projects supported by the World Bank and the Asian Development Bank that implemented drainage systems, polders and sluice gates were made all but irrelevant due to damage. (Omori et al., 2020). Many of the embankments that lined man-made canals or polders were busted as a result of flash floods (Omori et al., 2020). Sluice gates, barriers that are used to control river flow were also overrun in the storm (Omori et al., 2020), The very infrastructure that helps sustain high rates of rice production in Myanmar is clearly extremely susceptible to unpredictable weather in this era of climate crisis. Robert Brackenridge, the founder of the Flood Observatory at Dartmouth College, claims that reinforced and sustained flood and sediment management will be necessary to prevent future violent floods in Myanmar(Brackenridge, 2016). When considering if this kind of sustained management is possible in Myanmar, one must understand the exploitative role of Myanmar's military government in the history of rice production in Myanmar.

1.6 The Modern History of Rice Production in Myanmar

1.6.1 The 19th Century–The Industrialization of Rice

When the British arrived in Myanmar the rice industry in the country changed forever. Prior to British arrival in 1824, rice was cultivated mostly for home consumption and local trade (Siok Hwa, 1965) Occasionally rice was exported to nearby regions in Southeast Asia such as Sumatra in Indonesia, but most of the rice was produced for domestic consumption. In the mid 19th century, rice was becoming a desirable good in Europe as it was a cheap staple food and could be used for brewing, bread-making and as a textile (Siok Hwa, 1965). A large percentage of the rice being imported by European countries was sourced from the Carolinas in the United States (Siok Hwa, 1965). When the American Civil War broke out in 1861, rice exports from the United States declined rapidly and the European market looked to Southeast Asia to meet the demand for rice paddy (Siok Hwa, 1965).

In an effort to take advantage of this newfound demand, the British launched largescale land reclamation projects with the goal of converting the forestland and flood plains in southern Myanmar into arable land (Fujita, 2016). Along with land conversion, the British began building new flood control infrastructure mostly in the form of levees. This economic activity in the south was extremely attractive to farmers in Upper Myanmar, and many agricultural workers migrated south where there were ample job opportunities on farms and in busy ports (Siok Hwa, 1965). In addition to farmers migrating down from northern Myanmar, immigrant workers from India came flooding in throughout the ladder half of the 19th century. This new immigrant work force was composed of laborers looking for jobs in port cities and rice mills as well as wealthier land-owning immigrants known as Chettiars. Chettiars came down to Myanmar primarily to work in banking and moneylending, however the British government remained firmly in control of export and the majority of trade operations (Fujita, 2016). As a staple food, rice has always been extremely culturally significant in Myanmar. The industrialization of rice production in the southern deltas was transformative as it established rice production as the center of economic, political, and social life in the country.

1.6.2 The 20th Century–Rice Production in an Era of Political Transition

As more infrastructure was established and land was cleared for agriculture, rice production steadily increased throughout the first few decades of the 20th century. When the Great Depression struck in the late 1920s rice prices plummeted as many farmers could not pay off their debts and consequently lost land ownership (Fujita, 2016). Revolutionary movements and anti-colonial student-led protests gained traction during these times of economic hardship. Tax protests and hunger strikes led by Buddhist Monks quickly grew to a national insurrection against British rule (Martin Smith 1991, BurmaâĂŤInsurgency and the Politics of Ethnicity).

In 1937, Great Britain separated Burma from India and established Burma as an individual British colony with its own prime minister and national assembly (A History of Myanmar since ancient times, aung-thwin). When World War 2 started Burmese leaders used the opportunity to attempt to strike a deal with the British: military support in return for independence (A History of Myanmar since ancient times, aung-thwin). This agreement never came into fruition and when the Japanese promised Burma independence, the Burmese government formed the Burma Independence Army (BIA) and permitted the Japanese to occupy the region in 1943 (A History of Myanmar since ancient times, aung-thwin). Although the Japanese declared Burma was a sovereign nation, the Japanese military remained in control of the country's operations and Burmese leaders became increasingly frustrated. Aung San, the figurehead of the Burmese independence movement and the leader of the BIA, shifted the army's allegiance to Great Britain and expelled Japanese forces just two years after permitting the occupation of the country (A History of Myanmar since ancient times, aung-thwin).

In 1947 the British granted Burma complete independence, but the state of political stability that had defined the country for the previous 20 years continued. Several ethnic-based communist insurgencies ensued in the 14 years between independence and the creation of the Burma Socialist Programme Party (BSPP), which marked the start of the era of military controlled government in the country (A History of Myanmar since ancient times, aung-thwin). The constant state of political unrest and the amount of damaged infrastructure from the second world war left Myanmar's agricultural economy devastated.

«««< HEAD «««< HEAD ======= »»»> 126dbbbd5b991bcc977adb9b87ef5faf2d9f4cb6 The 1950s were a transformative period for rice production in Myanmar as land use and land tenure were altered drastically. In 1953, the Agricultural Land Act was enacted, and the government seized any plot of agricultural land larger than 50 acres for redistribution (Fujita, 2016). The act also prohibited the sale, rental, mortgage, and transfer of this new nationalized farmland, which essentially cemented the working class as agricultural laborers by preventing them from becoming tenant farmers (Fujita, 2016). This program exacerbated a growing class divide as the government avoided redistributing land to those who had never owned land previously as they feared that these farmers would fail to produce sufficient quantities of paddy (Fujita, 2016).

When the BSPP formally took control in 1962 they introduced an agricultural. This new procurement system was met with a level of resistance by some agricultural communities, but the BSPP responded by seizing the land from resistors and redistributing it to more cooperative farmers (Fujita, 2016). The procurement system was largely ineffective as it caused rice exports to decline, and only by accepting foreign aid was the BSPP able to keep the rice industry afloat throughout the 1970s (Fujita, 2016).

In the 1980s the gap between the procurement prices and market prices for rice steadily increased, culminating in large-scale farmer led protests that were part of the larger Democratic Movement of 1988 (Fujita, 2016). Amidst massive protests the government briefly liberalized the markets which led to a monumental surge in rice prices (Fujita, 2016). When the State Law and Order Restoration

Council (SLORC) squashed revolution attempts and seized control of the country's operations, they swiftly reinstated the procurement system. The liberalization of markets followed by the quick reinstitution of the procurement system hit working class agricultural workers extremely hard. Although flawed, the procurement system was acting as a safety net of sorts for many farmers. When this safety net was suddenly taken away during the Democratic Movement, rice prices skyrocketed but wages failed to follow suit and actually declined (Fujita, 2016).

Following the Democratic Movement of 1988 farmers lost out in 3 ways. First, the new SLORC, which later became the SPDC, decided they would no longer subsidize fertilizers, pesticides, and oil in the agricultural sector. Farmers now had to pay international prices for said goods without benefitting from the international demand for rice. Second, they continued to lose money as the procurement price remained well below the domestic market prices. Lastly, privatized rice export remained prohibited resulting in lost profits as international prices were substantially higher than domestic ones. The 1990s were not much better for rice farmers. Although, things appeared to get off to a better start when rice exports increased due to the introduction of the Summer Paddy Program (SPP) of 1992 which introduced new growing technologies such as double cropping in order to produce more paddy in the summer season. Many farmers preferred to supplement their rice crop income by growing beans and legumes in the summer and were reluctant to adopt the technologies and guidelines proposed by the SPP. Although the SPP increased rice production, it also contributed to the growing distrust and disapproval of government agricultural projects and programs that is still present in Myanmar today.

The exploitative nature of the procurement system continued through the late 1990s as farmers were prohibited from making any private deals before meeting the state quota (Fujita, 2016). Farmer's fatigue of the procurement system became evident as the quality of rice declined severely. Myanmar's export prices for rice were 70% of what Thailand was fetching, and 25% of Myanmar's rice was classified as damaged compared to Thailand's 5% (Fujita, 2016). The quality of rice was so poor that many state employees would immediately sell the product as animal feed instead of relaying the goods to domestic and global markets (Fujita, 2016).

1.6.3 The 21st Century-The Slow Process of Liberalization

In 2003 the SPDC once again briefly suspended the procurement system and tested the waters by allowing the private export of rice on the condition that the state kept half of the profits of these private sales (Fujita, 2016). Just like in 1988, rice prices increased rapidly, and the procurement system was reinstated. In 2007 the government began allowing private rice export using a quota system that collected a 10% export tax, a system that was much more successful than the 2003 attempt (Fujita, 2016). Still the procurement system remained problematic as instead of acting as means of food security following the onset of Cyclone Nargis in 2008, Myanmar's government continued to export rice despite a massive food shortage (Fujita, 2016).. In 2011, as a part of a wave of democratic reforms that were backed by the military government, the rice market was finally liberalized entirely. This decision was likely made due to narrow price differentials between export and domestic prices, which prevented rice prices from spiking at the time of liberalization (Fujita, 2016).

In addition to liberalizing agricultural markets, the government took steps to both increase rice production and create better food security. The Vacant, Fallow, and Virgin Lands Act of 2012 highlighted unused land that was suitable for agriculture. At this time Myanmar had the most undeveloped land of any country in Southeast Asia, and the hope was that some of this land could be converted to farmland in order to increase economic productivity, even if that meant sacrificing conservation efforts (Fujita, 2016). The government also created the National Buffer Stock

Committee which launched township-level committees that purchased rice as buffer stock, which helped to stabilize rice prices (Fujita, 2016). Throughout the 2010s the increasingly democratic government took steps to provide more stability to the agricultural workers who are the backbone of the economy. Although it is too early to tell the long-term effect that the 2021 military coupe will have on the rice industry, constant political turmoil and violence is damaging to the agricultural economy and the society that has developed alongside the rice industry.

1.7 Conclusion

Being the staple good in Myanmar, rice is of extreme cultural significance. The crop is eaten at practically every meal and more than half of the jobs in the country have something to do with the product. As detailed in the historical section, rice influenced people to immigrate. The crop created cultural and social hubs and is extremely tied to class. Rice is a wage-good, meaning its price has strong implications on the economy, wages, and the well-being of Burmese people (Fujita, 2016).

In his book âĂIJThe Myanmar EconomyâĂİ Koichi Fujita utilizes the term âĂIJrice trauma.âĂİ Rice trauma as a concept refers to the trauma that is tied to the rice industry, trauma experienced by Burmese citizens and by members of the Myanmar military government. Rice existing as a wage-crop in Myanmar links the good not just to wages, but also to movements. Protests in the 1930s, the 1988 uprising, and social unrest that followed Cyclone Nargis were all explicitly tied to rising rice prices. Burmese citizens experience rice trauma when prices rise and the economy becomes increasingly unstable, and the government experiences rice trauma because they associate changes in the rice industry as having potential to start political movements. This idea of rice trauma is a prime example of the political economy and ecology of rice. Throughout the history of the country, rice has acted as a political vessel.

As the onset of the climate crisis continues over the next century, scientists have stated that agriculture needs to change. Evidence shows that crops will need to become more resilient and agricultural practices must strive to be increasingly sustainable as the world begins to deal with extreme weather and increased temperatures. While alterations to established agricultural processes may be relatively easily to implement in countries with extensive resources and stable economies, a developing Southeast Asian country such as Myanmar will struggle to build upon weak infrastructure and will face strong opposition in the form of corruption and political instability.

The 2021 coup is evidence that while it is easy to highlight the agricultural technologies and reform that is needed, MyanmarâĂŹs complicated political history and continued political instability will hinder its ability to adapt in the face of the climate crisis. However, if a democratic government is successfully established in Myanmar, other Southeast Asian countries may look to Myanmar to lead the way as the country can set a precedent by sustainably developing the large intact landscapes that show economic and ecological promise throughout the country.

======= »»»> 149df0d4458d93bbad63d78a5c964710539d2e04 »»»> lucasflorsheim-EA30e21

Chapter 2

Tropical Cyclones in the Philippines

Ian Horsburgh

[MLH: maybe add to the chapter name: and the Carnot Engine and Climate Change... yes, too long, but you have some cool stuff at the end that needs to be made more visible!]

2.1 Tropical Cyclones in the Philippines

2.1.1 A Storm is Coming

The day is Wednesday, November 6th 2013. In the Visayan Islands, the central islands of the Philippine a[MLH: A?]rchipelago, the people prepare for a storm. Just days earlier, after a south Asian weather station had begun monitoring a low pressure area east of Micronesia, the storm had been named Haiyan, and been declared a category 5 super typhoon. While Hayian is expected to be the most powerful tropical cyclone ever to hit land, devastating tropical cyclones are not new to the Philippines. One rural Fillipino agricultural worker, Angeles Grefiel, speaks of how past storms have wiped out his crops, leaving him with no money to provide his children with a healthy diet. "We have generations of children that have grown up without having proper access to the right types of food," says Grefiel, a sentiment echoed by Evangeline Aloha, a resident of Leyte Province in the central Philippines, who worries she will have no income if the harvest is wiped out by the storm. As certain cash crops are easily wiped out by heavy rain, many farmworkers like Evangeline and Angeles are "so vulnerable to disasters that when one strikes, it takes them further and further into that cycle of poverty," says a local social worker, also in Leyte Province. To see why certain crops are planted and how they make the country so much more vulnerable to tropical cyclones, we must take a look back on the history of agriculture in the Philippines. [MLH: great intro!]

2.1.2 Agriculture and Cyclone Vulnerability?

Rural Filipino farmers are vulnerable to tropical storms in part due to their integration into worldwide markets. In particular, famine is often a product of the conditions surrounding access to food. "Famine must be seen not as an absolute scarcity of food in particular regions, but rather as a loss of oneâĂŹs[MLH: fix apostrophe] entitlements[MLH: does the word have a different meaning than to US uses?] to food and/or the means of subsistence," writes Warren (2018). As for Fillipino farmers, this loss of entitlement goes back to the colonial era. Throughout history, rice has been a staple crop in the Philippines. Due to the favorable and temperate climate, Fillipino farmers were able to harvest rice twice a year, while simultaneously planting root crops such as sweet potato. When typhoons "created severe food shortages for those who grew rice, these root crops became...the âĂŸ[MLH: look up how to do quotes and apostroshe's in LaTeX, you have it right in some sections. . . , the problem for me when I cut and paste in to Rstudio]refuge of the poorâĂŹ"(Warren, 2018). However, in the nineteenth century, this dynamic began to change. Spanish colonization of the Philippines began in the 1500[MLH: âĂŹ]s, although major agricultural change, especially as it relates to globalization and integration into market economies started in the early 19th century. This began with "the Spanish practice of rewarding the Catholic orders for their conversion efforts with land," which "turned the church into the largest landlord in the islands"(Ventura, 2016). Spanish catholic landlords then divided up their land, and under this system, "Inquilinos (tenant landlords) paid annual rents for lands they then subdivided among sharecroppers, who often further subdivided their portions, which would be worked by families living in a central town near the fields"(Ventura, 2016).[MLH: any figure could break up the text here] This system was a major step towards the integration of Filippino farming into the global economy, due to the fact that "as estates commercialized, they increasingly shared management with Chinese-Philippine mestizo businessmen," who had access to British capital (Ventura, 2016). When America resumed colonial control following their defeat of Spain in the Spanish-American war in 1898, there were a number of changes to this system, but integration into global markets continued. At the beginning of the United StatesâĂŹ rule,[MLH: super interesting!] the new leadership feigned effort to give farmers independent ownership over their land, but just two years later abandoned this effort, apocryphally citing lack of interest in this initiative by the peasants (Ventura, 2016). Former president William Howard t[MLH: T]aft, the civilian governor of the Philippines from 1901 to 1904, then changed direction entirely, saying that "easing the homestead lawâĂŹs limitations on corporate ownership to 2,500 acres[MLH: . . . is better spacing]...was a much better path to development." Following this reversion to a similar corporate control as implemented by Spain, "prevailing inequalities of landholding and rural wealth during the Spanish period multiplied under US rule." Ventura (2016) summarizes the issue, saying that the United StatesâĂŹ "failure to establish independent homesteads was akin to other alleged shortcomings in hygiene and sanitation, education, and banking, thus justifying the US presence in the islands," and consequently "ownership for large scale plantation agriculture." US Civil Service Advisor Roy Franklin Barton talks of the American reforms in the agricultural region of Ifugao, describing how the new "availability of wage labor jobs" makes way for "the introduction of money into the province replacing the old rice currency," and thus "the integration of a market economy" (Klock, 1995). Thus, Spanish and American policies in the Philippines transitioned the country from local to large scale plantation agriculture.[MLH: add a line if you want a new paragraph] This incorporation into large scale plantation agriculture and world trade had large impacts on the vulnerability of the area to natural disasters, such as typhoons "There is persuasive evidence that peasants and farm laborers became dramatically more pregnable to natural disasters after 1850 as their local economies were violently incorporated into the world market," writes Davis (2002). "The vulnerability of tropical agriculturalists to extreme climate events after 1870 was magnified by simultaneous restructurings of household and village linkages to regional production systems." In refuting claims that farmers chose to adopt to this new age agriculture because it provided a better life, Davis argues that âĂIJRecent scholarship confirms that it was subsistence adversity (high taxes, chronic indebtedness, inadequate acreage, loss of subsidiary employment opportunities, enclosure of common resources, dissolution of patrimonial obligations, and so on), not entrepreneurial opportunity, that typically promoted the turn to cash-crop cultivation.âĂİ[MLH: great quote, need page number] This cash crop cultivation became the primary type of farming in the Philippines by the mid 19th century, and even farmers who still owned land were increasingly "encouraged to plant cash crops of abaca, copra, tobacco and sugar, and were often forced to sell rice below market prices"(Warren, 2018). By the 20th century,much of the rice still produced by the Philippines was exported to China, while poor Filipinos lived "almost exclusively on imported rice, tubers and corn" (Warren, 2018). Thus, rather than the pre-colonial model of growing rice and root crops, a model that was fairly robust in the face of typhoons, farmers in the colonial Philippines who were encouraged to grow cash crops and buy imported rice, as well as those who now worked plantations for a wage, were left with no money and thus no food when cash crops were wiped out by typhoons. As many cash crops rely on long fertile growing seasons for harvest, and thus were much more easily disrupted by storms, "subsistence farmers, who increasingly chose to cultivate cash crops, counting on a better standard of living,[MLH: can you make a diagram of this? maybe not, just think about it] often found they had no visible means of sustaining themselves, because of the âĂŸeconomic predicamentâĂŹ triggered by typhoons," writes Warren (2018), again. Thus, in the shift from a diversified to monocrop economy, agricultural, and thus economic disaster became "a fact of life" In sum, as colonial powers such as the United States and Spain implemented policy that shifted Filippino agriculture toward cash crop cultivation within worldwide markets, and away from a local multicrop system, the country became more vulnerable to typhoons.[MLH: really interesting history!]

[MLH: I think this might be a good place to talk about how cyclone work...]

2.1.3 Ready or Not

[MLH: not very descriptive as a subsection name...] As the supertyphoon Hayian approached the Philippine islands, the government scrambled to alert those in danger, but to various degrees of success. While some in danger, like Retche Ycoy, did not receive any warning–"We didnâĂŹt expect this was going to happen. We were just sitting around in our house and the wind suddenly started"–others, like 62 year old taxi cab driver Eduardo did not realize what the warnings meant. Recalling the situation, he said, "What I understood was that there would be a strong wind. We never understood what a storm surge meant."[MLH: what's the source of these quotes?] Others still, like Celina Camposano of Leyte were told to evacuate. While these responses vary from having heard no warning whatsoever to being evacuated and sent to higher ground, they all share one sentiment: their past experiences with tropical storms did not prepare them for what was about to come. [MLH: paragraph] From educating and warning those in danger to helping those affected find food and shelter, the federal Philippine response to tropical cyclones like Haiyan has many obligations. In this section, we will investigate what this response entails, what areas it is successful in, and how it can improve.[MLH: seems odd that this is present tense, but I can think of ways that this work in the intro, but not sure about now...] While âĂŸdisaster mitigationâĂŹ can mean many things, we [MLH: ~~will~~] separate it into post disaster recovery, and pre-disaster preparation.

[MLH: to reference figure...Figure 2.1, bute needs a better reference name!]

2.1.4 Philippine Disaster Mitigation

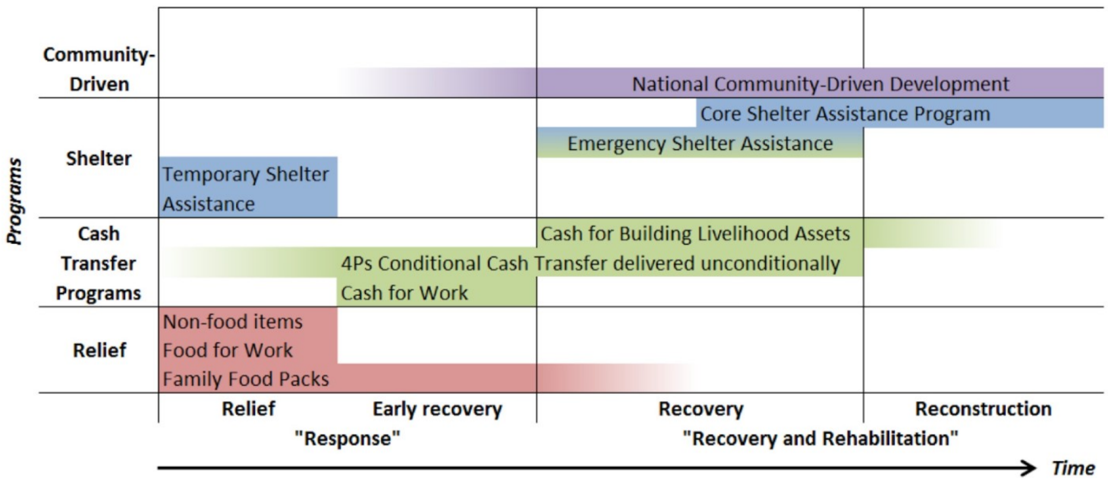
The Philippines has a number of programs aimed at disaster relief, as seen in figure 10.2.[MLH: add reference to auto number]Typhoon Haiyan, locally know as Typhoon Yolanda, was disasterous. With 195 mph 1-minute sustained wind speeds, Yolanda[MLH: confusing to have two names] was the most powerful storm ever to make landfall at the time. With 6300 people dead, and a million houses destroyed or damaged, the Philippine government had much work to do to provide relief for those that survived the devastating storm. Immediately after the storm, the Department of Social Welfare and Development (DSWD) provided shelter assistance to many displaced households. For nearly 60,000 household, this came in the form of emergency shelter kits. Although the kits were

Figure 2.1: A Ship is washed ashore in Tacloban City [MLH: let use a more descriptive label remember there are 16 chapters! also need to be one word or hyponated word.]

helpful in providing emergency shelter, the number of families that received the emergency shelter assistance was limited due to an insufficient supply of kits delivered. (Bowen, 2015). In addition to these kits, DSWD helped to coordinate the delivery of 136,267 roofing solutions to help with roofs that had been blown off, like PapooseâĂŹs. Concurrently, other families were sent to shelters or bunkhouses, and by the 5th month of the response, many of the families who were originally living in emergency shelter kit housing were transferred to more substantial bunkhouses as well. However, this relief housing was not sufficient for all. Another program implemented by DSWD was Food for Work.

In the DSWDâĂŹs food for work program, "Beneficiaries were given food packs in exchange for the provision of their labor to assist in the repacking and distribution of relief goods" (Bowen, 2015). This both helped to expedite the processing and distribution of food packs, and employ/guarantee food for those who lost their job as a result of the tropical cyclone. As the needs of the workers moved beyond immediate shelter and survival, this Food for Work program was replaced with Cash for Work. In the Cash for Work (CFW) program, which continued long into the relief effort, jobs included "loading/unloading of goods, repacking of relief goods, food preparation, sorting and inventory of damaged property, clearing of debris, coastal clean-up, and canal dredging, among other things" (Bowen, 2015). By 2014, 15,188 people were participating in CFW, which "helped to provide much needed additional assistance to DSWD relief programs on the ground, while providing beneficiaries with cash based assistance"(Bowen, 2015). Programs like Cash for Work, however, would not have been possible without existing cash transfer infrastructure. The DWWD, with the help of humanitarian organizations, capitalized on strong pre-existing social welfare programs, especially cash transfer infrastructure, to provide monetary relief in the wake of Hayian. In total, "Four agencies alone in the inter-agency response distributed around US$34 million, benefitting 1.4 million disaster-affected people"(Bowen, 2015). This money was distributed in various ways, with around 70[MLH: %] percent of cash transfers being conditional (Cash for work, etc), and 23 percent being unconditional. Although this system works well, the Phillippine government should learn from and refine this cash distribution process for future disasters, as a number of issues in "coordination leading to coverage gaps and duplication" of funds were reported during the Hayian relief period(Bowen, 2015).[MLH: maybe define the problem then tell how to solve?] In addition to government aid, local relief and community driven development was key to post-Haiyan recovery.[MLH: we could create a table of activities and their evaluation and recommended changes, make be better than to have all in text?] Community driven development refers primarily to the subsection of the DSWD

Figure 1: The primary response, recovery and reconstruction programs of DSWD in the case of Typhoon Yolanda



Note: "Relief, early recovery, recovery and reconstruction" refer the typical international conception of the post-disaster phases over time. "Response" and "recovery and rehabilitation" represent the GoP conception of these phases. They align as illustrated on the figure's x axis

Figure 2.2: DSWD Relief Programs

called the National Community Driven Development (NCDD) program that operates primarily on local levels and was established in 2002 to help alleviate rural poverty, especially surrounding disasters. In addition to implementing general infrastructure, the NCDD is well poised for disaster relief due to its geographical breadth and "has a well established network of community facilitators and community volunteers on the ground"(Bowen, 2015). Following Yolanda, the NCDD played a large part "in the rebuilding/rehabilitation process" of affected communities by taking on projects such as rebuilding roads, paths/trails, schools, flood/drainage control structures, water systems, and health stations. Thus, "The Yolanda experience has also demonstrated the important role that community driven development programs can play in the recovery of poor and vulnerable people from disasters"(Bowen, 2015). Finally, the Core Shelter Assistance Program helped those affected by the storm find housing. In an effort to build more secure and resilient housing, the DSWD implemented the Core Shelter Assistance Program (CSAP), which aims to establish permanent safe housing for the rural poor. Following emergency housing after a storm, the CSAP builds "a standardized two-room structure that is built to withstand 220 kmph wind-speeds"(Bowen, 2015). As a testament to the durability of these shelters, a local Social Welfare and Development officer stated that "The core shelter units built through the CSAP of DSWD are still standing even after the mighty force of Typhoon Yolanda...all 80 units built in 1991, 2000 and 2010 in Barangays Cansuso, San Marcelino, San Sebastian, and San Guillermo remain standing"(Bowen, 2015).[MLH: I don't know anything about construction, but that seems impressive! Is it?] Thus, this program provides robust housing that not only serves as relief for typhoon victims, but actually serves to mitigate future damage caused by natural disasters. Overall, the Philippine government has established a fairly robust system for addressing typhoon relief, combining immediate food and shelter relief with one of the best social protection programs in the region, which helps many residents with both immediate survival and monetary subsistence. However, despite these systems to address relief, many residents still live close to the poverty line. As seen in the figure 10.3[MLH: autoref using a refernce to a label], 44% of Philippine residents experience poverty at least once, and of those that do, 2 out of 3 are in and out of poverty, often triggered by typhoons like Yolanda. While the systems described above do well to provide relief following a tropical storm, thus making the poverty triggered by the storm only transitory, other adaptation and mitigation measures could help reduce the need for such extensive post disaster support as well as decrease the number of deaths immediately caused by typhoons. While some measures described above, such as robust housing, function in this way, there are a number of other measures that can be taken to reduce the effects of tropical cyclones.

[MLH: check this out..., is there something like this for the philippines? `https://cran.r-project.org/web/packages/hurricaneexposure/vignettes/hurricaneexposure.html`, if not it begs the question, great educational tool, perhaps]

[MLH: new section/subsection?] Disaster mitigation takes many forms, from long term prevention to recovery. As we have previously discussed recovery and post-disaster mitigation, which the Philippines has demonstrated great competency in, we will now talk about prevention, a sector which the south asian archipelago will need to invest in to mitigate damage caused by future storms. The first form this investment could take is protecting natural land features.[MLH: is there a science to disaster relief that we could add?] While man made structures such as walls and barriers offer some protection and psychological reassurance, they are not an ideal long term solution to cyclone mitigation (King et al., 2010). This stems from a few factors, the first of which being their high maintenance costs, which leads to neglect, and thus causes a dangerous scenario of false security, as was observed in hurricane Katrina in New Orleans in 2005. Another downside of man made structures is that if they are breached, they often keep water in, creating a ponding effect that "severely constrains response and recovery"(King et al., 2010). Instead of man made infrastructure, many researchers emphasize the importance of retaining natural land features. Natural features

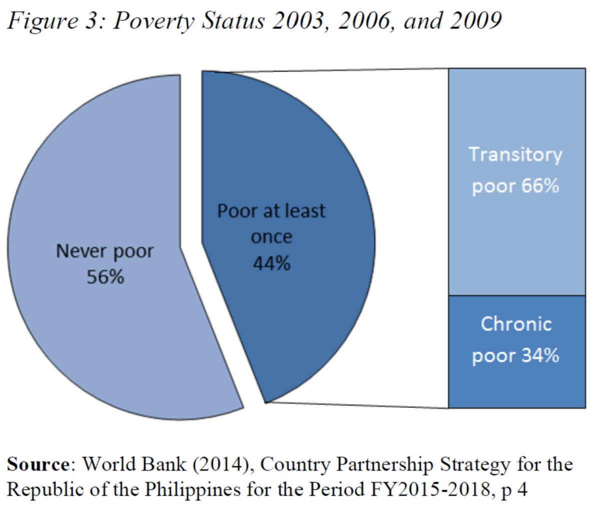


Figure 2.3: [MLH: change the reference label to something more descriptive and then we can use a reference in the text.]

such as coral reefs, mangroves, and dune ridges "are extremely effective in controlling storm surge flooding," writes King et al. (2010).[MLH: seems like this could / should be a new section to focus on 'best practices'] While coral reels are able to absorb "some of the power of tropical cyclone wind-generated waves and surges" before they hit land, mangroves are crucial to providing relief as they are extremely resilient to tropical storms, and often provide shelter and safety to people and boats around them (Williams et al., 2007). While only 20% of the once 500,000 mangroves in the Philippines remained by the early 1990âĂŹs, local and national authorities observed this effect of mangrove protection from tropical storms, and have planted 600,000 mangroves since 1996. In addition to typhoon protection, this has had other benefits such as improved fishing and ecotourism (Williams et al., 2007). Williams et al. (2007) notes, however, that although Philippine legislature in planting mangroves for cyclone protection could be considered a success story, enforcement is "often wanting," and continuous efforts must be made to maintain the progress the country has made in this respect. The final natural feature that has been observed to help prevent typhoon damage is coastal dunes, behind which "lagoonal wetlands absorb immundation"(King et al., 2010). Unfortunately, these are in great danger, as "coastal zones have been cleared, settled, and built over"(King et al., 2010). Thus land use planning and legislature are crucial to maintaining, or many cases such as that of mangroves, rebuilding natural infrastructure to mitigate typhoon damage. In addition to infrastructure, education is imperative to disaster mitigation. Mitigation measures have little to no impact "if the people do not know the hazard risk" or "are unaware of evacuation routes, sheltering strategies, and appropriate response to warnings," as demonstrated by Eduardo and Maria (King et al., 2010). "Many people who may have been through a Category 1 or 2 cyclone have no awareness from that experience of what a Category 3 or 4 will do," writes King et al. (2010), again. As the pre-existing idea of what the storm will look like may contradict official reports, vulnerable populations must be educated on what different categories of storms mean, and what responses are appropriate for the divergent levels. Once these warnings are understood, a robust warning system is extremely helpful in preventing injuries and casualties due to storms. In sum, the Philippine government has created a robust post-disaster relief system that encompasses housing, food, and work. However, to mitigate the damage caused by future storms, the country must invest in protecting natural features such as mangroves, coral reefs, and coastal dunes, as well as strengthen education programs on tropical cyclones.

[MLH: Okay, I like this, but let's integrate into the text..., perhaps this could be inerted into the areas where you talk about colonilizatoin and talk about long term land use affecting resilience of mangroves?? Maybe too much to force, but it might break up with history with some ecology in a nice way and demonstrate some vulneratility linked to colonial land use changes – if that actually happened???]

2.1.5 A Changing Game

[MLH: perhaps a better heading to be more transparent] Compounding issues of lack of education[MLH: lack of education is a strnge beast, some can 'see' this as a lack of interest by residents, lack of motivation, others will blame gov't. I wonder if we can make sure the reader gets your intention here] on tropical storms is the fact that the nature of these storms is changing. Some residents, such as Maria Flora Orbong of Tacloban City understood what the storm surge meant, yet was still underprepared for storms of HaiyanâĂŹs magnitude, remarking that "We knew that a strong typhoon was coming but we didnâĂŹt really expect the water [levels] to rise that high âĂę[MLH: ...] our neighbors evacuated but we thought we were safe. We were in the middle, surrounded [by cement houses]." Less than an hour after the storm hit the Island, however, things were far from expected. "The waves rose to six or eight metres (20 to 26 feet)...many people started to escape but the ships washed up and many people died," recalls Orbong. Celina Camposano of Leyte echoes the novelty of this storm, saying "WeâĂŹve never experienced something like this before âĂę [MLH: ...]weâĂŹve never had to evacuate before." While some of this gap between expectations and reality is due to lack of education on cyclone threat, another reason locals were unprepared for what typhoon brought was that the nature of these types of storms are changing. To understand this change, we must look at how tropical cyclones work and how they are affected by climate change.

2.1.6 Tropical Cyclones and Climate Change

Tropical cyclones, referred to as typhoons when taking place over the Pacific Ocean, occur in southeast Asia primarily in the late summer and fall. Distinct from the monsoon season, which describes the prevailing wind that causes a predictable rainy season in the summer months, typhoons are isolated and severe events, sometimes accounting for more precipitation than the entire monsoon season brings[MLH: interesting!]. Typhoons typically form in warm equatorial ocean waters, as the warm air near the surface rises, leaving an area of lower pressure below. Soon, a cycle forms, with surrounding air moving into the lower pressure region before heating up and rising itself. Once the risen air cools off, it forms clouds, which are then fed into the cycle, as seen in figure [MLH: 10.4] Other characteristics often accompany this air and cloud flow, such as torrential rains and a storm surge which can elevate the sea surface 20 feet and cause widespread flooding.

To represent how these tropical cyclones operate, climate scientists often employ the Carnot Engine model, a theoretical thermodynamic cycle that provides an upper limit on how powerful a storm can be (Emanuel, 1987). The model depicts fluid[MLH: air is modelled as a fluid, but I wonder if readers will get that? and why?] that performs work (a measure of energy transfer that occurs when an object is moved) on its surroundings while undergoing four stages, the fourth of which returns to the first, making it cyclic.[MLH: is there a figure that shows this? Are there some equations that might demonstrate how the model works? I wonder if we can create a little simulation? https://www.researchgate.net/figure/Carnot-cycle-Figure-5-Structure-of-a-hurricane-Air-is-cooled-through-con

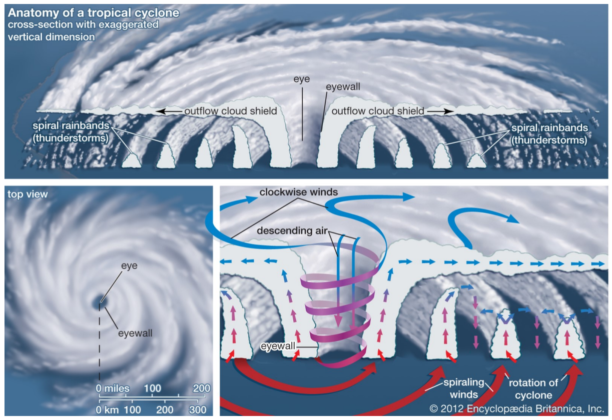


Figure 2.4

fig1_323693275] In the case of a cyclone, this fluid takes the form of a mixture of dry air, water vapor, and suspended condensed water, all of which are in thermal equilibrium (the same temperature). However, as the ocean and the atmosphere are in thermal disequilibrium (not the same temperature), the ocean loses heat to the atmosphere by evaporation of water, which has a large heat of vaporization (Emanuel, 2006).[MLH: this is super interesting and deserves more space if you can figure it out!] The carnot cycle uses this heat flow as an input to estimate the maximum power output that could be produced if the storm was perfectly efficient. Although this perfect efficiency is impossible, the carnot cycle is useful to give an upper bound on storm power, operating as described in figure 10.5.

[MLH: you should cite earlier chapters...] A quick aside on the greenhouse effect: YouâĂŹve probably heard the term “the greenhouse effect” thrown around, but if you forgot what it is or never learned, hereâĂŹs a brief summary. Of the light radiated by the sun, 30% is reflected by the clouds or surface and the rest is (mostly) absorbed by the earth. The earth then transmits energy up by radiation and convection currents, some of which are absorbed by certain elements in the atmosphere such as water vapor, methane, and carbon dioxide. These molecules are known as greenhouse gasses because they act on the climate as a greenhouse does on a garden, trapping heat in the atmosphere. As a higher concentration of greenhouse gases in the atmosphere leads to a higher temperature, the disequilibrium between the atmospheric temperature and the water increases, thus amplifying the heat flow powering the carnot cycle, which results in a higher upper bound for the intensity of the cyclone(Emanuel, 2006).

All this physics on tropical cyclone modeling provides good intuition for why an increase in greenhouse gas concentration in the atmosphere could lead to more powerful storms, but to really quantify this change, we must look to climate simulations and statistics. To investigate one statistic that is particularly pertinent to quantifying cyclone power and potential destructiveness, we look to meteorologist Kerry EmmaneulâĂŹs work. In his 2005 article Increasing Destructiveness of Tropical Cyclones, Emanuel (2005) noted that “Basic theory,” such as what we have looked at with the carnot cycle, “establishes a quantitative upper bound on hurricane intensity, as measured by maximum surface wind speed.” Observing that “the actual monetary loss in wind storms rises roughly as the cube of the wind speed,” Emmanuel [MLH: would giving a short biography of this person, create

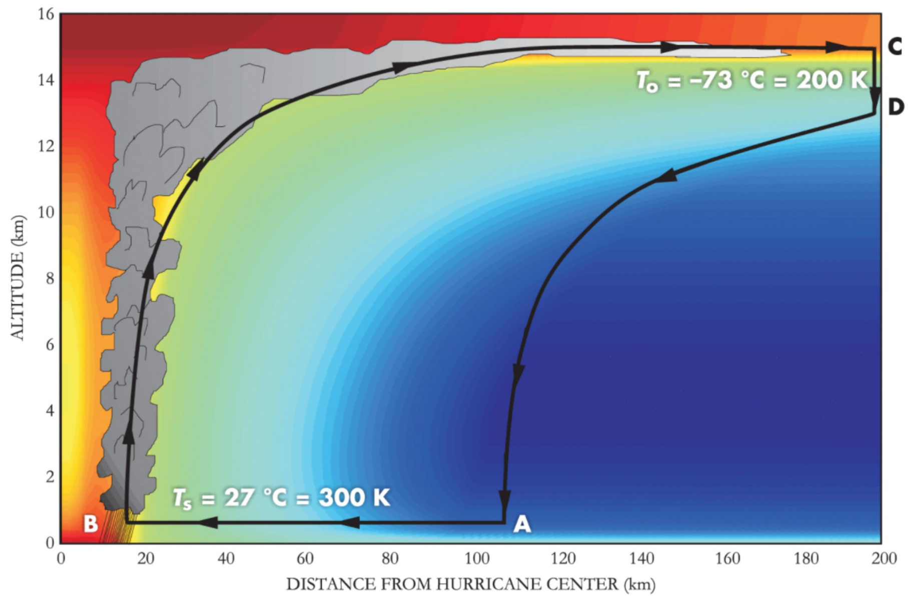


Figure 2.5

more interest in his/her work?]created the Power Dissipation Index, which he defines as:

$$PDI \equiv \int_0^t \mathsf{V_{max}}^3\,\mathsf{dt}$$

A quick refresher in calculus: the integral represents the area under a curve, so in this case the curve would be a graph of the maximum sustained wind speed of a storm over time (Velocity cubed), and the integral of V3 would be the area under this curve starting at the beginning of the storm $\mathtt{t0} = 0$, and ending at time t. This is shown by the 0 and t at the bottom and top, respectively, of the integral symbol. [MLH: great!, can we create a simulation and show PDI as it relates to t or v?] A simplification of a previous statistic that was problematic as it input data[MLH: what is the input data needed? I assume that t and V are not enough?] that was seldom recorded, Emanuel (2005) notes that "this [new] index is a better indicator of tropical cyclone threat than storm frequency or intensity alone." Because it does well to estimate the damage of tropical cyclones, only requires one input[MLH: but not measured?], and is easy to evaluate, it is often used to represent tropical storm damage. Using PDI to gauge storm intensity, numerous studies conclude that tropical cyclone intensity will increase under climate change (Zhang et al., 2017), (Emanuel, 2013), (Chen et al., 2021). To apply physics to large scale climatological events, scientists use climate models, which divide up the earth's surface into grid cells, and use complex equations based on fundamental laws of physics, fluid motion, and chemistry to describe how energy and the materials within the grid move through it (NOAA, ????). A visual of this type of model is given in the figure below.

When a model is âĂIJrunâĂİ,[MLH: we can move this the the climate change chapter if you would like and then just summarize the topic as it relates to your chapter, might be less repetitive for the reader and we'll add you to another chapter authorship] scientists set the variables to certain predictable climate conditions, such as greenhouse gas concentration, and solve the equations for those conditions (NOAA, ????). The results are then plugged into the next grid, and so on, repre-

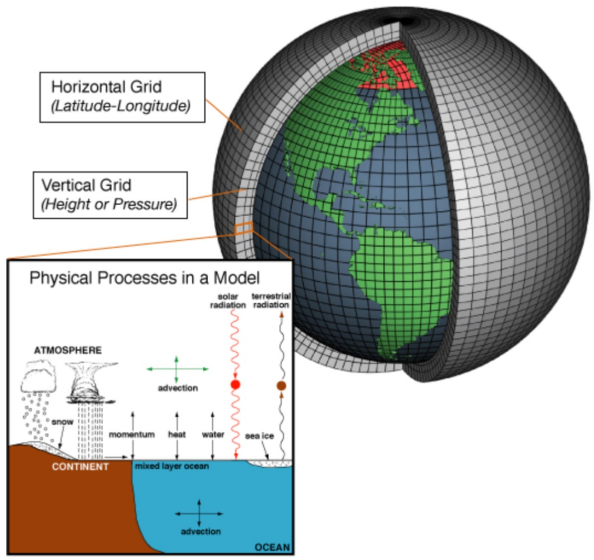


Figure 2.6

senting the passage of time. To test the models, climatologists run the models back in time, ensuring the results are similar to what has actually been observed before simulating future conditions.

[MLH: back to your topic, right?] Applied to tropical cyclones and climate change, these models allow scientists to make conclusions about how greenhouse gasses will affect storms. While the effects of climate change on storm frequency are unclear((Emanuel, 2013), (Chen et al., 2021)), multiple studies have shown an increase in tropical cyclone intensity due to climate change (Zhang et al., 2017), (Emanuel, 2013), (Chen et al., 2021). This finding is in consonance with what the physics of tropical storms predicted (Emanuel, 1987). Presented graphically, this can be seen by an increase in PDI in climate models set for expected greenhouse gas concentrations over the next century (recall that PDI is calculated using wind speed, one of the physical processes modeled in climate models). In sum, tropical cyclones can be modeled with the carnot cycle to predict the maximim power output of the storm. This model predicts that an increase in greenhouse gas concentration will cause storms to become more powerful, a prediction that is backed up by climate modeling.

[MLH: GREAT chapter, I love the physics and discussion of carnot cycle, I think we might back up and teach some thermodynamics as another "interuption" into the history of the phillipines, I have some ideas of you want to think about it]

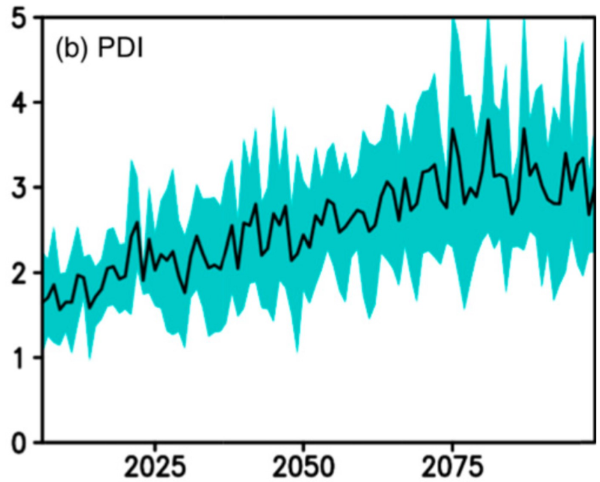


Figure 2.7

Chapter 3

Climate Infrastructure in Vietnam

3.1 Introductory

How climate change will impact Vietnam

Flooding (especially coastal urban areas)

Sea Level Rise

Land Erosion

Health outcomes

Current Adaptation Plans

Strengthen existing barriers and infrastructure

Adapt cities expecting sea level rise

Withdraw from the coastlines in areas that are well below sea level

What's Needed for the Future

Stronger healthcare system

Support for farmers and agricultural workers

Support for rural population near Mekong and Red river deltas

3.2 Conclusion

Implications for other places in the region

Chapter 4

Coral Reefs, Ecosystem Services, and Indigenous Peoples

David Chengwen Gorman

4.1 Coral Reef Ecosystem Functioning and Interactions

4.1.1 Rainforests of the Sea

In November 2018, North Sentinel Island, an island in the Bay of Bengal smaller than 60 square kilometers, drew international attention after its indigenous inhabitants killed an American missionary. The Sentinelese, one of the last uncontacted people groups in the world, have occupied North Sentinel island for the last 60,000 years. Surrounded by shallow, razor-sharp reefs, the Sentinelese have managed to remain isolated from the rapid development of neighboring Southeast Asian countries and still practice traditional customs and ways of life (Smith, 2018).

This hunter-gatherer tribe is just one of the thousands of Southeast Asian communities that rely on coral reefs for both protection and sustenance. While most do not practice the traditional hunter-gatherer harvesting practices of the Sentinelese, coral reefs remain fundamental to the lives of millions across Southeast Asia. Unfortunately, coral reefs face significant threats and at the current rate of degradation, reef survival is unlikely. The declining health, in terms of biodiversity, biomass, and fitness, of coral reefs impacts not only the overall condition of the global environment, but negatively affects the majority of the Southeast Asian population. Of these millions, marginalized groups like the indigenous peoples of Southeast Asia are affected disproportionately. Reef destruction will severely harm both the livelihoods and sovereignty of the Sentinelese and other groups like them.

The coral reefs have become vital components of many Southeast Asian, coastal communities and indigenous groups alike. This fragile, colorful marine ecosystem boasts high levels of both biodiversity and biomass, which are vital to both reef survival as well as the millions worldwide dependent on reefs for sustainably and economic prosperity. These life sustaining ecosystems are akin to the rainforests of the sea. There are nearly 100,000 square-kilometers of coral reefs in Southeast Asia supporting between 600-800 different coral species. Healthy coral reef ecosystems provide various anthropological benefits, or ecosystem services, to people of all socioeconomic backgrounds. Reefs, with their high levels of biodiversity and biomass, provide food to over a billion people annually, are a major destination for tourism, and hold great promise for biomedicine.

As a multi-faceted and dynamic ecosystem, the reefs are constantly changing. They face countless threats and stressors, including the effects of climate change, pollution, and overfishing; the reefs are struggling. General reef health serves as an indicator for both global and marine ecosystem health, and unfortunately, the easily observed reef degradation is representative of many other ecosystems worldwide (Burke et al., 2002).

This chapter describes coral reef ecosystems and current environmental and anthropocentric threats to coral reefs in Southeast Asia. Because of reefs high value to Earth and indigenous groups, conservation is essential; reef restoration efforts will also be highlighted. The following sections will detail the dynamics, threats, and benefits of the Southeastern Asian coral reefs, while focusing on indigenous interactions and their reef reliance. This chapter will stress the importance of reef protection and restoration, and how it is not only an ecological issue, but an environmental justice one as well.

After reading this chapter, the reader should appreciate:

- Coral reefs are threatened but vital ecosystems which sustain both marine and human life
- Threats to corals are threats to the reef ecosystem as a whole, and in turn are threats to the millions that rely on them
- Of the millions reliant on reefs, indigenous people are some of the most directly dependent; they are disproportionately affected by reef degradation and destruction

4.1.2 Coral Ecology

Coral is composed of tiny animals referred to as polyps. Hundreds of thousands of these polyps work together to build the visible coral structures which comprise reef ecosystems. Each coral polyp uses calcium and carbonate ions that have been dissociated in the surrounding water to create calcium-carbonate (limestone) skeletons (Figure 4.1). During the day, these vulnerable, nocturnal creatures hide in their limestone skeletons to protect themselves. At night, they extend either six (hexacorals) or eight (octocorals) tentacles to feed, using specialized cells called nematocysts to stun their prey before consumption. Most species of coral are extremely slow growing, and the majority grow by less than an inch every year (CORAL, 2021).

The majority of corals, and the ones more essential for the construction of the reef ecosystem, are classified as hard corals. These corals are reef-building corals, or hermatypes. They create the calcium carbonate skeletons which support the coral reef ecosystem. (CORAL, 2021). The body of each coral is transparent; the intricate colors come from single-celled eukaryotic cells called dinoflagellates, more commonly referred to as algae. This grouping of small, photosynthetic algae live inside the coral skeletons and maintain a close, interactive relationship advantageous to both species referred to as symbiosis. The algae symbiotes within the corals are generally referred to by their colloquial, zooxanthellae. (NOAA, 2019*b*). These algae grow inside the coral and photosynthesize, providing the necessary nutrients and oxygen the coral needs to grow and survive. The coral protects the zooxanthellae with its calcium-carbonate skeleton, and via respiration, provides the carbon-dioxide needed for photosynthesis. This symbiotic relationship between coral and algae is delicately balanced, and small disruptions can have catastrophic effects not only for the organisms involved, but also for the entire ecosystem as a whole. (Brandl et al., 2019)

Corals are slow growing, as they require a delicate balance of nutrients and environmental conditions. Both nutrient influxes and nutrient deficiencies interrupt the coral-zooxanthellae symbiosis, hurting both species. Most species only grow between 0.2-1 inch per year. A reason for this slow growth is that coral reproduction mechanisms are easily disrupted, either from localized pollutants

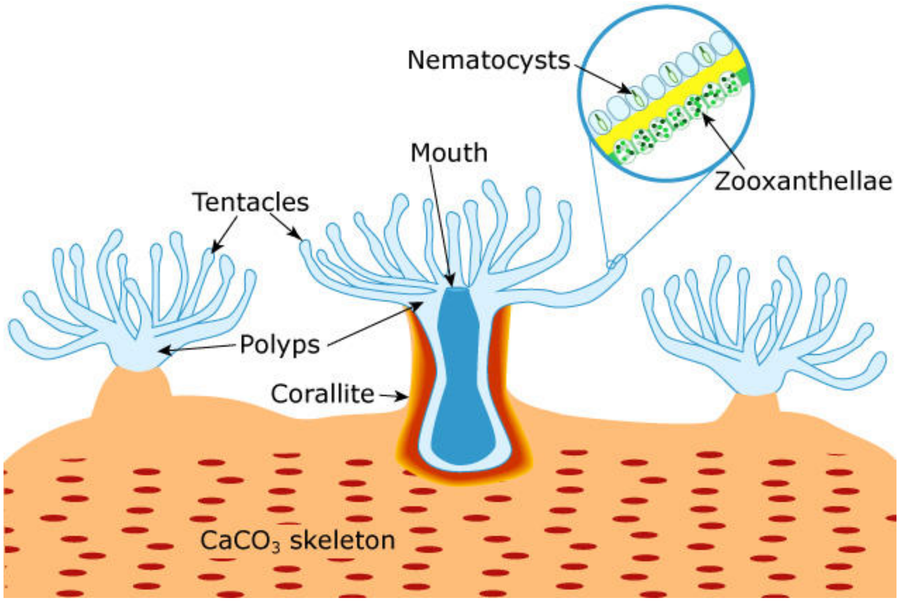


Figure 4.1: This simplified diagram illustrates the anatomy of each coral, its skeleton, and symbiotic zooxanthellae relationship. The mouth of each coral polyp is surrounded by tenacles, each full of stinging nematocyte cells. The zooxanthellae inhabit the tentacles, and, along the coral, use the limestone skeleton underneath for protection. Hundreds of thousands of these polyps compromise a single "visible coral," all working sharing the same calcium-carbonate skeleton (NOAA, 2019*b*).

or globalized climate change related issues. Coral reproductive processes are highly vulnerable to changes, as they are affected by the water temperature, time of the year, tidal cycles, and lunar cycles, and vary by species (CORAL, 2021).

For the duration of this chapter, the term "coral" will be used to describe the network of polyps which comprise the visual structures of the reefs.

4.1.3 Reef Organisms and Trophic Interactions

The coral reef food web (Figure 4.2), or the relationship between successive trophic levels of the community, starts as any other food web, with energy being derived from the sun by primary producers via photosynthesis. Primary producers include seaweed, grass, phytoplankton, and perhaps most importantly, the zooxanthellae coral symbiotes. As only about 10% of the energy in a trophic level is passed to each successive level, primary producers must be the most abundant group. The second trophic levels, the primary consumers, includes zooplankton, mollusks, squirrelfish, urchins, and of course, the coral polyps themselves. Following this are the secondary consumers, made up of triggerfish, Parrotfish, butterfly fish, and more. Finally, tertiary consumers like the reef shark and barracuda finish this food web, with detritivores like sea cucumbers or bacteria decomposing and recycling organic matter back into the ecosystem (McClanahan and Muthiga, 2016).

A wide range of species in the reef ecosystem depends on coral polyps, thus making them a keystone species. Corals are a specific classification of keystone species known as ecosystem engineers; they provide the entire structure and habitat from many reef-dwelling creatures with their calcium carbonate skeletons. The coral polyps themselves constitute a small percentage of the total biomass

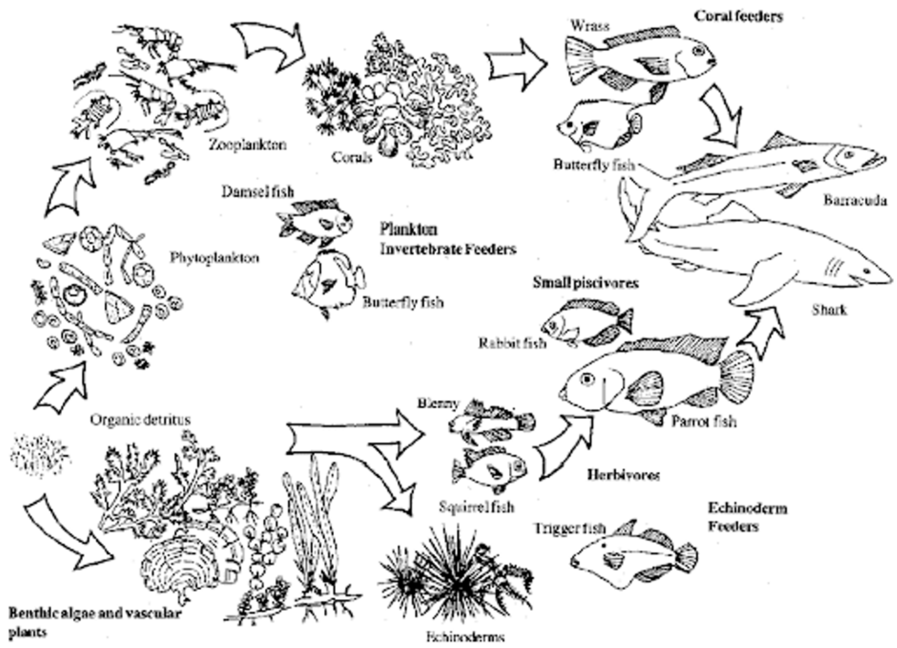


Figure 4.2: Food webs like the one displayed above illustrate the many different feeding interactions within the reef ecosystem. No food web can be completely comprehensive, as the reefs are home to thousands of different species, all interacting with each other. Species may fall into multiple trophic levels depending on their diet and feeding interactions. Food webs like the one shown above provide simplified examples of the feeding relationships and energy transfers within the ecosystem.(McClanahan and Muthiga, 2016).

of the ecosystem, as the average coral polyp is only around 1.5 cm large, yet their impact is vital to the ecosystem's survival. To the naked eye, observable "coral" includes these skeletons, and the symbiotic algae living within them; the coral polyps themselves make up a significantly smaller biomass percentage as one would perceive.

Many species depend on these coral skeletons for either protection or as hunting grounds. Fish, invertebrate, and other organisms aggregate around these underwater structures, accounting for the ecosystemâĂŹs dense biodiversity and high overall biomass. Some argue that the Parrotfish is another, secondary keystone species. This herbivorous fish eats algae latched onto the coral skeletons, which blocks sunlight and limits the photosynthetic abilities of the zooxanthellae. In a sense, its mutualistic niche is to "clean the coral," allowing normal function to continue. The Parrotfish is a highly targeted, overfished species, and because it fulfils an important niche, its removal negatively effects the entire reef ecosystem. This specific niche is just one of many, all which illustrate the complex relationships involved in the coral reef ecosystem and the importance of each species to the ecosystem (McClanahan and Muthiga, 2016).

These inter-species relationships can be further illustrated by an examination of the indirect actions which affect entire ecosystems and stem from trophic-level suppression, known as trophic cascades. For Southeast Asian reefs, the most prolific trophic cascade exists between urchins and the orange-lined triggerfish. The triggerfish is a keystone predator and limits uncontrolled urchin expansion. Without these predators, urchin populations would explode and consume everything on

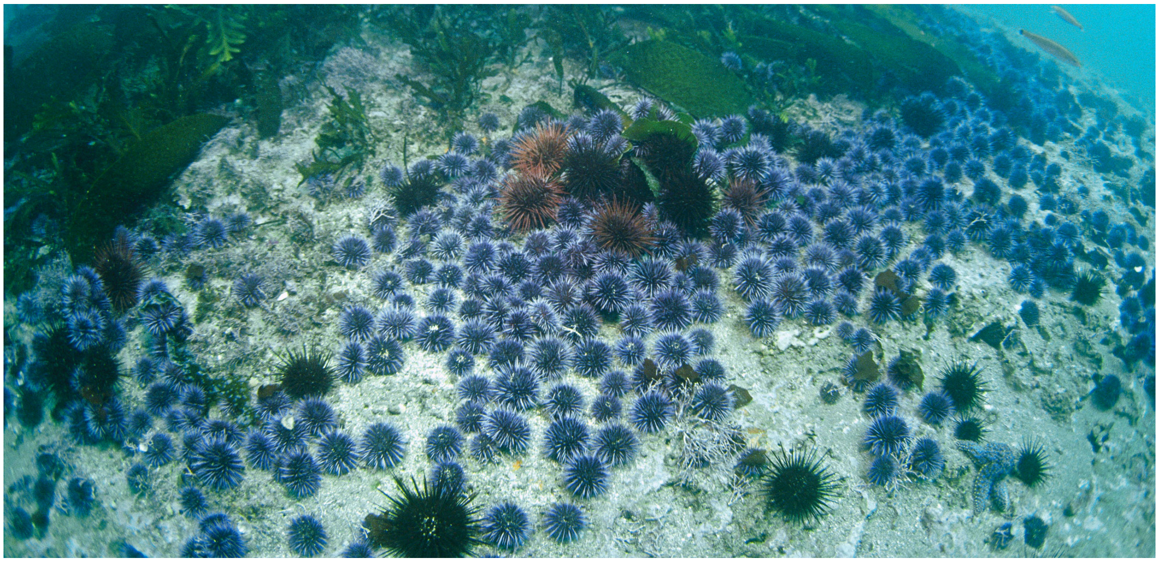


Figure 4.3: :Pictured above is a seafloor that has been completely overrun by urchins and cannot effectively sustain life anymore. As anthropologic activities influence organism within ecosystems, the natural checks and balances systems degrade and certain species may quickly become dominant, seen with the urchins and the creation of these urchin barrens. The simple removal of the urchinâĂŹs keystone predator, the orange-lined triggerfish, can be enough to cripple entire ecosystems, illustrating the fragile balances within the reef ecosystem (McClanahan and Muthiga, 2016).

the seafloor, creating urchin barrens (Figure 4.3) incapable of supporting life. These predator-prey interactions are disrupted by anthropocentric activities, mainly overfishing. As the fish are removed from the ecosystem at an unsustainable rate, the detrimental grazer effects of the urchins are exacerbated. While negative human influences will be discussed in future sections, this illustrates how interconnected reef species are the delicate equilibrium between them (McClanahan and Muthiga, 2016).

4.1.4 Necessary Climate and Nutrients

Coral reefs require a delicate balance of nutrients and external conditions, which is easily disturbed, making them especially vulnerable. As for physical needs, sunlight is a crucial limiting factor of the ecosystem. The zooxanthellae require shallow waters with low turbidity, or high clarity. This means they generally can only survive in waters under 50 meters, mostly free of sediment and debris. The water also cannot have too many nutrients, as rapid, uncontrollable, explosive algae growth can cloud waters and block the necessary sunlight needed for photosynthesis. Corals reefs exist in tropical climates usually, as they also need warmer waters of around 20-32 °C (68-90 °F). Finally, corals need water with a high salinity, or saltwater concentration. They cannot survive in brackish water or estuaries, or anywhere where freshwater sources like rivers drain into the ocean. The tropical, warm climate of Southeast Asia satisfies the aforementioned necessary reef-building conditions, explaining the abundance of coral reefs in the region (Brandl et al., 2019).

The first, blue cycle (Figure 4.4), calcium carbonate dynamics, is directly correlated with the coral skeleton formation. Bioerosion, or the breakdown of hard oceanic substrates, leaves behind calcium and carbonate ions, which coral polyps use to produce their limestone skeletons. The

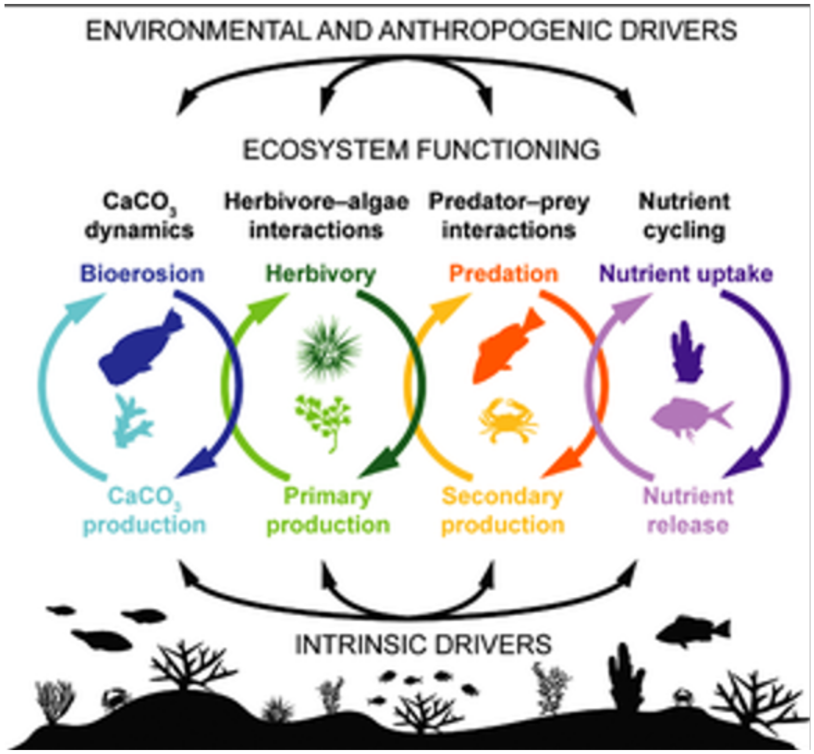


Figure 4.4: The above cycles and reciprocal processes are vital for coral growth and survival. They will be further discussed in the following paragraph. Figure from: (Brandl et al., 2019).

second, green cycle (Figure 4.4), herbivore-algae interactions, involves both primary production and herbivory. Photosynthetic organisms transform sunlight into chemical energy, which is then moved up in trophic levels by herbivores. A balance between the two must be maintained to prevent explosive growth of lower trophic levels, which in turn could suppress crucial processes carried out by other organisms in the ecosystem. Predator-prey interactions, the orange cycle (Figure 4.4), also regulate explosive trophic level growth, as successive trophic level limits the prior. Again, the balance keeps the biomass of one species from dominating and smothering other species. The final process driving success within the coral reef ecosystem is the purple cycle (Figure 4.4), nutrient cycling, or the uptake and release of nutrients among the organisms of the ecosystem. Nutrients must be cyclically moved efficiently and effectively while maintaining an equilibrium between retention and reintegration. (Brandl et al., 2019).

4.1.5 Southeast Asian Reefs by Country

Although coral reef locations are relatively limited (as the conditions from 4.1.4 must be satisfied), they can be found in over 100 countries, mainly between the Tropics of Cancer and Capricorn. Many reefs are concentrated in shallow waters surrounding islands of the Indo-Pacific, with Indonesia and the Philippines composing a majority of not only Southeast Asian reefs, but also reefs worldwide (Figure 4.5). Coral reefs cover 284,300 square kilometers (110,000 square miles) worldwide, yet the overall area of healthy reef is decreasing rapidly (Spaldin et al., 2001).

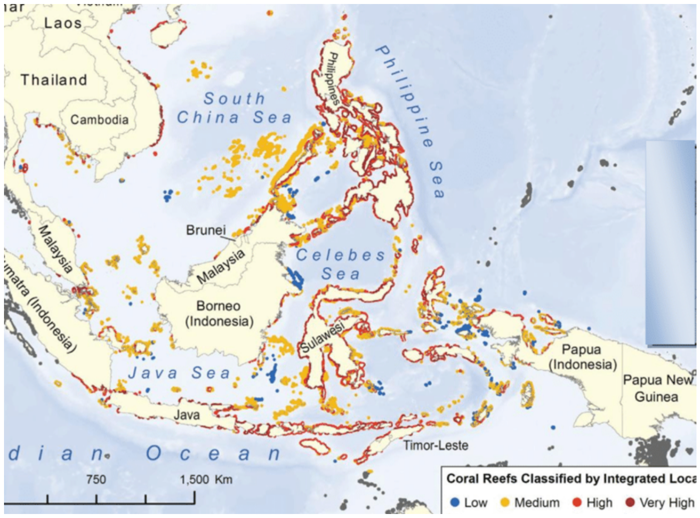


Figure 4.5: This map not only shows the locations of Southeast Asian coral reefs, but also the relative risk levels associated with each reef. The threat levels are as follows: blue = low, yellow=medium, red=high, maroon=very high. The suggested threat levels describe local threats; global threats like climate change are not accounted for (Spaldin et al., 2001).

Table 4.1: Southeast Asian Coral Reef Size by Country

Country	Rank	Reef Area	Percentage of World Total Reef Area
Indonesia	1	51,020	17.95%
Philippines	3	25,060	8.81%
Malaysia	17	3,600	1.27%
Japan	23	2,900	1.02%
Thailand	26	2,130	0.75%
Myanmar	27	1,870	0.66%

Southeast Asian countries account for over a quarter of all the worlds coral reefs (Table 4.1). While Indonesia and the Philippines dominate total reef area, many coastal Southeast Asian countries have reefs of their own, all which face similar anthropocentric pressures. (Spaldin et al., 2001).

4.2 Climate Change and Its Effects on Coral Reefs

4.2.1 The Indigenous Paradox

Climate change and global warming are undoubtedly one of the biggest contributors to the loss of biodiversity and overall destruction of coral reefs. The IUCN Red List Index (RLI), a comprehensive list tracking biodiversity loss and extinction risk, identifies this, stating corals as one of the fastest declining species (in terms of diversity and richness) in response to climate change (Almond and Petersen, 2020). Even if all localized reef threats and pollutants were eliminated, the overarching threats of ocean acidification and rising temperatures can eradicate reefs entirely (Keller et al., 2009).

In addition to reef eradication, climate change disproportionately effects lower socioeconomic classes, specifically, indigenous people groups. Many Southeast Asian indigenous coastal peoples are reliant on reefs not only for food and sustenance, but they also have strong cultural ties to the reefs and surrounding waters. Climate change threatens these indigenous people-reef ecosystem interactions, and these threats compound other climate change-associated dangers affecting indigenous groups. As many indigenous groups inhabit harsh and isolated environments, they are highly vulnerable to the rising sea levels and increased storm severity resulting from climate change. They are also often excluded from policy discussions and legislative responses to climate change, further increasing their susceptibility to climate change disturbances (Lyons et al., 2019).

The ecosystem expertise and resilience of Southeast Asian indigenous groups, coupled with a high vulnerability to climate change, creates what some call "The Indigenous Paradox." Indigenous groups are some of the most prepared groups to respond to climate change, while simultaneously disproportionately vulnerable to its negative effects. Indigenous groups are perpetually ransacked by reef degradation, however, plethora of knowledge concerning specific environments and ecosystems is passed down generationally which can be used to curtail and reverse climate change. The highly valuable resources offered by indigenous people are further discussed in Section 4.6.3 (Lyons et al., 2019).

4.2.2 Rising Sea Level

A primary issue when discussing climate change and the ocean is rising sea levels. This is due to both melting polar ice caps and thermal expansion of water molecules caused by the rapid increase in temperature, or thermal heat, in recent years. Sea levels are projected to continue to rise 0.5-1.5 meters by 2100, undoubtedly impacting both submerged ecosystems and coastlines worldwide. (Chen et al., 2018).

In contrast to the negative impacts, Brian Keller, Regional Science Coordinator of NOAA's Office National Marine Sanctuaries, and his colleagues conducted a study concerning sea level rise and its effect on corals on the Sanya Bay of the South China Sea, where they discovered a potentially unforeseen positive development: the sea level rise promoted coral growth. The previously degraded reef was able to recolonize via asexual fragmentation in response to the 16.2 ± 0.6 cm rise over the previous 30 years. Of the corals the study surveyed, 86% were under 30 years old, suggesting that the rise in sea level promoted their growth. This phenomenon can be explained by the rise in coral growth accommodation space, as sea level rise increases the vertical space a coral can grow in. As the coral gets closer to the surface, growth is inhibited by temperature, exposure, and sediment, but by increasing the overall depth, growth can occur in a greater area of water. This study is not predictive of universal coral growth, however, and holds significant uncertainties concerning prospective implications. Only specific coral species are suited for a rapid rise in accommodation space, which may select out other species. This leads to an increase in total growth but a decrease in biodiversity, and with organisms as vulnerable as coral, biodiversity is crucial (Chen et al., 2018). Coral growth capacity is likely to be inhibited by other factors, both regional and global, so an increase in accommodation space may have negligible overall impact (Keller et al., 2009).

As sea levels continue to rise, they pose risks to coastal regions, with the threat of washing entire communities into the ocean. Such catastrophic events would undoubtedly add sediment and pollutants to the water while also physically damaging corals and other organisms with the marine debris. Community submergence would also displace people groups, to other coastal areas. Thereby concentrating pressure on reefs not yet affected by coastline degradation. Increasing storm surge and flooding associated with climate change significantly influences coastal retreat. Already, over a million people in over 27 places worldwide have been forced to relocate, and this number will only increase as climate change worsens. (Sinay and Carter, 2020) Indigenous groups and other coastal communities are disproportionately threatened by sea level rise, as they are forced off their lands by both nature and self-serving corporations and governments. As rising sea levels and issues of displacement increase, even benevolent governments struggle to accommodate affected citizens and displaced people groups. These threats to coral reefs may seem distant, but they are quickly approaching realities imposed by climate change (Keller et al., 2009).

4.2.3 Ocean Warming and Acidification

Climate change has already begun to negatively impact reefs in quantifiable ways that can be observed at the molecular level. As greenhouse gases are released and trapped in the atmosphere, they prevent heat escape and also contribute to smog and air pollution. The primary greenhouse gas, carbon dioxide (CO_2), is released in high amounts when fossil fuels like coal and natural gases are burned for energy. Fossil fuel emissions release carbon dioxide into the atmosphere, but scientists believe about one third of the CO_2 is absorbed by the ocean. The increase in greenhouse gases emissions from fossil fuel burning contributes to both the warming of the planet and the acidification of the ocean (Keller et al., 2009).

As atmospheric CO_2 dissolves in the ocean, it reacts with water to create carbonic acid. This carbonic acid then dissociates into bicarbonate, releasing protons in the process. These protons, when added to the water, lower the pH, making it more acidic (Figure 4.6). Since the Industrial Revolution, a 0.1 pH drop has been observed on the ocean surface, and this drop is expected to increase as global emissions continue and CO_2 concentrations rise. In more acidic conditions, corals struggle to efficiently create their hard skeletons (Keller et al., 2009). The carbonate ion saturation, or aragonite saturation, is crucial for skeletal growth, as the carbonate ion is one of the two necessary ingredients needed for calcium-carbonate formation. The bicarbonate ion formed by the carbonic acid-carbonate interactions is unusable to corals, thus slowing skeletal growth (Figure 4.6). Today, up to 60% of reefs persist in waters with inadequate aragonite saturation (Ayala, 2009).

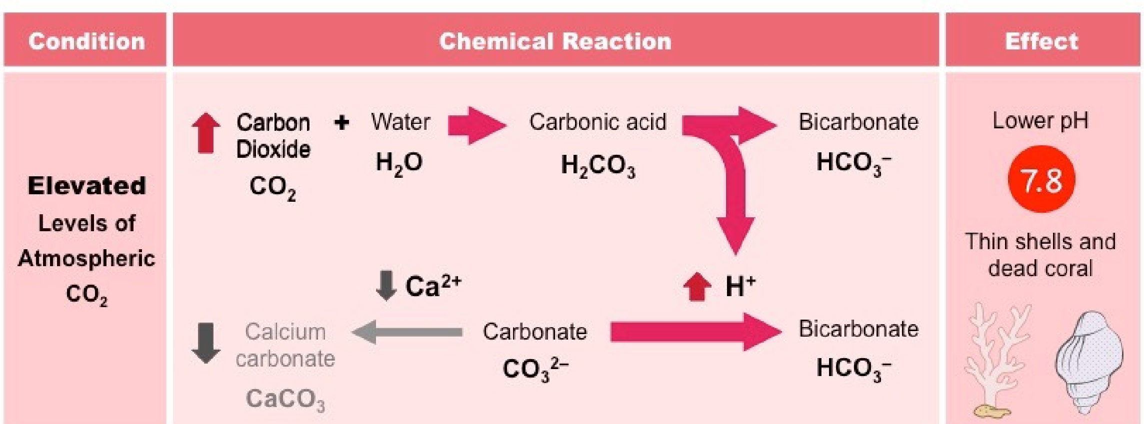


Figure 4.6: The above figure outlines the chemical reactions which connect ocean acidification with limestone formation. As carbon dioxide dissociates in the water, it creates carbonic acid, or H_2CO_3. The protons of carbonic acid are easily dissociated by the more polar water molecule (H_2O), thus dissociating and combining to form bicarbonate, or HCO_3. The dissociated protons may also form bicarbonate by reacting with carbonate ions. This chemical reaction removes carbonate ions from the water, which corals need to construct their calcium carbonate skeletons (Ayala, 2009).

The skeletons built by corals in waters lacking proper carbonate ion concentrations not only form slower but are also less robust and weaker. As a result, corals have fewer defenses to fight pressures and, combined with the slowed growth rates, may not be able to overcome the pre-existing stressors they face. Increasing acidification will likely cause coral production rates to fall below destruction rates, decreasing reef size and affecting the ecosystem as a whole. Additional stress from acidification and climate change only adds more threats to coral, creating a detrimental positive feedback loop for the already struggling polyps. The effects of ocean acidification compound on each other. The weaker skeletons stemming from low carbonate ion concentrations cannot adequately protect the corals, resulting in even lower skeletal production and exacerbating the preexisting consequences of ocean acidification on corals. (Ayala, 2009).

In addition to ocean acidification, as greenhouse gas emissions continue to cause earth's surface to warm, the ocean warms with it. This rise in temperature is the main cause of sea level rise, due to both glacial melt and the molecular expansion of water molecules in response to heat. Ocean warming and its effects on coral reefs is still a topic requiring more research, but its effects have already begun to be observed (Almond and Petersen, 2020).

Coral disease transmission is exacerbated by higher temperatures, which will be explored further in Section 4.4.4. Unusually high-water temperatures are the main cause of coral bleaching, and as ocean temperatures continue to rise, mass bleaching events are expected to increase in both frequency and severity(Keller et al., 2009). Ocean warming will have disastrous future effects on coral reefs. In 2018, Intergovernmental Panel for Climate Change, or IPCC, reported that a mere two-degree Celsius rise in temperature could completely eradicate the coral reefs, with an estimated loss of around 99% of reefs worldwide (Almond and Petersen, 2020).

4.2.4 Coral Bleaching

Most mass coral mortality events are driven by heat waves, which have increased with climate change and global warming. Coral and algae enjoy an obligate mutual relationship; they cannot survive without each other. Coral polyps react to warming water temperatures and other environmental stressors by expelling algae, a process known as coral bleaching (Figure 4.7) which has the potential to rapidly destroy entire reef ecosystems. The disruption of the coral-algae symbiosis caused by the loss of algal endosymbionts causes the corals to pale, as the algae are responsible for coral coloring. If the water does not cool or other stressors persist, algae cannot regrow, starving the coral. Emaciated corals crumble into white, lifeless skeletons (Suggett and Smith, 2020)

The depletion of a singular species shifts the organismal balance and negative ecological effects cascade throughout the ecosystem. Many habitats are destroyed as the coral, the keystone species and ecosystem engineers, are removed. The population balances within the ecosystem in turn shift, for the species more directly dependent on corals are disproportionately affected by the bleaching events.(Suggett and Smith, 2020).

Coral bleaching is the net outcome of complex, multifactorial stressors working at both the cellular and ecosystem levels (4.2.4). Other environmental exacerbators include, but are not limited to, light availability, salinity, oxygen demand, organic nutrient availability, and inorganic nutrient availability.

Cellular Level : Reactive oxygen species, or ROS, accumulates and triggers signaling cascades prompting corals to expel their zooxanthellae. These ROS are both produced and accumulated in response to environmental changes and stressors.

Ecosystem Seascape Level : The most common stressor is heat waves. The first-ever observed mass coral bleaching event in 1998 was driven by El Niño, and rising temperatures have been

Figure 4.7: This above split-image shows the same fire coral before (left) and after (right) coral bleaching has occurred. The vibrant colors on the left image result from the zooxanthellae symbiotes, and when the corals expel them, the ghostly white color seen on the right image is observed. This color change is universal across all coral species; only the color of the calcium carbonate skeleton remains after the algae are expelled (Suggett and Smith, 2020).

accredited with the increasing frequency of bleaching events. The two recent back-to-back bleaching events in both 2016 and 2017 gained national attention, showing the vulnerability of the coral ecosystem to change on a global scale. These events also demonstrated how climate change will only make coral bleaching more frequent and of greater severity.

While a single factor may not cause a mass bleaching event, they have cumulative effects on the fragile, unadaptable coral polyps. Additionally, each factor also exacerbates the coralsâĂŹ adaptability to rapid heat change. Global warming is the origin of negative effects to this intricate, dynamic system (Suggett and Smith, 2020).

4.3 Unsustainable Fishing Practices

4.3.1 The Live Reef Fish Trade

Unsustainable fishing practices are arguably the most detrimental local practice to Southeast Asian reefs. Over 55% of reefs worldwide are affected by overfishing and unsustainable fishing techniques, and this number is higher in Southeast Asian reefs. Overfishing disrupts trophic interactions, since macroalgae, without as many fish as predators, grow disproportionality and smother corals. An overfishing-driven decline in fish stocks has made fish harder to catch, leading to a shift away from sustainable fishing practices. Unsustainable fishing threatens not only fish stocks and ecosystems, but also local economies and the people that rely on fish for food. The methods currently used to catch live fish, like cyanide fishing or blast fishing, have been incredibly destructive to the coral reefs of Southeastern Asia. Both Indonesia and the Philippines offer textbook examples of unsustainable practices which still persist today, despite efforts to regulate and ban them (Brewer et al., 2013).

A major driver of unsustainable fishing practices is the Live Reef Fish Trade, or LRFT, where selective fish are caught, kept alive, and later sold. There are two branches of the LRFT: food and ornamental. The food trade makes up a majority of the LRFT, driven largely by wealthy Asian countries' affinity for particular fish as high-priced delicacies. Certain high-commodity fish, like leopard coral reef fish, are targeted and fished disproportionately, pressuring reef ecosystems and disrupting trophic interactions. These fish can sell for as much as $60 USD per kg instead of the average $2 USD per kg for most fish. In locales such as Palawan, Philippines, where the average monthly income is under $100 USD, it is no surprise the LRFT would flourish. Fishermen explain, "It's like hitting the jackpot every time." Fish are also live caught for ornamental reasons. Vibrant, colorful reef fish are highly desired in aquariums globally, sustaining demand and further fueling the LRFT. (Fabinyi, 2010).

Many of the practices for catching live fish are inherently destructive to reefs. Fish are often caught young and then grown to an edible size. This excessive juvenile capture removes fish before they can reproduce and contribute back to the ecosystem, further reducing the fish stocks of the selected species. Other more violent methods, like cyanide and blast fishing, have horrid effects on reefs, and these will be discussed in the following sections (Fabinyi, 2010).

The LRFT has continued to grow in both the Philippines and Indonesia despite both decreasing profitability and fish stocks. This dangerous combination has led to high levels of overfishing that further destroyed coral reefs. Fishermen are catching less fish and must travel farther distances to find them, causing large scale economic losses in both coastal communities and the individuals residing in them. Because the LRFT is poorly regulated and any existing regulations are often not enforced or disregarded, the harmful impact of the LRFT is likely to continue (Fabinyi, 2010).

4.3.2 Cyanide and Blast Fishing

Cyanide fishing is as simple as diving with a spray bottle containing crushed sodium cyanide tablets which can be injected into reef crevices or squirted directly into the faces of desired fish (Figure 4.8). While larger animals may only be stunned and can later revive, the same dose is fatal to smaller organisms. Cyanide is most often fatal to small fish, invertebrates, corals, and their symbiotic algae, disrupting ecosystem functioning on multiple levels (Pearce, 2003). After just 30 seconds of cyanide exposure, coral becomes stressed and begins to lose its ability to function normally. For every live fish caught with cyanide, a square meter of reef is destroyed.

At the turn of the century, 75% of all aquarium fish coming from Southeast Asia were estimated to be cyanide-caught. (Renaud, 1997). Despite being banned in both Indonesia and the Philippines, cyanide fishing still persists today, with an estimated 75% of aquarium fish from Southeast Asia being cyanide-caught. Many live fish are caught via cyanide fishing. The minimal regulations and negligible punishments for cyanide fishing enable this destructive practice to continue. In the last six years, only six case files regarding cyanide fishing have resulted in convictions (Pearce, 2003). Approximately two-thirds of all Filipino reefs are estimated to be affected in some way by cyanide poisoning (Renaud, 1997).

Blast fishing - detonating explosives in reefs to stun fish – is another destructive practice in the live trade industry. Like cyanide fishing, smaller organisms are often immediately killed by these blasts. In addition, blasts also break the preexisting coral skeletons, destroying both the habitat and ecosystem. (Fox and Caldwell, 2006).

The explosives used are almost always homemade and can be as simple as a kerosene-fertilizer mixture inside a glass soda bottle. Just one 300mL bottle can create an explosion which leaves behind a crater with a 1-meter radius capable of lasting multiple years. Besides the general fatalities from the blasts, one of the biggest issues associated with blast fishing is the leftover coral skeleton debris. Even after five years, the rubble and debris left inside the crater can be 5-10 cm deep. This additional sediment can smother both coral and algae, either blocking light and hindering

Figure 4.8: The diver in this picture is cyanide fishing in a Filipino reef. He uses cheap, makeshift gear which can be either made from scrap or re-purposed. The warm, coastal waters allow him to dive without a wetsuit, only using wood planks nailed to slippers as fins. His bottle contains crushed sodium cyanide tablets dissolved in water, a lethal solution which will decimate the reef he is injecting it into (Pearce, 2003).

photosynthesis or burning still-intact corals alive. Larger debris and skeletal pieces can also abrase growing corals, scraping off growing colonies or hindering recruitment by blocking secure surfaces for attachment (Fox and Caldwell, 2006).

Over half of all Southeast Asian reefs are currently threatened by blast fishing practices. Like cyanide fishing, blast fishing is legislatively banned, but this ban is barely enforced. Blast fishing was banned in Indonesia in 1985, yet it still continues today, not only in Indonesia, but also in most other reef-bearing Southeastern countries (Fox and Caldwell, 2006).

4.3.3 Economic Motivations for Indigenous Peoples

The semi-nomadic, indigenous maritime communities of Southeast Asia are highly dependent upon unsustainable reef fishing. These communities are reliant on the sea for subsistence, often inhabiting areas of high biomass and biodiversity, such as near coral reefs, where resources are bountiful. Reef survival corresponds with human survival (Hoogervorst, 2012). One such group, the Sama-Bajau, reside mainly in the Philippines and eastern Indonesia. Not only do the reefs supply the majority of the Sama-BajauâĂŹs protein intake, but also provide the most economic opportunities. The reef supports a wide range of activities, primarily fishing, and additionally boat building, guided tours, and sea trading. Some groups, like the Sama-Bajau, now live in stilt houses, increasing a sense of community and stability. Unfortunately, many other groups are not officially recognized and lack legal representation. Without recognition, the highly mobile lifestyle deprives these groups of land ownership, healthcare, education, and establishing economic prosperity (Hoogervorst, 2012).

Due to complex systemic indigenous suppression, the vast majority of the reef fishermen are poor and struggle to sustain themselves through traditional fishing practices. Viewed as primitive and uncivilized, the reef-reliant, seafaring lifestyle is commonly not respected among upper socioeconomic classes. As a result, indigenous children face widespread racial and cultural discrimination, leading them to drop out of school and pursue a less economically prosperous career, like fishing. As reefs are continually degraded by issues such as climate change and local problems (e.g. corporate overfishing and pollution), sustainable fishing practices become less viable. Many indigenous fishermen have turned to more profitable yet unsustainable fishing practices like blast fishing and cyanide fishing. With the high demand of the LRFT and aquarium trade, these destructive practices promise steady, higher payouts than traditional fishing methods but put indigenous groups in a vicious cycle of further reef degradation and economic opportunity loss. Indigenous participation in these activities is not driven by greed, but purely because they lack alternatives to feed their families (Hoogervorst, 2012).

4.4 Reefs Pollutants

4.4.1 Marine Debris and Ocean Contaminants

A significant number of anthropocentric activities contribute to reef pollution. Pollutants can be classified generally in three categories: toxins, sediments, and nutrients. Toxins cause physical harm to corals and other organisms at the cellular level. They can be organic or inorganic and are often found in chemical runoff. Sediments block sunlight and prevent photosynthesis and limit primary production. They also reduce the number of viable locations for coral larvae to attach to, as the loose sediment settles on the previously secure spots on the coral skeleton. Sediment also increases the turbidity of the water, blocking visibility. This can contribute to biodiversity loss, selecting for certain animals which do not primarily rely on eyesight. Finally, nutrients can promote algal blooms which smother corals, or they can disturb organismal balances within the ecosystem, disrupting critical interactions among populations. Excessive nutrient richness, or eutrophication, can also promote pathogenic growth among corals and lead to coral epidemics. A wide range of human activities contribute to reef pollution and is exacerbated with with globalization, population expansion, and development (Todd et al., 2010).

Marine debris is essentially human trash, which enters the water via boats or from land. (Figure 4.9). Floating trash can bear resemblance to jellyfish and is often consumed by animals, obstructing their gastrointestinal intestinal tract. Lost nets, lines, and other ghost fishing gear also often entangle corals and other reef organisms, severely hindering their mobility and often killing them. The levels of marine litter in Southeast Asia generally exceed the global average, with new coastal development, ineffective regulatory methods, and heavy shipping traffic throughout the region being main contributors (Todd et al., 2010).

Plastics and marine debris commonly snag corals and shade them, so that the zooxanthellae cannot adequately perform photosynthesis, and thus starving the corals. This trash entanglement also may break off chunks of coral, killing entire colonies (US EPA, 2017*b*).

The majority of marine trash is plastics, which account for 60-80% of all marine litter. Plastics take multiple generations to degrade and can act as a skin for chemical pollutants, carrying chemicals and toxins into the water from the land or anything else they were in contact with. At each successive trophic level, plastic can be ingested, as there is significant variation among the size of plastic particles. Plastics travel up the entire food chain, decreasing both energy reserves and feeding capacity. Plastic ingestion also decreases the ability to produce offspring, or fecundity. Oceanic plastic pollution is so high that it is estimated there is not a single ocean organism that is completely unaffected by plastic ingestion, either directly or indirectly (Reichert et al., 2018).

The traditional "plastic pollutant" is a macroplastic, that is, visible to the naked eye. In actuality, microplastics, or plastic particles under 5mm, comprise the majority of plastic pollution and are

Figure 4.9: Plastics and marine debris commonly snag corals and shade them, so that the zooxanthellae cannot adequately perform photosynthesis, and thus starving the corals. Coral engulfed by plastic bags like the one above are highly susceptible to disease, as the plastic bag creates a warm, hypoxic environment that is ideal for pathogen transmission and infectivity. This trash entanglement also may break off chunks of coral, killing entire colonies (US EPA, 2017*b*).

increasing in concentration at alarming rates. These microplastics can enter the surrounding reef waters as fragments from larger plastic debris or in terrestrial runoffs and waste dumps. They affect different species of coral differently, but each varying effect is almost always negative. They may attach to corals and disrupt cellular functioning, or they can cause excessive mucus production and overgrowth. Microplastics are small enough for corals to ingest, and the corals retain the plastic fragments for extended periods of time. Microplastic exposure may trigger signaling cascades related to cleaning and digestive responses among different coral species. In a microplastic-coral interaction study, five out of the six coral species examined displayed serious negative health effects when exposed to microplastics. In areas with higher concentrations of microplastics, bleaching and tissue necrosis was widely observed. To account for this studyâĂŹs short time period, corals were exposed to microplastic concentrations significantly higher than environmentally observed. While this produces considerable uncertainty, this study still shows that microplastics do negatively impact corals and calls for future studies over longer periods of time with environmentally realistic microplastic concentrations. Microplastic exposure is continually increasing, and poses a serious threat to reefs, corals, and reef organisms alike (Reichert et al., 2018).

Both sewage and wastewater discharge contribute a significant amount of toxins and contaminants to reef water. Chemicals, toxins, bacteria, and pathogens can enter reef ecosystems from cesspools, septic tanks, landfills, sewage treatment plants, and more. These chemicals have obvious negative effects on coral reefs, as many of them can either kill or infect corals and reef inhabitants. In Southeast Asia, over 80% of sewage deposited in the ocean is left untreated, inevitably depositing high levels of toxins and chemicals into the waters (Todd et al., 2010). One of the most prevalent chemicals affecting coral reefs, however, comes not from industrial waste and sewage, but from tourists and everyday people. Oxybenzone is a common component of sunscreen, which enters the water whenever people wearing sunscreen do. Along with other harmful chemicals in sunscreen, oxybenzone damages coral DNA and also accumulates in tissues, either causing death and deformities among adolescent coral colonies or inducing bleaching (US EPA, 2017*b*).

Another major source of reef contamination is crude oil, which blocks sunlight, smothering and starving reefs. Oil enters the ocean not only though spills, but also via operational discharge. This oil itself contains toxic components. One of these substance groups, polycyclic aromatic hydrocarbons (PAH), bind to coral DNA and proteins, and in turn disrupt necessary cellular functions (Todd et al., 2010). While the oils themselves are harmful, the dispersants used to clean up spills are actually more damaging to coral polyps. Surfactants, substances which reduce liquid surface tension when dissolved, are often used, as they dissolve and break apart large floating sheets of oil into smaller droplets. These dispersants are toxic to coral larvae and can kill large sections of young coral fairly quickly. They also prevent the fertilization of mature eggs and hinder coral maturation, or metamorphosis. Oil contamination and surfactant poisoning are increasing in Southeastern coral reefs, as development has continued to increase in Southeast Asian coastal regions (**?**).

4.4.2 Development, Industrialization, and the Agta People

Many coastal regions in Southeast Asia have seen rapid development in the past couple of decades. This development in itself has negative effects on reefs, as piers and other structures are often built on top of already struggling reefs, negating any chance of regeneration. Resources like sand and limestone are also sometimes extracted from reefs in a process called coral mining; large coral pieces and other reef materials are used as road fills, bricks, or cement components (CORAL, 2021). Much of this coastal development also releases high concentrations of sediment into the water, increasing turbidity and primary production within the reef. Coral reefs are continually polluted by the dredging, dumping, and shipping all associated with development as well. While development is typically a positive economic indicator, it often carries disastrous environmental side effects, as evidenced by the relationship between development and the coral reefs (US EPA, 2017*b*).

Road construction in particular generates many negative consequences for reef growth and survival. Not only does road construction release high levels of toxins into surrounding waters, but it also adds a great deal of sediment as well. Roads, as well as other impervious structures, do not allow liquids to seep into the soil. Instead, they flow across road surfaces and downward, generally towards sources of water. Even after construction is complete, runoff from coastal roads continue to contribute substantial amounts of toxins and sediment to the reefs. This is especially problematic during storms and in areas of high precipitation, as heavy rains pick up toxins and sediments from the ground and flow via roads directly into the ocean. Both Indonesia and the Philippines host monsoon climates, and because this stormwater cannot be filtered by the soil, it carries all of its pollutants into the reefs. Notable toxic substances reaching waters in greater quantities include metals like lead or mercury or organic chemicals like polychlorobiphenyls (PCBs). This particular carcinogenic dioxin not only takes a long period of time to break down, but also affects the growth rates, feeding patterns, defensive responses, and reproductive processes of all coral species. As road, industry, and urban development persist, the runoff will continue to carry chemicals, toxins, sediment, nutrients, and pathogens into surrounding reef water (US EPA, 2017*b*).

In addition to reef degradation, development and industrialization has often displaced indigenous groups. Development indirectly undermines indigenous groups by harming reefs, but also directly hurts them via displacement and relocation. One of these groups, the Agta people of Northeastern Luzon in the Philippines, perfectly exemplify this scenario. Over the past decades, infrastructural development has displaced many of the Agta, forcing them to live as landless peasants on the outskirts of other towns and villages. Despite national legislation ruling against displacement, one Agta group has been involved in a multi-decade struggle, fighting against displacement from their ancestral land, Dimasalansan. They do not legally own the land but instead were given settlement rights in the protected park by the Filipino government. This lack of quantifiable ownership, however, has made it easier for displacement to occur. One standout, displacing developmental project has been the construction of an 82km road through Dimasalansan. This project planned for indigenous displacement, stating that the construction will allow the Agta to adopt "the culture and ways of the (incoming) migrant population" and also that "relocation of livelihood/business and dwelling/camps...shall be formulated." Developmental projects often justify indigenous displacement by arguing that they are already semi-nomadic and not place-bound, so relocation is relative (Hagen and Minter, 2020).

This involuntary displacement forces indigenous groups to adopt differing ways of life. Much of the Agta lifestyle consists of spearfishing the shallow reefs of their native waters, and as they are displaced and pushed further inland, they cannot continue their traditional practices. Instead, they must adopt different livelihoods, and turn away from their ancestral reef reliance, breaking the longstanding cultural ties and connections to the water (Persoon and Minter, 2020).

4.4.3 Deforestation and Agriculture

As the aforementioned Agta are continually forced inland, they must find new economic activities to sustain themselves. The most commonly chosen new livelihood is small-scale, swidden agricultural cultivation. Slash-and-burn technique is used to clear areas for farming, contributing to both deforestation and agricultural issues in the near-coastal forests. Both are contributors of reef pollutants, further harming the already struggling reef ecosystems and the other indigenous coastal groups who still rely upon them (Persoon and Minter, 2020).

Deforestation adds high levels of sediment into the surrounding waters, smothering coral. Corals and their endosymbionts in sediment-filled water cannot carry out nightly respiration or daily photosynthesis in an efficient manner. In Indonesia, palm oil plantation growth is a major contributor to deforestation, while in the Philippines, the expansion of logging and agriculture industries is the main cause. In both countries, corruption, poor regulation, and economic greed have exacerbated this issue. One specific tree of interest is the mangrove, which is particularly important to reef protection. Many reef fish raise their young in the protected labyrinth of the mangrove forest, and without it, many offspring become easy prey. In addition to the traditional consequences of deforestation, mangrove destruction also means nursery loss. Mangrove forests also act as filtration systems for sediment, and without them acting as a barrier, more sediment from runoff and other human activities reaches reefs. Three quarters of the mangroves in the Philippines have already been lost, and as agriculture continues to expand, this number is likely to rise (CORAL, 2021).

Agricultural runoff also adds sediment to reef water, but more importantly, agricultural runoff adds excess nitrogen, phosphorus, and other nutrients. Generally, having more nutrients is beneficial, but the reef ecosystem is adapted to survive only at specific, lower-nutrient levels. Nutrient excess selects for other organisms like seagrass, however, which boom in population and outcompete corals for their required nutrients. This eutrophication stems mainly from runoff and discharge containing manure, fertilizers, aquaculture byproducts, and pesticides. Manure and other fertilizers cause phytoplankton booms which not only block sunlight but can also create toxins that are dispersed throughout the ecosystem. These massive algae blooms also require tremendous oxygenic support, causing hypoxic conditions in the water surrounding them. The already struggling organisms often succumb to hypoxia and die off in mass quantities. When pesticides reach the waters, they generally disrupt the symbiotic coral-algae relationship. Herbicides in particular are very dangerous, as they kill the algae and induce bleaching. Finally, when corals are exposed to too many nutrients, bacteria and other pathogenic growth are promoted. Diseases and coral contamination quickly follow (Todd et al., 2010).

4.4.4 Coral Diseases

Corals are highly susceptible to diseases. They lack virtually any dispersal barriers and spread rapidly due to how close in proximity coral colonies are to each other. Viruses, bacteria, and fungi can cause diseases among coral species, which all proliferate with temperature increases and lower water qualities. As a result, global warming and other anthropocentric activities have led to an increase in coral diseases(Keller et al., 2009).

Pathogens often enter the reef water through runoff and stormwater containing fecal matter, inadequately treated sewage, and other contaminants. One of the major human sources of coral diseases, however, is plastics. Land-based pathogens attach to micro-holes in plastics, and when they reach the reef, the pathogen can disconnect and then reattach to the polyps. A coral that has been in contact with any plastic is twenty times more likely to be infected with a disease than one that has not. For Southeast Asia, a region with an estimated 11 billion plastic reef entanglements, this is a major issue. Reefs that have no plastic exposure have a 4% lethal coral disease probability, which, while still high, pales in comparison to the 89% lethal disease probability of plastic-entangled reefs. Plastic entanglement can potentially create perfect conditions for viruses and bacteria, as sunlight and oxygen may be blocked, and temperatures can increase in sort of a greenhouse effect (Figure 4.9). As certain coral species are more likely to snag plastics than others, plastic-induced pathogens also contribute to biodiversity loss among coral species (Thompson, 2018).

Figure 4.10: :This picture shows a brain coral that has been infected with black-band disease. The left side of the coral is how healthy coral appears; the right side is diseased. This particular coral diseaseâĂŹs name is derived from the black circumferential band in the middle of the coral. As the disease progresses, the band travels along the coral, killing polyps and leaving behind a dying, empty skeleton (seen on the right half of the coral) (NOAA, 2019*a*).

Though the methods of transmission are well-theorized, the exact pathogenic causes of coral diseases are not well understood. The effects of coral diseases are nevertheless clear. Diseases always present some sort of indicator, including red, black, white, or yellow bands, discolored spots and blotches, or rapid degradation and general tissue loss (Figure 4.10). Coral diseases also cause large coral chunks to slough off, exposing the calcium carbonate skeleton underneath. After the area is exposed, small reef creatures inhabit it, using it for shelter and breeding. This over-colonization thus cannot be regrown with new corals, so instead of only the chunk dying, the entire colony passes with it. Very little treatment is available for coral diseases, as currently, black-band disease is the only treatable disease. Coral diseases pose great threats to reefs, as they are not easily combated and can spread rapidly through entire ecosystems (NOAA, 2019*a*).

4.5 Reef Ecosystem Services

4.5.1 Biomedicine

Coral reefs host a vast array of human benefits, which helps to explain why they have been so overused and exhausted. Coral reefs hold massive medical potential, though currently that field of biomedicine is lacking and underdeveloped. As stationary animals, corals need chemical defense mechanisms to protect themselves from predators. These chemical defenses also help to fight diseases and combat environmental stressors. Ideally, one would be able to replicate these chemical processes in drugs for humans to use as defenses to diseases and illnesses. Coral medicine is still in the early stages of development; its importance comes mainly from the potential it holds (Bruckner, 2002).

Coral reefs have been referred to not just as the medicine cabinet of the sea, but the medicine cabinet of the 21st century. These natural underwater pharmacies are genetic warehouses and hold colossal medical potential. Forty to fifty percent of all drugs currently used have natural origins, and coral reefs are estimated to have 300-400 times higher drug potentials than their terrestrial counterparts (Bruckner, 2002). New medicines to treat cancer, arthritis, AlzheimerâĂŹs, heart disease, viruses, bacterial infection, and more are currently being developed with corals as the centerpiece. One exemplary study conducted by Tseng et al. (2013) found secosteroids and norcembranoids from the coral *Sinularia nanolobata* inhibited carcinogenic skin cell growth in humans. As coral medical research is continually developed, the medical benefits of differing organic compounds in various coral species will likely be discovered. The medical potential of corals are unimaginably high (Bruckner, 2002).

With this great potential comes complications, however. Research and development into coral reef biomedicine are lacking and underdeveloped and will require a great deal of time and resources. While potentially preventing the next global pandemic or treating chronic diseases justifies the costs, the threat research may pose to corals is troublesome. Corals, as small and slow growing organisms, struggle to provide the adequate amount of product or a substance needed for research and development. While any type of harvest or removal poses potential risks to the already struggling corals, too much removal is sure to harm corals. Reefs hold massive medical potential, but any research must be conducted in an ethical and sustainable manner (Bruckner, 2002).

4.5.2 Food Sources

Despite only making up 1% of the ocean, coral reefs support over a quarter of all fish in the ocean (NOAA, 2019*b*). They are densely populated regions which provide food to people around the globe. It is no wonder six million fishermenâĂŤa quarter of the world's small-scale fishermen, actively fish the reefs (CORAL, 2021). Coral reefs provide both employment and food for the vast majority of the 350 million people living within 50km of Southeast Asian coastlines. In addition to harvesting food, reefs fisheries are vital economic players in Southeast Asia; fisheries generate over 2.4 billion US dollars every year. Indonesia and the Philippines dominate the majority of this revenue, as the total annual economic benefit is estimated at USD 1.6 billion and USD 1.1 billion, respectively. Fisheries compose the largest section of these earnings, and their true revenue is often underreported, as small-scale, sustainable fishermen often do not report reef catches in monetary values. These fishermen and their families are generally reliant on reefs for substance, and thus are more impacted by reef degradation (Burke et al., 2002).

Fish and seafood from the reefs, on average, make up around 40% of total animal protein intake for Southeast Asian diets, explaining why fishing in the Coral Triangle has continued to increase as global rates have flatlined. The Coral Triangle includes Indonesia, the Philippines, Papua New Guinea, the Solomon Islands, and Timur-Lee, but a majority of the coastal people living in the Coral Triangle reside in either the Philippines or Indonesia. Fish-related employment makes up 2% of the entire working population in the coral triangle, a whopping 4.6 million people. Over 18 million people, or 5% of the total Coral Triangle population, directly rely on reefs for food. Fishing has been estimated to account for over 5% of the gross domestic product of the countries in the Coral Triangle. The densely populated reefs rich with fish provide food for all types of people, from the average consumer shopping at a market to the indigenous person fishing purely for personal sustenance. Nevertheless, reef fisheries are crucial to sustaining Southeast AsiaâĂŹs large and growing population (Palma et al., 2014).

All socioeconomic groups across Southeast Asia are reliant in some way on coral reefs for food sources, however, lower classes are often more dependent on reefs for sustenance. The indigenous peoples of Southeast Asia are one of these heavily dependent groups. The Tagbanua People offer a case study on reef reliance representative of many other indigenous groups in the Coral Triangle. The Tagbanua People, or the People of the Village, inhabit Coron Island, Palawan on the Southwestern side of the Philippines (Figure 4.11). Thought to be descendants of the Tabon Man (16,500-year-old remains foundâĂŤ the earliest appearance of modern man), the Tagbanua are one of the oldest groups in the Philippines. They occupy a coastal region and have a very close relationship with both the water and the reefs (Capistrano, 2010).

The Tagbanua have been categorized as a semi-nomadic, seafaring native group. After agriculture, fishing is the second main economic activity. A vast majority of fishermen practice either traditional hook-and-line fishing or spearfishing and take only what is needed from the reefs. They fish both for personal sustenance and trade, but they donate excess catches to community members in need whenever possible. Tagbanua fishing is highly sustainable, as they hold high respect for the reefs and its inhabitants. As reef degradation continues, millions across Southeast Asia lose access to food and protein sources, but more directly dependent groups like lower socioeconomic classes and indigenous groups are disproportionately affected (Capistrano, 2010).

4.5.3 Tourism and the Tagbanua

Reefs attract tourists for various recreational activities. Shallow waters and high levels of biodiversity make for world-class snorkeling and diving. For the same reasons, boat tour charters and submarines also thrive from reef tourism. Coral reefs attract spear fishers as well, as there are many fish species which can be shot and caught, all while in relatively shallow water. Because reefs are natural breakwaters, they create world-class, incredibly consistent waves, which attract surfers from around the globe. Almost every world-famous wave breaks over the reef, and the shallow reef waters provide fast, hollow waves perfect for barrelsâĂŤevery surfer's dream. Bali, Indonesia, is just one example of a destination which attracts surfers of all skill levels solely to surf the reef-breaking waves (Almond and Petersen, 2020). Over 9% of all coastal tourism value is attributed to the coral reefs. They provide many incentives for travel, and this tourism brings both positive and negative effects (Spalding et al., 2017).

Figure 4.11: :The 12-15 million indigenous people living in the Philippines make up between 10-15% of the population. 110 groups are officially recognized, yet there are many more who have not been officially recognized by the PhilippinesâĂŹ government. Above pictured are the Tagbanua, one of these indigenous people groups of the Philippines. They either spearfish or fish from simple wooden boats like seen above. These boats are used to traverse the shallow reefs and harvest fish, lobster, squid, octopus, and other protein sources. Many other indigenous groups maintain a similar reef-relationship, one consisting of simple fishing practices, and transportation methods (Capistrano, 2010).

Globally, reef tourism is estimated to generate USD 36 billion yearly, and the mean value of reef per square hectare is thought to be around USD 96,000. Many recreational reef activities have been commercialized. Coral reef tourism helps to stimulate and support local economies. The general appeal of reefs has developed strong tourist economies in the Southeastern coastal areas. This reef-adjacent tourism, including hotels, rentals, restaurants, and more, has created additional jobs and stimulated economic growth. 30% of the worldâĂŹs reefs are involved in the tourism sector, and they provide employment to over one hundred different sectors. The importance of reef tourism has provided economic incentives for reef conservation and sustainable practices. Tourism provides opportunities for conservation education and great awareness, which allows issues to be displayed on a global scale instead of only in local communities. Tourists may also become emotionally attached to reefs, providing additional incentives to support reef restoration and protection efforts, either directly or financially (Spalding et al., 2017).

While tourism does aid in economic development, it also can lead to heightened economic disparity and steal wealth from local communities. Foreign corporations and large companies often dominate tourist areas, making it so local people cannot own businesses, but instead must work for them. As tourism can be such a dominating economic force, it can also edge out other economic sectors, and large corporations can easily obtain monopolies on entire regional economies. This allows them to mistreat and underpay their workers, who are typically mainly local people (Spalding et al., 2017).

Reef tourism has also contributed to countless culturally insensitive developmental projects, which negatively affect the indigenous groups, including the Tagbanua. They are consistently pressured to lease out their land for tourism purposes, as their "pristine" surroundings are easy selling points. Tourists who have come close to indigenous lands have left pollutants and contributed to reef degradation, further harming native populations. As reefs are continually degraded, native peoples are continually harmed. The TagbanuaâĂŹs recent self-determination and land reclamation efforts are complicated by tourism and the economic greed that accompanies it. The reefs surrounding indigenous lands are highly desired, as they have not been subject to as many unsustainable practices. It is very difficult for indigenous groups like the Tagbanua to become involved in the "democratic process however," as previously only those who are formally dressed and speak fluent English are allowed to attend and participate in policy dialogues. As a result, indigenous groups can be purposefully underrepresented and their land is commonly encroached on, a practice exacerbated by tourism and perfectly exemplified by the struggles of the Tagbanua (Capistrano, 2010).

Tourism also contributes heavily to marine degradation and reef destruction. It breeds development, as hotels, piers, roads and other structures are built to accommodate tourists. This development adds sediment and other contaminants to reefs, as previously discussed in Section 4.4.1 (Spalding et al., 2017). Tourists themselves can also harm reefs during their on-reef recreational activities. They may step on corals while diving and kick up sediment while snorkeling. Tourists often are also not environmentally conscious, and they leave behind trash which pollutes reefs. They may wear chemically harmful sunscreen while in the water, leaving pollutants and chemicals in the reefs (CORAL, 2021). From buying unsustainable coral jewelry to accidentally spearing an endangered fish, tourists themselves can threaten reefs in countless ways. Tourism as a whole can be beneficial or detrimental to reefs, depending on how it is implemented, who holds the power, and how well-educated the tourists are (Spalding et al., 2017).

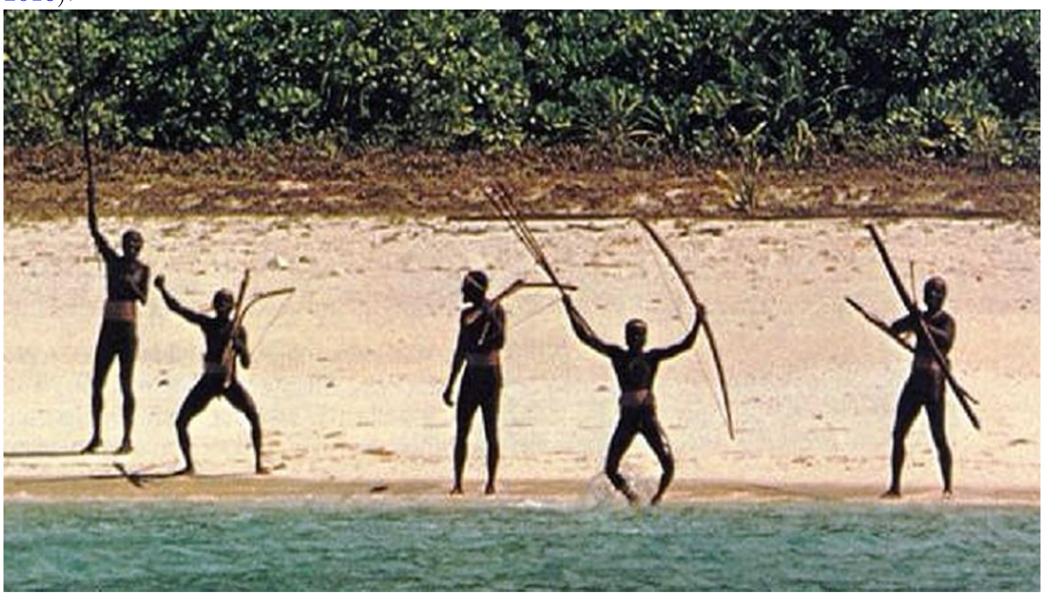
4.5.4 Coastline Protection

Worldwide, over 200 million people depend on coral reefs for protection from storm surges, rough waves, and flooding (Almond and Petersen, 2020). Waves break over patches of shallow water, and because reefs extend vertically up the water column, they serve as natural breakwaters. They reduce the power, size, and energy of waves (Beck, 2019). Reefs have been shown to reduce wave energy by up to 97%, and wave height by 84%. Waves first break over the shallowest part of the reef, the reef crest, which alone can dissipate around 86% of a waveâĂŹs energy. Without reefs, waves would break over sandbars closer to the coast, flooding terrestrial settlements and destroying dwellings. (Pelton, 2017).

In addition to acting as breakwaters, reefs provide buffers for coastlines against floods, storms, and erosion. Southeast Asian reefs protect billions of dollars' worth of coastline, as reefs continue to dissipate wave energy during natural disasters. In the monsoon climates of both Indonesia and the Philippines, typhoons occur often, and without reefs as protectors, coastlines would be hit significantly harder. Reefs protect coastlines not just from typhoons, but also from hurricanes and tsunamis. The global cost of storm damage is estimated to double without reef protection. The submerged reefs are crucial natural defense systems, protecting millions of coastal inhabitants in Southeast Asia and around the globe (Beck, 2019).

4.5.5 The Sentinelese People

Another Southeast Asian indigenous group in close relation with the reefs are the Sentinelese people of the Indian OceanâĂŹs North Sentinel Island. This group drew international attention when they killed an American tourist who traveled on their land illegally, and then shot arrows and threw spears at the helicopter sent to recover his body. The estimated 80-150 people currently living on the island are some of the last untouched native peoples. Their sovereignty is protected by North Sentinel IslandâĂŹs lack of natural harbors and the surrounding sharp, shallow reefs. The Indian government has also enacted laws protecting their sovereignty, leaving them very isolated from foreign interference (Smith, 2018).



While little is truly known about the Sentinelese, their relationship with the reef is relatively understood. Their hunter-gatherer lifestyle is mainly fueled by the reefs. They use small, narrow, outrigger canoes and long poles to navigate and harvest the shallow reefs in the surrounding waters. A vast majority of their consumed protein comes from the reefs; they fish, harvest, and consume both reef fish and invertebrates. It can be assumed that many other Southeast Asian indigenous groups in coastal areas maintain a similar relationship with coral reefs, though they may lack government protection. Reef degradation is often viewed solely in ecological terms, but we must also consider its anthropologic effects, especially on indigenous populations (Smith, 2018).

4.6 Reef Restoration, Protection, and Conservation

4.6.1 Ecosystem Based Adaptations

Coral reefs, in their current state, cannot be restored passively by simply eliminating stressors. Active restoration efforts are critical for the survival of the corals and the reef ecosystem. Two highly successful restoration efforts include ecosystem-based adaptations and the formation of marine-protected areas. Reef restoration is a complex task requiring community engagement, government support, foreign aid, and restorative projects that are backed by research (Westoby et al., 2020).

Ecosystem-Based Adaptations, or EbAs, are a form of active coral restoration which aims to rebuild natural capital and ecosystems in order to aid in preservation and protection, while also promoting and defending vulnerable ecosystems, like the coral reefs. The first EbA restorative efforts took place in the reefs of the Philippines, but they have since been expanded for worldwide use. In Southeast Asia, EbA are still very prevalent and have had great success when it is properly implemented. It is mainly carried out at the community level but offers involvement opportunities to a wide range of people and groups, from tourists to NGOs to scientists and more. EbA, especially in Southeast Asian coastal communities, drives co-benefits between people and nature, as reef restoration coincides with economic growth and prosperity (Westoby et al., 2020).

Coral gardening is a widely used EbA composed of two phases. In the first, the nursery phase, corals are grown via asexual coral propagation. Coral colonies that have already been destroyed or broken off, or corals of opportunities, are harvested and brought to nurseries where they are grown for the next 6-12 months. Nurseries can be either ocean-based or land-based. Ocean-based nurseries are cheaper but more vulnerable, while land-based nurseries resemble labs and are more expensive and protected (Figure 4.12). During this phase, a hundred colonies can easily become thousands, which are then implanted directly into the reef (Lirman and Schopmeyer, 2021). A newly emerging and highly successful type of coral gardening is microplanning. Newly grown colonies are commonly arranged a few inches apart from each other on a rock-like base and subsequently doused with a growth elixir in a lab. The corals grow up to 25 times faster and connect to form one massive colony, which is then later transplanted into a living reef ecosystem (Morin, 2014).

Direct transplantation, another EbA, involves transplanting broken corals to other locations. This strategy is often employed after storms, as rough waters may break pieces of coral away from their main structure which survive without anchoring. Colonies are then relocated to areas with more inhabitable conditions where odds of survival and reproduction are higher. Corals need stable, secure structures, which are fabricated by securing a colony to a cement base attached to the seafloor with cable ties or by simply affixing cable ties to corals which are driven into the seafloor. Direct transplantation also applies to the second phase of coral gardening. EbAs commonly overlap and build off each other to achieve the best restorative results (Scott, 2018).

Artificial reef creation, another EbA, has seen high levels of success in reef restoration. For a reef to be artificially made, pre-existing materials like oil rigs and other large steel or concrete structures, are sunken in reef areas and act as anchors or attachment zones for reefs to form (Figure 4.12). As reef restorative technology has progressed, artificial reef creation has progressed with it. Mineral accretion devices such as Biorock have been very promising and hold great potential. These electrified artificial reefs are essentially metal webs with weak electric current flowing through them, which not only prevents rusting but also causes minerals to precipitate out of the water and collect on the metal. The attached coral colonies can in turn make calcium carbonate skeletons three-to-five times faster than before, as they have an abundance of substrate and easy access to it as well. Mineral accretion devices also protect corals from bleaching and other external disturbances, making them highly effective options for artificial reef promotion. They are expensive and hard to maintain, however. Because of the funding and expertise required, mineral accretion devices are difficult to implement at a local level without an external partner (Scott, 2018).

Reef restoration via EbAs is by no means cheap, but it is a necessary step in coral reef protection and restoration. The benefits far outweigh the costs, for future issues stemming from a lack of coral reefs will cost more fiscally and harm already struggling populations. EbAâĂŹs require significant government support, which is harder to obtain in the developing coastal countries of Southeast Asia than in developed countries. Developing countries have fiscal advantages, however, as restorative efforts are estimated to be thirty times cheaper than in developed nations, because community and

Figure 4.12: Coral restoration techniques and EbAs often do not fall into a single category but are a mix of multiple. As seen in this picture, this open-ocean coral nursery is also acting as an artificial reef. As the corals are propagated, they will be either transplanted to preexisting communities or remain as an artificial reef, depending on the condition of the reefs in the surrounding water. EbAs must be adaptive to maximize their potential, as the natural world is a dynamic, ever changing system.(Lirman and Schopmeyer, 2021)

volunteer participation significantly lower costs. Case studies in both Indonesia and the Philippines confirmed that local participation and community involvement not reduced costs of restoration, but also contributed to long-term benefits in sustainability and within the community (Westoby et al., 2020).

4.6.2 Marine Protected Areas

Marine Protected Areas, or MPAs, are areas that purposefully restrict human activities in effort to either promote conservation or restoration. They give fish and other reef populations areas to recover, as they cannot be affected by overfishing and other unsustainable practices. As coral conservation efforts continue, the specific areas of the Indo-Pacific have been made MPAs, which have led to significant positive reef growth and restoration. The Philippines Marine Sanctuary Strategy of 2004 declared that 10% of coral reefs would be no-take MPAs by 2020, but currently, only 2.7-3.4% of reefs are MPAs. On top of this, 85% of the Philippines MPAs are concentrated in only two areas, leaving them highly susceptible to ecological disturbances (Weeks et al., 2010).

MPA networks have been deemed more effective than single, large-area MPAs, as disturbances concentrated in one area, like an oil spill or heat wave, will not destroy the entire implemented MPA system. Smaller networked MPAs are also more easily managed locally, a vital component of MPA effectiveness. A large, singular MPA may stop an entire community from harvesting reef resources, making multiple small MPAs much more suitable options when still considering anthropocentric factors(Keller et al., 2009). Finally, effective MPAs must be adaptive, as reefs are constantly changing, but also must be long-term and well-enforced. MPAs are much more easily enforced when local communities and governments are involved with the decision-making process and implementation, as shown by Locally Managed Marine Areas, or LMMAs. LMMAs are not managed in the traditional top-down style with a national government presiding over the area, but instead are managed at local levels in conjunction with local traditions and community practices. In the Indo-Pacific, regions where LMMAs have been implemented have led to high levels of reef renewal and restoration (Lirman and Schopmeyer, 2021).

When MPAs are properly implemented and effectively managed, they have been proven to be highly successful. Indonesia's Convention of Biological Diversity and Sustainable Development Goals pledged to turn 32.5 million ha, or 10% of the total coral reefs, into MPAs. A study conducted across 622 Indonesian coral reefs spanning 17 geographic regions concluded that successfully implemented MPAs had significantly higher biomasses (1.4 times higher). In general, reefs need a measured biomass of 500-650 kb/ha to sustain functionality, and this was accomplished in around 40% of all Indonesian MPAs surveyed. In contrast, only 25% of open reefs were above this threshold. Both no-take and gear-restricted MPAs promote biomass by providing safe spots for struggling reef populations to recover without external, anthropocentric threats. This allows fish and other reef populations to better recover from overfishing and other unsustainable activities, further stressing the importance of MPAs (Campbell et al., 2020).

One less common type of MPA results not from governmental restrictions, but indigenous efforts. To many indigenous groups, particular reef sections are culturally significant, and some waters are even thought to be sacred. One of these groups, the already-discussed Tagbanua, believe some nature spirits, or Panyain, dwell in reefs. Panlalambot, a giant-humanoid octopus, is one of these reef-dwelling Panyains that inhabits a reef section in off Coron Island. As a result, these areas are highly protected and act as fish sanctuaries, allowing certain struggling populations to recover from the many unsustainable practices and pollutants effecting marine ecosystems. While these "MPAs" are culturally motivated, they are still highly effective and beneficial to reef restoration efforts (Capistrano, 2010).

4.6.3 Intersectional Efforts

While local management and grassroots projects have been highly effective, they must be paired with involvement by national government and programs in order to enact effective, long-lasting reef protections and restorative efforts. Intersectional efforts also maintain an environmental justice lens, as both environmental and anthropogenic factors are considered in policy making. This protects marginalized groups like the indigenous people of Southeast Asia, for purely environmental efforts often do not consider the needs of groups directly reliant on specific ecosystems. When consulted in policy making, indigenous groups are not only given their deserved voice, but also offer generational knowledge. These indigenous groups and local communities also do not carry the same financial or lobbying ties and biases as other groups may. Generally, they want what is best for the reefs, as it is best for themselves as well. This anthropologic lens developed through intersectionality promotes an inclusive approach to ecological restoration (Lyons et al., 2019).

IndonesiaâĂŹs Coral Reef Rehabilitation and Management Program, COREMAP, demonstrates the positive outcomes possible through collaboration between national government and local communities. COREMAP has successfully implemented over 350 collaborative management plans between local communities and governments. Through COREMAP, rare and endangered species have rebounded. In six of the seven project districts, COREMAP policies and initiatives lead to a 17% growth in coral cover, as well as a 20% income growth among district residents, illustrating the correlation between coral restoration and economic prosperity. COREMAPâĂŹs national scale and intersectional nature allows for both a broader range of achievements while still accounting for the interests of local communities (Aquino and Kaczan, 2019).

4.7 Coral Reefs: Conclusion

Figure 4.13: Pictured is a healthy Southeast Asian coral reef. Bursting with color and biodiversity, reefs like these support lives for thousands of species, including humans. Reef restoration and protection are crucial to maintaining already thriving reefs like this and also reviving the many degraded reefs of Southeast Asia. Reef conservation will allow these coral reefs to remain rich in biodiversity and continue sustaining the indigenous peoples and coastal communities of Southeast Asia.

From localized threats, like unsustainable fishing and pollutants, to global stressors such as ocean acidification and climate change, coral reefs are highly threatened. These biodiverse ecosystems support millions across Southeast Asia; not only do they provide food and protection, but many coastal economies are directly reliant on reefs. Threats to reefs are threats to people, especially to already struggling poor coastal communities and indigenous groups of Southeast Asia. Indigenous groups are commonly disproportionately affected by reef destruction, as they are more directly reliant on them. Reef degradation in turn is not simply an ecological issue, but an environmental justice one was well. Pollutants and malpractices must be eliminated, but reefs will also require active restoration efforts, as anthropocentric actions have degraded reefs to the point where they are no longer capable of healing independently. Saving the coral reefs is not saving a few fish species; it is saving millions of organisms and the millions of people who rely on them. Coral reef conservation should not be viewed simply as an ecological issue, but as a complex problem requiring multidisciplinary efforts to achieve success.

Chapter 5

Air Pollution & Social Justice in Hong Kong

Neenah Vittum

5.1 Opening

Urbanization and air pollution [MLH: go hand in hand–can you be more precise]. As many Asian countries have undergone rapid industrialization and rural-to-urban migrations, air pollution has become a key issue. The consequences of air pollution, [MLH: like many other environmental issues, are vast and far from–revise remove?] equitably distributed. To better understand the complex intersections between environmental justice, marginalization and air pollution[MLH: âĂŹ]s human health effects, we will focus specifically on Hong Kong.

(UNFINISHED)

5.2 A Brief Overview of Hong Kong

Hong Kong is a small special administrative region of China consisting of a series of small islands in the South China Sea and the Kowloon peninsula, which borders China[MLH: âĂŹ]s southern Guangdong province to the north. Despite Hong KongâĂŹs relatively small size, 1110 km2 [MLH: km^{2}I created a custom shortcut command for this!] (add source), Hong Kong is not a singularly urban area. The territory consists of rural, mountainous regions and densely populated communities concentrated near the coast and ports. Though not administratively defined, Hong KongâĂŹs urban population is primarily concentrated in the Victoria City and Kowloon areas.

5.3 Hong Kong's History

(UNFINISHED) [MLH: try to stay focused on the history that is important to the reader of the chapter]

5.4 Air Pollution in Hong Kong

Hong Kong, like many other cities, experiences urbanization issues.[MLH: odd statement – all cities are the result of urbanization..., what's the opposite of an oxymoron? not sure :-), but maybe this might be called redundant?] A combination of poor air circulation from tall buildings, and dense activity including both shipping and motor vehicle traffic has underscored Hong KongâĂŹs air pollution issues. Hong KongâĂŹs air quality is monitored by the Hong Kong Environmental Protection Department (HKEPD), whose network of stations covers Hong Kong Island, Kowloon, and the New Territories (Xia 2004)[MLH: example of a citation...(Ref, Year)]. In those regions, the HKEPD has a total of 16 stations, 13 general stations installed on rooftops and 3 roadside stations (source EPD), which consistently measure common air pollutants including sulfur dioxide (SO_2), nitric oxide (NO), nitrogen dioxide (NO_2), carbon monoxide (CO), and ozone (O_3), and respirable suspended particulates (RSP) such as $PM_{2.5}$ and PM_{10} (Xia 2004).[MLH: can we get a map of HK that includes these?]

Hong KongâĂŹs air pollution levels come from a number of different notable sources. The primary source of Hong KongâĂŹs air pollution is motor vehicle emissions. Motor vehicle emissions are a major source of air pollution in most major cities throughout the world (Xia 2004). Urban areas, especially in recent history, tend to house a larger portion of the worldâĂŹs population[MLH: be exact? make a graph of proportion with time?]. This increase in activity in urban areas has been shown to escalate air pollution issues (Wong 2019, Gurjar 2010). Air pollution emitted from motor vehicles includes nitrogen oxides (NO_x)[MLH: nice!], CO, volatile organic compounds (VOCs), and PM (Xia 2004). We will see later on how these concentrated amounts of these pollutants can cause detrimental human health issues. [MLH: are we doing to assume the reader knows what all these things are?]

Another source of air pollution in Hong Kong is its harbor and shipping port. Hong KongâĂŹs Victoria Harbor is the fourth busiest shipping port in the world (Ng 2013). Shipping contributes to about 36[MLH: %]of SO_2 emissions in Hong Kong. Regulation in recent years has worked to greatly and effectively reduce shipping emissions,[MLH: will you expand later? If not, details would be useful here] but persistent issues still remain (Mason 2019).

5.5 Air Pollution and Human Health

The human health effects of air pollutants are part of what certain chemicals as air [MLH: âĂIJ]pollution.[MLH: âĂİ] [MLH: see guides]These effects have been widely studied in many different parts of the world.[MLH: to what effect?] Gurjar et. al developed a risk of mortality model to examine the human health effects of air pollution in megacities (Gurjar 2010). They found that elevated levels of total suspended particles (a measure of PM), SO_2, and NO_2 led to more cases[MLH: be more exact in what they found] of respiratory mortality. Furthermore, they found a higher number of hospital admissions due to chronic obstructive pulmonary disease (COPD)[MLH: more detail]. Patients with COPD have been known to experience more symptoms on days when the air quality is worse (Harre 1997). As we saw in the previous section, Hong Kong has significant problems with all of these pollutants and thus threats to human health are cause for concern.

A number of Hong Kong-specific studies have looked into the human health effects of air pollution. Kan et. al[MLH: âĂŹ]s 2010 included Hong Kong in its study of SO_2 and daily mortality in a number of cities across Asia. Their short-term study found an association between the two, concluding that SO_2 can cause cardiorespiratory health effects, act as a respiratory irritant, and can cause cardiovascular abnormalities by action as a bronchoconstrictor (Kan 2010).[MLH: nice!] Furthermore, SO_2âĂŹs association with shipping has been particularly worrisome for Hong Kong as a shipping port. A 2012 assessment by Hong KongâĂŹs Civic Exchange Department concluded that SO_2 was responsible for 519 premature deaths across the Pearl River Delta. Of those 519 deaths, 385 were in Hong Kong (Mason 2019). Experts estimate high exposure for a population as dense as Hong Kong with a probable 3.8 million people living near coastal areas directly exposed to shipping emissions like SO_2, NO_x, and PM_{10} (Kilburn 2012). [MLH: let's create a table of pollutants and describe them?]

Air pollution has also been closely tied to COPD. In Hong Kong specifically, several studies have shown an increased risk of hospitalization associated with air pollution (Ko 2007, Wong 1999). Gaseous pollutants, [MLH: EXAMPLES coming?], tend to exacerbate human health effects and lead to more hospitalization when the weather is cold, which Qiu et. al. confirmed in their 2012 study of Hong Kong. Though Hong KongâĂŹs winter months are milder than most cold temperatures associated with increased hospitalizations, they believe that Hong KongâĂŹs relatively warmer winter and lack of reliance on central heating encourages residents to open their windows for ventilation leading to prolonged outdoor exposure (Qiu 2012)[MLH: interesting!]. Furthermore, Qiu et. al found that humidity plays a role in COPD hospital admissions. Lower humidity saw fewer effects of PM_{10}, SO_2, and NO_2 on COPD admissions. They believe that high humidity contributes to the protection of the windpipe and the dissolution of certain elements of gaseous chemicals (Qiu 2012).

Air pollution has also been associated with Ischaemic[MLH: I don't know what this this is...] heart disease (IHD), one of the leading causes of death worldwide (World Health Stats SOURCE). In Hong Kong, both mortality and hospital admissions have been associated with PM_{10}, $PM_{2.5}$, NO_2, O_3, and SO_2 (Tam 2015).

5.6 Population Density, Income Inequality, and Housing

5.6.1 Income Inequality and Zoning Laws

Analyzing Hong Kong[MLH: âĂŹ]s population density goes hand in hand with the territoryâĂŹs deepening socio-economic divides. As of the governmentâĂŹs latest census in 2016, Hong KongâĂŹs GINI coefficient, a measurement of income distribution on a scale from 0 to 1, is 0.539 (Wong 2018). For the sake of comparison, SingaporeâĂŹs GINI coefficient was 0.458 in 2016, and the United States and United Kingdom recorded coefficients of 0.394 and 0.358, respectively, a couple years prior (Yiu 2017).[MLH: good place for a table!] Many point to the territoryâĂŹs emphasis on free market activity, general lack of government regulation, and history of development as reasons why Hong KongâĂŹs income inequality is so high (Zhao 2005).

Hong KongâĂŹs income inequality and urban population density issues are inexplicably tied. The governmentâĂŹs land-zoning practices prioritize revenue collection through real-estate development, a trade-off of low market taxes, and consequently concentrate the population into a variety of high-density living situations (Tang 2017). Though overall population density is generally high, true density measures vary from neighborhood to neighborhood, and thus the problems associated with population density, like psychological issues and disease spread (Romanova 2018), are not evenly distributed over the entirety of Hong KongâĂŹs territory. In other words, there is a wide variety of experiences among Hong KongâĂŹs many residents.

5.6.2 Public Housing

Hong KongâĂŹs housing situation has many interesting implications. To examine this further, we will look at the differences between public and private housing. Hong KongâĂŹs population is split nearly evenly between private housing provided by real estate developers and public housing subsidized by the government (Fan 2012). Public housing is a necessity given Hong KongâĂŹs extreme income inequality issues . On average, those who live in private housing earn double the amount of those in public housing (Fan 2012). Public and private housing appear in different concentrations throughout Hong KongâĂŹs territory with private housing generally in older, less dense areas and public housing in newer regions (Fan 2012).

(IMAGE: Public/Private Housing Distribution)

Location plays an important role in aspects of urban life that influence the quality of the environment and the health of residents. For instance, public housing tends to be more densely populated (Fan 2012). Increased concentrations of residents mean increased traffic, more street-level vehicle emissions, less open spaces, and differences in air ventilation (Fan 2012, Stern 2003, Tang 2017).[MLH: show some details from these studies] All of these factors influence pollution levels and the health effects associated with them. Coupled with the information that public housing, which is denser that private housing, is typically occupied by those of a lower socioeconomic status, it is evident[MLH: passive voice] that Hong KongâĂŹs poorer residents are consistently at a higher risk of respiratory disease, cardiovascular disease, and other negative health impacts of air pollution (Stern 2003, Fan 2012, Li 2017).

5.6.3 Economic Mobility

Economic mobility is an important consideration in understanding issues of environmental justice (EXPAND). Political scientist (?) Rachel SternâĂŹs 2003 article Hong Kong Haze concisely pointed out that several then-members of Hong KongâĂŹs government lived in a neighborhood named Deep Water Bay, which was known as a âĂIJgreen settingâĂİ characterized by tranquility and low pollution levels (Stern 2003). Even with the pervasive and wide-spread nature of air pollution, those with resources are able to buy their way out of potentially dangerous living conditions.[MLH: nicely stated] Those with higher incomes and higher levels of wealth are able to afford the elevated cost of a clean environment. In other words, they benefit from economic mobility. Private housing, in general, allows for a certain degree of choice that is not afforded to residents of public housing (Fan 2012).

It is important[MLH: Passive voice] to note that not all residents of low socioeconomic status live in public housing. Many low-to-middle class neighborhoods experience the same high population density problems (Stern 2003). (EXPAND)

Furthermore, Hong KongâĂŹs unhoused population is growing, with many unable to afford increasing rent prices (Yiu 2018). (INSERT RECENT STATS) Public housing is not always a viable option or effective solution, too, because the Hong Kong government has been experiencing public housing shortages. As of 2018, the waiting time for public housing is five years and three months (Ng and Xinqi 2018). (FIND HISTORICAL DATA) Hong Kong[MLH: âĂŹ]s unhoused population is estimated to be around (updated number) (SOURCE). (ADD comparison statistic to better explain what # [MLH: see guide on special characters] means) Though it has not been widely studied in Hong Kong, living outside exacerbates many of the issues associated with outdoor air pollution (FIND study in another location that talks about this). Direct, prolonged exposure, without indoor ventilation or other filtration aids, will likely increase the risk of developing diseases linked to poor air quality.

5.7 Indoor Air Pollution

Hong Kong[MLH: âĂŹ]s air quality pollution issues extend to indoor spaces as well (Stern 2003). This is an important consideration given the way in which Hong KongâĂŹs population density and

Figure 5.1: caption

housing shortage problems have led to increasingly cramped living conditions. Living conditions driven by the housing shortage made headlines in Western media a couple of years ago. To afford housing, many of Hong KongâĂŹs residents share apartments, renting single rooms, beds, or simply caged-off areas.

Indoor air quality can be negatively affected by activities like smoking, cooking, or burning incense. Though these activities are not necessarily associated with low socioeconomic status, [MLH: it is important] to consider the volume of space in which they are performed. The level of total suspended particles released through these activities is higher in smaller areas because they have less room to disperse. These high concentrations lead to prolonged exposure. Additionally, those who are unable to afford air conditioning may opt to open windows during the warmer months. This brings the negative health effects of outdoor air pollution into the home (Stern 2003).

5.8 Open Spaces and Other Patterns of Environmental Inequity

Hong KongâĂŹs zoning practices also influence the territoryâĂŹs distribution of âĂIJOpen Space Zones.âĂİ Open Space [MLH: z]ones are designated for public recreation in the midst of Hong KongâĂŹs urban areas. These Open Space zones are not as explicitly tied to air pollution issues, but they do reflect general trends in environmental inequity in Hong Kong. A proportionally higher number of Hong KongâĂŹs Open Space zones are in expensive low-density neighborhoods[MLH: can you show explicit data/maps?]. Furthermore, Hong KongâĂŹs government has future plans to continue open space zoning and construction in these areas, as well as commercial centers in order to encourage consumption and tourism (Tang 2017). Hong KongâĂŹs low-middle income neighborhoods, the most densely populated urban areas of the territory are not afforded the same opportunities.

Building design and air circulation are important factors in air pollution and air quality determination[MLH: let's find more peer reivewed literature on this]. Urban streets can be categorized as either open streets or street canyons. Open streets have built structures on one side, while street canyons have built structures on both sides (Wong 2019). Street canyons, depending on their positioning and wind patterns, may lead to less circulation and higher exposure to air pollution (Wong 2019). With what we know about Hong KongâĂŹs tendency to place open spaces, which would imply open streets, in wealthier low-density neighborhoods, the open space issue becomes even more explicitly tied to air pollution beyond general trends of environmental injustice.

5.9 Environmental Activism in Hong Kong

(UNFINISHED)

5.10 Beyond Hong Kong

(UNFINISHED)

Chapter 6

Environmental Economies East Asia

Chhavi Monga

6.1 Air Quality and Economics

6.1.1 COVID-19 and Environmental Health Threat

The case study below includes snippets from the 2020 World Air Quality report, published by IQAir. The goal here is to get the reader acquainted with one of the major environmental issues countries in East Asia face (AIR, 2020).

Among criteria pollutants commonly measured in real time, fine particulate matter (PM2.5) is currently understood to be the most harmful to human health due to its prevalence and far-reaching health risks. Exposure to PM2.5 has been linked to negative health effects like cardiovascular disease, respiratory illness, and premature mortality. PM2.5 is defined as ambient airborne particulates that measure up to 2.5 microns in size. These particles include a range of chemical makeups and come from a range of sources. The most common human-made sources include fossil-fuel powered motor vehicles, power generation, industrial activity, agriculture and biomass burning. The microscopic size of PM2.5 allows these particles to be absorbed deep into the bloodstream upon inhalation, potentially causing far-reaching health effects like asthma, lung cancer, and heart disease. PM2.5 exposure has also been associated with low birth weight, increased acute respiratory infections, and stroke.

More than 90% of the global population breathes dangerously high levels of air pollution. Due to its ubiquity and severity, air pollution constitutes the world's biggest environmental health hazard, contributing to as many as 7 million premature deaths globally per year (more than 3 times higher than deaths associated with COVID-19). Air pollution also burdens the global economy with more than $5 trillion in welfare losses.

In 2020, the spread of COVID-19 raised new concerns, as exposure to particle pollution was found to increase vulnerability to the virus and its health impacts. Early reporting suggests that the proportion of COVID-19 deaths attributed to air pollution exposure ranges from 7-33%.

In a year defined by dramatic measures taken around the world to reduce the spread of COVID-19, IQAir published its 2020 World Air Quality Report to raise awareness around air pollution - a silent killer.

The 2020 World Air Quality report aggregates PM2.5 data from 106 countries, collected from ground-based government monitors and a growing network of validated, non-governmental air quality

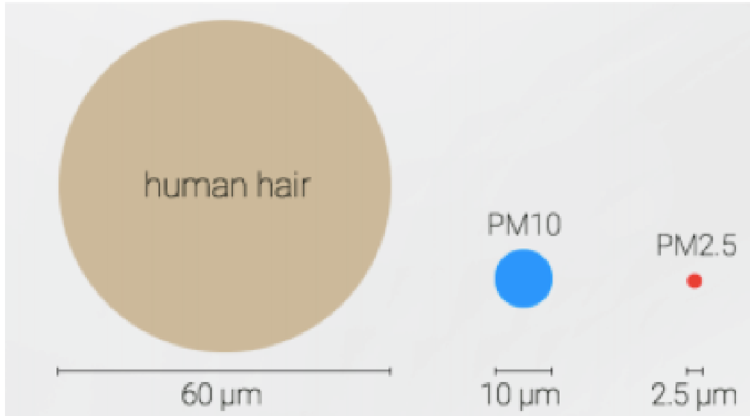


Figure 6.1: Comparative size of the human hair, PM10 and PM2.5 in microns or 10^{-6} meters (AIR, 2020).

monitors contributed by organizations and individuals in order to learn from the world's largest air pollution database.

Three East Asian cities observed the greatest reductions in PM2.5 emission from the sample: Singapore (-25%), Beijing (-23%), and Bangkok (-20%) .

China Air Quality Changes

86% of Chinese cities experienced cleaner air than the year prior, while annual PM2.5 exposure by population fell 11%. Despite this progress, China continues to dominate the ranking of top 100 most polluted cities globally, with 42 cities represented. Hotan, a desert oasis in Xinjiang province, ranked as the most polluted city globally, with pollution levels 11 times higher than the WHO target for annual pollution exposure (< 10 μg m^{-3}). The city also had the highest monthly PM2.5 averages worldwide from March to June, when weather typically increases the intensity of sandstorms (with March peaking at an average 264.4 μg m^{-3}). Beijing experienced improved air quality for its 8th consecutive year, with air pollution levels falling 11 percent from 2019. Air pollution still remains a dire concern in the Chinese capital, with 58 percent of annual days exceeding daily WHO PM2.5 targets (< 25 μg m^{-3}).

South Korea Air Quality Changes

No South Korean cities achieved the WHO target for annual PM2.5 exposure (< 10 μg m^{-3}) in 2020. Only 5 (of 60) cities in South Korea met the country's less stringent standard for annual PM2.5 of < 15 μg m^{-3}. Despite chronically high pollution levels, South Korea did observe dramatic air quality improvements in 2020, with population-weighted PM2.5 exposure falling 21 percent. These improvements, however, are largely attributed to short-term measures intended to reduce the spread of COVID-19 and limit coal factory emissions during the polluted winter months.Long-term policy and changes in human behavior are necessary to further reduce South Korea's PM2.5 levels.

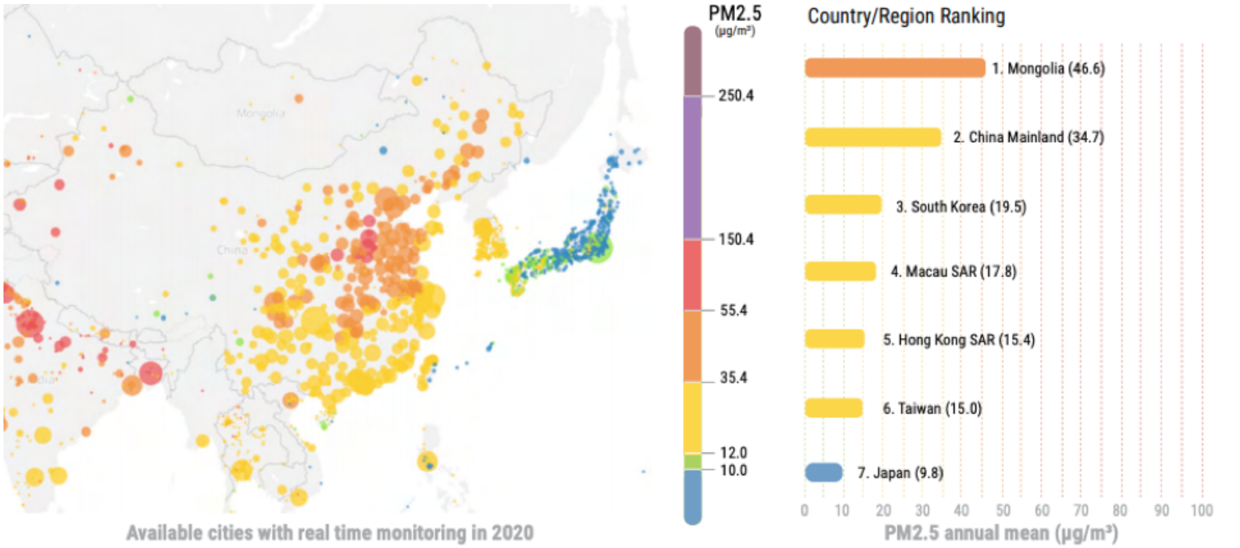


Figure 6.2: East Asia is estimated to carry the highest regional share of global outdoor air pollution-related deaths (37%).20 Air pollution also costs 7.5% of this region's annual gross domestic product (GDP) in welfare losses. While cities from this region comprise 42 of the 100 most polluted cities globally, PM2.5 concentrations are trending downward overall (AIR, 2020).

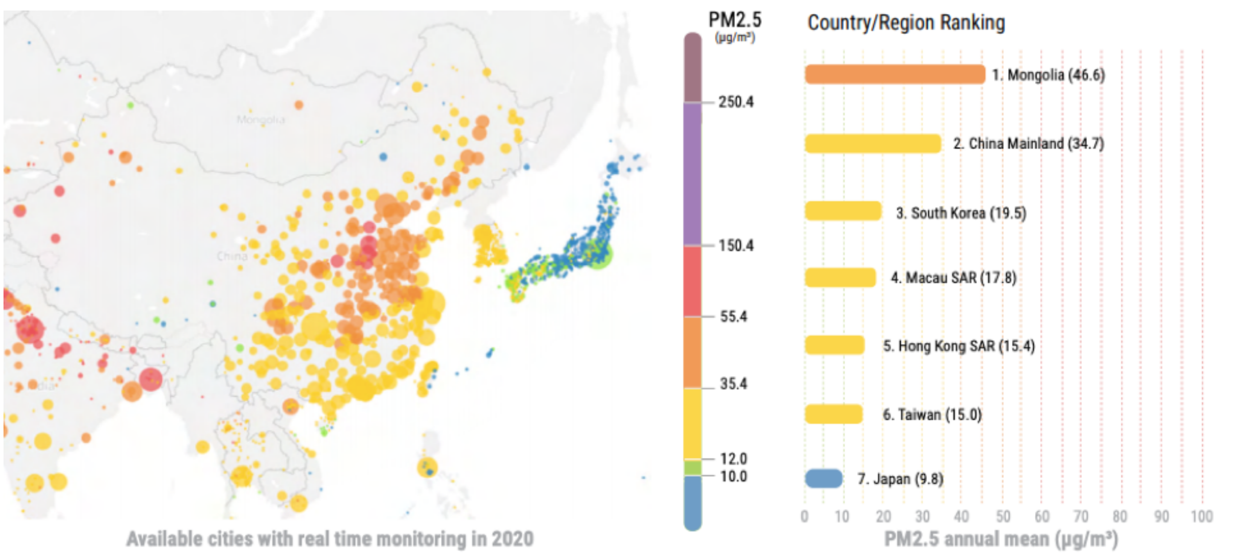


Figure 6.3: Southeast Asia faces air pollution challenges largely stemming from rapid population growth and economic development. The region's energy demand has steeply increased as a result, with electricity demand increasing at around 6% per year.[MLH: 36?] The region mostly relies on fossil fuels for energy, with oil as the leading and coal the fastest-growing source. PM2.5 emission sources in Southeast Asia vary by country and environment. In urban areas, dominant emission sources include construction, industry, and transportation (AIR, 2020).

Table 6.1: Annual Reductions in Selected Cities

City	Change
Delhi	-15%
Seoul	-16%
Wuhan	-18%
Los Angeles	+15%

Southeast Asia Air Quality Changes

Air pollution remains a severe problem facing the Southeast Asia region: only 10.8 percent of cities here breathe air quality that meets annual PM2.5 exposure targets set by the WHO. Despite the continual health burden, 70 percent of cities in Southeast Asia observed improved air quality in 2020. Cities that did not observe direct improvements over 2019 were predominantly located in northern Thailand, which suffered from huge smoke emissions resulting from the agricultural burning season. The capital cities of Jakarta (39.6 μg m^{-3}) and Hanoi (37.9 μg m^{-3}) again ranked higher than notoriously polluted Beijing (37.5 μg m^{-3}) in 2020.

Global Trends in Air Quality

Lock-down measures and changes in human behavior in response to the spread of the novel corona-virus resulted in healthier air overall in 2020. Air quality improvements over 2019 were observed in 84% of countries (weighted by city population) and 65% of global cities.

The most significant air quality improvements were observed during the first lock-down period, when countries around the world mandated relatively strict social distancing measures in an effort to contain the virus.

Cities with higher average PM2.5 levels and denser populations tended to observe the most significant PM2.5 reductions from COVID-19 lock-down measures. Delhi (-60%), Seoul (-54%) and Wuhan (-44%), for example, all observed substantial drops during their respective lock-down periods as compared to the same time frame in 2019. Los Angeles experienced a PM2.5 reduction of -31% during its lock-down period as well as a record-breaking stretch of air quality that met WHO air quality guidelines ($< 10\mu$g m^{-3}).

Often, these initial improvements were short-lived. By the end of 2020, rebounds in industry and transport resulted in smaller average annual reductions (Table 6.1).

To isolate the effect of corona-virus-motivated changes on air quality, the Centre for Research on Energy and Clean Air (CREA) applied a "weather correction" to the report's dataset. The correction removed the influence of weather from observed PM2.5 levels.

Weather can greatly influence observed PM2.5 levels by affecting how pollution coagulates (gathers and falls to the ground), disperses, and transforms as a result of chemical reactions.

While the influence of weather on the dataset varies from city to city, the resulting "de-weathered" figure paints a clearer picture of true changes in PM2.5 levels from 2019 to 2020. This could be the result of social distancing measures for COVID-19, new air pollution policy, or changing trends in human behavior.

6.2 An Economist's View of the Environment

The case study presented above shows that environmental issues such as air pollution can negatively impact the overall health of an economy. However, if we look at "progress" in particular, we see a general upward trend in most East Asian Countries (see 6.4). This is counter-intuitive, given that we just learned about the ongoing trend of bad air quality in East Asia. In what sense, then, are these countries 'growing'? How is this progress measured, and why do nation states not take into account environmental damage when calculating their growth rates?

This chapter will try to answer these questions and in this process attempt to determine a relationship between the environment and economics. Through discussing terms such as sustainable development, the Environmental Kuznet's Curve and the Social Cost of Carbon, the chapter explores the question of whether economic growth can be sustainable.

6.3 GDP as a Primary Measure of Growth

Most economies use 'GDP' to calculate growth, and this measure has been at the forefront of economic policy for a long time. GDP stands for Gross Domestic Product and measures the final monetary value of all goods and services produced within an economy in a year. In simpler terms, it measures total economic output or production. The GDP growth over time for countries from around the world is presented in Figure 6.4. Over time, East Asia's contribution to the world GDP has increased considerably, which indicates that there has been a boost in the overall economic output of countries within this region see Figure 6.4. This of course, does not take into account the extensive environmental damage that has been caused in order to achieve the economic output.

Another measure, GDP per capita, provides a slightly more accurate description of the overall prosperity of a nation and is used alongside the GDP. It is calculated by dividing the GDP of a country by its population and shows how much economic production value can be attributed to each individual citizen. GDP per capita hence translates to a measure of national wealth while also serving as a prosperity measure, and can give us an idea about the standard of living of a particular country (see Figure 6.5). For example, the overall GDP of China might be higher than that of Japan (see Figure 6.6), but that does not mean that its people are necessarily better off (monetarily). When you divide the GDP by population, you get a better picture of how much each person is earning on average (Figure 6.7).

East Asia, including both Northeast and Southeast Asia, has undergone great industrialization and urbanization during the last decades (Mori 2013). These activities allowed the region to enjoy rapid growth compared to the West and is on its way to becoming the world's center of economic growth. As is evident in figure 6.4, the GDP share of East Asia has shown an upward trend and has steadily been contributing more and more to the world GDP. Rapid economic growth has brought a sharp reduction in poverty as well, and this can be seen in Figure 6.5 showcased by rising per capita GDP.

However, although industrialization and urbanization have contributed significantly to economic growth, they have brought along serious environmental degradation. Industrial plants have increased the discharge of untreated air and water pollutants and solid wastes, increasing energy demands, and numbers of automobiles have made air pollution more serious. High-emitting sectors like power, transport, construction, even agriculture, have served as the backbone in economic growth. With little to no adequate policies to control emissions, pollution from all these new and increasing sources accumulate (see Figure 6.8). "Since air pollution is such a chronic problem in Asia, many in the region – including some politicians – have decided to live with it as a necessary cost in the pursuit of development, which it isn't," Kakuko Nagatani-Yoshida, the United Nations Environment Program

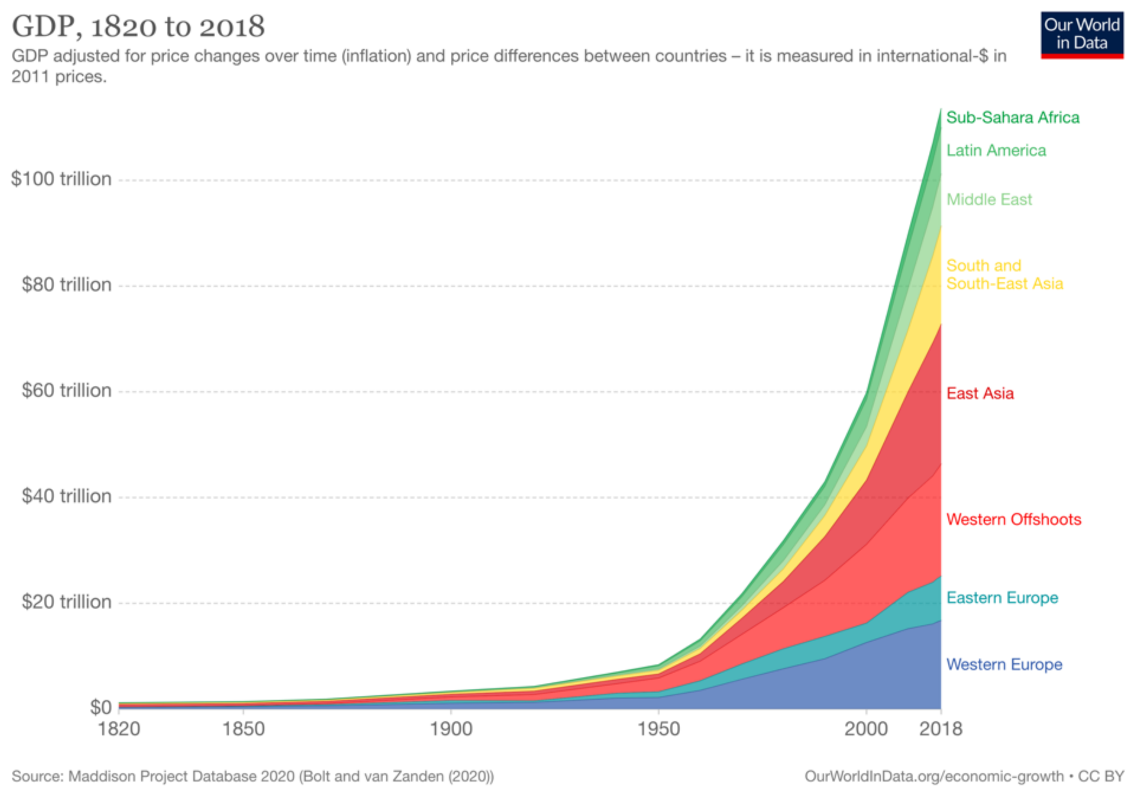


Figure 6.4: GDP growth over the years (Bolt and van Zanden, 2020).

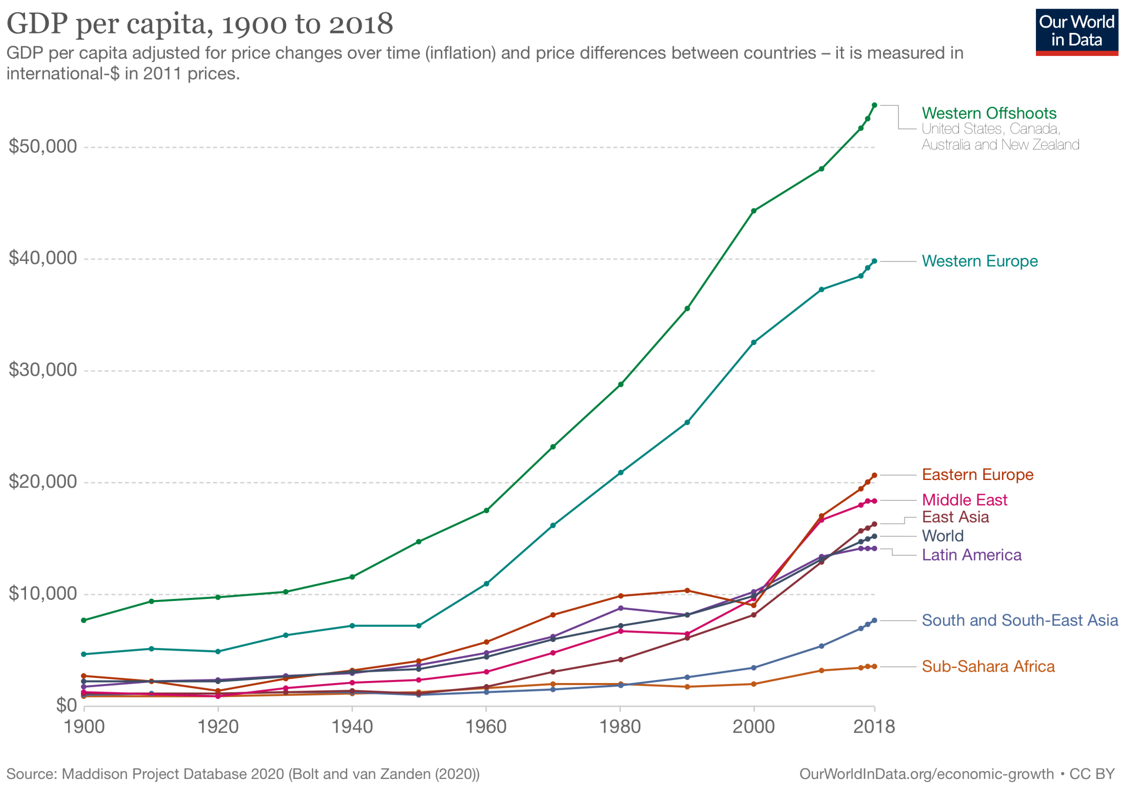


Figure 6.5: GDP per capita over the years. We see that on average, the East Asian population is economically worse off than Western populations, but is better off than Sub Saharan African populations (Bolt and van Zanden, 2020).

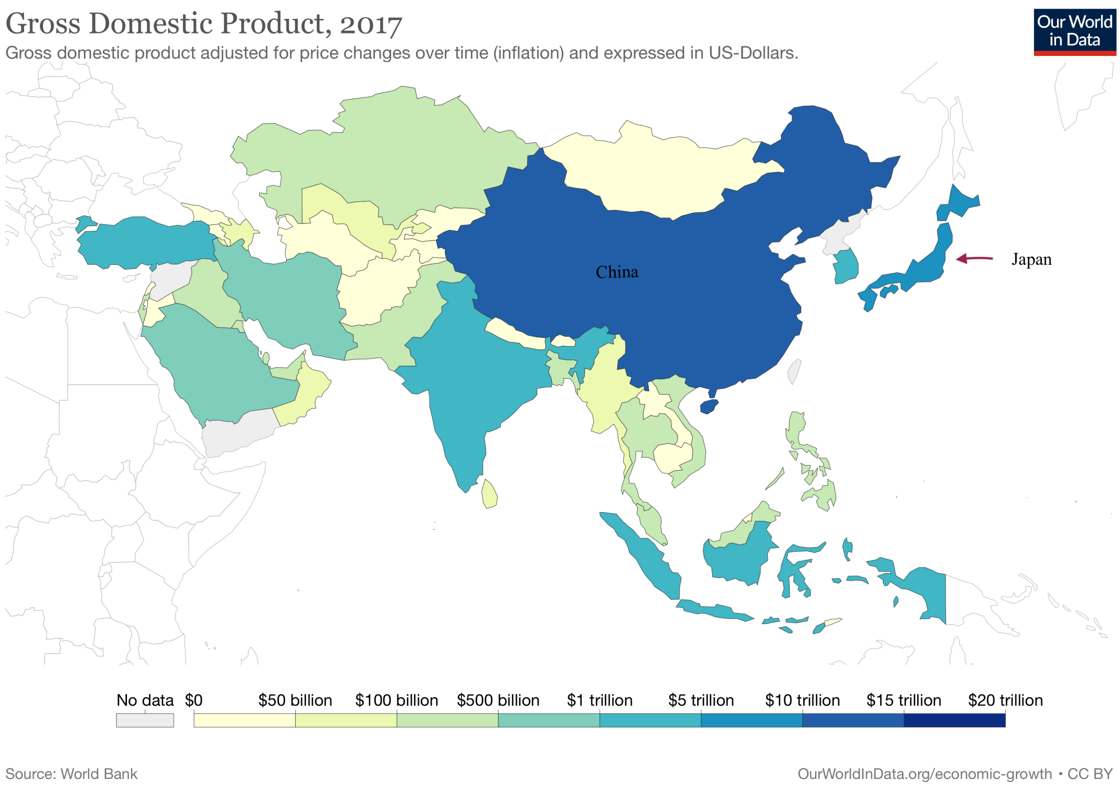


Figure 6.6: China's overall GDP higher than Japan's overall GDP (Bank, 2017).

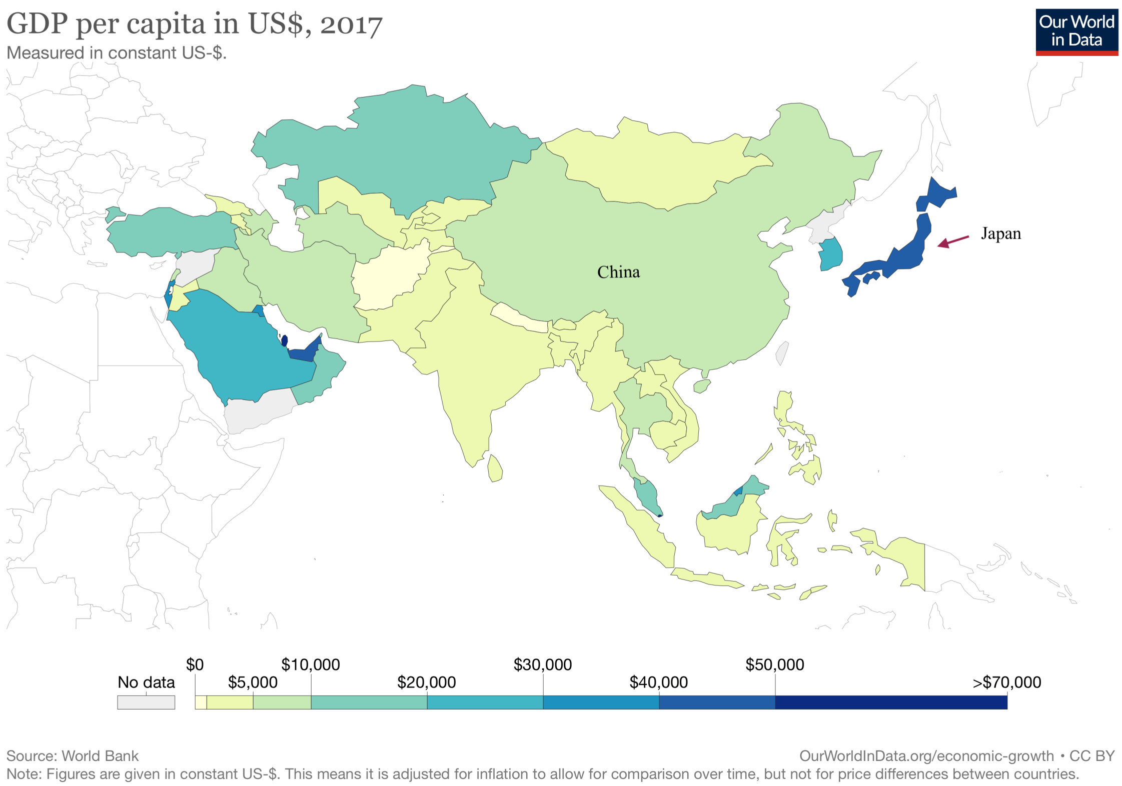


Figure 6.7: Japan's GDP per capita is significantly higher than China's GDP per capita despite China having a higher overall GDP (Bank, 2017).

regional coordinator for chemicals, waste and air quality in Bangkok, told Nikkei (Faulden, 2021). The result of that is why more and more cities are recording higher PM2.5 levels every year. As evidence, today, seven of the world's 20 cities with the highest levels of particulate air pollution were located in East Asia, and 19 out of 20 were located in Asia (AIR, 2020). Although countries like Japan have very low PM2.5 levels, Japanese megabanks like Mizuho Financial Group, Sumitomo Mitsui Group and Mitsubishi UFJ Financial Group continue to fund oil- and gas-powered projects, indirectly contributing to pollution levels across the world (Faulden, 2021) (Figure 6.8).

6.4 Environmental Economics and Ecological Economics

There are two main fields of study dedicated solely to studying how economies interact with the environment and the trade-offs between economic growth and environment protection; Environmental economics and Ecological Economics.

Environmental Economics developed in its present form in the 1960s as a result of the intensification of pollution and the heightened awareness among the general public in Western countries about the environment and its importance to our existence (Al-Attili, A, 2021). It started becoming evident to economists that, for economic growth to be indefinitely 'sustainable', the economic system needs to be held accountable for the way it has been exploiting natural resources in order to maintain high levels of economic growth. Environmental economists therefore view the environment as a form of natural capital which performs life support, amenity, and other functions that cannot be supplied by man-made capital (Al-Attili, A, 2021). This stock of natural capital includes natural resources plus ecological systems, land and biodiversity.

The growth of environmental economics in the 1970s was initially within the neo-classical paradigm, according to which consumers, workers, and firms all make a rational calculation as to what is in their own best interests. In general, this approach to the environment is concerned with issues of market failure, inappropriate resource allocation, and how to manage public goods (Al-Attili, A, 2021). In other words, little attention was paid towards the underlying relationships between the economy and the environment.

Concerns about the limits of the environmental economics approach led some environmental economists to develop what is now referred to as ecological economics. Ecological economics views the relationship of the economy and the environment as central and any analysis places economic activity within the environment (as opposed to the two being separate). This distinction is best illustrated with reference to debates concerning sustainable development and the difference between weak and strong sustainability (SOAS). Ecological economics supports the notion of strong sustainability- a view of sustainability that assumes that not all forms of capital (i.e. human and natural) are perfectly substitutable (this will be discussed in the next section). The subject deems it necessary to get a more integrated picture of how human interactions with the environment have been in the past, and make predictions about future interactions. Ecological economists view humans as beings embedded in their ecological life-support system, as opposed to being separate from the environment.

East Asian policies have mostly relied on studies by environmental economists rather than ecological economists, which explains why they did not reflect local conditions of the environment in a particular country as they were taken from the West. Since ecological economics generally tends to support the notion that the natural environment must be nurtured and protected, as, without it, an economy and human life cannot function, this field has a more conservative perspective regarding economic activity and how it impacts the natural environment (Dean et al., 2014). As a result, ecological economists emphasize that East Asian countries may need to rethink the standard orthodox economic concepts such as endless economic growth and want fulfillment on which their

Comparing Asia's carbon capitals

(Air Quality Index based on PM2.5 level, monthly average in 2020)

Good: 0-50 Moderate: 51-100
Unhealthy for sensitive groups: 101-150 Unhealthy: 151-200
Very unhealthy: 201-300 Hazardous: Higher than 300

	Chiang Mai	Beijing	Delhi *(U.S. Embassy)*	Tokyo *(Hibiya Park)*
January	120	128	213	40
February	140	119	188	44
March	173	94	125	41
April	140	94	106	43
May	81	99	121	45
June	53	97	113	44
July	52	114	88	31
August	58	90	68	40
September	61	77	116	26
October	No data	99	190	36
November	No data	95	255	45
December	80	88	250	44

Figures rounded to the nearest whole number
Source: World Air Quality Project

Figure 6.8: Asian countries have some of the worst recorded pollution levels. Agricultural burning and forest fires are well recognized as a source of dangerous smog affecting many parts of Asia, compounding the industrial and transport air pollution that is a byproduct of Asia's export-led economic growth.

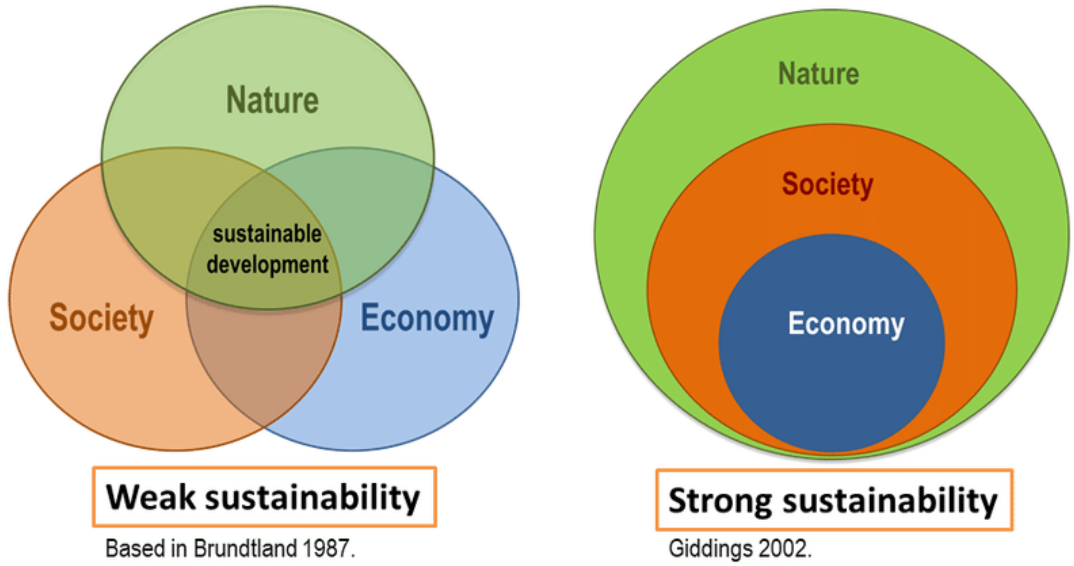


Figure 6.9: Difference between weak sustainability and strong sustainability. (Source: Imura et al. (????))

current environmental policies are based.

6.5 Sustainability and Sustainable Development

Sustainable development defined by the Brundtland Commission as development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

In addition, there are two main definitions in use currently — strong sustainability and weak sustainability.

Weak sustainability is mostly used by economic growth theorists and environmental economists often within the field of economics. It draws a clear distinction between "economic capital" and "natural capital". Economic capital consists of land, labor, capital (machines), and human capital (knowledge). Natural capital comprises the environment and natural resources.

Weak sustainability assumes that natural capital and manufactured capital are essentially substitutable and considers that there are no essential differences between the kinds of well-being they generate (Ekins et al., 2003); (Neumayer, 2012). The only issue that matters is the total value of the aggregate stock of capital (the combination of land, labor, physical and human capital), which should be at least maintained or ideally increased for the sake of future generations (Solow et al., 1993). In such a perspective: "it does not matter whether the current generation uses up nonrenewable resources or dumps CO_2 in the atmosphere as long as enough machinery, roads and ports are built in compensation" (Neumayer, 2003). Such a position leads to maximizing monetary compensations for environmental degradation. In addition, from a weak sustainability perspective, technological progress is assumed to continually generate technical solutions to the environmental problems caused by the increased production of goods and services (Ekins et al., 2003).

On the other hand, the strong sustainability emphasizes that natural capital cannot be viewed as a mere stock of resources. Rather, natural capital is seen as a set of complex systems consisting of evolving biotic and abiotic elements that interact in ways that determine the ecosystem's capacity to provide human society directly and/or indirectly with a wide array of functions and services (Ekins et al., 2003). This approach is very popular among ecological economists.

6.6 The Growth Debate

Having acquainted ourselves with the definitions presented above, we are now equipped to understand and engage with the very important and widely debated concept of whether economic growth can be sustainable. In this process, we will also determine a relationship between economic growth and environmental performance.

"Anyone who believes that exponential growth can go on forever in a finite world is either a madman or an economist," is a famous quote by economist Kenneth Boulding.

However, economic growth, measured by GDP has been at the forefront of policy making across the world for the past 70 years. Global output (GDP) is now more than eight times higher than it was in 1950, and if it continues to grow at the same average rate, then the world economy will be 17 times bigger in 2100 than it is today: a staggering 146-fold increase in economic scale in the space of just a few generations (the, 2015).

Neo classical economics, a broad theory that focuses on supply and demand as the driving forces behind the production, pricing, and consumption of goods and services, seems to take for granted that economic growth increases social welfare. However there has been some criticism on this assumption in recent times.

Since 'social welfare' is not unambiguously measurable, one can discuss endlessly the so called 'meaningful measures' of welfare. For example, just because a country's global output or GDP is growing, it does not mean that its people are always happier, and that its environment is being looked after. GDP is only measured in terms of money, and does not really take into account, for example, environmental damage, which one would argue is essential for measuring 'welfare'. To elaborate, the last 50 years have been accompanied by the degradation of an estimated 60% of the world's ecosystems, and the Stockholm Resilience Centre at Stockholm University in 2015 (sto, ????) identified four key areas in which human activity already lies beyond the "safe operating space" of the planet: climate change, land-use change, loss of biosphere integrity and overload in biogeochemical cycles (see Figure 6.10). In other words, the unprecedented increase in economic activity fails to take into account the ecological constraints of a finite planet.

6.7 Case Study: The Environmental Performance Index (EPI)

As we have just established, the impact human activities have on the environment has not been positive. However, it could advance in one of the two directions. First, excessive and irresponsible industrial production has resulted in pollution, natural resource depletion, and ecosystem deterioration. But on the other hand, effective environmental governance and eco-friendly technologies alleviate the burden on the ecosystem, reduce environmental risks to human health and promote sustainable growth.

We can find evidence of this by looking at The 2020 Environmental Performance Index (EPI) (epi, 2021), which provides a data-driven summary of the state of sustainability around the world. It uses 32 performance indicators across 11 issue categories and ranks 180 countries on environmental health and ecosystem vitality. These indicators provide insights at a national scale of how close countries

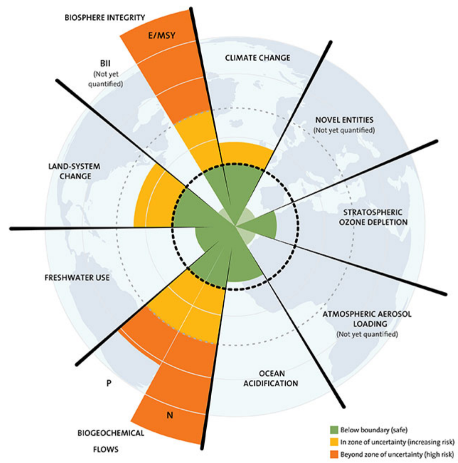


Figure 6.10: Estimates of how the different control variables for seven planetary boundaries have changed from 1950 to present. The green shaded polygon represents the safe operating space (sto, ????).

are to achieving the environmental policy targets they establish. The indicators also provide a way to spot problems, set targets, track trends, understand outcomes, and identify best policy practices. This analysis can also help government officials refine their policy agendas, facilitate communications with key stakeholders, and maximize the return on environmental investments. Overall EPI rankings indicate which countries are best addressing the environmental challenges that every nation faces. Going beyond the aggregate scores and drilling down into the data to analyze performance by issue category, policy objective, peer group, and country offers even greater value for policymakers (see Figure 6.11). This granular view and comparative perspective can assist in understanding the determinants of environmental progress and in refining policy choices (EPI Yale).

Figure 6.12 graphs the relationship between GDP per capita of a country, and its EPI score. The higher the EPI score, the better the country is considered at promoting sustainable development and conserving its environment. GDP per capita, as discussed in section **??**, serves as a prosperity measure by measuring how much each person within a country is earning on average. The figure shows a positive correlation between the two variables, indicating that good policy results are associated with wealth (GDP per capita). For example, China has a low GDP per capita and also a low EPI score, whereas Singapore has a high GDP per capita as well as a high EPI score. In other words, economic prosperity makes it possible for nations to invest in policies and programs that promote sustainable development. Therefore, if we consider an increasing GDP per capita to be an indicator of economic growth, then we can conclude that economic growth can be sustainable.

6.8 The Environmental Kuznet's Curve: An Approach Used by Environmental Economists

According to Huang et al, the driving factors that affect environmental performance can be divided into two broad categories. The first category consists of socioeconomic factors including national economic achievement and the advancement in production technologies. The second category is

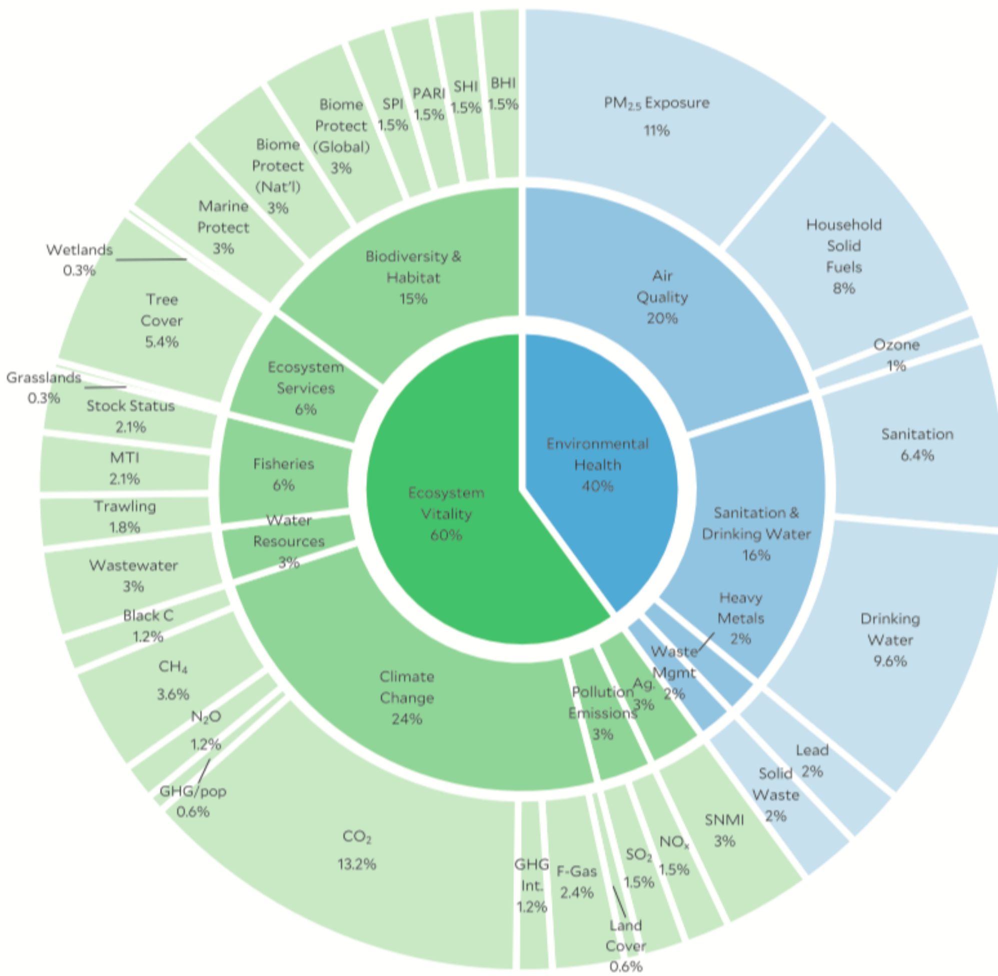


Figure 6.11: The 2020 EPI Framework. The framework organizes 32 indicators into 11 issue categories and two policy objectives, with weights shown at each level as a percentage of the total score (epi, 2021).

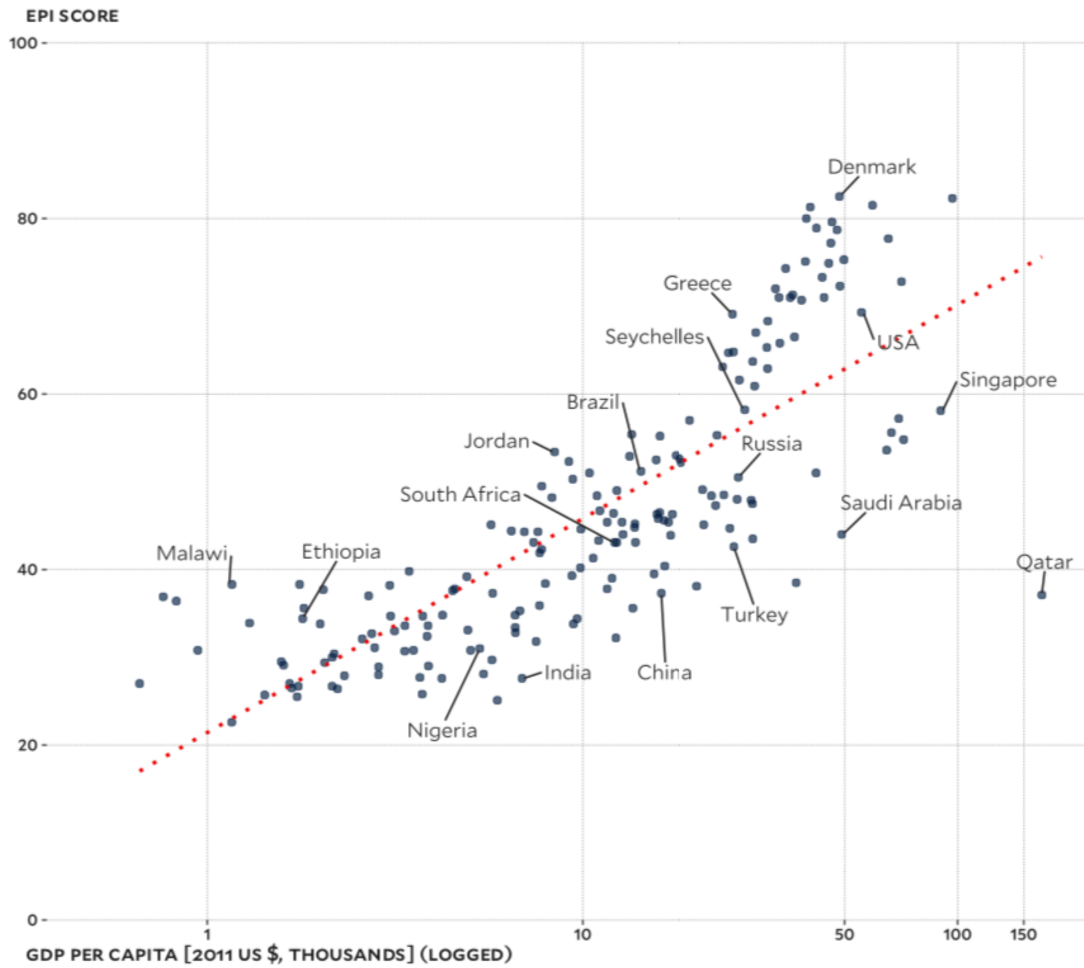


Figure 6.12: The relationship between 2020 EPI Score and GDP per capita shows a strong positive correlation between GDP per capita and EPI score, indicating that on average richer countries have a better environment (epi, 2021).

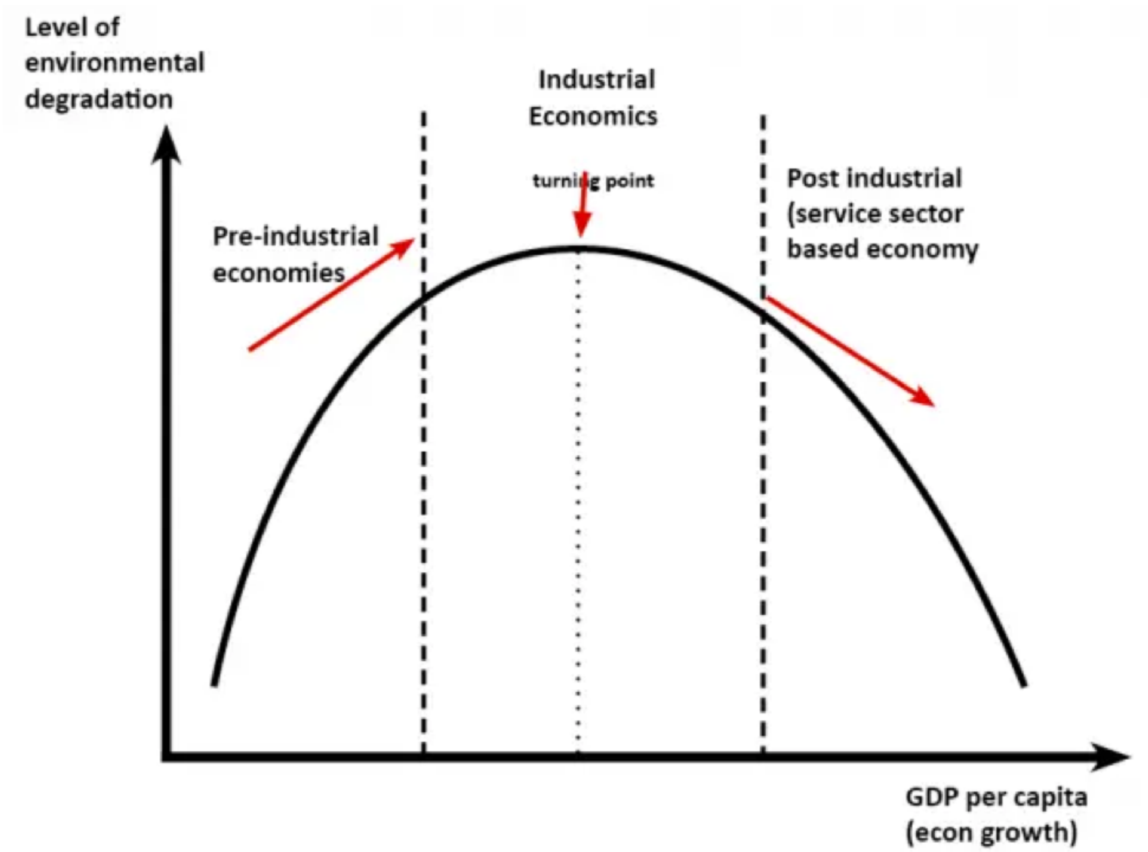


Figure 6.13: The Environmental Kuznet's Curve showing how different stages of economic development influence a countryâĂŹs environmental status. Usually, pollution grows rapidly in the early stage of industrialization when clean air and water are not priorities compared to jobs and growth, and then as an economy becomes wealthier and more concerned with environmental quality, pollution gradually falls to the pre-industrial level (Taguchi, 2013)

concerned with the effectiveness of government regulation for issues concerning government fiscal commitment to environmental governance and the stringency of environmental regulation.

The Environmental Kuznet's Curve (EKC) attempts to answer the question of whether rising income levels and economic growth improve or deteriorate the environmental performance of a country. The theory essentially emphasizes that different stages of economic development influence a countryâĂŹs environmental status, and posits inverted-U relationship between pollution and economic development (see figure 6.13): usually, pollution grows rapidly in the early stage of industrialization when clean air and water are not priorities compared to jobs and growth, and then as an economy becomes wealthier and more concerned with environmental quality, pollution gradually falls to the pre-industrial level (Grossman and Krueger, 1991).

Dasgupta and others (Dasgupta et al., 2002), however, point out that the conventional EKC 6.14 has been challenged by numerous critics. The negative view is that the curve will rise to a horizontal line (see figure 6.14) denoting maximum existing pollution levels, as globalization promotes a "race to the bottom" when it comes to upholding environmental standards. Under this scenario,

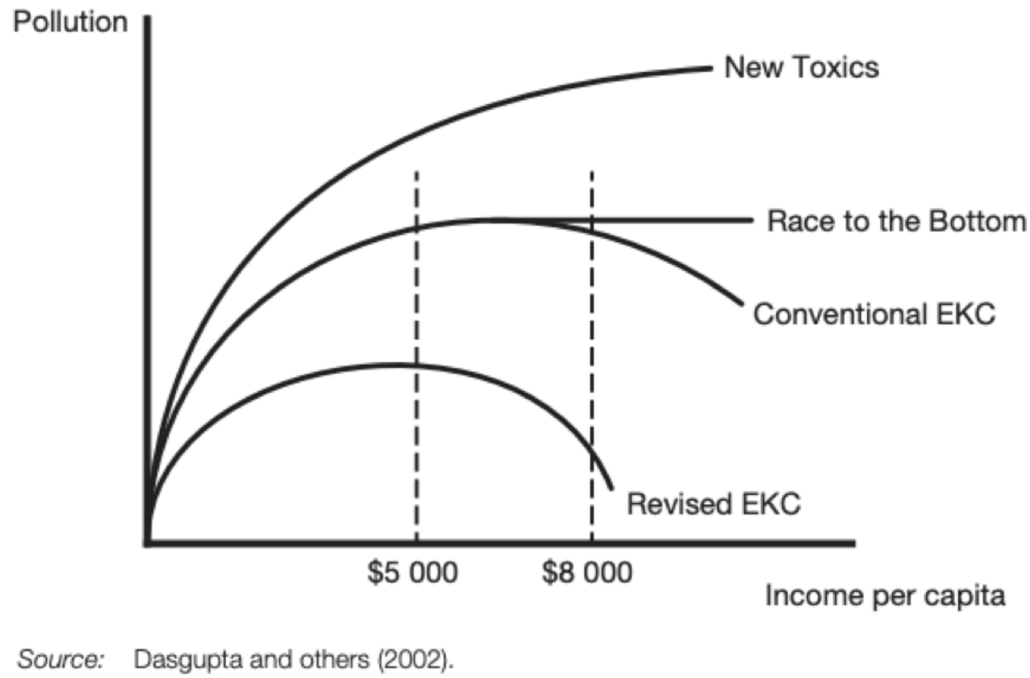


Figure 6.14: The Environmental Kuznet's Curve, different versions (Taguchi, 2013)

relatively high environmental standards in high-income economies impose high costs on polluters, prompting shareholders to drive firms to relocate to low-income countries with weak or non-existent environmental regulations (Taguchi, 2013). This results in increased capital outflows, and forces governments in high-income countries to begin relaxing environmental standards .

The second scenario, entitled New Toxics 6.14, is also pessimistic: industrial society continuously creates new, unregulated and potentially toxic pollutants, thereby the overall environmental risks from these new pollutants continue to grow even if some sources of pollution are reduced (Taguchi, 2013).

The scenario of the Revised EKC 6.14 on the other hand is optimistic. It assumes that due to growing public concern and research knowledge about environmental quality and regulation, developing societies can experience an EKC that is lower and flatter than the conventional one would suggest; these societies may develop from low levels of per capita income with little or no degradation in environmental quality (Taguchi, 2013). In Figure 6.14, the revised EKG curve is lower than the Conventional EKG, and the Conventional EKG is flatter.

6.8.1 EKG in East Asia

Asian economies are at different stages of development consisting of high-income countries, such as Japan and the Republic of Korea, middle-income countries, such as Malaysia and Thailand, and low-income countries,such as Cambodia and Myanmar, so a particular country is expected to lie on a specified point on the Kuznets curve depending on the stage of development it is in. (Taguchi,

2013) examined whether the scenarios of Conventional EKC, Race to the Bottom and Revised EKC were applicable in Asia to representative environmental indices, namely sulfur emissions and carbon emissions. He found that sulphur emissions (see Figure 6.15) follow the expected inverted U-shape pattern of the conventional EKC, while carbon emissions tend to increase with per capita income in the observed range. As for the Race to the Bottom and Revised EKC scenarios, the latter was verified in sulphur emissions, while the former was not present in sulfur or carbon emissions.

The reason that sulfur emissions follow the conventional Kuznets curve could be attributed to policy. Local pollutants, such as sulphur emissions, are subject to regulation. In fact, the pollution controls on sulphur emissions have been promoted intensively over a broad area of Asia since the 1970s (Taguchi, 2013). According to Iwami (Iwami et al., 2001), the remarkable reduction of sulphur emissions in Japan from the beginning of 1970s to the mid 1980s comes from environmental regulations reinforced by central and local governments, and technological development for desulphurization and energy efficiency promoted by private companies. International regulations also influenced the sudden action taken by governments. For example, in 1972, the Stockholm Declaration came into being. This declaration represented a first major attempt at considering the global human impact on the environment, and an international attempt to address the challenge of preserving and enhancing the human environment (Assessment, 2002). It espouses mostly broad environmental policy goals and objectives rather than detailed normative positions.

On the other hand, global pollutants such as carbon emissions are easily externalized, i.e. their effects are felt by parties other than the ones directly producing them. Thus they are not subject to regulation, mainly because they are so difficult to regulate. For example, China's CO_2 emissions will be felt by its neighboring countries and have a negative effect on their air quality. This is why in the Figure 6.15, we see that carbon emissions do not follow the Conventional EKG. Regulatory frameworks on greenhouse gas were set domestically and internationally only after the Kyoto Protocol was approved in 1997. Asian countries, with the exception of Japan, are, however, non-Annex I countries and so they have no legal obligation nor incentive to reduce carbon emission (Yaguchi et al., 2007). Moreover, even though Japan has policies in place for reducing carbon emissions, it has not been successful in doing so, so no spillover effects (benefits) may be expected for other lower-income East Asian countries.

As for the revised EKG, we see that it pertains to developing countries in East Asia for sulfur concentrations 6.15. According to Iwami (Iwami et al., 2001), for instance, in the early 1970s, air pollution, particularly sulphur concentration, in the large metropolitan areas of South-East Asia was less prevalent, despite rapid economic growth in their respective countries when compared with metropolitan areas of Japan. This is because their governments and firms implemented initiatives in the early stage of development; from the late 1970s to the early 1980s, Indonesia, Malaysia, the Philippines, and Thailand moved forward with establishing fundamental frameworks for environmental protection including regulations pertaining to sulfur emissions, such as laws, standards, and institutions (Taguchi, 2013).

To sum up the discussion we may conclude that emission control policies play an important role in lowering emissions, and countries with strong environmental policies and regulation often see a decline in their emissions.

6.9 Conclusion

In this chapter, we have looked at different models and theories in order to understand how countries in East Asia and around the world measure progress and growth. Progress is often measured by versions of GDP, and non-monetary factors are usually not taken into consideration. We also learned

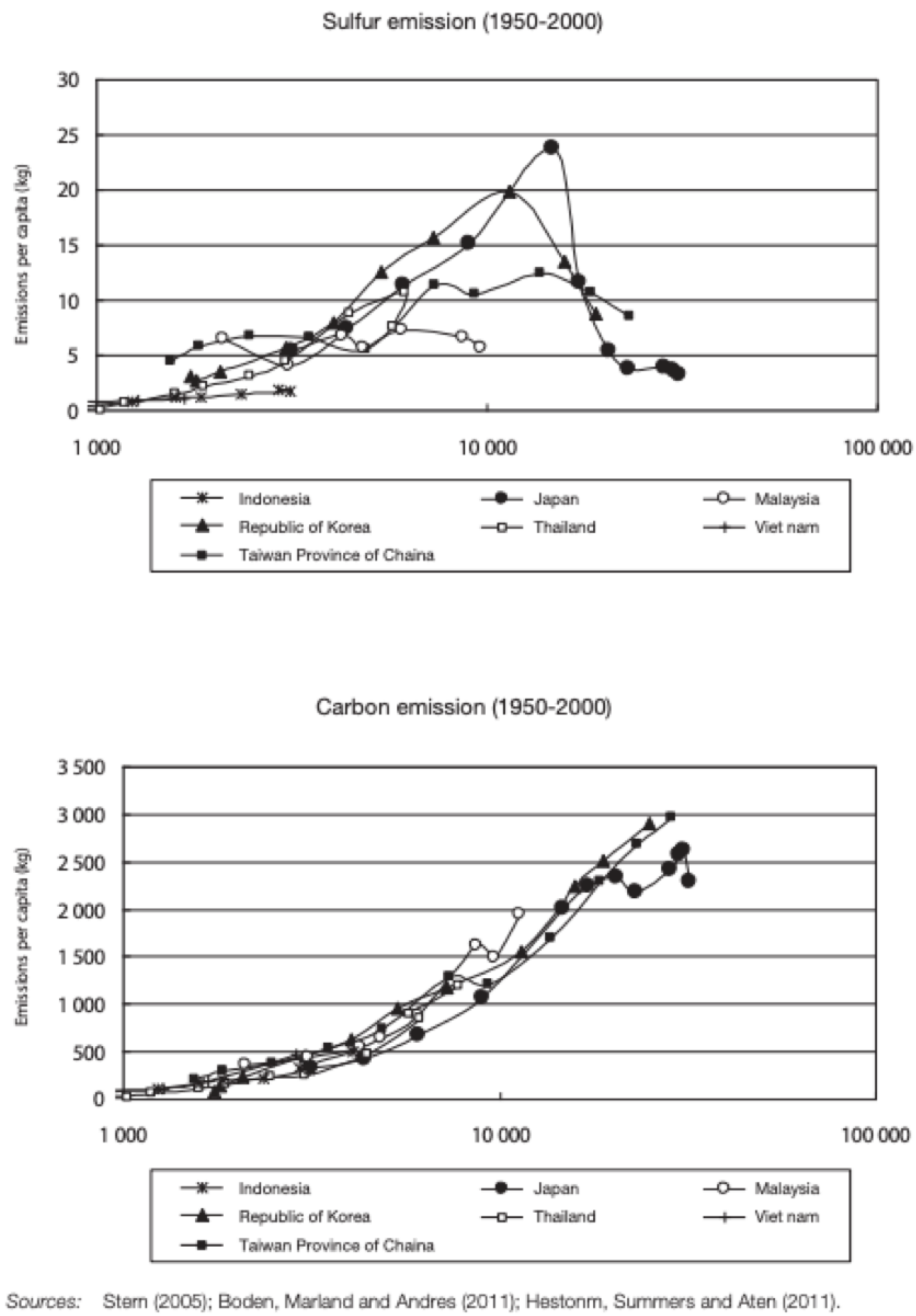


Figure 6.15: The Environmental Kuznet's Curve in East and South-East Asia (Taguchi, 2013).

that there has been evidence that economic growth can be sustainable, as shown by the EKC and the EPI score.

As countries in Asia continue to pursue growth, finding the right balance between growth and sustainability through effective policies and institutions will be an important theme in policy making in the coming decades.

Chapter 7

Unpacking Plastic Pollution and Recycling in Japan

Eleanor Dunn

7.1 History of Plastic in Japan

7.1.1 Introduction

Japan is a unique case study in plastic consumption and recycling in East Asia. Not only is Japan the second largest consumer of single use plastics in the world after the United States (Johnston, 2020), it also leads the world in recycling (McCurry, 2011) with 84 percent of 2018‘s collected plastic ending up recycled (PWMI, 2019). In the face of this impressive percentage, defining what exactly the Japanese government means by "recycling" is significant in revealing the social justice issues associated with this process. This chapter will analyze the reasons for unmanageable plastic consumption in industrial societies, define what it means to recycle and why reliance on "recycling" as it stands is unsustainable given the social and environmental implications of thermal recycling and the global plastic trade, acknowledging solutions and barriers to progress through the lens of Japan.

7.1.2 Urbanization

Today, 92 percent of Japan's population lives in an urban environment (World Bank, 2018). Japan's rapid urbanization and industrialization began in the late 1800s during the Meiji Restoration. After World War Two, Japan's economy boomed once again, reaching a high in the 60s and 70s. During this period, grocery and convenience stores became ubiquitous. The 80s and 90s also brought significant economic growth, in a time known as the "bubble economy" period (Japan Environmental Sanitation Center, 2014). The late 90s saw the rise of the *konbini*, a type of convenience store, as well as a shift from reusable containers to single use packaging (Cwiertka, 2020). Today, Japan has the third-largest packaging market in the world (Cwiertka, 2020).

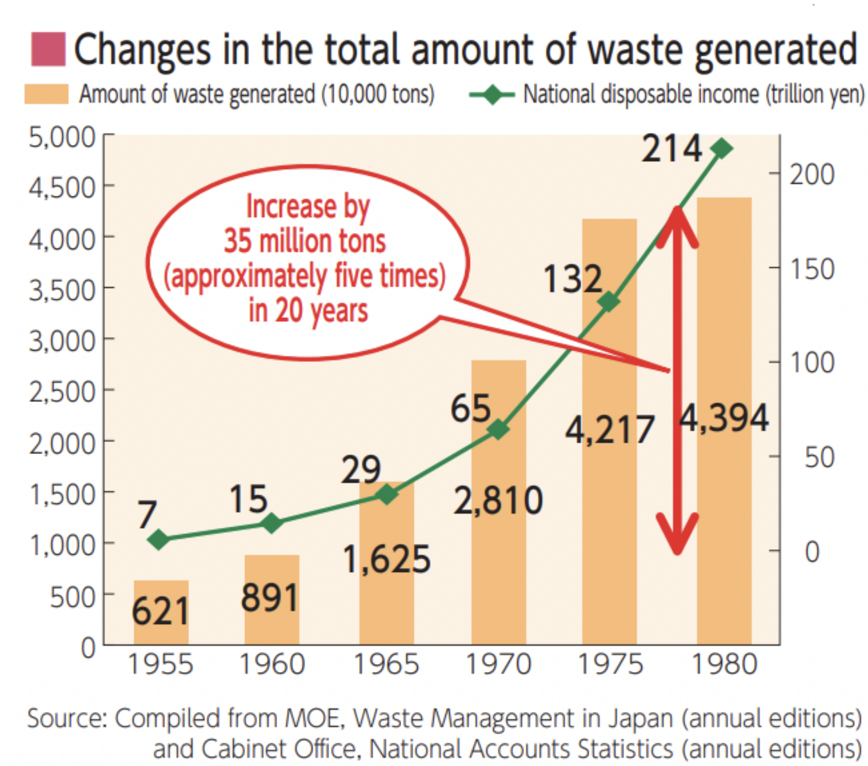


Figure 7.1: This chart demonstrates waste production and national disposable income from 1955 to 1980. There is a distinct positive correlation between income and waste production (Source: Japan Environmental Sanitation Center (2014)).

Managing Waste in an Urban Society

Waste management became a mounting problem in the face of urbanization, particularly beginning after World War Two, when there was little waste management infrastructure and waste was dumped into waterways or left in the open, attracting pests and spreading disease (Japan Environmental Sanitation Center, 2014). Landfills began to overflow during industrialization, and illegal dumping caused human and environmental health crises, including the Minamata disease of the 50s. Illegally dumped mercury from a chemical factory contaminated fish and as people ate it, they suffered neurological symptoms impacting eyesight and hearing (Japan Environmental Sanitation Center, 2014).

Japan has the third largest economy in the world (Lee, 2021) despite ranking 62nd in land area (worldometer, 2021), creating a situation of high consumption with minimal disposal space, an issue faced worldwide, but exemplified on such a small archipelago. To cope with issues of waste storage space, Japan began building incinerators inside cities in the 1960s, and today, Japan has the most advanced incineration infrastructure in the world (Japan Environmental Sanitation Center, 2014), while only one percent of waste ends up in landfills (Sturmer, 2018). Incinerators reduce waste volume to one-twentieth of its original size (Sturmer, 2018).

Despite blame-placing rhetoric on East Asian countries for the world's plastic crisis, signified by articles titled "Japan's Plastic Addiction" (Mahoney, 2020) and "Southeast Asia's plastic 'addiction' blights world's oceans" (Kittisilpa, 2018), on average individuals in Japan throw away half as much garbage as Americans yearly (Harden, 2008).

Commuter Culture and Konbini

In recent decades, Japan has gained international attention for its work culture. Workers are hesitant to use their vacation days, and in 2018, over half of paid vacation days went unused (Demetriou, 2020). People fear being judged or told off for taking days off, many interviewed said that they typically even came in to work if they were sick (Demetriou, 2020). Stress from this culture of overwork has been linked to adverse health impacts, and even suicide (List, 2017). The term "karoshi" means death from overwork (Whitelaw, 2018) (List, 2017) and has been used in Japan since the 1970s (Whitelaw, 2018). This culture will likely face impacts from the Covid-19 pandemic, on which more research likely will develop in coming years. With this capitalist culture, a lack of free time combined with commuting make konbini an oasis for workers. Most urban Japanese people frequent konbini daily (Whitelaw, 2018), often purchasing bento lunches, young folks meet with friends and peruse new offerings, and homeless people pick returnable cans from the recycling bins outside (Whitelaw, 2018). These stores, available 24 hours a day, offer "food, entertainment, money, shelter, anonymity, and, sometimes, intimacy" (Whitelaw, 2018). They also offer an explanation as to how urbanization, capitalist work culture and consumption can contribute to a mounting waste issue worldwide.

To this end, anthropologist Gavin Whitelaw decided to only consume food from konbini for a full month. In the first week of this experiment, he already collected 28 plastic bags, 6 plastic straws, 13 chopsticks, 11 plastic spoons of various sizes, a few plastic forks, and two 10-litre bin bags of plastic plates, covers, cellophane wrapping, and PET bottles" (Whitelaw, 2018).

Figure 7.2: Here are plastic wrapped fruits that you could find in konbini or other grocery stores in Japan. Source: (Denyer, 2019).

7.1.3 Cultural Significance of Packaging

While convenience and food safety are practical reasons for plastic consumption, there is historical and cultural significance to packaging in Japan. This section does not seek to proliferate western ideas of hyper traditionalism and exoticism of Asian countries, but rather to create a more complete overview of Japan's plastic consumption.

Aesthetics have always been important to Japanese culture, guiding art and daily practices alike (Saito, 1999). "The allure of the hidden" is a cultural appeal based in indigenous Shintoism and a reason for historic attention to packaging, even before global ubiquity of plastics. The tactile experience of opening packages is also significant:

"Both Buddhist temples and Shinto Shrines are wrapped with a series of enclosures, consisting of walls, gates, and vegetation, that regulate our experience of the respective space by offering a progressing sequence of going from the outer to the inner. The glimpse of the inner gradually unfolds as we keep going through the walls and gates" (Saito, 1999).

Thus, may influence the consumer products that are layered in plastic as a culturally based marketing technique. An anthropological study of Japanese wrapping offers that "by carefully wrapping an object, one is apparently expressing politeness and care, care for the object, and therefore care for the recipient" (Ben-Ari et al., 1990) These traditions and cultural sensibilities give more depth to the merchandizing outsiders hypocritically criticize. While thoughtful wrapping has roots in traditional Japanese culture, aesthetically pleasing packaging is ubiquitous in the global marketplace, and it's fair to say just about everyone enjoys opening presents.

7.1.4 Internal Plastic Demand

In 2015, around 71 percent of Japan's domestic plastic demand came from industries, while household demand accounted for 39 percent (Nakatani et al., 2020). In terms of plastic production in Japan, 40 percent of consumed plastic is for bags, plastic sheets for construction, and similar forms of plastic (PWMI, 2019). Polyethylene and polypropylene usually constitute these items, reference chapter about plastic composition, therefore these specific plastics account for half of all plastic production in Japan (PWMI, 2019).

7.2 Problems of Plastic Pollution

7.2.1 Ocean Plastics and Ingestion

What are the human implications of the plastic pollution? Japan is the largest seafood importer in the world, consuming six percent of global fish harvests (Bird, 2012). This dietary fact is concerning given that eighty percent of anchovies in Tokyo Bay contain plastic (Denyer, 2019). While Japan imports much of its seafood, this statistic speaks to an inevitability of consuming trace amounts of plastic when eating fish. Although researchers have not concluded direct correlation between microplastics in fish and negative health outcomes, some plastics contain endocrine disruptors, which have known negative impacts on human health (Royte, 2018) such as increased risk of cancer, immune and nervous system interruption, and reproductive issues (US EPA, 2017*a*).

While microplastics and other "mismanaged" plastic waste pose health problems for the world's people, the 84 percent of Japan's plastic that is recycled also holds implications for human health and social justice.

7.3 What Does Recycling *Really* Mean?

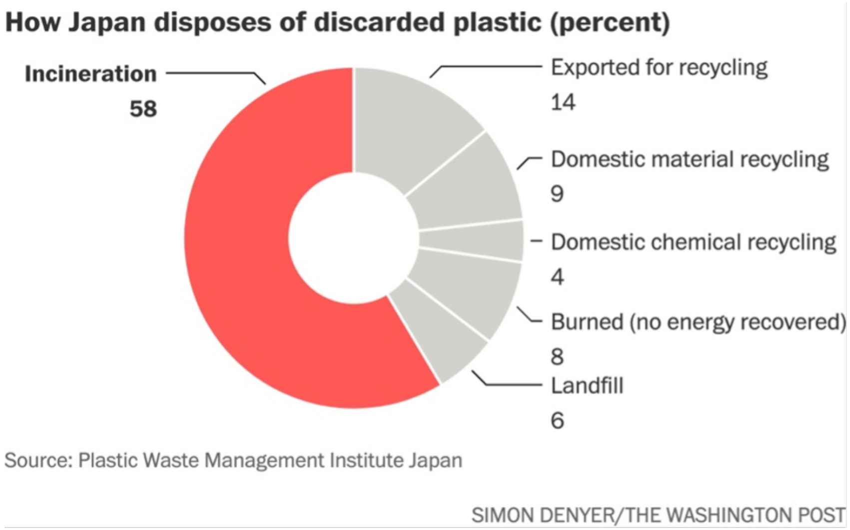


Figure 7.3: This graph offers the catergories in which Japan disposes of discarded plastic. As you can see, most discarded plastic ends up in some recycling category. For the purpose of this chapter, lets unpack the "Incineration" and "Exported for recycling" categories. Source: (Denyer, 2019).

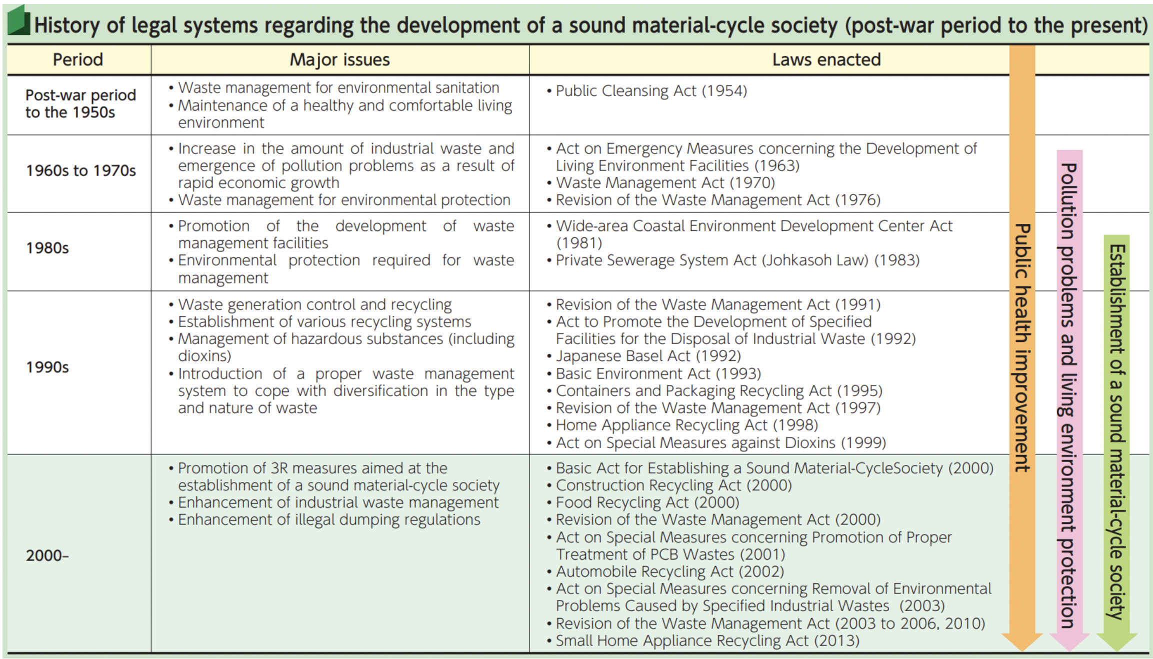
7.3.1 Recycling Laws and Public Cooperation

Japan has plethora laws to ensure waste is treated and recycled properly 7.4. Individuals in Japan tend to be fastidious about sorting their recycling into an average of nine categories, most homes even display a calendar of when the municipality will pick up each category (Jaramillo, 2020). The time consuming individual efforts like washing, deconstructing, and sorting of recycling (Jaramillo, 2020) don't always reflect what happens further down the recycling line when waste is incinerated or shipped to other countries.

7.3.2 Incineration

Japan has used incineration for waste management for around eighty years, though as stated they weren't used in cities until the 1960 (Japan Environmental Sanitation Center, 2014). In 2009, Japan had nearly 1500 incinerators, 70 percent of which were stoker furnaces, others included fluidized bed furnaces and gasification fusion resource furnaces. Incinerators generate electricity as the burning waste heats up water, turning it into steam. The steam then propels a turbine generator which creates electricity (Administration, 2020). Countries all over the world use incinerators, particularly the Nordic countries of Denmark, Norway, and Sweden, which, like Japan, have high recycling rates (Seltenrich, 2013).

Incinerators are effective at reducing waste volume, an important benefit to a small island nation where many landfills are at capacity (Harden, 2008). Additionally, they generate electricity through the process detailed above, or **thermal recycling**, which is better for the environment than some other forms of steam turbine energy production, like coal burning. Generally, one ton of waste creates as much electricity as one ton of coal. (Watson, 2016).



History of legal systems regarding the development of a sound material-cycle society (post-war period to the present)

Period	Major issues	Laws enacted
Post-war period to the 1950s	• Waste management for environmental sanitation • Maintenance of a healthy and comfortable living environment	• Public Cleansing Act (1954)
1960s to 1970s	• Increase in the amount of industrial waste and emergence of pollution problems as a result of rapid economic growth • Waste management for environmental protection	• Act on Emergency Measures concerning the Development of Living Environment Facilities (1963) • Waste Management Act (1970) • Revision of the Waste Management Act (1976)
1980s	• Promotion of the development of waste management facilities • Environmental protection required for waste management	• Wide-area Coastal Environment Development Center Act (1981) • Private Sewerage System Act (Johkasoh Law) (1983)
1990s	• Waste generation control and recycling • Establishment of various recycling systems • Management of hazardous substances (including dioxins) • Introduction of a proper waste management system to cope with diversification in the type and nature of waste	• Revision of the Waste Management Act (1991) • Act to Promote the Development of Specified Facilities for the Disposal of Industrial Waste (1992) • Japanese Basel Act (1992) • Basic Environment Act (1993) • Containers and Packaging Recycling Act (1995) • Revision of the Waste Management Act (1997) • Home Appliance Recycling Act (1998) • Act on Special Measures against Dioxins (1999)
2000–	• Promotion of 3R measures aimed at the establishment of a sound material-cycle society • Enhancement of industrial waste management • Enhancement of illegal dumping regulations	• Basic Act for Establishing a Sound Material-CycleSociety (2000) • Construction Recycling Act (2000) • Food Recycling Act (2000) • Revision of the Waste Management Act (2000) • Act on Special Measures concerning Promotion of Proper Treatment of PCB Wastes (2001) • Automobile Recycling Act (2002) • Act on Special Measures concerning Removal of Environmental Problems Caused by Specified Industrial Wastes (2003) • Revision of the Waste Management Act (2003 to 2006, 2010) • Small Home Appliance Recycling Act (2013)

Figure 7.4: This chart demonstrates Japan's extensive waste management legislation and the major events that inspired it. Source:(Japan Environmental Sanitation Center, 2014).

Health and Environmental Justice

Most studies on the health and social justice implications of incinerating waste include little data on East Asia. Generally, older incinerator technologies correlate to adverse health impacts. Though Japan has replaced most older incinerators in recent years, reducing incinerator related dioxin emissions by 98 percent since 1997 (Japan Environmental Sanitation Center, 2014), not enough time has passed for adequate evaluation of possible health impacts of newer technologies (Tait et al., 2020). While demographic evaluations of communities near incinerators in Japan are scarce, in Europe and the United States, incinerators tend to be in areas with minority and lower socioeconomically positioned populations (Martuzzi et al., 2010). As a country that recycles 58 percent 7.3of its plastic waste through incineration, the government should continue research and offer transparency about the process of choosing where incinerators will be built and who might have suffered disproportionately from the hazardous incineration technologies of the past.

One of the largest concerns with incinerators is **dioxin** emissions. Between 1997-1998, a study in Japan found a higher incidence of infant mortality related to congenital birth defects in areas near incinerators with higher soil dioxin levels (Tait et al., 2020). Dioxins have a seven-year half-life cite and can persist in soil and the body for multiple times longer cite. Therefore, despite Japan's drastic 98 percent reduction in dioxin emissions since 1997, the harmful chemical compounds are likely still impacting the populations closest to them or who eat food from those areas, even if direct emissions no longer pose a significant threat. Although, a 2005 study in Osaka showed a positive correlation between school incinerator proximity and number of children experiencing "wheeze, headache, stomachache, and fatigue" (Miyake et al., 2005). These problems could also be attributable to ash or heavy metal contamination, two additional byproducts of thermal recycling.

Figure 7.5: Here is a picture of the Maishima Incineration Plant in Osaka. Austrian artist Friedensreich Hundertwasser designed it with curved lines and greenery "as a symbol of harmony with nature". Source: (Sturmer, 2018).

Conversely, a study conducted from 2000-2007 reviewed the health and dioxin exposure of incinerator workers in comparison to the rest of Japan's population (Yamamoto et al., 2015). The study concluded that this occupation did not have significant impacts on the health or dioxin levels of the workers. This study, conducted with oversight from Japan Industrial Safety and Health (Yamamoto et al., 2015), implies the safety of incinerators by concluding that even those who work around incinerators daily do not experience negative impacts.

These contradictions suggest the need for further research into incinerator impacts. A pamphlet published by the Ministry of the Environment, offers that the research and development of more efficient, cleaner incinerators are ongoing (Japan Environmental Sanitation Center, 2014), and the government communicates with residents about building plans, negotiating until they have consent (Harden, 2008). Additionally, modern incinerators in cities like Tokyo and Hiroshima serve as tourist attractions and community gathering spaces, featuring swimming pools, fitness centers, and health clinics for the local elderly population. These incinerators are odorless and have tall smokestacks, so that they expel smoke, greenhouse gasses, and trace toxic compounds above the skyscrapers (Harden, 2008).

The height increases of smokestacks is dubious in itself, performative even. US companies began building taller smokestacks after the passing of the Clean Air Act in 1970, with the goal of reducing measurable emissions by putting them higher in the atmosphere. This just dispersed pollutants over state lines (Edmonson, 2011). In Japan, I wonder if with the increase of tall smokestacks pollutants are finding their way into other countries or the ocean at higher rates.

While incineration is an effective and evolving way to reduce plastic waste volume while generating electricity and modern incinerators in Japan can seem like a magic solution to crushing waste volume, the human and environmental costs require further investigation. Governmental assurances of safety coupled with contradictory studies of dioxin impacts prove incineration to be a complex environmental justice issue as Japan continues to rely on the process for waste management. Consider this issue with regard to the two dominant theories of pollution: matter out of place and thresholds of harm (Liboiron, 2016). Despite strict emissions regulations (Japan Environmental Sanitation Center, 2014), Japan's remarkable incinerators still emit "carbon dioxide, water vapor and trace amounts of toxic particulates" (Harden, 2008).

The matter out of place theory would suggest that any amount of contamination from these chemicals in the soil, air, or human body, is unacceptable. The thresholds of harm theory, which seems to inform current environmental legislation, makes the distinction between "perceived" and "demonstrated harm" (Liboiron, 2016), basically, that forms of contamination are non-violent until the moment harm is scientifically proven, not anecdotally or psychosomatically.

Although Japan's incinerators are a solution to overflowing landfills and contribute significantly *less* dioxins than landfill fires (Watson, 2016), they still emit. Any toxic emissions can constitute a slow violence to those living and working nearby, and the full extent of human and environmental impacts of new incinerator technologies will likely not be demonstrable for decades, if ever. Also, the extent to which dioxins and contaminants from past, more unclean incineration, persists soil, food systems, and bodies requires more research so that offending actors can compensate those impacted (NRDC, 1991).

7.3.3 The Global Plastic Trade

Per figure 7.3, Japan exports fourteen percent of its recycled plastic waste. China, formerly the primary importer of plastic, halted plastic imports in 2018, increasing the import pressure on less wealthy countries like Thailand, Malaysia, and Vietnam (Bauman, 2019) and compounding the social justice issues of the global plastic trade. Japan counts these waste exports towards their recycling percentage, even though the countries that are importing the plastic have even more limited infrastructure for recycling and waste management (Denyer, 2019). Additionally, most of the exported plastic is not in good enough condition for recycling (Staff, 2019). Much of the plastic that ends up in the oceans comes from these countries (Mahoney, 2020), spurring international blame on poorer Asian countries for polluting the oceans, despite that wealthier, more consumptive countries like Japan and the United States are the sources of the plastic. It was not until January 1, 2021, that importing countries had to provide consent to receive contaminated plastic waste. The Tokyo Plastic Strategy highlights concerns over this protective international legislation, offering that illegal dumping might increase in Japan as exporting becomes more difficult (Bureau of Environment, 2019). Japan‘s opposition to this legislation speaks to a global hegemony of wealthy countries and the role of nationalism in environmental justice.

"The Recycling Myth" - The Global Plastic Trade and Malaysia

In 2018, Greenpeace Malaysia released a paper called The Recycling Myth, outlining the impacts of plastic imports on Malaysia, problematizing recycling as the developed world has come to understand it. Countries like Japan ship their plastic to Malaysia, where waste management facilities or private disposers sort it into high and low grade. High grade plastics are for recycling, though much of those end up dumped or burned, and low grade, typically single-use items, are slotted for disposal. As low as 30 percent of all plastics imported to Malaysia end up recycled.

Individuals in Malaysia have found illegal economic opportunity burning and dumping plastic waste outside of licensed incineration or waste management facilities. Some Malaysians have protested the plastic waste trade and the harm it has done to their communities with varying success. The government has decided to phase out plastic imports, but Greenpeace suggests more could be done.

Fatma, a mother from Jenjoram, Malaysia, recounts her son's complaints of the health impacts from unregulated plastic burning: "Mother, it is always hazy in the mornings at my school.' I said, 'Oh, it's fine. It's always hazy, and the haze is from Indonesia.' He said, 'No! Every day is hazyâĂę Since the beginning of the year, my eldest son aged 13 years old-he has this health problem: his eyes are red, itchy and tearing". There are illegal dumpsites near fisheries, contaminating the waters of prawn and other food sources with aluminum levels 300 times higher than the acceptable limit (Greenpeace, 2018). This imagery is reminiscent of conditions under which Minamata disease spread in Japan in the 1950s, did they just pass their illegal dumping issue to a less wealthy nation?

The UN Basel Convention, which came into effect the first of January 2021, sets regulations for plastic waste exports. Essentially, they must be clean and easy to recycle (Staff, 2021) and importing countries must give consent to import contaminated waste. As of 2019, Malaysia began sending hundreds of containers of contaminated or poor-quality waste back to offending countries (Staff, 2021).

7.4 Conclusion and Moving Forward

7.4.1 Mitigation Efforts

Long Term Goals

Japan's goals for reducing plastic usage on a national level include a 25 percent reduction in single use plastic waste and 60 percent reuse rate, and 2 megaton usage of biobased plastic alternatives by 2030 (Nakatani et al., 2020). Figure 7.4 demonstrates the history of waste management laws in Japan thus far.

Ecotowns

Most of Japan's citizenry is conscious of their waste. Some small-town residents have taken this interest to new levels, serving as an example for the rest of the country and world. There are 26 **ecotowns** in Japan (Higuchi and Norton, 2008), including Kamikatsu and Shikoku. Both towns aim to codify the Reduce, Reuse, Recycle, or the 3Rs and Japan's national calls for creating a sound material or circular society. Chapter refcirculareconomychapt explains waste management for a circular economy in further detail. Kamikatsu replaced its out-of-date incinerator with a 45-category waste separation center, reusing and upcycling most of their waste. Shikoku has a similar separation center with a swap shop, where one person's trash truly becomes another's treasure. Shikoku residents have reclaimed 11 tons of waste this way (Crossley-Baxter, 2020). Residents dedicate much effort to the proper separation of waste, and voice skepticism that such involved effort may not work in more populated areas, as Kamikatsu only has 1,500 residents (McCoy, 2019).

Focus on local as opposed to national adaptation to climate environmental issues has gained popularity in the past decade given that different locales experience climate impacts in unique ways and municipalities are more in touch with their citizenry's needs (Measham et al., 2011).

Despite these efforts, one Kamikatsu resident offers that "the recycling system treats a symptom of our dependency on single-use plastic" () and even further, the recycling system itself is less perfect than it may seem.

Mottainai Campaign

The Mottainai Campaign is an NGO that attempts to add a fourth R, respect, into reduce, reuse, recycle (Hoy, 2018). This Japanese term, meaning, "without importance" /citephoy gained international attention when Kenyan environmentalist and Nobel Prize winner, Wangari Maathi visited Japan in 2005 and learned of how the word was being used to discourage waste(Siniawer, 2014). She began using this term in international environmental forums. Soon enough, companies including as the ItÅŊchÅń Corporation, involved in international trade, and Panasonic, the electronics company, began using Mottaini as a **greenwashing** marketing technique. Japanese politicians too began to promote this phrase, participating in gubernatorial greenwashing of their own environmental issues (Siniawer, 2014).

The Mottainai Campaign hosts flea markets and craft fairs (Hoy, 2018), materializing these concepts in a social setting. Proceeds from these events go towards the Green Belt Movement which aims to reforest Maathi's home country, Kenya(Hoy, 2018). While this effort speaks to aspirational international collaboration, it is also problematic.

Aside from greenwashing issues, in some ways, international attention towards mottainai comes off as **orientalist**. The title of a BBC article: "Japan's Ancient Way to Save the Planet"(Crossley-Baxter, 2020), indicates a sort of fascination with or nostalgia for "ancient" elements of Asian culture. Politicians like former Prime Minister of Japan Koizumi Jun'ichirÅŊ attempted to internationalize the word while stressing how hard it would be for foreigners to understand such an inherently Japanese concept (Siniawer, 2014). Both of these examples point to a sort of othering. While this term has been internationalized, various actors, internally and externally, stress how *essentially* Japanese it is.

7.4.2 Conclusion

Perhaps, then, there are better ways to tackle the global problem of plastics and a dangerous recycling system that focus on what highly consumptive, capitalist countries have in common: disproportionate impacts of their economies on less wealthy nations, government prioritization of corporate rights over environmental justice, and a worldwide issue of space.

Ecotowns and mottainai, both sparking international inspiration, and both helpful in their own small ways, are not the solution this plastic crisis and the social justice impacts of recycling. In the ideal situation, the world's wealthiest nations will agree to phase out plastic production in favor of eco-friendly alternatives, whether those are biodegradables, paper, or reliance on reusable packaging. Also, to tackle industry, local and national governments must enforce plastic reduction goals, making it more economically attractive for companies to use less plastic.

Three of **The 17 Principles of Environmental Justice**, "demand the right to participate as equal partners at every level of decision making, including needs assessment, planning, implementation, enforcement and evaluation", "affirms the right of all workers to a safe and healthy work environment without being forced to choose between an unsafe livelihood and unemployment. It also affirms the right of those who work at home to be free from environmental hazards" and "protects the right of victims of environmental injustice to receive full compensation and reparations for damages as well as quality health care" (NRDC, 1991). Ideally, powerful plastic producing and consuming nations will take these principles into account in their plastic reduction plans, not only moving forwad with less plastic, but seeking to repair harm done to effected nations and individuals.

Chapter 8

Wastewater Management for a Circular Economy

Matias Ceccarelli

8.1 Overview

The First Law of Thermodynamics states: “energy can be neither created nor destroyed, but can be transformed from one form to another.” The energy constituting EarthâĂŹs resources is constant but always changing form. By understanding this law we can begin to outline sustainable waste management systems and shift from a linear extraction based/single-use economy, to a regenerative circular economy that sustains human/environmental health. While every human activity generates waste, in nature, waste does not exist. Nature operates as a circular system, turning decay into energy; nature is the model for a circular economy; it inspires biomimetic systems that function as a whole in synergy with the environment.

The majority of the world uses a linear supply chain model, ending with disposal rather than reusal. Circularity is gaining enormous traction as the best way to sustain life on Earth. The United Nations and international governments are echoing the need to transition from a linear to a circular economy. Circularity is a way of life still practiced by first nation peoples around the world: “do not take more than you need,” “replenish what is taken” (Sharp and SharpReporter@5thEstate, 2019).

Waste management is an important yet often forgotten sector underlying all systems. It is the foundation of a circular economy. ItâĂŹs not within this paperâĂŹs scope to cover the intricacies of the supply chain, waste management, or circular economics; covered here is an analysis of linear and circular wastewater treatment systems that process sustainable and unsustainable waste from household, industrial, and agricultural facilities. This paper agrees, linear-waste is unsustainable and a danger to humans and the environment (Mustafa and Hayder, 2020) (Braungart et al., 2011) (Bown, ????). This paper postulates that if sustainable-waste is processed by bio-regenerative-wastewater-treatment-systems, defined by ingredient recovery apparatus, a circular economy will be more readily realized and humans as well as the environment will prosper. It is hoped this analysis will elucidate the interdependence of all systems, human and nonhuman, through life’s fundamental elementâĂŞâĂŞwater. This analysis is organized by multiple case studies examining distinct linear and circular wastewater treatment systems in SouthEast Asia. Here, linear wastewater treatment includes: open defecation, septic latrines, and the majority of municipal sewage waste treatment facilities; Linear waste includes pesticides and chemicals; Circular wastewater treatment includes: double-vault-compost latrines, anaerobic digesters with biogas recovery, and phytoremediation systems. Linear ends with waste; circular is wasteless.

8.1.1 Linear Economy

The primary challenge of sustainable development comes from the energy/material stream between humans and the environment. The current and traditional linear production model: "take, make, [use], waste," is unsustainable and originates from the Industrialization Revolution (1760-1840) (Braungart et al., 2011). The linear-supply-chain is fueled by the desire to make products as fast as possible, produce the greatest number of goods, and deliver them to the highest number of people. This process is often extractive and harmful to the environment (convenience economics). Standardized mass-production regards Earth's limited resources as endless; reuse is not a function, instead, disposal is the outcome. Pollutants generated are harmful to humans and the environment. The linear system is a major source of todayâĂŹs socio-economic injustices; it is the source of climate change (Braungart et al., 2011).

The linear system begins with raw resource extraction and ends with waste disposal. Pollution is created, emissions are released, and valuable materials are lost. Since this system doesnâĂŹt restore what is extracted, the results are: 1. resource scarcity and 2. dangerous waste substances are released into land, water, and air, causing harm to humans and the environment. As a result of the linear system, quantitative geo analysis shows EarthâĂŹs usable surface area is diminishing in size and volume (Braungart et al., 2011). Additionally, waste emissions are emitting greenhouse gases (GHG), which are expanding deserts, causing sea level rise, changing climates, and causing the reduction of biodiversity and the extinction of species. Furthermore, unsustainable industrial and agricultural chemicals and heavy metal waste are accumulating in the environment, causing harm to humans, animals, and plants; rapid population growth is exacerbating these issues (UN, ????*a*).

8.1.2 Circular Economy

"Nature operates as a system of nutrients and metabolisms. In nature there is no waste" (Braungart et al., 2011). In circular economics (CE), waste is regarded as a resource, just like in nature. Waste treatment is the metabolization process, which produces nutrients that can be repurposed. Materials can be divided into biological and technical mass (technical being industrial). Biological nutrients which contribute to the biosphere return to the Earth, while technical mass becomes nutrients to the "technosphere" (Braungart et al., 2011). Thus, CE treats all forms of waste as food for biological and technical systems. Before being disposed of, materials are recovered for reuse, refurbishment and repair, then for remanufacturing and only later for raw material utilization (Braungart et al., 2011). However, some materials used today (chemicals, plastics, etc) engage with the bio and technosphere simultaneously, often causing harm to organisms in both spheres; many argue these alien materials should be made bio-technically neutral (Braungart et al., 2011).

According to CE, combustion for energy comes before landïňĄll disposal, thus energy stored in materials can be used and not "wasted." With resource recovery, a materialâĂŹs value and quality is sustained for the longest possible. Energy used for resource recovery is expected to be energy efficient. The Circular Economy is intended to utilize present natural systems for preserving materials/energy in a form which nature can use in its own systems.

With linear and circular systems now in mind, the following sections will present linear systems and materials with circular solutions.

8.2 Water Is Life

One of the most pressing concerns of the linear model is the pollution of EarthâĂŹs water. At the most basic level this is a problem of industry, consumption, lack of effective wastewater-treatment infrastructure, education and policy. Only 2.5% of EarthâĂŹs ecosystem contains freshwater, moreover, only 1% is potable. Almost all available freshwater originates from groundwater, which sources rivers and wetlands (other sources are lakes and dams constituting 1% of drinkable water) (Misachi, 2018). “Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environmentâĂİ (UN, ????*c*). There is a limited amount of freshwater, and a great percentage is contaminated by human and livestock faeces, as well as chemicals and heavy metal runoff (University, ????). In South-east Asia more than 140 million people lack access to safe drinking water; worldwide, 2.1 billion people lack access (Arshad, 2016) (WHO, ????). Water is used everyday, domestically and industrially for waste disposal: “sullage,âĂİ coming from kitchens and bathrooms, and “sewageâĂİ waste, composed of human excreta, sullage, and industrial/agricultural runoff (EPA, 2018). Waste and water are inextricably linked; to discuss waste is to discuss water, and vice versa. Highlighted here is the importance of responsible, circular, and cost-effective wastewater treatment. The following passages will present case studies demonstrating linear waste-water-management systems.

8.3 Wastewater Systems

8.3.1 Open Defecation: Linear

In China 14 million people defecate in the open; in Cambodia 8.6 million (WHO, ????). Open defecation is a linear system because untreated excreta-waste introduces dangerous pathogens (cholera, typhoid, hepatitis, polio, cryptosporidiosis, ascariasis, and schistosomiasis) into surface drinking water sources (1). Additionally, sewage contains valuable materials (nitrogen, phosphorus, and biogas) which could be recovered for fertilizer and fuel (explained later).

Open defecation is a serious issue that must be addressed by low cost wastewater treatment systems for low-income communities

8.3.2 Septic Systems: Linear

In the 1860âĂŹs a Frenchman by the name of Jean-Louis Mouras invented the earliest known septic system (Supeck, 2019). Within a short period of time it expanded throughout Europe, the United States, and parts of Asia, deemed a much better alternative to throwing faeces out the window or defecating in the open. Septic systems are used widely today and are far safer than open defecation, nonetheless, they are a linear waste stream and can pose a danger to humans and the environment.

Septic systems are underground wastewater treatment structures, commonly used in rural areas where centralized sewage systems are not present. The tank is a water-tight-container made from concrete, fiberglass, or polyethylene (EPA, 2018). There are a variety of septic design systems, the majority have naturally occurring aerobic and anaerobic microbes that biodegrade sludge/pathogens, as well as technology. Septic systems often treat wastewater from a houseâĂŹs bathroom (sewage), kitchen and laundry (sullage) (EPA, 2018). A septic system includes a septic tank and a drainfield. The septic tank separates hydrophobic particles (oils and grease) which float to the top, from solids and organic matter (sludge which collects at the bottom). The drainfield is a soil-based system in the yard that releases treated liquid effluent from the septic tank into a number of pipes that release the fluid into the soil, ultimately entering the groundwater (EPA, 2018). (If the drainfield is overloaded

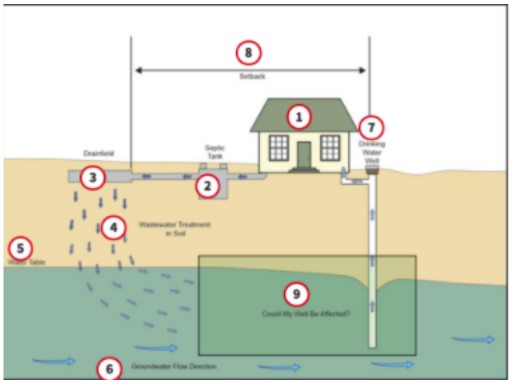


Figure 8.1: Illustration of a septic tank

with too much liquid, sewage will begin to flood posing a health hazard). As filtered wastewater travels through the ground, the soil will filter it again, removing most bacteria and pathogens; the soil cannot treat cleaning products, medication (antibiotics), and other harmful chemicals (Bown, ????). It is important to note rural septic systems may be close to a homeowners well. If toxic chemicals , and sometimes pathogens, seep into the water table, the homeownerâĂŹs drinking water is compromised. Chemicals furthermore pose a threat to the rest of the environment (Bown, ????).

A septic tank must be cleaned every year to ensure successful bacterial decomposition of solid waste and prevent sludge build ups. As stated, a variety of septic systems exist. Some use pumps or gravity sending effluent into the soil, alternatively a system may evaporate the wastewater before releasing it into the Earth. Alternatively a home may use an on site aerobic sewage system which can remove between 85-98 percent of the organic matter and solids from the wastewater (EPA, 2018). In the United States, aerobic systems are often efficient. Aerobic systems include: a pre-treatment tank, an aeration/settling chamber, and a chlorination chamber (anaerobic microbes are present). The aerobic system is a miniaturized version of a municipal wastewater treatment facility (both septic, and the majority of municipal wastewater treatment facilities, do not remove harmful GHGs, pharmaceuticals and other chemicals) (USGS, ????) (EPA, 2020).

Figure 8.1

Septic systems are a linear form of disposal as they release high concentrations of methane (CH4) into the atmosphere. Methane is 30 times more powerful than CO2 and comprises 16% of global GHG emissions (Fu et al., 2017). A study found 85% of households in Hanoi, Vietnam; Mandalay, Myanmar; and Kota Surakarta, Indonesia use septic systems (Huynh et al., 2021). While many use different designs, it was found they all release methane CH4 through anaerobic decomposition. The United States Environmental Protection Agency (USEPA) estimated global methane production from septic systems as 3.0 Tg-CH4 per year, which is 10.4% of global CH4 emissions from domestic wastewater (epa, ????). Because of the study, CH4 emissions from septic tanks are now roughly accounted for in net global GHG emissions. Many septic systems in East Asia do not have a drainfield, they process only sewage, while sullage is emptied into the environment. The climate of Southeast Asia (77-97ÂřF) promotes anaerobic digestion conditions increasing GHG emissions (Huynh et al., 2021). The study found high concentrations of CH4, CO2, and dismissal amounts of N2O in septic tanks in Hanoi. The table below illustrates CH4 emissions reflective of the amount of time sewage remained in septic tanks. The study found if septic tanks are regularly emptied, there are less GHG emissions.

Figure 8.2

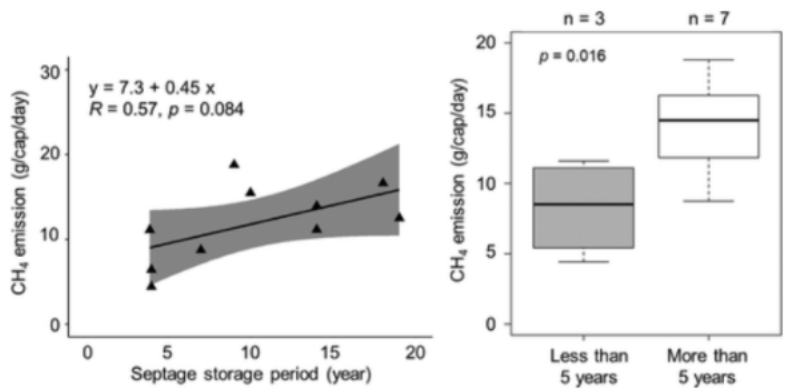


Figure 8.2: Illustrates CH4 levels in septic storage over periods of time

The CH4 found in the average septic tank in Hanoi was oversaturated by 24,444%, while the CH4 in lagoons when measured was 260âĂŞ128,420% (Huynh et al., 2021). Therefore, when compounded, septic tanks in Hanoi, and other parts of SE Asia, contribute greatly to atmospheric methane levels. Additionally, sewage was reported to be released into a non centralized sewer or directly into a waterbody, demonstrating the linearity of present septic systems in Hanoi and much of SE Asia. The study shows only 2-6% of sewage in Hanoi was treated at a sewage facility, some went to a landfill site, and unknown amounts were disposed of illegally (Huynh et al., 2021). The study found the average septic tank to have CH4: 11.92 Âś 4.52 g/capacity/day, while CO2 was 20.24 Âś 9.15 g/cap/day. Septic tanks are effective at reducing pathogens, however, their methods of disposal are linear as they do not not capture or resource CH4 for energy, thus they release methane, a very potent GHG into the environment. They also, often, do not resource nitrogen and phosphorus for fertilizer. Additionally, if chemicals are present in the effluent, they are released into the groundwater (Huynh et al., 2021).

8.3.3 VietnamâĂŹs Double-Vault Latrine: A Circular Treatment Comparison To Septic Systems

For centuries farmers in Vietnam and China used untreated human excreta and urine as a fertiliser for rice and other crops (nitrogen in excreta and phosphorus in urine, are extremely rich materials for fertilizer). However, in 1956, to combat the hazardous practice, Vietnam health authorities instituted the first double-vault composting latrine program, which uses similar principles, but with sanitary measures (Pebler, 2015). Since then DVC technology has been widely supported and adopted by other countries. In 2007 the Government of Vietnam assessed 25% of rural households were without a toilet (to be further referred to as a latrine), and 19% were found to have an unhygienic latrine (Cole et al., 2009) . Given the startling figures, Vietnam implemented a goal of constructing 2,600,000 hygienic latrines by 2010 (Cole et al., 2009). The government compared the double-vault composting latrine (DVC latrine), the septic tank latrine, pour-flush water sealed latrine and ventilated pit latrines, and found the most hygienic, as well as versatile, system to be the DVC latrine, which the Government subsequently funded.

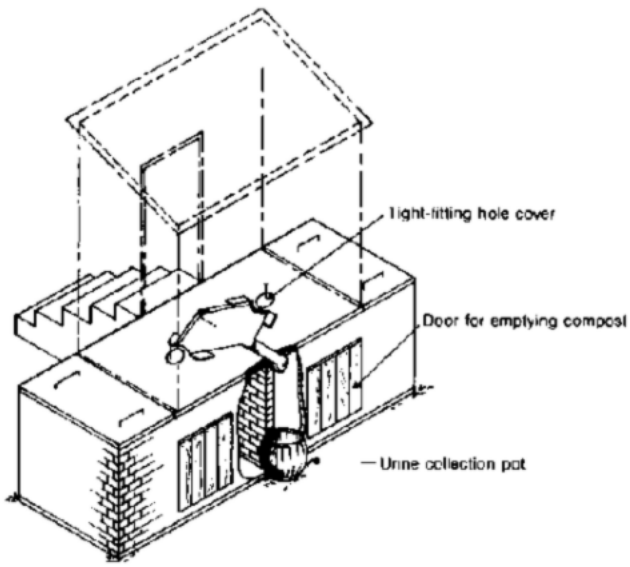


Fig. 6.32. Double-vault latrine

WHO 91451

Figure 8.3: Representation of the DVC Latrine

The DVC latrine is simple, easily constructed, requires moderate maintenance, is cost-effective($70 us), and creates a valuable byproduct. The DVC is a closed-cycle-system: it saves water, prevents groundwater pollution, and produces a fertilizer/soil conditioner for agriculture. Treated human excreta can be used as a fertilizer to increase the water holding and ion-buffering capacity of soil (Cole et al., 2009). Proper construction and use of the DVC are important, so as to prevent pathogenic contamination on agricultural produce.

How it works: The DVC can be built above or in the ground, if in the ground, the water table should not be close. The DVC consists of two vaults, one is in use, the other contains decomposing excreta. Each vault is ideally built two accommodate one year of excreta. Excreta enters the vault free from urine (it is a dry system and urine is collected in jars). Sawdust or ash are thrown into the vault after each use, reducing moisture content. When the vault is 75% full, it is completely filled with dry Earth and the squat hole is sealed. For the following 6-12 months microorganisms (aerobic and anaerobic) decompose the excreta and pathogens die (the vault is often painted black to increase the rate of dehydration, and solar panels can be used) (NZDL, ????). During this time the other vault is used. After said time, the decomposing vault is emptied and used for fertilizer (Figure 8.3).

A study found that after emptying decomposed containers, 63% of households immediately used the contents for fertilizer; the remaining households conducted a secondary form of composting. 61% of households reported using urine on crops and garden trees. Researchers found 91% of households were satisfied with the DVC latrine. However, 73% of households reported emptying the vault 1-2 times per year, prior to rice planting (February and June). This suggests the vaults were often emptied before the recommended 6-12 month storage period (Cole et al., 2009). Reported problems with the system were fly pestilence and odors. Ultimately, the DVC is a more circular system than the septic latrine as it produces fertilizer and preserves water; nonetheless, it still releases GHGs.

8.3.4 Municipal Utility Sewage Treatment: Linear

Many parts of SE Asia do not have the funds for large scale wastewater treatment facilities like those present in Europe and the United States. Although developed countries have formidable facilities, the majority use linear processes that refine water (as described by aerated septic systems) but do not capture GHGs produced through anaerobic microbial decomposition. Sludge waste collected through water refinement, is sent to landfills where CH4 and other GHGs are furthermore released (USGS, ????; EPA, 2018).

8.3.5 The Anaerobic Digester and Biogas: Circular Sewage Treatment

According to the United Nations, 80% of wastewater flows into the ecosystem without being treated or reused. This creates a multitude of problems for the environment and human health: great amounts of GHGs are released into the atmosphere and roughly 1.8 billion people drink and use the pathogenic water, risking infection: cholera, dysentery, typhoid and polio, and ingest of toxic chemicals (UN, ????*b*).

Polluted rivers contribute significantly to global warming. The New Territories of Hong Kong may appear clean and lush with agricultural fields, expansive greenery and mountains; however, in reality, the rivers flowing through these areas are saturated with three primary greenhouse gases: methane, carbon dioxide, and nitrous oxide. A study found the concentration of said gases were 4.5 times greater in the rivers flowing near Hong Kong, than found at atmospheric levels. The cause of pollution is discharge from agricultural livestock (farm waste contributes to 58% of world methane emissions) and human effluents [MLH: citepsmith–citation broken]. It's estimated that rivers and streams release up to 3.9 billion tonnes of carbon each year (around four times the amount of carbon emitted annually by the global aviation industry) (bbc, 2019). Moreover, itâĂŹs estimated global rivers and lakes are the cause of more than 50% of atmospheric methane concentrations, largely due to unrecovered methane in untreated wastewater. The more polluted the rivers, the higher the emissions. "When rivers become polluted, their global warming potential (GWP) can increase from two to 10 times" says Long Tuan Ho, researcher at Ghent University, Belgium (Matthew, ????). Moreover, the CO2 and N2O concentrations of water zones close to urban areas were found to be four times higher than those at natural sites; in the case of methane, this ratio was 25 times higher. Again, the primary culprit is untreated wastewater runoff. When untreated effluents enter bodies of water, biogeochemical reactions occur via anaerobic microorganisms which create GHGs (CO2, N2O, CH4), consequently resulting in a positive (warming) feedback loop. The septic system, double-vault-composting latrine, and the vast majority of municipal wastewater treatment sites release GHGs into the atmosphere. These linear waste management systems are increasing the rate of global warming and untreated wastewater is infecting limited drinking water supply with pathogens.

Water is precious and so is energy. Anaerobic wastewater digestion with biogas recovery is a circular "waste-to-energy technologyâĂİ that can greatly reduce world methane emission, furthermore, the captured CH4 can be used for a variety of human energy needs. The system is low-cost, readily available, carbon-neutral, and reduces environmental degradation caused by fossil fuels.

How it works: During natural decomposition, anaerobic microorganisms transform biomass (organic matterâĂŤsewage, food waste, animal manure) into methane gas and digestate (the material that remains after anaerobic digestion). Biogas can be converted into electricity or fuel, and then used throughout the energy sector, ie: cooking, lighting, transportation, building conditioning (wilkie, ????). Digestate is nutrient dense and can be used as a non synthetic fertilizer for crops. Biogas is 40%âĂŞ60% methane, the remainder is CO2, small amounts of water vapor, and other gases. Biogas can be burned directly, used to generate electricity, or treated to become biomethane–a low carbon "pipeline-qualityâĂİ fuel (EIA, ????) (Environmental and , EESI) (EPA, 2018) (wilkie, ????).

When methane is burned, the potent GHG is transformed into energy and CO2 is released. While CO2 is also a potent GHG, the CO2 being produced is not adding new carbon to the atmosphere, this is the CO2 naturally sequestered by plantsâĂŞâĂŞthus the CO2 is carbon neutral. Burning methane is far better than having it escape into the atmosphere. If biogas is used in place of fossil fuels, the net emissions are "negligibleâĂİ in comparison (Fu et al., 2017). While many wastewater treatment centers have anaerobic digesters, the majority do not have energy recovery systems, thus they incinerate sludge or dispose it into landfills, which releases methane, CO2 and nitrous oxide into the atmosphere; consequently, these linear disposal systems increase the rate of climate change and society loses a valuable source of energy. Wastewater treatment with biogas-recovery systems are an example of circular waste management: they save money, capture energy, and reduce global warming.

A pilot project in Xiangyang, China, illustrates how sludge to energy refinement can power the treatment facility itself, recover valuable nutrients and energy, reduce GHG emissions, prevent land and water pollution, and be cost-effective. Over the course of its lifetime, the treatment facility reduces GHG emissions by more than 95 percent (Liu, ????). A 2015 report found the plant can supply 300 cars with natural gas daily. The system is also profitable making the plant $ 1.5 million annually. Four large cities in China: Beijing, Changsha, Chengdu and Hefei have implemented, or plan to install, sludge to energy facilities, which will reduce 700,000 tons of CO2 emitted per year and are estimated to produce 40 millions cubic meters of compressed gas to be used by municipal vehicles (WRI, 2015).

Developing countries lacking sewage treatment infrastructure can benefit greatly at the village and city level by adopting sludge to energy systems. This is exemplified at the local level in Indonesia as 80% of Indonesian households dispose their waste into septic tanks; 60% of these septic tanks are located less than 32 feet from the household wells which results in high concentrations of E. coli in drinking water (Andriani et al., 2015; , ????). Similar conditions are described in Vietnam and other SE Asian countries. Small and affordable ($ 35-100 usd) decentralized digesters can be used at homes for kitchen waste as well as for livestock and human excreta (wor, ????). The biogas produced can be used directly for cooking and electricity generation. Educating and supporting low-income communities to use anaerobic digester systems will reduce deforestation for firewood, improve water quality, and mitigate climate change. Further research may elucidate if anaerobic digesters can be used in conjunction with the double-vault-compost latrine and septic tanks.

Biomass to energy systems can be applied to any form of organic waste; therefore, 3.9 trillion kg of human/livestock faeces p/y and the 1.3 billion tonnes of global food wasted each year, could be repurposed and turned into carbon-neutral energy (FAO, ????). The electricity generated from biogas could meet the needs of about 40 million people globally, 22 percent of global electricity consumptionâĂİ (aquatech, ????). By 2030 it is estimated the planet will be generating more than one trillion kg of faeces each year, this number is expected only to rise with population growth (Berendes et al., 2018) (UN, ????*a*). The rising population with associated life consumption waste (food, agriculture, and excreta), makes biogas sequestration a great circular and sustainable technology for wastewater treatment. According to Niclas Svenningsen, manager for the Global Climate Action team at the United Nations:

"[Biogas] is a win-win-win-win-win industry: win for turning GHG into energy; win by using that energy to replace fossil fuels; win by turning global waste, that releases dangerous levels of methane gas every day, into a valuable resource; win by creating jobs and contributing to the new low-carbon economy; win by offering a stable energy source that can be built and used even at the household scale in remote areas" (Hughes, 2019). Biogas is a highly recommended wastewater-nutrient-energy technology for the world and SE Asia.

8.3.6 Phytoremediation: Wastewater Circularity

Phytoremediation, "plant remedy," is considered an effective, aesthetically pleasing, and cost-effective sustainable wastewater treatment technology which is governed by the principles of interdependence and circularity (Ali et al., 2020). Phytoremediation has been used for the last 300 years, but became well known in 1983 (Stephenson and Black, 2014). A phytoremediation site can treat a multitude of industrial and municipal pollutants including: pesticides, chlorinated solvents, polycyclic aromatic hydrocarbons (PAHs), Polychlorinated biphenyl (PCBs), petroleum hydrocarbons, radio nucleosides, surfactants, explosive elements, heavy metals[1], as well as sewage and livestock excreta. Phytoremediation prevents soil erosion reducing the spread of contaminants (groundwater leaching can occur) (Ali et al., 2020). The treatment method is cost-effective, and does not require exclusive equipment or highly trained workers. The clean up cost is dismal, giving it a special place among green technologies. The disadvantages include a slower treatment time, possible source of dangerous mosquitoes, and is limited to shallow contaminants (Mustafa and Hayder, 2020). The aquatic plants (macrophytes) used have the following characteristics: they are fast growing, produce a high biomass yield, transport metals and pollutants into above ground part of the plants, and can tolerate high levels of metal toxicity.

Plant selection is the most important aspect of phytoremediation. Water hyacinth (Eichhornia crassipes), water lettuce (Pistia stratiotes) and Duckweed (Lemna minor) are prominent phytoremediation plants. These plants create a thriving environment for microorganisms, fungi and bacteria, providing them with enzymes from their roots. The microbes reduce pathogens and metal toxicity; they also provide plants with nutrients, increasing a plantâĂŹs phytoremediation ability (Kaur, 2020). This plant-microbe mutualism showcases circularity in action. Figure 8.4

How phytoremediation works: Wastewater travels through matrices of floating plants, the plantâĂŹs roots filter the water (rhizofiltration), absorbing nutrients and heavy metals. The leaves above water sequester carbon and hold pollutants. During photosynthesis, the plants release oxygen, aerating the water for aerobic microbes, which in turn break down faecal pathogens and supply nutrients to plants.

Water hyacinth (Eichhornia crassipes) has been deemed a problematic and invasive plant because of its high growth rate, but is now used for phytoremediation technology. Water hyacinth is the recommended treatment plant for industrial wastewater, domestic wastewater, sewage effluents, and sludge ponds because it absorbs high rates of organic and inorganic contaminants, can tolerate extreme pollution, has a high biomass production rate, absorbs nitrogen and phosphorous, and can remediate metals like arsenic, zinc, mercury, nickel, copper and lead (Mustafa and Hayder, 2020). The associated wastewater processing time of water hyacinth is 1-2 months (Mustafa and Hayder, 2020). Sewage pathogens are broken down by predators, protozoa and bacteriophages, living near the plantâĂŹs roots (Aguainc, 2015). Nitrogen, a rich element present in sludge, leads to the eutrophication of the environment, while phosphorus (present in urine) can lead to cyanobacterial (algae) blooms causing ecological imbalances (Aguainc, 2015). Nitrogen and phosphorus accumulate

[1] Heavy metals are said to cause damage to DNA and produce carcinogenic effects in animals and humans (Kaur, 2020). Linear waste activities such as mining, municipal waste, application of fertilizer, discharge of urban effluent, vehicle exhausts, waste incineration, fuel production, and smelting release heavy metal contaminants into the wastewater stream (1).

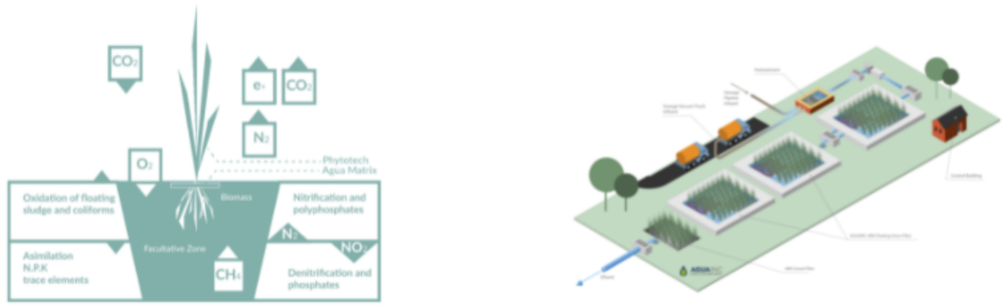


Figure 8.4: Phytoremediation facility and how the biotechnology works

in the roots of water hyacinth, which can be later harvested for compost, fertilizer, and biofuel (Kulkari, ????) (Aguainc, 2015). Metals that have accumulated in the plant stem and leaves can also be recovered (Aguainc, 2015). Phytoremediation plants can be used in all forms of wastewater treatment, as well as implemented in rivers and other bodies of water. Phytoremediation is an important circular technology, treating a variety of pollutants. It is a sustainable bio-wastewater treatment system that can provide solutions to communities through SE Asia and other parts of the world.

In Cambodia, about 100,000 people live in floating communities on the Tonle Sap Lake (Wetlands, 2019). During the low-water dry-season, much of the community's ambient water becomes infected with human excreta. Children, especially, are at high risk of pathogenic exposure as they play in the lakeâĂŹs water. Wetlands Work, a social enterprise, has developed the "Handy Pod,âĂİ a circular, cost-effective, waste water treatment system for these floating communities (Figure 8.5). The system uses microbes and phytoremediation to refine sewage to "grey waterâĂİ levelsâĂŞâĂŞdeemed low risk. The effluent quality tested 28-100 colony forming units (cfu)/100 ml in a one-half cubic meter volume of ambient water; this is significantly less than the Cambodian standard maximum: 1000 cfu/100 for contact recreation water quality. The system reduces E-coli by 99.9%.

The Handy Pod costs $ 30US to assemble. It is then placed beneath the floating houseâĂŹs latrine. After use, excreta travels into an expandable bag, which is treated by naturally occurring microbes, the remaining effluent is then processed by water hyacinth plants, pathogens stick to their roots and are further broken down by microbes. The treated water then flows into the lake (Akpan, 2014). The Pod was tested for three years and has been deemed successful. It has no smells, is aesthetic, there are no mosquitoes, no chemicals, it has demonstrated stability during storms, and requires little to zero maintenance. While problems still face the Handy Pod, like residual pathogens, it is a positive step forward for sanitation in impoverished zones. It illustrates how small circular systems can be made, as well as exemplifying the effectiveness of microbial digestion and phytoremediation. A point of further research is to know if biogas recovery systems could be implemented in conjunction with the Handy Pod.

Figure 8.5: The HandyPod

8.4 Linear Chemicals in Wastewater: Pesticides in Taiwan

Pesticides and chemicals are a concern for wastewater treatment since they pass untreated through the majority of wastewater facilities, collecting in humans, animals, and the environment. Synthetically formulated pesticides became widespread after WWII. They enable large farm yields; nevertheless, pesticides are toxic to humans, animals, and a large number of non-invasive insects. Many pesticides are "persistentâĂİ (not breaking down easily) so they donâĂŹt have to be reapplied often, and they are hydrophobic, to not be washed off by rain. Pesticides are a classic example of a linear product that is low cost, used widely, results in great yields, and is of harm to humans and the environment (OregonState, ????). Today synthetic pesticides are still used throughout the world, especially in SouthEast Asia where agriculture is a principal commodity.

Taiwan is a relatively small island in SE Asia (13,974 mi^2), surrounded in the north by the East China Sea and to the south by the Pacific Ocean. Located in the semi-tropics, Taiwan is one of the most densely populated islands in the world with 23.57 million people (bbc, 2019). The following case study examines the presence of toxic pesticides located in the Danshui River (largest river in Taiwan), which ultimately passes through a waste treatment plant; pesticides still flow into the ocean. Figure 8.6 illustrates points of sampled sediments, the greatest being at D13, the wastewater treatment site.

The island experiences a dry and wet season. During the dry season, pesticides were found in river sediments. During the wet season, characterized by winter and summer/fall monsoons, pesticides were found in the ocean ecosystem and marine organisms. The river is defined as a primary transport process and the ocean as a second transport process. Each section of the river is important and sheds light on understanding the pesticide life-cycle in the environment. The Da-han River (top of the Dan Shui) brings fresh water to agriculturists; the Shin-dan River (mid-point of the Dan Shui) provides water to tea farms in drinking water for citizens in Taipei (2.646 million inhabitants) and neighboring counties; finally, the Keelung River (last leg of the Dan Shui) is distinguished by many industrial plants located within the the riverâĂŹs drainage basin; The waste-water treatment facility

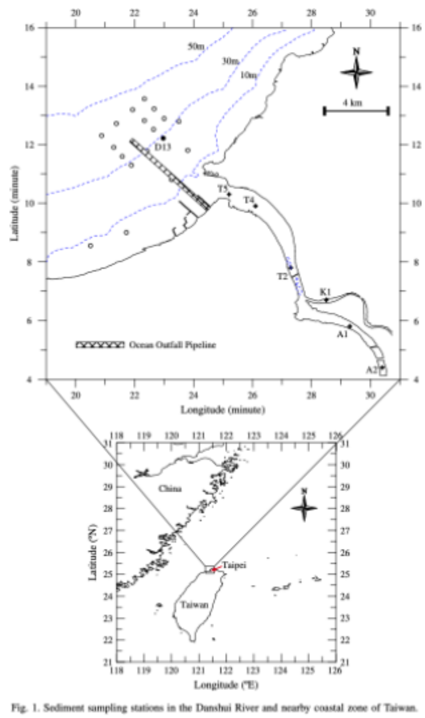


Figure 8.6: A representation of the advantages of a Circular Economy

located at the mouth of the estuary (where the river flows into the ocean) was the point of highest pesticide contamination and is where oysters and other sea creatures were found to have pesticides in their bodies (Hung et al., 2007).

The pesticides were found in sediments and the marine ecosystem. Pesticides, which are made from hydrophobic carbon-chain molecules, adhere to carbon-based particles in the water, which eventually fall into river sediments. The pesticides are "stickyâĂİ and layer onto each other. There are many pesticides in use (tetrachlorobenzene, HCHs, aldrin, dieldrin, chlorpyrifos, mirex, DDEs, DDDs, and DDTs) and it becomes hard for scientists to differentiate between them since they mesh together (Hung et al., 2007). When the chemicals enter the marine ecosystem they attach to phytoplankton which are ingested by clams and fish, which die and enter ocean sediments or are consumed by other aquatic organisms, or humans (Huertos, conversation). "The sum of pesticides, including tetrachlorobenzene, HCHs, aldrin, dieldrin, chlorpyrifos, mirex, DDEs, DDDs, and DDTs, was found in offshore sediments at station D13, approximately 6e7 km from the Danshui River mouth (Fig. 1). Coincidently, the discharge point, with several output pipelines connecting to the main pipeline, of the marine outfall pipeline from the Pali sewage treatment plant is located near this station (Sinotech, 1997)...... Therefore, the fact that individual pesticide concentrations that are found at the station near the marine outfall pipe are high or highest suggests that the sewage treatment plant is still discharging pesticides from residual activated sludges and/or fine particles" (Hung et al., 2007). Pesticides from present and past agricultural practices were found in the ecosystem, illustrating pesticide persistence. This study illustrates the importance of understanding where pesticides end up (always into the ecosystem and into organisms) and their main outlet source. The Pali sewage treatment plant illustrates how many municipal wastewater treatment facilities ineffectively treat pesticides. Pesticides are illustrated here as single-use linear products, which pass through waste management systems, accumulating in the environment and harming organisms. This is of great concern as pesticides exposure has been linked with health defects in humans, animals, and plants (Sharma et al., 2019). This study also raises questions on the quality of drinking water in Taipei.

8.4.1 Pesticides in Taipei Food Toxicology: (further research is needed for drinking water)

Taiwan ranks third globally in pesticide usage "per unit of area plantedâĂİ (Japan is number one). Without pesticides, the annual output of rice would decrease by 15% the first harvest and 30% the second (similar results would occur with other produce) (Ministry of Foreign Affairs, ????). Nonetheless, pesticides are problematic for the environment and detrimental to human and animal health. Acute exposure to humans can cause: stinging eyes, rashes, blisters, blindness, nausea, dizziness, diarrhea and death. Known chronic exposure can result in: cancer, birth defects, reproductive harm, neurological and developmental toxicity, immunotoxicity, and disruption of the endocrine system (Nicolopoulou-Stamati et al., 2016). Pesticide awareness is growing and many people throughout SE Asia are raising the red flag. Greenpeace, an NGO in Taiwan, measured pesticide residue on 60 vegetables and fruit sold at major retail outlets throughout Taiwan: RT-Mart, Pxmart, Carrefour, Wellcome, A. Mart, Costco, 7-Eleven and FamilyMart. The study found 73% (44/60) of the tested specimens contained pesticide residue, 27% (12/44) were above pesticide safety levels, and five contained prohibited pesticides (Ministry of Foreign Affairs, ????). These dangerous chemicals were found in oranges and passion fruit from A. Mart, as well as oilseed, lettuce and jujubes from Carrefour. Green beans from Costco were found to contain fungicide residue 69 times higher than the legal amount. Lo Ko-jung, the project manager at Greenpeace said: "The solution to pesticide residue in food relies on retailers proposing specific measures to ban pesticide-containing products, but Costco ignores the consumerâĂŹs right to know because it has refused to disclose its pesticide management policy" (Ministry of Foreign Affairs, ????). Trade secrecy laws allow manufacturers to exclude specific ingredients or chemical quantities on labels if doing so would decrease profitâĂŤillustrated by Costco.

Pesticides are a waste management issue because agriculture runoff and improper disposal release pesticides into wastewater flow, processed by treatment facilities lacking expensive pesticide removal technology; consequently, pesticides enter humans and the environment. If dangerous substances are passed untreated through wastewater treatment facilities, they are a waste management issueâĂŤthis is regarded to be true for any synthetic chemical. Most countries in SE Asia lack a pesticide waste management framework, 80% of pesticides are imported illegally and are uncontrolled, they are cheap and high in toxicity (Thuy et al., 2012). Pesticides are a linear commodity whose end-life produces toxic water, which accumulates in sediment, enters living organisms, or circulates through the hydrologic cycle (Thuy et al., 2012). Pesticides and other chemicals are regarded here as neither technical nor biological nutrients, as they pose a threat to humans and the environment alike.

8.4.2 Circular Biopesticides: An Alternative To Hazardous Synthetic Pesticides

A circular alternative to pesticides are biopesticides and bioherbicides. They have been used since the 1950âĂŹs but are now gaining global attention as they provide a sustainable and safe alternative for agricultural needs stefanski2020potential (Hubbard et al., 2014). Biocontrol products are produced from naturally occuring funguses, microbes, plant metabolites, and biochemicals, which mitigate unwanted pests and weeds with little or no health/environmental effects. “Biopesticides from fungi are employed to control weeds, beneficial bacterial pesticides are used to control fungal and bacterial disease and viral pesticides are used to resist insect pestsâĂİ (Usta, 2013). The most effective biopesticides have been reported to be those which utilize compounds produced by microorganisms. Chemicals created by microbes produce toxic proteins, their production can be optimized through fermentation. Biopesticides target pests and do not negatively impact human health, animals or the environment, they are therefore circular and can be regarded as effective alternatives compared with synthetic pesticides.

Their advantages and disadvantages include the following: biopesticides are not “persistent,âĂİ they break down into the environment becoming part of the biosphere, thus creating a closed cycle. Because of their short life, more biopesticide application is required, this can potentially boost job markets. Bioinsecticides do not cause air or water quality problems. They often contain Bacillus thuringeinsis, a microbe which targets specific pests without harming other beneficial organisms (pollinators, humans, animals, etc). Nevertheless, if many pests are present, selective methods do not serve the intended purpose of a pesticide (however, given biopesticides come in multiple forms, this caveat may be remediated) (McCoy et al., 2020). The creation and application of biopesticides is often more complicated and their use requires more knowledge, for instance, nematodes must be refrigerated and used within two weeks for effectiveness. Thus, education is important for biopesticide implementation. Furthermore, biopesticide microbes utilize “multiple modes of actionâĂİ preventing pest resistance; this is advantageous as synthetic pesticides use “single modes of action,âĂİ which pests become resistant to (Hubbard et al., 2014). While initially more expensive, natural pesticides do not cause health issues, thus saving one from suffering and health expenses in the long run. Additionally, biopesticides have a registration time of less than a year (because they are seen as less dangerous), compared with synthetics which call for three years (Mordor, ????).

More than 225 microbial biopesticides are currently being manufactured in 30 countries in the Organization of Economic Development and Cooperation. The US, Canada, and Mexico account for 45% of all biopesticides sold; Asia accounts only for 6% which demonstrates AsiaâĂŹs lack of organic agriculture practice, yet presents an incredible opportunity for SE Asia to increase its health/environmental wellbeing, while also increasing economic prosperity (Hubbard et al., 2014) (Mordor, ????). A shift in pesticide use is now occurring in Asia as countries like Vietnam are recognizing the advantages of using bioinsecticides. The biopesticide market is expected to reach USD 60.61 million by 2024 (MarketWatch, 2021). The International Rice Research Institute (IRRI) has called for a ban of certain synthetic pesticides, increasing awareness and demand for biopesticides in SE Asia. China was recently placed first in the field of biopesticides research and development worldwide (Mordor, ????). Demand for sustainable agriculture is building and biopesticides are an important part of the shift. Further research in biotechnology and chemistry can potentially help lower biopesticide prices and increase their presence throughout the world, especially in SE Asia (Hubbard et al., 2014).

8.5 Further Research Needed: Linear Chemical WasteäÿĂ“Forever Chemicals”

An individual chemical can persist in the environment for long periods of time, moreover, they build up. The majority of these man made chemicals are polyfluoroalkyl substances (PFAS: PFOAs and PFOs) (different from pesticides): they are a broad class of more than 5,000 chemicals used in a great number of products including “clothing, furniture, nonstick cookware, food packaging, firefighting foams, and electrical wire insulation,âĂİ furthermore, they are found in seafood, agriculture produce, and drinking water (Hersher, 2019). Linda Birnbaum, the director of the National Institute of Environmental Health Sciences and the National Toxicology Program, says: "We're finding them not only in the environment, but we're finding them in people" (Hersher, 2019). These persistent materials are called "forever chemicals,âĂİ and are resilient to natural degradation processesâĂŞâĂŞchemical, biological and photolyticâĂŞâĂŞbecause of strong covalent bonds between carbon and fluorine atoms (ACS, ????). PFAS can dissolve in water, and because of their chemical properties, traditional wastewater treatment technologies are not able to remove them (EPA, 2018) (IPEN, ????). These chemicals often enter into organisms through water or food, bioaccumulating in tissues and binding to proteins; as organisms are consumed, the chemicals cycle through the food chain, just like pesticides. In humans PFAS are often found in blood, liver and kidneys (IPEN, ????). However, recent studies have found PFAS contamination in breast milk in India, Indonesia, Japan, Sri Lanka (bood), Malaysia, and Vietnam which have been found in fetusâĂŹ (IPEN, ????).

Epidemiologists have found a "probable link" between long-term exposure to the PFAS chemicals and certain medical conditions such as: kidney cancer, thyroid disease, (female and male) infertility and developmental effects, lung defects, and more. These chemicals are also found in the blood, liver and kidneys of wildlife. Sewage treatment plants have been identified as major polluting sources of PFAS, evidenced by Japan, Thailand, Vietnam and other countries (IPEN, ????). These chemicals are linear, and circular solutions are deemed necessary to phase them out internationally (Land et al., 2018).

There are many valuable resources present in wastewater; however, these do not include pesticides and "forever chemicals.âĂİ It has been 82 years since industrial chemicals (PFAS and pesticides) were first created, yet they are still causing harm to humans and the environment, and still people don't know what to do with them. Phasing them out and replacing them with alternatives is a priority.

8.5.1 Household Products

The average home throughout the developed world contains a multitude of cleaning products which may contain forever chemicals. Given cleaning productsâĂŹ wide usage, they are often overlooked as dangerous to human and environmental health. When cleaners are washed down the drain by millions of people, even trace amounts become a serious problem. The problem extends to septic tanks and municipal sewage (Bown, ????).

Municipal sludge, a valuable fertilizer, often cannot be repurposed because itâĂŹs laden with pharmaceuticals, chemicals and PFAS, which make people and the environment sick through fertilizer use (Perkins, 2019). Global wastewater can contain hormones, pathogens, heavy metals (lead, cadmium, arsenic and mercury), as well as chemicals: pesticides, pharmaceuticals, PCBs, PFAS, BPAs and other harmful substances (Perkins, 2019). Effective wastewater treatment addresses the conglomerate of elements present in water. Given wastewater treatment plants in developed nations still emit dangerous chemicals, their expensive installation is not an advisable trajectory for developing nations to follow, rather a global phasing out of "persistentâĂİ toxic substances is in order. Further research is needed to understand PFAS wastewater treatment and how to phase them out.

8.6 Conclusion

The linear production model will not sustain life on Earth. Consumption is a necessity for life, but creating waste is not. Energy, which constitutes all things, can neither be created nor destroyed, it

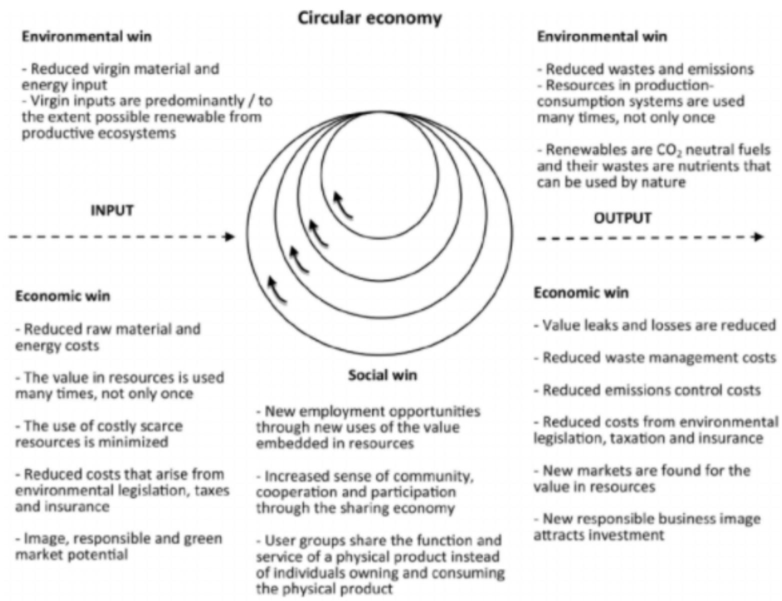


Figure 8.7: A representation of the advantages of a Circular Economy

only changes form. It makes sense for humans to live in accordance with this law of the universe; circular systems are a way to do so. Circular economics is being pushed forward as a new alternative, nevertheless circular living has been iterated for thousands of years by first nation people, who to this day live in this way. Through biomimetic systems, society can exist in synergy with the environment. The circular economy is underdevelopment and has a ways to go, but as illustrated by case studies from SE Asia, bio-regenerative-wastewater-treatment-systems with ingredient recovery are fundamental to its realization.

The double-vault-compost latrine, the anaerobic digester, and phytoremediation use natural microbes to treat wastewater, thus demonstrating how humans can design with nature's existing systems. Valuable nutrients: fertilizer, bioenergy, and metal, can all be recovered through engineered solutions informed by natural chemistry. Similarly, by understanding microorganisms, biopesticides are developed. These case studies demonstrate SE Asia and the world can benefit greatly by adopting bio-regenerative-wastewater-treatment-systems, increasing wellbeing, environmental protection, and economic prosperity (Figure 8.7).

Further research is needed to understand how to remediate PFAS and other toxic chemicals including pharmaceuticals and cleaners; to understand the low-cost construction details of decentralized anaerobic digesters and how they can be attached to DVC latrines, and septic tanks (Gihiandelli, 1; Mang, 1). Questions to be further researched: what circular biomimic innovations can be made for landfills; how can further research into interconnectivity resolve societies issues; how can existing linear systems and supply-chains be made circular?

Part I

Backmatter

Glossary

entry my entry description.. xix

peat is cool.. xvi

References

????

???? A low-priced water reuse process that also delivers renewable energy in rural areas. URL https://blogs.worldbank.org/water/low-priced-water-reuse-process-also-delivers-renewable-energy-rural-areas.

???? The nine planetary boundaries. URL https://www.stockholmresilience.org/research/planetary-boundaries/planetary-boundaries/about-the-research/the-nine-planetary-boundaries.html.

2015. The case for slower growth. URL https://www.economist.com/the-world-if/2015/07/30/the-case-for-slower-growth.

2019. Taiwan country profile. URL https://www.bbc.com/news/world-asia-16164639.

2021. Welcome. URL https://epi.yale.edu/.

ACS. ???? ChemMatters Demystifying Everday Chemisty Teachers Guide.

Administration, U. E. I. 2020. Waste-to-energy (MSW) in depth - U.S. Energy Information Administration (EIA). URL https://www.eia.gov/energyexplained/biomass/waste-to-energy-in-depth.php.

Aguainc. 2015. Turning dumps into oases-this startup is shaping the future of water management - unreasonable. URL https://unreasonablegroup.com/articles/agua-inc/.

AIR, I. 2020. Report: Covid-19 impact on air quality in 10 major cities.

Akpan, N. 2014. Floating toilets that clean themselves grow on a lake. URL http://www.npr.org/sections/goatsandsoda/2014/12/23/371862099/floating-toilets-that-clean-themselves-grow-on-a-lake.

Al-Attili, A. 2021. Environmental and ecological economics. URL https://www.soas.ac.uk/cedep-demos/000_P570_IEEP_K3736-Demo/unit1/page_12.html.

Ali, S., Z. Abbas, M. Rizwan, I. E. Zaheer, İ. Yavaş, A. Ünay, M. M. Abdel-Daim, M. Bin-Jumah, M. Hasanuzzaman, and D. Kalderis. 2020. Application of floating aquatic plants in phytoremediation of heavy metals polluted water: a review. Sustainability, **12**:1927.

Almond, G. M., R.E.A. and T. Petersen. 2020. Living planet report 2020 bending the curve of biodiversity loss. World Wildlife Foundation, pages 453–460. URL https://f.hubspotusercontent20.net/hubfs/4783129/LPR/PDFs/ENGLISH-FULL.pdf.

Andriani, D., A. Wresta, A. Saepudin, and B. Prawara. 2015. A review of recycling of human excreta to energy through biogas generation: Indonesia case. Energy Procedia, **68**:219–225.

aquatech. ???? Biogas: an untapped energy source to avert a climate crisis? URL https://www.aquatechtrade.com/news/wastewater/biogas-energy-source-to-avert-climate-change/.

Aquino, A. and D. Kaczan. 2019. Marine science for healthy reefs and resilient communities 21 years of coremap in indonesia. World Bank. URL https://blogs.worldbank.org/eastasiapacific/marine-science-healthy-reefs-and-resilient-communities-21-years-coremap-indonesia.

Arshad, A. 2016. 140m in se-asia do not have clean water. URL https://www.straitstimes.com/asia/se-asia/140m-in-se-asia-do-not-have-clean-water.

Assessment, W. 2002. United nations environment programme.

Ayala, C. 2009. Effects of ocean acidification on corals. Oceana USA. URL https://usa.oceana.org/effects-ocean-acidification-corals.

Bank, W. 2017. The World Bank Annual Report 2017. The World Bank.

Bauman, B. 2019. Why plastics can be garbage for the climate. URL https://yaleclimatemediaforum.org/2019/08/how-plastics-contribute-to-climate-change/.

Beck, M. 2019. Coral reefs provide flood protection worth $1.8 billion every year-itâĂŹs time to protect them. The Conversation. URL http://theconversation.com/coral-reefs-provide-flood-protection-worth-1-8-billion-every-year-its-time-to-protect-them-116636.

Ben-Ari, E., B. Moeran, and J. Valentine. 1990. Unwrapping Japan: Society and Culture in Anthropological Perspective. Manchester University Press. Google-Books-ID: aYC7AAAAIAAJ.

Berendes, D. M., P. J. Yang, A. Lai, D. Hu, and J. Brown. 2018. Estimation of global recoverable human and animal faecal biomass. URL https://www.nature.com/articles/s41893-018-0167-0.

Bird, W. 2012. Will Fish-Loving Japan Embrace Sustainable Seafood? URL https://e360.yale.edu/features/will_fish-loving_japan_embrace_sustainable_seafood.

Bolt, J. and J. L. van Zanden. 2020. Maddison style estimates of the evolution of the world economy. a new 2020 update. University of Groningen, Groningen Growth and Development Centre, Maddison Project Working Paper.

Bowen, T. 2015. Social protection and disaster risk management in the Philippines: the case of typhoon Yolanda (Haiyan). The World Bank.

Bown, C. ???? Household hazardous products and hazardous waste: A summary for consumers.

Brandl, S. J., D. B. Rasher, I. M. CÃťtÃľ, J. M. Casey, E. S. Darling, J. S. Lefcheck, and J. E. Duffy. 2019. Coral reef ecosystem functioning: eight core processes and the role of biodiversity. Frontiers in Ecology and the Environment, **17**:445–454. URL https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1002/fee.2088.

Braungart, M., W. McDonough, and H. S. Kroese. 2011. Cradle to cradle: afval=voedsel. Search Knowledge.

Brewer, T. D., J. E. Cinner, A. Green, and R. L. Pressey. 2013. Effects of human population density and proximity to markets on coral reef fishes vulnerable to extinction by fishing. Conservation Biology, **27**:443 – 452. URL http://search.ebscohost.com.ccl.idm.oclc.org/login.aspx?direct=true&AuthType=sso&db=8gh&AN=87671764&site=ehost-live&scope=site&custid=s8438901.

Bruckner, A. W. 2002. Life-saving products from coral reefs. Issues in Science and Technology. URL https://issues.org/p_bruckner-coral-reefs-importance/.

Bureau of Environment, T. M. G. 2019. Tokyo plastic strategy.

Burke, L., E. Selig, and M. Spanlding. 2002. Reefs at Risk in Southeast Asia.

Campbell, S. J., E. S. Darling, S. Pardede, G. Ahmadia, S. Mangubhai, Amkieltiela, Estradivari, and E. Maire. 2020. Fishing restrictions and remoteness deliver conservation outcomes for indonesia's coral reef fisheries. Conservation Letters, **13**:e12698. URL https://conbio.onlinelibrary.wiley.com/doi/abs/10.1111/conl.12698.

Capistrano, R. C. G. 2010. Reclaiming the ancestral waters of indigenous peoples in the philippines the tagbanua experience with fishing rights and indigenous rights. Marine Policy, **34**:453–460. URL http://search.ebscohost.com/login.aspx?direct=true&AuthType=sso&db=8gh&AN=48260001&site=ehost-live&scope=site&custid=s8438901.

Chen, T., G. Roff, L. McCook, J. Zhao, and S. Li. 2018. Recolonization of marginal coral reef flats in response to recent sea-level rise. Journal of Geophysical Research: Oceans, **123**:7618–7628. URL https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2018JC014534.

Chen, Y., Z. Duan, J. Yang, Y. Deng, T. Wu, and J. Ou. 2021. Typhoons of western north pacific basin under warming climate and implications for future wind hazard of east asia. Journal of Wind Engineering and Industrial Aerodynamics, **208**:104415.

Cole, B., P. D. Phuc, and J. Collett. 2009. A qualitative and physical investigation of a double-vault composting latrine programme in northern vietnam. Waterlines, **28**:333âĂŞ342.

CORAL. 2021. Coral reef ecology. URL https://coral.org/coral-reefs-101/coral-reef-ecology/.

Crossley-Baxter, L. 2020. Japan's ancient way to save the planet. URL file:///Users/eleanordunn/Zotero/storage/BBLWIFX6/20200308-japans-ancient-way-to-save-the-planet.html.

Cwiertka, K. J. 2020. Packaging of Food and Drink in Japan. In H. L. Meiselman, editor, Handbook of Eating and Drinking, pages 509–524. Springer International Publishing, Cham. URL http://link.springer.com/10.1007/978-3-030-14504-0_165.

Dasgupta, S., B. Laplante, H. Wang, and D. Wheeler. 2002. Confronting the environmental kuznets curve. Journal of economic perspectives, **16**:147–168.

Davis, M. 2002. Late Victorian holocausts: El Nino famines and the making of the third world. Verso Books.

Dean, E. et al. 2014. Principles of Microeconomics: Scarcity and Social Provisioning. Open Oregon Educational Resources.

Demetriou, D. 2020. How the Japanese are putting an end to extreme work weeks. URL https://www.bbc.com/worklife/article/20200114-how-the-japanese-are-putting-an-end-to-death-from-overwork.

Denyer, S. 2019. Japan wraps everything in plastic. now it wants to fight against plastic pollution. URL https://www.washingtonpost.com/world/asia_pacific/japan-wraps-everything-in-plastic-now-it-wants-to-fight-against-plastic-pollution/2019/06/18/463fa73c-7298-11e9-9331-30bc5836f48e_story.html.

Edmonson, S. 2011. HeightâĂŤGood For Basketball, Bad For Air. URL https://earthjustice.org/blog/2011-june/height-good-for-basketball-bad-for-air.

EIA. ???? U.s. energy information administration - eia - independent statistics and analysis. URL https://www.eia.gov/energyexplained/biomass/landfill-gas-and-biogas.php#:~:text=Biogasisanenergy-rich,andcarbondioxide(CO2).

Ekins, P., S. Simon, L. Deutsch, C. Folke, and R. De Groot. 2003. A framework for the practical application of the concepts of critical natural capital and strong sustainability. Ecological economics, **44**:165–185.

Emanuel, K. 2005. Increasing destructiveness of tropical cyclones over the past 30 years. Nature, **436**:686–688.

Emanuel, K. 2006. Hurricanes: Tempests in a greenhouse. Physics Today, **59**:74–75.

Emanuel, K. A. 1987. The dependence of hurricane intensity on climate. Nature, **326**:483–485.

Emanuel, K. A. 2013. Downscaling cmip5 climate models shows increased tropical cyclone activity over the 21st century. Proceedings of the National Academy of Sciences, **110**:12219–12224.

Environmental and E. S. I. (EESI). ???? Fact sheet: Biogas: Converting waste to energy. URL https://www.eesi.org/papers/view/fact-sheet-biogasconverting-waste-to-energy.

epa. ???? Improvements to the u.s. wastewater methane and nitrous oxide emissions estimates. U.S. Environmental Protection Agency.

EPA. 2018. Reducing pfas in drinking water with treatment technologies. URL https://www.epa.gov/sciencematters/reducing-pfas-drinking-water-treatment-technologies.

EPA. 2020. Septic systems and drinking water. URL https://www.epa.gov/septic/septic-systems-and-drinking-water.

Fabinyi, M. 2010. The intensification of fishing and the rise of tourism: Competing coastal livelihoods in the calamianes islands, philippines. Human Ecology, **38**:415–427. URL http://www.jstor.org/stable/40603032.

FAO. ???? Food loss and food waste. URL http://www.fao.org/food-loss-and-food-waste/flw-data)#:~:text=One-thirdoffoodproduced,1.3billiontonnesperyear.

Faulden, D. 2021. Air pollution: Asia's deadliest public health crisis isn't covid. URL https://asia.nikkei.com/Spotlight/The-Big-Story/Air-pollution-Asia-s-deadliest-public-health-crisis-isn-t-COVID.

Fox, H. E. and R. L. Caldwell. 2006. Recovery from blast fishing on coral reefs : a tale of two scales. Ecological Applications, **16**:1631–1635. URL https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/1051-0761%282006%29016%5B1631%3ARFBFOC%5D2.0.CO%3B2.

Fu, X., L. Schleifer, and L. Zhong. 2017. Wastewater: The best hidden energy source you've never heard of. URL https://www.wri.org/insights/wastewater-best-hidden-energy-source-youve-never-heard.

Greenpeace, M. 2018. The recycling myth. URL https://www.greenpeace.org/static/planet4-malaysia-stateless/2019/04/2fe6f833-the-recycling-myth-malaysia-and-the-broken-global-recycling-system.pdf.

Grossman, G. M. and A. B. Krueger. 1991. Environmental impacts of a north american free trade agreement. Technical report, National Bureau of economic research.

Hagen, R. V. and T. Minter. 2020. Displacement in the name of development. how indigenous rights legislation fails to protect philippine hunter-gatherers. Society and Natural Resources, **33**:65âĂŞ82.

Harden, B. 2008. Japan Stanches Stench of Mass Trash Incinerators - washingtonpost.com. URL http://large.stanford.edu/publications/coal/references/harden/.

Hersher, R. 2019. Scientists dig into hard questions about the fluorinated pollutants known as pfas. URL https://www.npr.org/sections/health-shots/2019/04/22/708863848/scientists-dig-into-hard-questions-about-the-fluorinated-pollutants-known-as-pfa.

Higuchi, K. and M. G. Norton. 2008. JapanâĂŹs eco-towns and innovation clusters-synergy towards sustainability. Global Environment, **1**:224–243.

Hoogervorst, T. G. 2012. Ethnicity and aquatic lifestyles: exploring southeast asiaâĂŹs past and present seascapes. Water History, **4**:245–265. URL https://link.springer.com/article/10.1007%2Fs12685-012-0060-0.

Hoy, S. 2018. Mottainai reduce reuse recycle - and respect. URL https://www.gov-online.go.jp/pdf/hlj/20180701/28-29.pdf.

Hubbard, M., R. K. Hynes, M. Erlandson, and K. L. Bailey. 2014. The biochemistry behind biopesticide efficacy. Sustainable Chemical Processes, **2**:1–8.

Hughes, J. 2019. Press release: Biogas can fill important place in climate emergency agenda says un climate change. URL https://www.worldbiogasassociation.org/press-release-biogas-can-fill-important-place-in-climate-emergency-agenda-says-un-climate-change/.

Hung, C.-C., G.-C. Gong, H.-Y. Chen, H.-L. Hsieh, P. H. Santschi, T. L. Wade, and J. L. Sericano. 2007. Relationships between pesticides and organic carbon fractions in sediments of the danshui river estuary and adjacent coastal areas of taiwan. Environmental Pollution, **148**:546–554.

Huynh, L. T., H. Harada, S. Fujii, L. P. H. Nguyen, T.-H. T. Hoang, and H. T. Huynh. 2021. Greenhouse gas emissions from blackwater septic systems. Environmental science & technology, **55**:1209–1217.

Imura, H., S. Yedla, H. Shirakawa, and M. A. Memon. ???? Inter-research "eci home. URL https://www.int-res.com/ecology-institute/eci-home/.

IPEN. ???? Pfas. URL https://ipen.org/tags/pfas.

Iwami, T. et al. 2001. "'advantage of late-comer'in abating air-pollution: Experience in east asia"(in japanese). Technical report, CIRJE, Faculty of Economics, University of Tokyo.

Japan Environmental Sanitation Center, M. o. t. E. 2014. History and current state of waste management in Japan. URL https://www.env.go.jp/en/recycle/smcs/attach/hcswm.pdf.

Jaramillo, J. 2020. Is Japan's High Recycling Rate Enough? URL https://www.earthisland.org/journal/index.php/articles/entry/japans-high-recycling-rate-plastic/.

Johnston, E. 2020. Awareness of issue of plastic garbage in Japan slowly gaining steam | The Japan Times. URL https://www.japantimes.co.jp/news/2020/01/03/national/awareness-issue-plastic-garbage-japan-slowly-gaining-steam/.

Kaur, L. 2020. Role of phytoremediation strategies in removal of heavy metals. Emerging Issues in the Water Environment during Anthropocene, pages 223–259.

Keller, B., D. Gleason, E. Mcleod, C. Woodley, S. Airamé, B. Causey, A. Friedlander, R. Grober-Dunsmore, J. Johnson, S. L. Miller, and R. Steneck. 2009. Climate change, coral reef ecosystems, and management options for marine protected areas. Environmental Management, **44**:1069 – 1088.

King, D., J. Davidson, and L. Anderson-Berry. 2010. Disaster mitigation and societal impacts. In Global perspectives on tropical cyclones: From science to mitigation, pages 409–436. World Scientific.

Kittisilpa, P. T., Juarawee. 2018. Southeast Asia's plastic 'addiction' blights world's oceans. Reuters. URL https://www.reuters.com/article/us-environment-day-plastic-idUSKCN1J10LM.

Klock, J. S. 1995. Agricultural and forest policies of the american colonial regime in ifugao territory, luzon, philippines, 1901-1945. Philippine quarterly of culture and society, **23**:3–19.

Kulkari, B. ???? Phytoremediation process, water hyacinth, sewage treatment plants. URL https://www.fibre2fashion.com/industry-article/3390/phytoremediation-of-textile-process-effluent-by-using-water-hyacinth-a-polishing-treatment.

Land, M., C. A. De Wit, A. Bignert, I. T. Cousins, D. Herzke, J. H. Johansson, and J. W. Martin. 2018. What is the effect of phasing out long-chain per-and polyfluoroalkyl substances on the concentrations of perfluoroalkyl acids and their precursors in the environment? a systematic review. Environmental Evidence, **7**:1–32.

Lee, Y. N. 2021. Here are the 10 biggest economies in the world before the pandemic vs now. URL https://www.cnbc.com/2021/04/21/coronavirus-worlds-10-biggest-economies-before-covid-pandemic-vs-now.html.

Liboiron, M. 2016. Redefining pollution and action: The matter of plastics. Journal of material culture, **21**:87–110.

Lirman and Schopmeyer. 2021. Coral gardening. The Nature Conservancy. URL https://reefresilience.org/restoration/coral-populations/coral-gardening/.

List, B. v. d. 2017. Working to death: the fatal consequences of Japan's overtime culture. Risk Management, **64**:30–35. URL https://go.gale.com/ps/i.do?p=AONE&sw=w&issn=00355593&v=2.1&it=r&id=GALE%7CA491910455&sid=googleScholar&linkaccess=abs. Publisher: Sabinet Online.

Liu, C. ???? Innovative sludge-to-energy plant makes a breakthrough in china. URL https://www.newsecuritybeat.org/2016/05/innovative-sludge-to-energy-plant-breakthrough-china/.

Lyons, I., R. Hill, S. Deshong, G. Mooney, and G. Turpin. 2019. Putting uncertainty under the cultural lens of traditional owners from the great barrier reef catchments. Regional Environmental Change, **19**:1597 – 1610. URL http://search.ebscohost.com/login.aspx?direct=true&AuthType=sso&db=8gh&AN=137721495&site=ehost-live&scope=site&custid=s8438901.

Mahoney, L. 2020. JapanâĂŹs plastic addiction is affecting oceans and burdening marine life. URL https://japantoday.com/category/features/opinions/japan%E2%80%99s-plastic-addiction-is-affecting-oceans-and-burdening-marine-life.

MarketWatch. 2021. Vietnam biopesticides market share ,size 2021 global opportunities, trends, regional overview, global growth, leading company analysis, and key country forecast to 2024. URL https://www.marketwatch.com/press-release/vietnam-biopesticides-market-share-size-2021-global-opportunities-trends-regional-overview-global-gro

Martuzzi, M., F. Mitis, and F. Forastiere. 2010. Inequalities, inequities, environmental justice in waste management and health. European Journal of Public Health, **20**:21–26. URL https://doi.org/10.1093/eurpub/ckp216.

Matthew, K. ???? The rivers that 'breathe' greenhouse gases. URL https://www.bbc.com/future/article/20210323-climate-change-the-rivers-that-breathe-greenhouse-gases.

McClanahan, T. R. and N. A. Muthiga. 2016. Geographic extent and variation of a coral reef trophic cascade. Ecology, **97**:1862–1872. URL https://esajournals.onlinelibrary.wiley.com/doi/abs/10.1890/15-1492.1.

McCoy, T. 2019. In a world drowning in trash, these cities have slashed waste by 80 percent. URL https://www.washingtonpost.com/lifestyle/2019/02/13/world-is-drowning-trash-can-zero-waste-save-it-before-its-too-late/.

McCoy, T., D. Frank, et al. 2020. Organic vs. conventional (synthetic) pesticides: Advantages and disadvantages.

McCurry, J. 2011. Japan streets ahead in global plastic recycling race. URL http://www.theguardian.com/environment/2011/dec/29/japan-leads-field-plastic-recycling. Section: Environment.

Measham, T. G., B. L. Preston, T. F. Smith, C. Brooke, R. Gorddard, G. Withycombe, and C. Morrison. 2011. Adapting to climate change through local municipal planning: barriers and challenges. Mitigation and Adaptation Strategies for Global Change, **16**:889–909. URL https://doi.org/10.1007/s11027-011-9301-2.

Ministry of Foreign Affairs, R. o. C. T. ???? Pesticide problems.

Misachi, J. 2018. What percentage of the earth's water is drinkable? URL http://www.worldatlas.com/articles/what-percentage-of-the-earth-s-water-is-drinkable.html.

Miyake, Y., A. Yura, H. Misaki, Y. Ikeda, T. Usui, M. Iki, and T. Shimizu. 2005. Relationship between distance of schools from the nearest municipal waste incineration plant and child health in Japan. European Journal of Epidemiology, **20**:1023–1029.

Mordor. ???? Asia-pacific biopesticides market: Share: Analysis (2020 - 2025). URL https://www.mordorintelligence.com/industry-reports/asia-pacific-biopesticides-market-industry.

Morin, R. 2014. A lifesaving transplant for coral reefs. The New York Times. URL https://www.nytimes.com/2014/11/25/science/a-lifesaving-transplant-for-coral-reefs.html.

Mustafa, H. M. and G. Hayder. 2020. Recent studies on applications of aquatic weed plants in phytoremediation of wastewater: A review article. Ain Shams Engineering Journal.

Naing, T. A. A., A. Kingsbury, A. Buerkert, and M. R. Finckh. 2008. A survey of myanmar rice production and constraints. Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS), **109**:151–168.

Nakatani, J., T. Maruyama, and Y. Moriguchi. 2020. Revealing the intersectoral material flow of plastic containers and packaging in Japan. Proceedings of the National Academy of Sciences, **117**:19844–19853. URL https://www.pnas.org/content/117/33/19844. Publisher: National Academy of Sciences Section: Social Sciences.

Neumayer, E. 2003. Weak versus strong sustainability: exploring the limits of two opposing paradigms. Edward Elgar Publishing.

Neumayer, E. 2012. Human development and sustainability. Journal of Human Development and Capabilities, **13**.

Nicolopoulou-Stamati, P., S. Maipas, C. Kotampasi, P. Stamatis, and L. Hens. 2016. Chemical pesticides and human health: the urgent need for a new concept in agriculture. Frontiers in public health, **4**:148.

NOAA. ???? Climate models.

NOAA. 2019*a*. Coral diseases: Corals tutorial. URL https://oceanservice.noaa.gov/education/tutorial_corals/coral10_disease.html.

NOAA. 2019*b*. Marine life: Coral reef ecosystems. US Department of Commerce, National Oceanic and Atmospheric Administration. URL https://www.noaa.gov/education/resource-collections/marine-life/coral-reef-ecosystems.

NRDC, o. 1991. The principles of envrionmental justice. URL https://www.nrdc.org/sites/default/files/ej-principles.pdf.

NZDL. ???? URL http://www.nzdl.org/cgi-bin/library?e=d-00000-00---off-0cdl--00-0----0-10-0---0---0direct-10---4-------0-1l--11-en-50---20-about-CL2.7&d=HASH01126ded49ea86cbd5af6b15.4.2.14%3E.

OregonState. ???? A. history of pesticide use. URL http://people.oregonstate.edu/~muirp/pesthist.htm.

Palma, J., J. Manula, J. P. Gaudiano, and M. Matillano. 2014. Economies of Fisherues and Aquaculture in the Coral Triangle.

Pearce, F. 2003. Cyanide: an easy but deadly way to catch fish. World Wildlife Foundation. URL https://wwf.panda.org/wwf_news/?5563/Cyanide-an-easy-but-deadly-way-to-catch-fish.

Pebler, P. T. 2015. Double vault composting latrines in rural paraguay: Feasible construction and optimal use.

Pelton, B. 2017. Why reefs matter. URL https://marine.unc.edu/reefs-matter/.

Perkins, T. 2019. Biosolids: mix human waste with toxic chemicals, then spread on crops. URL https://www.theguardian.com/environment/2019/oct/05/biosolids-toxic-chemicals-pollution.

Persoon, G. A. and T. Minter. 2020. Knowledge and practices of indigenous peoples in the context of resource management in relation to climate change in southeast asia. Sustainability, **12**:1–23. URL https://ideas.repec.org/a/gam/jsusta/v12y2020i19p7983-d420111.html.

PWMI, P. W. M. I. 2019. An introduction to plastic recycling. URL https://www.pwmi.or.jp/ei/plastic_recycling_2019.pdf.

Ref. Year. REFERENCE(S) TO BE ADDED. .

Reichert, J., J. Schellenberg, P. Schubert, and T. Wilke. 2018. Responses of reef building corals to microplastic exposure. Environmental Pollution, **237**:955 – 960. URL http://search.ebscohost.com.ccl.idm.oclc.org/login.aspx?direct=true&AuthType=sso&db=8gh&AN=129073346&site=ehost-live&scope=site&custid=s8438901.

Renaud, C. 1997. Coral calamity. Environment, **39**:23. URL http://search.ebscohost.com.ccl.idm.oclc.org/login.aspx?direct=true&AuthType=sso&db=8gh&AN=9703130241&site=ehost-live&scope=site&custid=s8438901.

Royte, E. 2018. We Know Plastic Is Harming Marine Life. What About Us? URL https://www.nationalgeographic.com/magazine/article/plastic-planet-health-pollution-waste-microplastics. Section: Magazine.

Saito, Y. 1999. Japanese Aesthetics of Packaging. The Journal of Aesthetics and Art Criticism, **57**:257–265. URL https://www.jstor.org/stable/432317. Publisher: [Wiley, American Society for Aesthetics].

Scott, C. 2018. Artificial reefs: What works and what doesnâĂŹt. New Heaven Reef Conservation Program. URL https://newheavenreefconservation.org/marine-blog/147-artificial-reefs-what-works-and-what-doesn-t.

Seltenrich, N. 2013. Incineration versus recycling: In europe, a debate over trash. Retrieved February, **15**:2015.

Sharma, A., V. Kumar, A. Thukral, and R. Bhardwaj. 2019. Responses of plants to pesticide toxicity: An overview. Planta Daninha, **37**.

Sharp, B. and J. t. . M. SharpReporter@5thEstate. 2019. What you should know about the circular economy. URL https://www.nationalobserver.com/2019/06/17/news/what-you-should-know-about-circular-economy.

Sinay, L. and R. W. B. Carter. 2020. Climate change adaptation options for coastal communities and local governments. Climate, **8**:7. URL http://dx.doi.org/10.3390/cli8010007.

Siniawer, E. M. 2014. " affluence of the heart": Wastefulness and the search for meaning in millennial japan. The Journal of Asian Studies, pages 165–186.

Smith, K. N. 2018. Everything we know about the isolated sentinelese people of north sentinel island. Forbes. URL https://www.forbes.com/sites/kionasmith/2018/11/30/everything-we-know-about-the-isolated-sentinelese-people-of-north-sentinel-island/.

Solow, A., S. Polasky, and J. Broadus. 1993. On the measurement of biological diversity. Climate, **24**:60–68.

Spaldin, M., C. Ravilious, and E. Green. 2001. World Atlas of Coral Reefs, volume 3. URL https://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.14871.

Spalding, M., L. Burke, S. A.Wood, J. Ashpole, J. Hutchisone, and P. Ermgassen. 2017. Mapping the global value and distribution of coral reef tourism. Marine Policy, **82**:104–113.

Staff, N. 2019. Chinese Ban Leaves Plastic Waste with Nowhere to Go. URL https://www.nippon.com/en/japan-data/h00473/chinese-ban-leaves-plastic-waste-with-nowhere-to-go.html.

Staff, R. 2021. Malaysia sends back over 300 containers of illicit plastic waste. Reuters. URL https://www.reuters.com/article/malaysia-environment-plastic-idINKBN2BT29I.

Stephenson, C. and C. R. Black. 2014. One step forward, two steps back: the evolution of phytoremediation into commercial technologies. Bioscience Horizons: The International Journal of Student Research, **7**.

Sturmer, J. 2018. Osaka rubbish incinerator maishima looks like disneyland but is part of japan's waste strategy.

Suggett, D. J. and D. J. Smith. 2020. Coral bleaching patterns are the outcome of complex biological and environmental networking. Global Change Biology, **26**:68–79. URL https://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.14871.

Supeck. 2019. The history of the septic system. URL https://supeckseptic.com/blog/the-history-of-the-septic-system/#:~:text=Jean%2DLouis%20Mouras%20invented%20the,emptied%20from%20time%20to%20time.

Taguchi, H. 2013. The environmental kuznets curve in asia: The case of sulphur and carbon emissions. Asia-Pacific Development Journal, **19**:77–92.

Tait, P. W., J. Brew, A. Che, A. Costanzo, A. Danyluk, M. Davis, A. Khalaf, K. McMahon, A. Watson, K. Rowcliff, and D. Bowles. 2020. The health impacts of waste incineration: a systematic review. Australian and New Zealand Journal of Public Health, **44**:40–48. URL http://onlinelibrary.wiley.com/doi/abs/10.1111/1753-6405.12939. _eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1111/1753-6405.12939.

Thompson, A. 2018. Where plastic goes, coral disease follows. Scientific American. URL https:

//www.scientificamerican.com/article/where-plastic-goes-coral-disease-follows/.

Thuy, P. T., S. Van Geluwe, V.-A. Nguyen, and B. Van der Bruggen. 2012. Current pesticide practices and environmental issues in vietnam: management challenges for sustainable use of pesticides for tropical crops in (south-east) asia to avoid environmental pollution. Journal of Material Cycles and Waste Management, **14**:379–387.

Todd, P. A., O. Xueyuan, and C. Loke Ming. 2010. Impacts of pollution on marine life in southeast asia. Biodiversity & Conservation, **19**:1063 – 1082. URL http://search.ebscohost.com.ccl.idm.oclc.org/login.aspx?direct=true&AuthType=sso&db=8gh&AN=48847774&site=ehost-live&scope=site&custid=s8438901.

Tseng, Y.-J., S.-K. Wang, and C.-Y. Duh. 2013. Secosteroids and norcembranoids from the soft coral sinularia nanolobata. Marine Drugs, **11**:3288âĂŞ3296. URL http://dx.doi.org/10.3390/md11093288.

UN. ????*a*. The dublin principles on water and the environment. URL http://www.futurelearn.com/info/courses/sustainability-society-and-you/0/steps/4626.

UN. ????*b*. Growing at a slower pace, world population is expected to reach 9.7 billion in 2050 and could peak at nearly 11 billion around 2100 | un desa department of economic and social affairs.

UN. ????*c*. Quality and wastewater: Un-water. URL https://www.unwater.org/water-facts/quality-and-wastewater/#:~:text=Challenges%20and%20opportunities&text=The%20availability%20of%20safe%20and,water%20resources%20around%20the%20world.

University, P. ???? On-site wastewater disposal and public health.

US EPA, a. 2017*a*. What is endocrine disruption. URL file:///Users/eleanordunn/Zotero/storage/PZW8MWRE/what-endocrine-disruption.html.

US EPA, O. 2017*b*. Threats to coral reefs. URL https://www.epa.gov/coral-reefs/threats-coral-reefs.

USGS. ???? URL http://www.usgs.gov/special-topic/water-science-school/science/a-visit-a-wastewater-treatment-plant?qt-science_center_objects=0#qt-science_center_objects.

Usta, C. 2013. Microorganisms in biological pest controlâĂŤa review (bacterial toxin application and effect of environmental factors). In Current progress in biological research, pages 287–317. InTech Rijeka.

Ventura, T. 2016. From small farms to progressive plantations: the trajectory of land reform in the american colonial philippines, 1900–1916. Agricultural History, **90**:459–483.

Warren, J. F. 2018. Typhoons and droughts: Food shortages and famine in the philippines since the seventeenth century. International Review of Environmental History, **4**:27–44.

Wassmann, R., N. X. Hien, C. T. Hoanh, and T. P. Tuong. 2004. Sea level rise affecting the vietnamese mekong delta: water elevation in the flood season and implications for rice production. Climatic Change, **66**:89–107.

Watson, B. 2016. Can incineration and landfills save us from the recycling crisis? URL http://www.theguardian.com/sustainable-business/2016/jun/14/green-waste-distribution-methods-recycling-plastic-oil-epa. Section: Guardian Sustainable Business.

Weeks, R., G. R. Russ, A. C. Alcala, and A. T. White. 2010. Effectiveness of marine protected areas in the philippines for biodiversity conservation. Conservation Biology, **24**:531–540. URL http://www.jstor.org/stable/40603378.

Westoby, R., S. Becken, A. Laria, and Prieto. 2020. Perspectives on the human dimensions of coral restoration. Regional Environmental Change, **20**. URL http://search.ebscohost.com/login.aspx?direct=true&AuthType=sso&db=8gh&AN=145514965&site=ehost-live&scope=site&custid=s8438901.

Wetlands. 2019. Floating villages and the handypod. URL https://wetlandswork.com/products-and-services/sanitation-in-challenging-environments/handy-pods/.

Whitelaw, G. 2018. Konbini-Nation: The Rise of the Convenience Store in Post-Industrial Japan. In Consuming Life in Post-Bubble Japan, pages 69–88. Journal Abbreviation: Consuming Life in Post-Bubble Japan.

WHO. ???? 2.1 billion people lack safe drinking water at home, more than twice as many lack safe sanitation. URL https://www.who.int/news/item/12-07-2017-2-1-billion-people-lack-safe-drinking-water-at-home-more-than-twice-as-many-lack-s wilkie. ???? Frequently asked questions (biogas faq). URL https://biogas.ifas.ufl.edu/FAQ.asp.

Williams, M. J., R. Coles, and J. H. Primavera. 2007. A lesson from cyclone larry: An untold story of the success of good coastal planning. Estuarine, Coastal and Shelf Science, **71**:364–367.

World Bank, o. 2018. Urban population Japan. URL https://data.worldbank.org/indicator/SP.URB.TOTL.IN.ZS?locations=JP.

worldometer, s. 2021. Largest countries in the world. URL https://www.worldometers.info/geography/largest-countries-in-the-world/.

WRI. 2015. Chinese cities begin turning sludge into energy. URL https://www.wri.org/outcomes/chinese-cities-begin-turning-sludge-energy#:~:text=Sludge-to-energysystemsare,gasâĂŞallwhilesavingmoney.

Yaguchi, Y., T. Sonobe, and K. Otsuka. 2007. Beyond the environmental kuznets curve: a comparative study of soâĆĆ and coâĆĆ emissions between japan and china. Environment and Development Economics, pages 445–470.

Yamamoto, K., M. Kudo, H. Arito, Y. Ogawa, and T. Takata. 2015. A cross-sectional analysis of dioxins and health effects in municipal and private waste incinerator workers in Japan. Industrial Health, **53**:465–479. URL https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4591139/.

Zhang, L., K. B. Karnauskas, J. P. Donnelly, and K. Emanuel. 2017. Response of the north pacific tropical cyclone climatology to global warming: Application of dynamical downscaling to cmip5 models. Journal of Climate, **30**:1233–1243.