

# Environmental Issues in East Asia

EA30e Spring 2021

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# Preface

## 0.1 Guiding Principles

Environmental issues in East Asia are not unique or particularly more pervasive than other parts of the world. However, the issues are born 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.

### 0.1.1 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.

### 0.1.2 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?

### 0.1.3 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.

### 0.1.4 Activity

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

**0.2 East Asia and the World****0.3 Acknowledgments**

Everyone in the world!

# L<sup>A</sup>T<sub>E</sub>X Guide

## Why Learn L<sup>A</sup>T<sub>E</sub>X?

In the past, I used L<sup>A</sup>T<sub>E</sub>X to make publication quality text. In fact, many prefer writing in L<sup>A</sup>T<sub>E</sub>X because they can focus on the text and avoid worrying about formatting. However, it is NOT WYSIWYG (“what you see is what you get”) word processor. In reality, the processing or compiling is a separate step.

Nevertheless, the quality of the output and ability to integrate with R (or Python) allows us to have an exceptional tool to make reproducible documents.

## How to Learn L<sup>A</sup>T<sub>E</sub>X?

There are several ways to learn L<sup>A</sup>T<sub>E</sub>X. I suggest you find a decent tutorial to get the basics. For example, here are some suggestions:

- [Learning L<sup>A</sup>T<sub>E</sub>X in 30 minutes](#)

If you are like me and can't remember commands very well, then here's a [cheat sheet](#) that might be helpful.

## R Chunks

To create effective graphics, each chapter will have a rchunk that creates a graphic for the chapter. To review and learn R, here are some resources:

- [Marc's Video Description](#)
- [RMarkdown for Scientists \(super helpful!\)](#)
- [R Studio Tutorial](#)
- [R Studio's Cheatsheet](#)
- [R Markdown Cookbook – Robust Source](#)

## Noting Your Contribution

Because this is an ongoing project, you should record your contribution to each chapter – but also let go of these contributions at some point; Others might revise and their authorship might take some precedence, so you should both invest in the product but also be willing to detach from the final outcome as others contribute. This will feel uncomfortable at times, but please note from the beginning this is a social process and as such subject to negotiation. Please be generous to the authors that laid the foundation and be respectful of those that follow.

## 0.4 Setting Up Book Project–Type Setting w/ L<sup>A</sup>T<sub>E</sub>X

### 0.4.1 Latex Book Class

Currently, the text is written using the standard book class.

### 0.4.2 Structuring the Text with Nested Hierarchies

Contributors divide their contributions into sections and subsections. This format allows a consistent approach to structuring the text and forcing themes to be organized in blocks that can be used to organize the overall text. We use section, subsection, and subsubsection to break up the topic into bite sizes.

To accomplish this, contributors use the `\section{Section}` command for major sections, and the `\subsection{Subsection}` command for subsections, and a similar approach for subsubsections.

NOTE: for each nested level, it MUST be followed by the lowest level in the section before a paragraph is started – in contrast to what is shown above!

NOTE: We may dispense with subsubsections in the future to provide a less blocky structure, but for now they remain useful.

### 0.4.3 Font Changes

We can use various methods to alter the typeset: *Emphasize*, **Bold**, *Italics*, and *Slanted*. We can also typeset Roman, Sans Serif, SMALL CAPS, and **Typewriter** texts. Look online to see the commands to accomplish these changes.

You can also apply the special, mathematics only commands **BLACKBOARD**, **BOLD**, *CALLIGRAPHIC*, and **f $\ddot{r}$ aktur**. Note that blackboard bold and calligraphic are correct only when applied to uppercase letters A through Z.

You can apply the size tags – Format menu, Font size submenu – , , , , , , , ,  and .

You can use the `\begin{quote}` etc. `\end{quote}` environment for typesetting short quotations. Select the text then click on Insert, Quotations, Short Quotations:

The buck stops here. *Harry Truman*

Ask not what your country can do for you; ask what you can do for your country. *John F Kennedy*

I am not a crook. *Richard Nixon*

I did not have sexual relations with that woman, Miss Lewinsky. *Bill Clinton*

The Quotation environment is used for quotations of more than one paragraph. Following is the beginning of description of L<sup>A</sup>T<sub>E</sub>X from *Wikipedia*:

LaTeX (/ltx/ LAH-tekh or /letx/ LAY-tekh, often stylized as L<sup>A</sup>T<sub>E</sub>X) is a software system for document preparation. When writing, the writer uses plain text as opposed to the formatted text found in “What You See Is What You Get” word processors like Microsoft Word, LibreOffice Writer and Apple Pages. The writer uses markup tagging conventions to define the general structure of a document (such as article, book, and letter), to stylise text throughout a document (such as bold and italics), and to add

citations and cross-references. A TeXdistribution such as TeXLive or MiKTeXis used to produce an output file (such as PDF or DVI) suitable for printing or digital distribution.

LaTeX is widely used in academia for the communication and publication of scientific documents in many fields, including mathematics, statistics, computer science, engineering, physics, economics, linguistics, quantitative psychology, philosophy, and political science. It also has a prominent role in the preparation and publication of books and articles that contain complex multilingual materials, such as Sanskrit and Greek. LATEXuses the TeX typesetting program for formatting its output, and is itself written in the TeX macro language.”

Use the Verbatim environment if you want LATEX to preserve spacing, perhaps when including a fragment from a program such as:

```
#read csv data // read data into R
my.dataframe <- read.csv(file.choose()) // read data from a popup window.

str(my.dataframe) // display data structure
```

(After selecting the text click on Insert, Code Environments, Code.)

#### 0.4.4 Mathematics and Specialized Characters

##### Warning: Special Characters

When you use percent and ampersand symbols, hash tags, and other non-standard ASCII characters, LATEXwill be very uncooperative. LATEX doesn’t like a range of characters or they reserved for special behavior. So, do yourself a favor and make sure you understand that these are used for special typesetting functions. To use them you have to “escape” and use commands to get them to do what you might usually expect!

The following symbols \$, %, #, &, è, ñ, “ and ” do not reflect the key stroke you might expect.

For example, the & is used for tabs in a table environment. % is used to make comments, thus stuff behind a % is ignored. There are lots of others, but these come up the most. If you want to show use the ampersand or one of these characters, put a backslash in front of the dollar sybmol, e.g. \\$. See Table 1.

If you want to a superscript (raised to 3nd power), we can create text in math mode, with \$ to start and end the text in math mode, e.g.  $m^3$  is written in LATEXas m\$^3\$. A subscript uses an underscore, x\$\_1\$ creates  $x_1$ . If you need more than one character as a subscript or superscript then enclose the content in curly brakets, e.g.  $x^{2c}$  (x\$^{\{2c\}}\$) and  $t_{step}$  (t\$\_{\{step\}}\$).

**Table 1:** Table of Symbols in LATEX

Symbol	LATEXcode	Symbol	LATEXcode
&	\&	\$	\\$
“	\`	”	\`
mg L <sup>-1</sup>	mg~L\$^{-1}\$		

#### 0.4.5 Creating equations

One of the most powerful parts of L<sup>A</sup>T<sub>E</sub>X is how it can be used to write complex equations, with all those symbols and Greek letters! This can be done inline  $y = mx + b + \epsilon$  for fairly simple equations, or set apart for more complex equations:

$$\int_0^\infty e^{-x^2} dx = \frac{\sqrt{\pi}}{2} \quad (1)$$

#### Theorems, etc

**Theorem 1** (*The Currant minimax principle.*) Let  $T$  be completely continuous selfadjoint operator in a Hilbert space  $H$ . Let  $n$  be an arbitrary integer and let  $u_1, \dots, u_{n-1}$  be an arbitrary system of  $n-1$  linearly independent elements of  $H$ . Denote

$$\max_{\substack{v \in H, v \neq 0 \\ (v, u_1) = 0, \dots, (v, u_n) = 0}} \frac{(Tv, v)}{(v, v)} = m(u_1, \dots, u_{n-1}) \quad (2)$$

Then the  $n$ -th eigenvalue of  $T$  is equal to the minimum of these maxima, when minimizing over all linearly independent systems  $u_1, \dots, u_{n-1}$  in  $H$ ,

$$\mu_n = \min_{u_1, \dots, u_{n-1} \in H} m(u_1, \dots, u_{n-1}) \quad (3)$$

The above equations are automatically numbered as equation (2) and (3).

#### 0.4.6 Lists Environments: Making bulleted, numbered, description lists

We use special commands to create an itemized list.

You can create numbered, bulleted, and description lists (Use the Itemization or Enumeration buttons, or click on the Insert menu then chose an item from the Enumeration submenu):

- 1. List item 1
- 2. List item 2
  - (a) A list item under a list item.
  - (b) Just another list item under a list item.
    - i. Third level list item under a list item.
    - A. Fourth and final level of list items allowed.
- Bullet item 1
- Bullet item 2
  - Second level bullet item.
  - \* Third level bullet item.
    - Fourth (and final) level bullet item.

**Description List** Each description list item has a term followed by the description of that term.

**Bunyip** Mythical beast of Australian Aboriginal legends.

**Figure 1:** My plot's caption is here!

### 0.4.7 Theorem-Like Environments

The following theorem-like environments (in alphabetical order) are available in this style.

**Example 2** *This is an example*

**Exercise 3** *This is an exercise*

**Theorem 4** *This is a theorem*

### 0.4.8 Peer Review Commenting

You can put your comments in square brackets and in color for things that need help. [This section is confusing, I am not sure what commenting means.]

### 0.4.9 Adding Figures, etc

#### Using Rnw Files

To generate R figures, we use R chunks in and Rnw file, where the text is integrated. When we compile into a PDF, the program converts the files into TeX files and then combines them into a single pdf.

For each chapter, we create a “child” document and Marc will help you create that text when you begin.

#### Creating a floating figure

This is my floating figure (Figure 1).

#### Using R to Create Effective Figures

R Markdown can be a very powerful tool to integrate R code, figures and text. Making high quality figures that are both clear and aestically pleasing will be something that we need to think about it.

- Axis Labels – Labelled with clarity
- Axis Text – Size, Orientation
- Captions (usually better than titles)
- References connecting labels to references
- ADA accessible (e.g. color impairment mitigation)

For example, here’s code to generate a pretty good figure:

```
## Error in ggplot(train.data, aes(decimal.date, average)): object 'train.data'
not found
```

**Figure 2:** Carbon Dioxide Concentrations (Mauna Loa, HI). Data demonstrate the CO<sub>2</sub> concentrations are increases, but that a seasonal impact is embedded in the long-term trend. Source: Scripps/NOAA.

```
## Error in file(file, "rt"): cannot open the connection
## Error in createDataPartition(., p = 0.8, list = FALSE): object 'maunaloa' not found
## Error in eval(expr, envir, enclos): object 'maunaloa' not found
## Error in eval(expr, envir, enclos): object 'maunaloa' not found
## Error in eval(expr, envir, enclos): object 'maunaloa' not found
## Error in is.data.frame(data): object 'maunaloa' not found
## Error in summary(model): object 'model' not found
## Error in predict(., test.data): object 'model' not found
## Error in mean((pred - obs)^2, na.rm = na.rm): object 'predictions' not found
```

In the case of Figure 2, we can create a figure that has all of the characteristics listed above, except perhaps ADA. Creating a "alt text" for the figure is something we might want to consider – For now a decent caption about what the reader is seeing is super helpful.

#### 0.4.10 Using Boxes

##### 0.4.11 minibox X

Some text

#### 0.4.12 Cross-References, Citations, and Glossaries

##### Cross-References

We can cross-reference sections (e.g. Section 3 or figures (Figure ??) using several methods. I suggest you look at the this Rmd file to see how I did it in these examples.

You can also create links to URLs or hyperlinks, e.g. <http://texblog.org>. However, if these addresses change, then the link will break, so I suggest you only link to internal references.

##### Bibliography generation

There will be two steps to cite our sources. First, we need to add the reference to a database, or bib file. This is titled 'References.bib' and is located in the main folder in our respository. When you add information to the bib file, be sure to paste in the reference using a bibTeX format.

Second, we'll need to place in-line citations, using \citet{knitr}, which produces [Xie, 2021], by using a key, which is knitr in this case.

For example, you might write, "This document was produced in RStudio using the knitr package ([Xie, 2021]). Also try \citet{LosHuertos2017OverviewR} to create use the author name as the subject: Los Huertos [2018] wrote an guide to help students learn R.

Note: You will see these citations automatically put in alphabetic order in the Bibliography at the end of the PDF.

### Creating glossary words

**Definition 5** This is a definition and the word is use in an glossary, e.g. **peat**. **Peat** is when you want to capitalize the defined word without having to re-define a capitalized version, the only downside of case sensitivity in L<sup>A</sup>T<sub>E</sub>X.



# Template Chapter Title

CHAPTER AUTHOR

<sup>1</sup>

## 0.5 Section Heading

### 0.5.1 Subsection Headings

Some text here...The hierarchy structure is described in the Author Guide, Section [0.4](#) – NOTE: This is a section cross reference.

if you cut and paste, be sure to make sure you don't include formatted characters outside the ASCII values. See Author Guide, Section [0.4.4](#). NOTE: This is a subsection cross reference.

### Optional Subsubsection Headings

some text here.... and a subsubsection cross reference (See Section [0.5.1](#)).

## 0.6 Goals of this template

This template will NOT teach you how to use L<sup>A</sup>T<sub>E</sub>X! To accomplish that, we'll rely on some great online resources that you can find on in Chapter [0.3](#).

Instead this section of the document is designed to demonstrate how our textbook will look, feel, and ultimately how we contribute to the project.

This document also compiles all of our projects into a single PDF, where each chapter is composed of a input tex file.

## 0.7 Here's figure

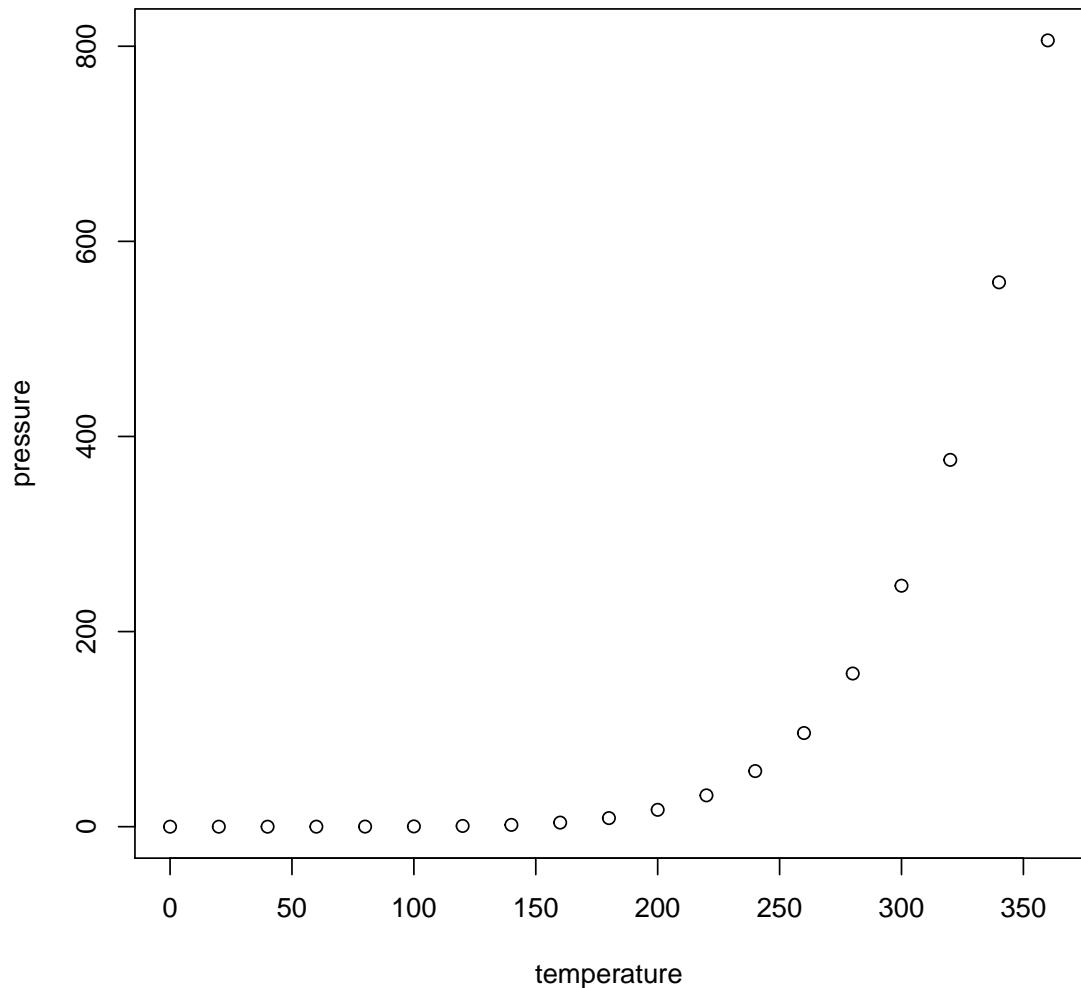
### 0.7.1 R Created Figures

First we create an R chunk and add some code. In this case, I created a floating figure which can be referenced (Figure [3](#))!

---

<sup>1</sup>Statement of Contributions– For example, “The chapter was first drafted by Marc Los Huertos (2021). The author received valuable feedback from X, and Y and Z to improve the chapter. Slater revised the chapter in 2022 with suggestions from Cater.” Note: I am still working on the formatting for this to improve it.

```
plot(pressure)
```



**Figure 3:** Figure Caption...we should turn "echo=False" in the R chunk options, but I left it true for now. (source: ??)



**Figure 4:** Vadose zone is neato (Source: [Lee et al. \[2017\]](#)).

### 0.7.2 Floating Figures from External Sources

All figures and images that are imported should be put into the “images” subdirectory to keep stuff organized. Even better to create a subdirectory with your images, but we can navigate as we go.

Figure 4 is a good example of inserting an image from an external source.

In this case, I had to specify the width so it would fit on the page! See the Rnw file for the code. Notice, I was also able to “reference” the figure in the text.

## 0.8 Adding Citations

See the Guide, as well, but my video is probably the most helpful.

Generally, there are many environmental trends in Asia [[Imura et al., 2005](#)].

[Imura et al. \[2005\]](#) describes the how urbanization has affected the hydrology of East Asia.  
articleknitr



# Plastic

NORA

→

4/23 1. made new project titled ERTA2020-NewEA30e21-Project 2. did the single branch clone for EA30e21 3. switched the Git brach pull down to EA30e21 in remote: ORIGIN 4. testing if I can push to my branch only 5. save changes 6. commit - TEST NEW PROJECT PUSH TO BRANCH at 2:04 did it work? 2:03 est YES 2:16 est

1.added Marc's repo as the "upstream" to be able to pull from his branch when things are changed there 2.tried to fetch from

## 0.9 What the Polar Vortex and why do we care?

test commit and pull request

### 0.9.1 What Factors Drive Land Use Change?



# Chapter 1

# The Earth System

MARC LOS HUERTOS

## 1.1 The Sun's Energy and the Earth's Temperature

The temperature of the Earth's surface is the result of a balance – the energy entering the atmosphere and the leaving the atmosphere. Most of this energy is in the form of light or electromagnetic radiation (Figure 1.1).

Light enters the atmosphere, where some is absorbed and some is reflected. Light interacts in different ways with land, oceans, and vegetation, which is beyond the scope of our project. The “quality” of light changes through these processes.

### 1.1.1 The Spectrum of Light Entering and Exiting the Earth's Surface

As the sun's electromagnetic radiation interacts with the Earth's Atmosphere, certain wavelengths are absorbed and filtered out (Figure 1.2).

### 1.1.2 The Atmosphere and Greenhouse Effect

## 1.2 Carbon Biogeochemistry

### 1.2.1 Long and Short Time Scales

The carbon cycle processes occur at wide range of temporal scales from hundreds of millions of years to seasons of the year. These have been referred to as long and short carbon cycles. However, for our purposes, I will call them “geologic carbon” and ”biosphere carbon” processes.

### 1.2.2 Rock Cycle and Geologic Carbon

The carbon cycle describes changes in the fluxes and reservoirs of carbon in the Earth system. On very long time-scales, millions of years, the primary reservoirs of carbon are the atmosphere, ocean, and rocks (limestone). Carbon moves between these reservoirs through volcanic outgassing, silicate weathering, and limestone sedimentation. The carbon cycle is linked to Earth's energy balance through atmospheric carbon in the form of CO<sub>2</sub> , a greenhouse gas.



Figure 1.1: caption



**Figure 1.2:** Various wavelengths of solar electromagnetic radiation penetrate Earth's atmosphere to various depths. Fortunately for us, all of the high energy X-rays and most UV is filtered out long before it reaches the ground. Much of the infrared radiation is also absorbed by our atmosphere far above our heads. Most radio waves do make it to the ground, along with a narrow 'window' of IR, UV, and visible light frequencies. Source: STCI/JHU/NASA.



**Figure 1.3:** Carbon reservoirs and cycles in the Earth. The figure shows short-and long-term cycles; biosphere and geologic carbon reservoirs and fluxes, and the relative sizes and residence times (y axis) of respective carbon. Numbers in brackets refer to the total mass of carbon in a given reservoir, in Pg C (1Pg C =  $10^{15}$  g carbon). All reservoirs are pre-industrial. Abbreviations: C org = organic carbon; DIC = dissolved inorganic carbon; MOR = mid ocean ridge; seds = sedimentary rocks. Adapted from Lee et al. (2019 And references therein).

## Mountains and Erosion

### 1.3

#### Subduction Burial and Carbon Recycling

Figure ??

#### 1.2.3 Photosynthesis, Respiration, and Biosphere Carbon

##### Soil Respiration and the Soil Profile

Carbon in soils is respired – but different pools might have different rates of respiration. Sometimes these pools are distinguished as an active soil organic carbon pool and slow soil organic carbon pool. Although the reference of “slow” causes confusion with long-term, geologic carbon, but soil organic carbon remains a component of what we are referring to as biosphere carbon.

The surface of the soil tends to have more SOC and microbes that can use that carbon for respiration. Lower down in the soil profile, we tend to see lower amounts of SOC and lower microbial



**Figure 1.4:** Schematic of the long-term carbon cycle (from Bice, 2001)

biomass (Figure ??). In addition, soils in the lower part of the profile tend to have more aggregation that protects SOC from microbial attack, thus a key area that soil carbon can sequester carbon.

In addition to these microbial biomass and aggregate patterns, the microbes are more sensitive to temperature changes near the surface as measured by Q<sub>10</sub> – the rate of biochemical processes with a 10 degree C increase in temperature. Thus, soil processes, such as respiration, is likely to increase more near the surface with global warming than the lower part of the soil profile.

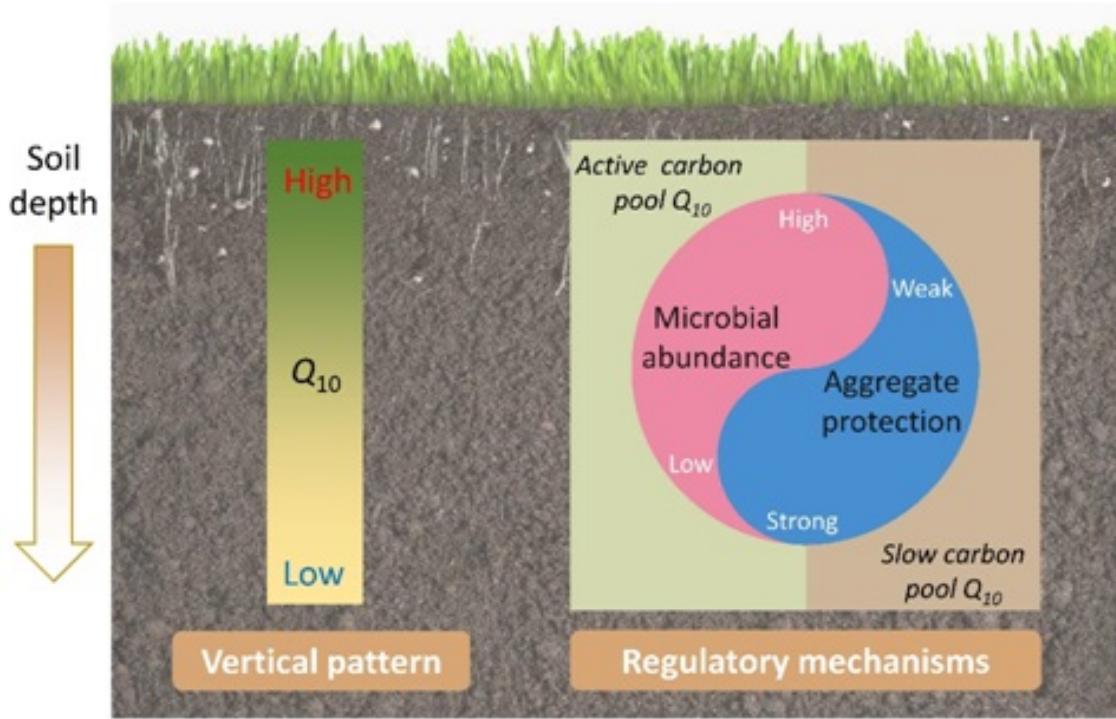
## 1.3 Fossil Fuels and Carbon Dioxide Trends

As part of the industrial revolution, our energy sources have put more CO<sub>2</sub> from the biosphere (soils and forests) and geologic carbon (coal, petroleum).

### 1.3.1 The Signal of Geologic and Biosphere Carbon in Atmosphere

The combined contribution from geologic and biosphere carbon in the atmosphere is clearly documented from numerous sources. First, look at data collected at the Mauna Loa where CO<sub>2</sub> measurements have been taken continuously since the late 1950s.

Figure 1.6



**Figure 1.5:** Regulatory Mechanisms of the Temperature Sensitivity of Soil Organic Matter Decomposition in Alpine Grasslands (Source: [Qin et al. \[2019\]](#), [Institute of Botany \[2021\]](#)).

```
## Error in ggplot(train.data, aes(decimal.date, average)): object 'train.data' not found
```

**Figure 1.6:** Carbon Dioxide Measure on Mauna Loa, HI

## Chapter 2

# Monsoons and East Asia Climates

### 2.1 Temperature Gradients and Latitude



# Chapter 3

## Critical Zone

MARC LOS HUERTOS

<sup>1</sup>

### 3.1 What is the Critical Zone

The critical zone refers to the portion of the Earth's skin where rock meets life.  
The Critical Zone supports all terrestrial life.

The critical zone includes the following:

- A permeable layer from the tops of the trees to the bottom of the groundwater;
- An environment where rock, soil, water, air, and living organisms interact and shape the Earth's surface;
- Water and atmospheric gases move through the porous Critical Zone, and living systems thrive in its surface and subsurface environments, shaped over time by biota, geology, and climate.

All this activity transforms rock and biomass into the central component of the Critical Zone - soil; it also creates one of the most heterogeneous and complex regions on Earth.

Its complex interactions regulate the natural habitat and determine the availability of life-sustaining resources, such as food production and water quality.

These are but two of the many benefits or services provided by the Critical Zone. Such 'Critical-Zone Services' expand upon the benefits provided by ecosystems to also include the coupled hydrologic, geochemical, and geomorphic processes that underpin those ecosystems.

#### 3.1.1 What are the environmental implications of the Critical Zone?

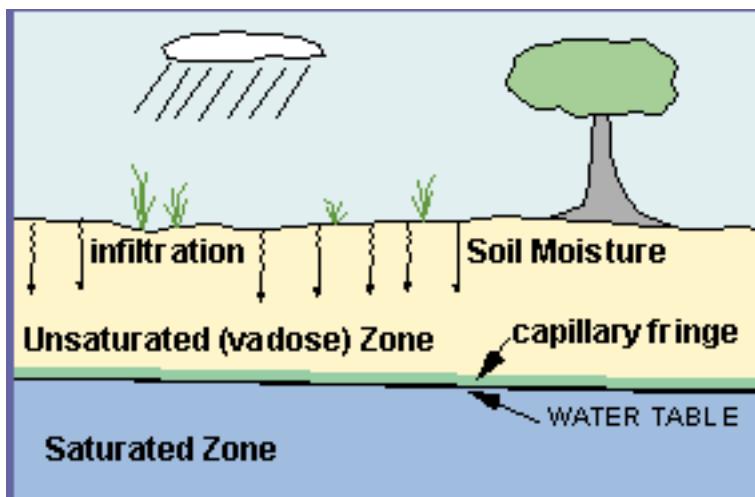
The critical zone as a concept and as a material space pushes us to think of the porosity of the Earth's surface — the gas and fluid flows through rocks, soils, and plants. We can begin to appreciate the complexity of the transport and fate of chemical pollutants as they enter the soil and become part of the vadose zone and perhaps the ground water table — moving with water and diffusing through the water, simultaneously.

---

<sup>1</sup>The chapter was first drafted by Marc Los Huertos (2021). The author received valuable feedback from X, and Y and Z to improve the chapter.



**Figure 3.1:** The Critical Zone is an interdisciplinary field of research exploring the interactions among the land surface, vegetation, and water bodies, and extends through the pedosphere, unsaturated vadose zone, and saturated groundwater zone. Critical Zone science is the integration of Earth surface processes (such as landscape evolution, weathering, hydrology, geochemistry, and ecology) at multiple spatial and temporal scales and across anthropogenic gradients. These processes impact mass and energy exchange necessary for biomass productivity, chemical cycling, and water storage.



**Figure 3.2:** Diagram of Ground Water.

## 3.2 Hydrologic Aspects

### 3.2.1 Subsurface Hydrology

As water percolates into the soil or flows in the pore space below the surface waters it becomes part of the ground water. The study of this water might be called subsurface hydrology or ground water hydrology or hydrogeology.

There are two main areas of subsurface waters: saturated zone and unsaturated zone (Figure 3.2).

The saturated zone is the region where all the spaces between the particles are filled by water. The surface of the saturated zone is the water table.

The unsaturated zone is also called the vadose zone has some percentage of the pore spaces have air. The vadose zone also includes an area called the capillary fringe. Because of the surface tension of water, water is found in between particles above the water table and this zone is referred to as the capillary fringe.

### 3.2.2 Saturated Zone

#### Aquifers and Aquitards

#### Confined and Unconfined Aquifers

#### Ground Water Flow

TAKE A LOOK at some flow net sketches that will help clarify the relationships between aquifer matrix, and groundwater movement.

In general, water flow is driven by potential energy, e.g. where water flows down hill, driven by gravity. If water flows from point A to point B, the potential energy for the flow is the height of the water at point A minus the height at point B, which can be symbolized as  $dl$ . The head potential is the height difference divided by the distance between the two points.

DARCY'S LAW

$$Q = KIA \quad (3.1)$$

In 1856, Henry Darcy studied the movement of water through porous material. He determined an equation that described groundwater flow. The following description tell how Darcy determined his equation:

A horizontal pipe filled with sand is used to demonstrate Darcy's experiment. Water is applied under pressure through end A, flows through the pipe, and discharges at end B. Water pressure is measured using piezometer tubes (thin vertical pipes installed at each end of the horizontal pipe). The difference in hydraulic head (between points A and B) is  $dh$  (change in height). Divide this by the flow length (i.e. the distance between the two tubes),  $dl$ , and you get the hydraulic gradient ( $I$ ).

The velocity of groundwater is based on hydraulic conductivity ( $K$ ), as well as the hydraulic head ( $I$ ). Therefore, the equation determined by Darcy to describe the basic relationship between subsurface materials and the movement of water through them is  $Q = KIA$  where  $Q$  is the volumetric flow rate (or discharge) and  $A$  is the area that the groundwater is flowing through. This relationship is known as Darcys law.

DISCHARGE

AREA OF FLOW

Now, rearrange the equation to  $Q/A = KI$ , which is known as the flux ( $v$ ), which is an apparent velocity. Actual groundwater velocity is lower than that determined by Darcy, and is called Darcy Flux ( $v_x$ )

FLUX

DARCY FLUX

Darcy's law is used extensively in groundwater studies. It can help answer important questions such as what direction an aquifer pollution plume is moving in, and how fast it is traveling

### 3.2.3 The Vadose Zone

The vadose zone is the

Jeji is a volcanic island is located some XX km south of the Korean Peninsula. Water runs off the steep slopes quickly and water supplies are limited on the island. To adddress this...[Lee et al. \[2017\]](#).

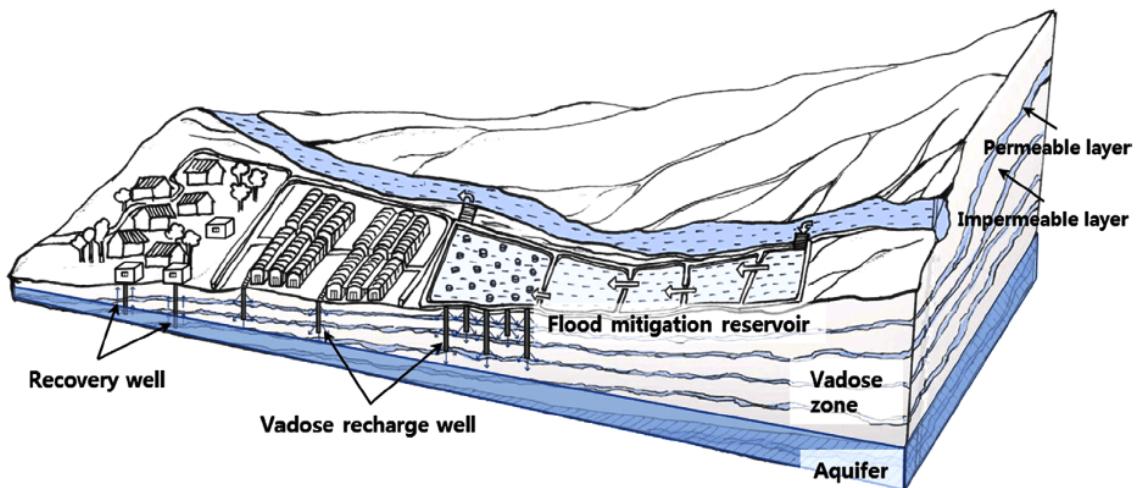


Figure 3.3: ... (Source: [Lee et al., 2017]).



## Chapter 4

# Land Change and Monitoring: Science of Remote Sensing on Biogeochemical Changes to the Land

SAMANTHA BEATON

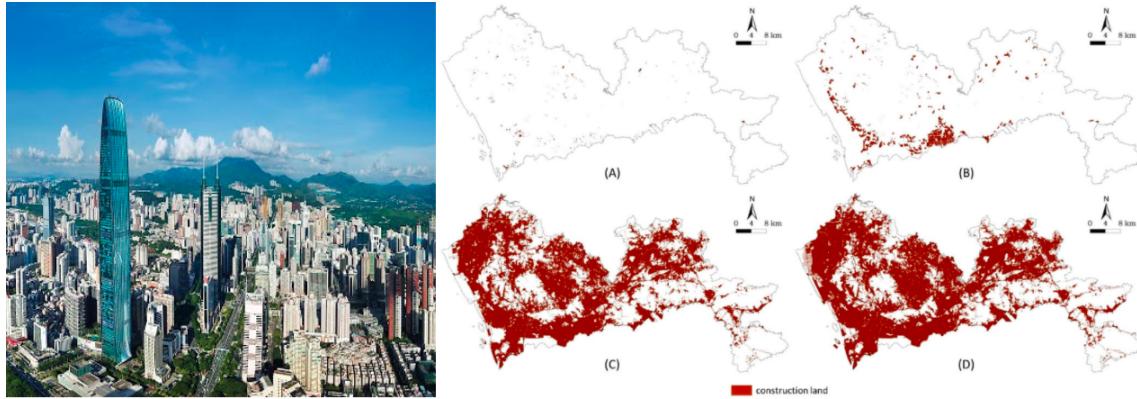
### 4.1 Example of a Place: Urbanization and Land Use Change in Shenzhen, China

Following the late 20th century reform period, China has embarked on a mass urban renewal project, and so it is a particularly interesting place to begin analyzing land use change. A study analyzing land use change in Shenzhen recorded a significant drop in arable land (covered by grassland or forests) between 1996 to 2006 from 51.36% to 45.72% (Qian et al.). Regardless of potential impacts, it cannot be ignored that the land is changing at a rapid pace. This phenomenon, reflected in Figure 1, may be particularly felt in South East Asia, as is the scope of this chapter, but is certainly relevant worldwide. How does land use change affect the environment?

Figure ??

As most scholars would agree, we are currently situated in the Anthropocene, or at least an age dominated by the systems of humans. The supposed "age of man," as described by environmental artist and engineer Natalie Jeremijenko, asserts how humans are "major biogeochemical forces in the world." By simple definition, humans have a true impact on the land, which then responds. Humans are entangled in the forces of nature.

An interesting perspective to consider land use change can be situated in a comparison to the body through traditional Chinese medicine (TCM). In a paper understanding climate change through Qi, et al. describes how climate represents the Qi of nature, the larger body. In this framework, humans act as cells within this body. As with the traditional understanding of the human body, when the dynamic between the cells and body are disrupted, as with one dominating the other, the greater system suffers. Furthermore, in the context of yin-yang, in which two opposite factors are interrelated as one, all actions or changes yield a response. Changing the landscape always



**Figure 4.1:** (A) Shenzhen cityscape, China. (B) Change in construction land within Shenzhen from 1979, 1986, 2005, and 2014.

yields a response from the environment that can be positive or negative, depending on the action. When humans perform an action disharmonious to natural systems, the responses are negative for the entire body. The big question thus becomes how to impact the environment and live within it "sustainably," in a way progressing from our current practices with radical change, deconstructs power systems, and moreover reimagines our relationship with nature.

"Land use changes" encapsulates all the ways that humans change the land, which is particularly fascinating when analyzing highly urbanized spaces, and what that means for the surrounding environment. It goes into the discourse of where nature belongs, and how different people experience nature differently. What does nature look like in and around a city? How is the greater environment changed? While land use changes may only be implicated onto local land, they can be a contributing influence to places across the globe. Within the context of South East Asia, this chapter will specifically analyze land use changes through various places to understand its most prominent, intersecting issues.

## 4.2 What is Land Use Change?

Simply, land use changes are the ways in which land is converted or transformed by humans to serve another purpose than its previous. In a largely industrial, capitalist society, land conversion is most often described to its economic productive role: land is most often shifted to satisfy agricultural and urban needs.

### 4.2.1 What Factors Drive Land Use Change?

Land use changes are influenced by both proximate (direct changes to environment from proximate sources) and underlying (indicative of larger social/biophysical processes that drive change) forces that set certain conditions specific to the place. Underlying forces are largely considered to include economic, policy and institutional, technological, sociopolitical and cultural, demographic factors. As used in a study analyzing land-use change across 8 regions in Southeast Asia over 10 years, proximate causes focused on agricultural expansion, wood extraction, and infrastructural development as the main factors, with space for others in a miscellaneous category (Fox and Vogler). In corroboration with previous research, this study found that multiple causes contributed to land use

change, with agriculture being a common thread. On the underlying level, state policies (especially in relation to climate and property rights) influenced these motivations the strongest, as well as economic market pressures to establish commercial agriculture sites and the general impact of land tenure systems that determine land ownership.

#### 4.2.2 How is Land Use Change Measured and Quantified?

Land use change is primarily measured through processes of remote sensing. Temporal and spatial data are compiled from aerial photos, satellite images, and various radar sensing systems to be analyzed into topographic maps and more. It may also integrate interdisciplinary practices to further understand socioeconomic and institutional factors that affect a given landscape, as well as how that land has changed through history.

### 4.3 The Science, Art, and History of Remote Sensing

Socrates once wrote: "Man must rise above the Earth to the top of the atmosphere and beyond, only thus will he fully understand the world in which he lives." The science of remote sensing attempts to do just that. The term "remote sensing" is attributed to be first officially used in the early 1960s by Evelyn Pruitt, a geographer within the U.S. Office of Naval Research (Fussel et al., 1986). In short, it is used to describe the science and art of identifying, observing, measuring, and analyzing a target object from a distance without direct contact (NASA, 1999).

#### 4.3.1 Invention of Aerial Photography: Pigeons, Kites, Balloons

Roots of remote sensing began upon the invention of photography, with one of the first practical processes developed in 1839 by Louis Daguerre in France (Moore, 1979). Aerial photography (that was also full-spectrum-sensitive) can be traced back to 1868 when Nadar aka Gaspard-Flix Tournachon captured the first from aboard a hot air balloon (Salomonson, 2015). From then, aerial photography was captured with cameras attached to pigeons, kites, and even more balloons. By the year 1909, the first photograph was finally taken from an airplane (HSU, 2019).

#### 4.3.2 Remote Sensing in the Early-to-Mid 20th Century and Military Reconnaissance

Soon after, aerial photography was quickly taken up by the U.S. military for various reconnaissance purposes. The progressive development of aerial photography is deeply tied to military advances and demands beginning during World War I when cameras were mounted to German and American aircrafts to monitor positions of troops (Salomonson, 2015). In 1918, it was recorded that the French military in particular captured and developed up to 10,000 photos per day from such camera mounts (Moore, 1979). During World War II, non-photographic remote sensing methodologies were developed using radar (radio detection/ranging), thermal infra-red detection, and sonar (sound navigation) systems (Moore, 1979). In particular, radar systems were developed by Britain and the U.S. to track ships and aircrafts (Salomonson, 2015). In the 1950s, the University of Michigan spearheaded development of other systems including infrared radar and synthetic aperture radar (SAR) imagery, which was used (and later declassified) during the 1960s in experimental programs by the U.S. National Reconnaissance Office (Salomonson, 2015; Xiao et al., 2019).

### 4.3.3 Satellites in Space: Remotely Sensed Earth Observations

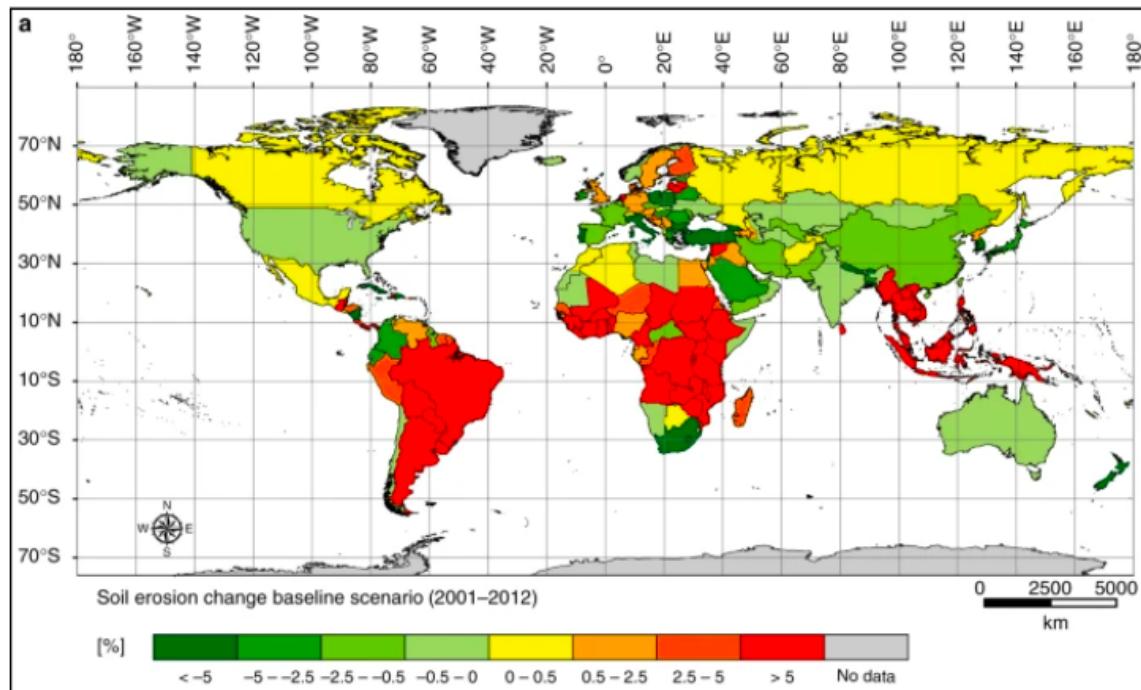
The beginning of remote sensing from space began with V-2 rockets, the first long-range missiles developed during World War II (Salomonson, 2015). As the late 1940s saw the end of WWII and the very beginnings of the Cold War, the Soviet Union and U.S. both took advantage of captured V-2 rockets to start research and development on launch vehicles for space programs (Britannica). While the first picture taken of Earth from the sky (high enough to see its curvature) was captured in 1935 on a balloon 13.7 miles high, it was in March of 1947 when a camera placed in the nose shell of a V-2 rocket flew more than 100 miles above ground; once the series of pictures were stitched together, it clearly showed for the first time Earth against the black space, spanning more than a million miles together (NASA, 2017). It was these pictures that set the stage for the potential of remote sensing to be used to monitor Earth's processes. Still, it was not until the mass development and launching of various satellites during the Space Race when this prospect was cemented as reality.

In 1957, the Soviet Union launched the first satellite into space, the Sputnik 1, with the U.S. following shortly behind (HSU, 2019). In 1964, photographs obtained from the Mercury-4 spacecraft were recognized as highly-valuable to understanding Earth sciences (Moore, 1979). National institutions aside from NASA, such as the U.S. Department of Agriculture (USDA), U.S. Geological Survey (USGS), and National Oceanic and Atmospheric Administration (NOAA) all realized the potential application of remote sensing to fields of agriculture, hydrology, archaeology, geography, oceanography, and meteorology (Bauer, 2019). In 1960, NASA launched its first low-orbital experimental weather satellite, the TIROS-1, whose success proved the feasibility of capturing images of Earth from space (NASA, 2017). Thus welcomed the 1968 development of the Earth Resources Technology Satellite series, now called LANDSAT, sent to record worldwide images on a continual basis—a series that has continued ever since (Moore, 1979). From these developments, images would from then on not only be turned towards enemy troops, nor towards space, but also towards the Earth—the beginning of modern remote sensing.

### 4.3.4 Critical Remote Sensing

Still, the history of remote sensing cannot be understood without analyzing its use in producing and controlling knowledge to monitor and manage global resources and populations. After all, the purpose behind remote sensing is deeply tied to map-making and cartography, which itself has a fundamentally colonial history. During the Western world's Age of Exploration, or Age of Information, between the 15th and 18th centuries, Europe financed global expeditions not only to conquer and colonize, but to gather information on the lands' resources and people (Bennet, 2020). In this way, maps were used to classify life for the purposes of exploitations. They were used to mark territory, regardless of local dynamics, for the use of settlers. Maps, then, were essential to the imperialist settler colonial state in dominating a land. As noted by University of Hong Kong Geography professor Mia Bennet, the quest for information is "an activity critical to empire" (Bennet, 2020). If so, what then must be true to our current quest for information? What must we be critical of if remote sensing is just another rendition, albeit modernized, version of the colonizing tactics of those in power?

Additionally, a key component to colonial mapmaking was the arbitrary creation of boundaries. Remote sensing analyses can fall into a similar "territorial trap" that disregards how human activities, resources, and environmental change occurs as natural flows that transcend transnational boundaries (Bennett, 2020). By working within discrete state boundaries, data and resulting maps can reproduce certain narratives, particularly ones that suppress developing countries over developed ones. We can see this in the map below (Figure 2) on soil erosion rates and vulnerabilities across the globe, dictated by national boundaries. While developing countries are illustrated in red, indicating



**Figure 4.2:** Global land use change and soil erosion estimates, measured on a scale of severity by colors green (low erosion risk) to red (high erosion risk). As denoted by the red color, Southeast Asia is expected to experience a higher risk of soil erosion compared to other regions in the world (Borelli, et al.).

high rates of soil erosion and land degradation, developed Western countries look perfectly clean. This example is just one in a long line of historical misrepresentations of local occurrences that are ever-more complex than what can (and molded to) be portrayed in bordered images. Systems of remote sensing must strive to actively dismantle the colonial, militaristic foundation it is so strongly built upon.

#### Figure 4.2

In an analysis of China's "One Belt, One Road" policy (aka the Belt and Road Initiative or BRI), which as of 2019 lacked an official map shifting the focus to governmental remote sensing illustrations for accountability of the policy's efficacy, Bennett importantly points out an illusory distinction between traditional maps and those obtained through remote sensing: "Whereas maps are considered malleable representations, satellite imagery is imagined as objective, neutral, and importantly, rational—a key word in Chinese narratives of development and modernization." In other words, while remote sensing may easily be seen as perfectly objective, it in fact requires interpretation and representation, so it too is inherently political. While the goal of remote sensing is to accurately capture reality, the "processing of billions of pixels" can just as easily be edited or reframed to help turn policies into self-fulfilling prophecies (Bennett, 2020). Remote sensing produces entire analyses of landscape that may look rational or self-evident; the challenge thus requires a critical look into each trillion pixels and the spaces left unattended within its representation.

Bennett thus presents a methodology of three main principles to foster critical remote sensing:

1. Any analysis must be sensitive to the (geo)politics involved in the production and analysis of

satellite imagery by looking closely at the motivations of goals of the controlling state 2. Analysis should not conform but rather act to contest dominant social meta-narratives and discourses about modernization and development that often use sensing to sustain development and paint a pretty picture of modernization. Critical remote sensing includings the encouragement of political debate. 3. Sensing should include mixed methods of qualitative and quantitative analysis at various research scales and levels throughout its production.

Ultimately, the increased use of remote sensing systems within government agendas and policy initiatives requires the need for active critique on the politics and positionalities ingrained in satellite imagery, especially due to how "images present the guise of the entire truth in a way that can dissuade debate" (Bennet, 2020). Data must be transparent, management must be accessible, and analysis must be critical to rightly expose the complexities of the (sociopolitical) environment. Lastly, while remote sensing is without a doubt an advantageous to our modern society, it cannot entirely replace local observation and place-based understanding, but rather is best kept in balance.

One further point of hindrance to a more fair and just remote sensing system is that the large majority of imaging satellites currently being used are operated and controlled by the most powerful of countries. Increased participation in remote sensing can be created by giving smaller states, organizations, and universities the opportunity to launch their own satellites rather than needing to depend on powerful governments: a "democratization of space" (Bennett, 2020). While this potential is increasing in actuality, it is far from truly increasing representation. Still, it was promising in 2008 when the USGS decided to make all LANDSAT records available to the public for free, when previously it was kept behind a paywall (Xiao et al., 2019). As remote sensing becomes increasingly popular, it is also increasingly common for data to be released and available to the global public. Using this available data, researchers, scientists, and the public are dedicating more time to analyzing ecological effects of land use change within Earth's systems. It is a practice becoming evidently more important as land degradation and desertification intensifies, necessitating directive action with transparent sources of data.

## 4.4 Ecological Effects of Land Use Change on Soil, Air, and Water

Land use change is associated with deforestation and the general destruction of land (at least the land that existed upon conversion), and is thus the biggest driver in terrestrial biodiversity loss. What other long-term impacts does land use change have on the environment, especially when the land is converted into agricultural or urban spaces?

Land use change is the encroachment into habitat for greater space, whether for farmland or urbanization, and so is therefore acted upon through deforestation. By replacing native vegetation with crops or buildings, the soil degrades, suffering a loss of stability that the vegetation provided. It is for this reason that anthropogenic land use change is the primary accelerant of soil erosion. Forests, by far, hold the lowest soil erosion value, certainly in comparison to semi-natural and cropland vegetation (Bonelli, et al.). Additionally, uprooting the land and changing its function creates a loss potential for carbon sequestration. It is estimated that approximately 12.5% to 17% of carbon emissions have originated from loss during land use and land cover changes (Houghton, et al., Paustian, et al.).

#### 4.4.1 An Introduction to Land Use Change

##### Soil Classification

Soil is the combination of biotic organisms and dirtit is the thick, rich, brown substance that gives rise to life on earth. Soil also exists as layers, divided generally into five horizons. The first layer is the O horizon where organic matter such as plant residue accumulates (NRCS, 2010). Decomposing material mixes with dark nutrient-rich mineral soil in the A horizon (Montgomery, 2007). Layers O and A characterize the topsoil where most plant activity takes place as well as weathering processes and erosion, so it is the layers of soil most relevant to land use change. The first layer within the subsoil is the B horizon where the soil is generally thicker and denser with less organic content; leached materials and minerals from above also accumulate here (Montgomery, 2007). The subsequent C horizon contains older materials than those above it, and overlies the lowest R horizon which makes up the bedrock (NRCS, 2010). Again, the topmost layers of soil have the greatest relevance to agriculture and land use change.

##### Weathering, Soil Formation, and Erosion

Soil is a function of five main environmental factors: 1) regional climate, taking into account average temperature and precipitation 2) topography that describes the landscape shape and slope 3) parent material from which the soil has formed 4) organisms and 5) time (Birkeland, 1999). Aside from basic geology of the landscape, topography in particular proximity to the water table, degree of slope, etc. can help predict the effects of weathering that the soil may take from the other factors.

Rocks and soils at Earth's surface represent two stories: an original formation and a secondary breakdown. Weathering describes this secondary breakdown which, like soil formation, is similarly dependent upon climate, parent material composition, biotic influences, and other factors. It is the process of rock and mineral alteration to more stable forms under the variable conditions of moisture, temperature, and biological activity that prevail at the surface (Birkeland, 1999). Physical or mechanical weathering breaks rocks into smaller pieces. Chemical weathering breaks rock or soil bonds at the atomic level i.e. through dissolution (polarity of water molecules pull apart atoms), oxidation, hydrolysis, and other biological reactions (Wiese, 2019). Both physical and chemical weathering processes occur simultaneously in reinforcing each other, and biological activity from plants, microorganisms, or other animals work to increase those processes. The products of weathering contribute to soil profiles. Through chemical processes, released ions may participate in further synthesis or may be removed from the soil environment via transportation of the dissolving water (Birkeland, 1999). If the environment has high levels of aluminum, silica, or oxygen, they could hydrolyze with water to form various types of clay (Wiese, 2019). The resulting soil composition, ever dynamic, depends in large part on the elements, minerals, structures of those elements, and the interactions of those particles with the greater environment. Soil is thus characterized by the rocks from which it is formed, which in turn became available via weathering.

Erosion is the natural removal of weathered debris by agents including water, wind, glaciers, or simple gravity (Wiese, 2019). In replacement of the lost mass, new rock rises up bringing with it essential minerals that replenish the soil and further parent material can be deposited from elsewhere. In the words of Montgomery, 2007, the "soil regulates the transfer of elements from inside the earth to the surrounding atmosphere. Life needs erosion to keep refreshing the soil" (p.16). In this way, soil integrity is dependent upon weathering and deposition to replenish its nutrient stocks.

Soil will develop notwithstanding weathering, that is, until the rate of erosion exceeds the rate of soil formation (Birkeland, 1999; Montgomery, 2007). In general, erosion increases with steepness of slopes, sparser vegetation holding the ground, and greater precipitation that all work to weather the

soil/rock surface. As described by Montgomery, 2007, landscapes can often get caught in positive feedback loops of erosion, particularly if human influences are involved: when vegetation is removed exposing bare soil, precipitation can more rapidly and forcefully erode soil, reaching deeper to denser layers unable to absorb water, thus increasing runoff and ever more rapid stripping of the topsoil. This phenomenon can of course be compounded by the type of soil being eroded and human influences acting upon it.

#### 4.4.2 Impacts of Agriculture on Soil, Air, and Hydrological Cycles

##### Industrialized Monoculture in the 20th Century

The thin topsoil layer that covers Earth's land feeds the world is the foundation of a thriving civilization, yet due to intensive and extensive land use, is experiencing massive risk of degradation and erosion. Big-ag systems of monoculture have been driven by advanced farming technology in response to rising food demands and growing populations worldwide. Induction of high-yielding varieties of crops, including wheat and rice, that require chemical fertilizers and pesticide has also been a defining feature of this age. This intensive, tillage-based agricultural system is associated with many long-term negative ecological impacts, including: a decrease in soil organic matter, biodiversity, nutrient-use efficiency, and water table level, as well as an increase in soil erosion risk, soil quality degradation, groundwater pollution, air pollution, and greenhouse gas (GHG) emissions. Since most land use change is associated with agriculture, the understanding of intensive systems and the promotion of alternatives is an imperative facet to this discussion.

##### Soil and Carbon Nutrient Cycling

Carbon is the foundation to life on Earth and is an imperative global cycle, especially in soil where twice as much carbon exists compared to the atmosphere (FAO; Batjes and Sombroek, 1997). Carbon stocks are maintained in an important balance between inputs and outputs with significant implications to the production of atmospheric carbon dioxide. This is important to land use change because the biggest negative driver to soil carbon loss is land-use change (Poeplau et al., 2011). Following industrial processes and fossil fuel combustion, land use change is the second largest contributor to global greenhouse gases (EPA). Land use change is thus an imperative process to consider in analyzing threats to carbon cycles balances.

Moreover, understanding shifting land uses on carbon cycling is important to understand nutrient stock dynamics. Due to growing socioeconomic pressures, natural vegetation cover has been steadily decreasing. More and more, forest and grasslands are extensively and intensively being converted to agricultural lands or other urban needs, while reforestation projects are also growing in popularity. Poeplau et al., 2011 reviewed shifting carbon stocks in soil following five different types of land use change types across nearly 350 sites in the temperate zone, in which China and much of Eastern Asia resides. Unsurprisingly, complete deforestation resulted in a -3220% decrease in equilibrium SOC over 23 years, and grassland to cropland similarly resulted in a -365% equilibrium decrease after 17 years. These numbers in particular reflect the relative vulnerability of topsoil to intensive change.

Figure 4.3

In comparison with other land use change transitions, restoration of grasslands has one of the greatest potentials for carbon stock restoration. As displayed in Figure 4, shifting croplands to grasslands can result in a 12823% increase in SOCgrasslands in particular are long-lasting nutrient sinks (Poeplau et al., 2011). This is due in part to how grasses form extensive fine root systems. Decomposing roots are considered to be major contributors to organic biomass in soil, further

Land-use change	Equilibrium (years)	$\Delta\text{SOC}$ 20 years (%)	$\Delta\text{SOC}$ 100 years (%)	Initial stock (Mg ha <sup>-1</sup> )
Cropland to grassland	>120	39.8 ± 11	128.4 ± 23.2	46.2 ± 20.7
Grassland to cropland	17	-36.1 ± 4.6	-36.1 ± 4.6	115 ± 66.3
Forest to cropland	23	-31.4 ± 20.4	-32.2 ± 19.9	147 ± 52.2
Cropland to forest (forest floor included)	>120	22.4 ± 10.4	116.6 ± 53.9	68.4 ± 33.8
Cropland to forest (only mineral soil)	>120	16.0 ± 7.4	83.4 ± 38.8	55.5 ± 33.5
Grassland to forest (forest floor included)	>200	-4.0 ± 5.7	27.9 ± 11.0	86.4 ± 28.2
Grassland to forest (only mineral soil)	>150	-4.3 ± 3.7	-6.5 ± 22.6	77.2 ± 43

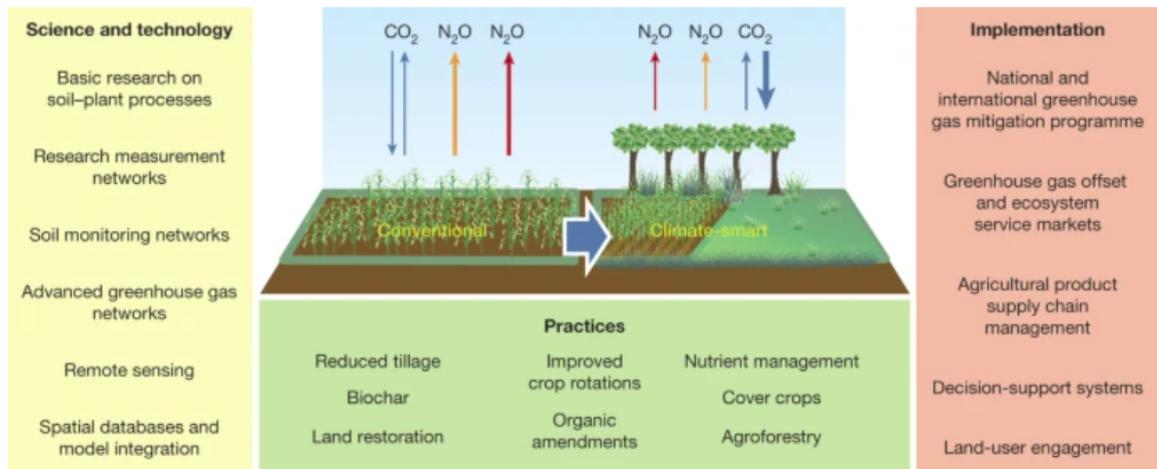
**Figure 4.3:** Comparison of land use change types on years to reach equilibrium, predicted change rates of soil organic carbon stock after 20 and 100 years, and average initial stock value (Poeplau et al., 2011). Note the rapid rates of deforestation (values 17 and 23) compared to longer predicted rates of reforestation land use changes.

bolstering nutrient loads (Wei et al., 2009). While land degradation and loss of carbon can be a relatively rapid process compared to longer rates of restoration, native grassland restoration at least presents a big potential for successful carbon sequestration, especially in comparison to other land use transitions.

### Shifting Practices

Still, global populations depend on agricultural land: shifting land practices even if for agricultural purposes is important. More and more studies are providing evidence for both economic and environmental potentials in shifting management practices to return to a more regenerative strategy. This is particularly important in a region like Northeast China where the land provides 30% of total national maize production for a crop already being one of the biggest food crops in the country. Differences in production potentials can be measured by yield: potential yield is the theoretical ceiling yield for a given place, partially dependent upon its specific environmental conditions, under perfect management. In general, the yield gap between the potential and actual is usually constrained by 1) non-controllable factors (i.e. environmental conditions, access to technology) 2) agronomic and 3) socioeconomic factors (Liu et al., 2016). Compared to other areas of improvement, such as chosen crop variety, the largest potential for increased yield is found to be associated with management practices. These practices move away from intensive systems towards regenerative or conservationist strategies, including the incorporation of crop residue and low-to-no-till practices that combat shallow topsoil.

An increasing demand in maize and rice not only exists in China but largely South East Asia within the continent, in part due to growing populations and the dependence on such crops. According to some studies, rice production in particular needs to increase an estimated 42% by 2050 to meet rising global demands (Ray, et al.). One of the biggest biotic constraints on actual yields are diseases and pests, including root-parasitic nematodes. Suong et al., 2019 contrasted conventional plough-based tillage rice farming practices to a direct-seeding mulch-based rice cropping system (described closely to practices of regenerative agriculture) based on population densities of root-parasitic nematodes. They found that while nematode population densities were significantly higher in the regenerative system than the conventional system, the rice yields were still higher. These results thus show how regenerative systems improve soil fertility and quality both for more productive plants and microbial communities; the higher-nutrient-dense soil not only provided a better environment for microbial biodiversity and nematofauna, but it was moreover productive enough to compensate



**Figure 4.4:** Integrated strategy of scientific research, management practices, and widespread implementation of GHG-mitigation-driven agricultural systems (Paustian et al., 2019).

for any plant damage from the nematodes. These results add to the immense body of research and knowledge that the level of microbiodiversity is a key indicator for soil health. Any land use system that supports this life, then, is most beneficial and sustainable.

Sustainable, regenerative, conservation, or permaculture-based land systems are all names for a common approach in using the land. This approach has the potential to not only ensure food security, but most importantly, has the ability to sustain soil health, promote carbon sequestration (along with other nutrients), decrease GHG emissions, and protect functional ecosystems that then can provide humanity various services. Regenerative agriculture presents an alternative approach characterized by no-to-minimal soil disturbance, diverse crop rotation, and residue retention to enhance nutrient cycling. In short, this integrated, holistic management of land is meant to mimic the natural world rather than interfere with intensive systems, it is meant to work with existing natural systems.

"The art of agriculture is a sacred act of collaboration between heaven, earth, and humanity for the production of life-sustaining food." Torizo Kurosawa

Figure 4.4

Direct impacts on soil: enhances water infiltration/retention, aeration, structure, porosity these conditions naturally promote robust root growth, easy nutrient cycling, carbon sequestration (specific values of course vary across climates and soil types)

Enhances microbial biomass and activity: essential to biogeochemical cycling and providing nutrients to plants (essential symbiotic relationships)

Conversely, intensive tillage practices destroy soil ecosystems via changing soil structure, interfering with nutrient dynamics, and altering the soil habitat

### Impacts on Local Watersheds

Land-use changes can alter hydrology of land i.e. infiltration/pollution, groundwater recharge, flow of river basins, runoff Higher risk of flooding and droughts

## 4.5 Regeneration Efforts in the Loess Plateau, China

Due to its long history within northeastern China, the Loess Plateau is an apt case study to analyze how a place so important to humanity is related to soil degradation, land management, the potential for restoration, and how to critically go about such a process.

### 4.5.1 The Cradle of Eastern Civilization

The Loess Plateau, with agriculture beginning in the region nearly 7000 years ago, was once the cradle of Chinese civilization. It receives its name from the loose, porous, easy-to-farm sedimentary deposits originating from the Gobi Desert that define the region. Covering approximately 640,000 sq km, the Loess Plateau was also once the largest distribution of such fertile soil on Earth.

However, due to intense human activity in the past 2500 years (largely agriculture as well as social conflicts), the high flat plain has experienced severe erosion, transforming it into a land marked by steep, barren hills and deep-cutting ravines. Agricultural processes led to the overgrazing of land that, over a very long period of time, damaged the vegetation. Without trees or plants rooted in the earth, water no longer seeped into the soil but rather evaporated immediately or slid off the hillsides, eroding massive amounts of topsoil away with it. The land of the plateau eroded seasonally, both by wind and water (Xiao et al., 2009). Over time, massive amounts of silt swept into the Yellow River (thus giving the river its distinct name), with an estimation of 90% river sediment originating from Loess Plateau erosion, hence the name of the river. Due to lack of water retention, this phenomenon contributed to increased flooding events: as quickly as water would come, it would just as quickly go away so that the region experienced severe droughts. While this is all true, it must be kept in balance with the knowledge that the Loess Plateau was, for thousands of years, a place that built civilization. Generations of people who lived within the region, a center for traditional pastoral life, gave and received a great deal from the soil. The longstanding history of humanity within the region should not be taken for granted beneath the landscape we may see today.

### 4.5.2 Beginnings of Modern-Day Restoration

Beginning in the 1960s, mass efforts have been made to restore the Loess Plateau. After all, one must only look to the neighboring provinces with rich environments, such as Sichuan, to realize the potential of such efforts. The primary goal of these endeavors were, and continue to be, increase biomass and biodiversity in all ways within the environment. Methods include terracing of the hills that level out parts of the steep slopes, natural vegetation rehabilitation to restore soil productivity, and additional efforts in check dams for sediment control. A study analyzing the Loess Plateau rehabilitation reflected a trend of increased retention of water in the land, especially since 2000, seen through decreased streamflow and sediment concentration into the Yellow River. (have to regain access to the articlewill input figures and explanations of the science here). While restoration is actively being worked upon on a comparatively small area in the big region, the Loess Plateau rehabilitation effort is representative of the true potential to restore massively degraded land from harmful land usage (Figure 4.5).

### 4.5.3 Importance of Grasslands and Cautions Against Afforestation

The Loess Plateau and its unique (yet universal) history of land degradation highlights the importance of maintaining native habitats, particularly grassland ecosystems. Historically, the Loess Plateau was dominated by a grassland ecosystem with the most common native grasses including bunge needlegrass (*Stipa bungeana*) and Daurian bush clover (*Lespedeza daurica*) (Wei et al., 2009).



**Figure 4.5:** Comparison of Loess Plateau from 1995 to 2009 (Liu).

Beginning predominantly in the 1970s when the push to "green slopes" reached its highest point in political agendas, large populations of non-grassland vegetation were introduced to reduce erosion. Some of the most popular included the Chinese Pine (*Pine armandii*) and Korshinsky Peashrub (*Caragana korshinskii*) (Wei et al., 2009).

In a study comparing the soil organic carbon, nitrogen, and phosphorous stocks of native grassland and implanted woody ecosystems dominated by the pine and peashrub, Wei et al., 2009 found that the soil of native grass exhibited the highest concentration of SOC and nitrogen stocks. While much of the rhetoric surrounding the fight against desertification centers around reforestation, regeneration of grasslands, especially if it is the historically native ecosystem, can be overlooked at least in predominant media. Still, especially in the Loess Plateau, native grasslands are the ecosystems that generally hold a greater potential for carbon and nitrogen stocks, contributing to more productive soil. Ultimately, grassland root systems play an essential role in nutrient cycling and stocks within soil of the Loess Plateau, and are thus an important measure to consider in relation to land use change.

## 4.6 How GIS Can Be Used to Inform Loess Plateau Restoration

Just as the ecosystems it attempts to restore, regeneration efforts like that being done in the Plateau are different everywhere. Processes must consider the historical, natural habitat and current conditions an area made possible in using remote sensing. Remote sensing can be used to develop a site history or a place, an especially important tactic when dealing with projects involving development or restoration. Remote sensing can be used to assess an ecosystem and its soil surface conditions, local hydrology, nutrient cycles, vegetation, and overall geology (Abdullah et al., 2015). Especially in terms of restoration sites, remote sensing can be used to identify reference sites with similar characteristics to further evaluate the target site, thus contributing to a more robust directive towards proper objectives, plans, and action. This was done in modern studies of the Loess Plateau in comparing it to its neighboring region of Sichuan which hosts a rich, lush ecosystem of vegetation and biota. Monitoring is, of course, also important to keep track of long-term changes in vegetation cover and efficacy of restoration methods.

#### **4.7 Conclusion & Prospect of Sustainable Urbanization/Land Use Change**



# **Chapter 5**

## **Deforestation**

XINLAN CHEN

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### **5.1 Section Heading**

#### **5.1.1 Subsection Headings**

### **5.2 Overall**

Deforestation is not a small issue in East Asia, since most countries here depend on the money source they got from the wood export industry. There are many issues that could be caused by deforestation with but not limited to air pollution, water pollution and climate change. Upon having looked at all the presentations that people make, I realized that most East Asia countries that was originally covered mostly in forest have significantly reduced in their forest coverage, and nevertheless, nature is punishing them for that. Over-logging is when the level of deforestation exceeds the self-sustaining state of the ecosystem, leading to desertification. Excessive cutting of trees can bring a series of troubles and problems. Many countries have started having regulations on business regarding wood exports and forests protection, more have to be done in order to resolve the issue that people have done in the past that resulted in deforestation.

### **5.3 Damage Done by Deforestation Example of China**

After soil erosion and deforestation, the bare land cannot withstand the wind and rain. On sunny days, due to the sun exposure, the ground temperature rises, the process of organic matter decomposition into soluble mineral elements is accelerated; On rainy days, rainwater is washed directly, carrying the fertile topsoil along with mineral elements into rivers. It is estimated that more than 5 billion tons of soil are washed into rivers in China every year. The siltation of quicksand blocked the channel of the reservoir. Sediment concentration in the Yellow River in China is the highest

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in the world, and when floods come, water and sand are equally divided. Due to the deposition of quicksand, the riverbed in some places in the lower reaches of the Yellow River is 12 meters higher than the land beyond the embankment and even higher than the city wall of Kaifeng City, posing a serious threat to the safety of people's lives and property. The deteriorate of environment always accompanies with frequent disasters. The forest coverage rate in Wanning County, Hainan Province, used to be as high as 63 percent. Due to forest regulation, there was no drought in the 1940s and 1950s. Since then, natural disasters have been on the rise. From the 1960s to the 1970s, droughts hit an average of six out of every ten years, cutting the flow of 21 rivers, reducing the output of three-quarters of farmland and drying up 25 reservoirs. In particular, the destruction of the forest, so that some rare animals lost their breeding base. Animals there can't survive. China's Hainan slope deer, South China tiger, black - crested gibbon and other precious animals are endangered due to habitat destruction. There is less oxygen supply when deforestation issue is present, consequently there is more carbon dioxide and less natural filters. The ecological environment was forcibly occupied, and the law of ecological circulation was destroyed. The temperature can change, causing unstable changes in the climate.

## 5.4 Overall Losses Example of Indonesia and Thailand

In the past decade, Southeast Asia has suffered the greatest loss of forest area, with a net loss of more than 900,000 hectares a year. Trees are widely used as materials in construction, decoration, paper making, metallurgy, chemical industry. Used in paper making, as furniture, chopsticks and other main daily necessities, wood floor, plywood, ceiling and other industrial supplies. Cutting down trees so that people can use the land in their own benefits. To sum up, people cut down trees mainly for their own needs. In some parts of Thailand, inspectors inspect thousands of smuggled trucks at roadblocks every day. Instead of guns and drugs, they are carrying wood. Thailand, once a major teak producer in the world, is now on the verge of disappearing its forest resources, and most of the forest areas have become a mess of tree stumps. According to government statistics, Thailand's forest cover has almost halved in two decades. In 1961, it still accounted for 53% of China's forest areas, and in 1981, it only accounted for 28%. Some experts believe that the actual forest coverage is much less at present. According to the latest survey report of the United Nations, in South Asia, Southeast Asia and the Pacific Islands, forests are disappearing at the rate of 12500 hectares per day, that is, 4.5 million hectares per year. The report also points out that Indonesia, the largest producer of tropical hardwood in the world, loses more than 1.2 million hectares of forest land every year. Thailand is more serious, with an annual deforestation of 800000 hectares, while the land area of this country is only one fourth that of Indonesia. The large-scale disappearance of forests has caused climate change and the death of wild animals and caused ecological disasters. In Thailand, 42 people died of floods in 1979. If effective measures to protect wildlife areas are not formulated, wild elephants may disappear in 30-40 years. Another reason for the destruction of forests is that mountain tribes in Thailand still carry out primitive farming. They cut down trees to burn wasteland and clear land for farming. According to the United Nations survey, 70% of the forests in the north have been destroyed. Online Thailand has changed from a major log exporter to an importer, with an annual cost of US \$4400 in foreign exchange. Since 1968, Thailand has divided nearly half of the country's forests into more than 500 leased plots for logging. The annual deforestation rate of Southeast Asian countries is relatively high, and the annual reduction of forest area is increasing year by year. Indonesia has increased from 600000 hectares before the 1990s to 1084000 hectares between 1990 and 1995. At the same time, Thailand increased from 244000 ha to 329000 ha, Malaysia from 255000 ha to 400000 ha, Philippines from 91000 ha to 262000 ha,

Myanmar from 102000 ha to 387000 ha. Compared with the period before the 1990s, the annual average amount of logging in these countries increased by one cup in the first half of the 1990s, and even tripled in some countries. Since Vietnam's reform and opening up, due to a large number of logging and fire, the forest area has also been greatly reduced. From 1990 to 1995, a total of 1.5 million hectares of forest were lost, that is, 26000 hectares per year. In recent years, four of the six countries with the most deforestation in the world are Southeast Asian countries. Their average annual felling rates are 513300 acres in Thailand, 400500 acres in Myanmar, 396000 acres in Malaysia and 316100 acres in the Philippines. From 1969 to 1993, about 6000 square kilometers of forests, swamps and grasslands were opened up for agricultural use by immigrants in Indonesia. Although forest is a renewable resource, its growth cycle is decades or even hundreds of years. For a long time, a large number of forests have been cut down in Southeast Asia, but the work of forest restoration and afforestation has not been given due attention. The speed of forest restoration is far behind the speed of deforestation, resulting in the decrease of forest area year by year.

## 5.5 Correlation Between Deforestation and Pandemic

Deforestation has led to more outbreaks of human infectious diseases, and in 1997, in Indonesia, a haze shrouded the rainforests, an area the size of Pennsylvania was burned to promote agriculture, and droughts exacerbated the fires. Under the smog, the trees are unable to bear fruit, leaving local fruit bats with no choice but to fly elsewhere in search of food, and carry with them a deadly disease. Soon after the bats took up residence in the trees in the Malaysian orchards, nearby pigs began to get sick – probably from eating fallen fruit eaten by the bats, and local pig farmers also began to get sick. By 1999, 265 people had severe encephalitis and 105 had died. This was the first known case of Nipah virus in humans, and since then there have been a series of repeated outbreaks across Southeast Asia. Such infectious diseases are usually confined to wild animals but are spreading to areas where forests are being cleared rapidly. Human infections vary from asymptomatic to fatal encephalitis. Infected people initially develop flu-like symptoms: fever, headache, muscle pain, vomiting and sore throat. This may be followed by dizziness, lethargy, confusion, and neurological signs that indicate acute encephalitis. Some people may also develop atypical pneumonia and serious respiratory problems, including acute respiratory distress. In severe cases, encephalitis and epilepsy develop, leading to coma within 24 to 48 hours. The time between infection and onset of symptoms ranges from four to 45 days. Most acute encephalitis survivors who recovered from it are left with residual neurological consequences, such as persistent seizures and personality changes. A small number of people recover and relapse or develop delayed encephalitis. Over the long term, persistent neurological dysfunction has been observed in more than 15% of the population. The case mortality rate is estimated at 40% to 75%. Over the past two decades, scientific evidence has mounted that deforestation sets off a complex chain reaction that sets the stage for a host of deadly pathogens to spread to humans, like Nipah and Lassa viruses, as well as the parasites that cause malaria and Lyme disease. Today, large areas of the Amazon rainforest, parts of Africa and Southeast Asia are still burning, and experts are concerned about the health of people living on the edge of deforestation. They also worry that the next serious pandemic could emerge from the planet's forests. Researchers have identified the correlation between malaria and deforestation, which kills more than a million people a year and is mainly transmitted by the malaria parasite carried by mosquitoes.

## 5.6 Data Proving the Damage of Deforestation as a Broader Picture and Policy Implemented

In Southeast Asia, the area of forest is gradually decreasing, and the forest coverage rate is decreasing due to the migration and reclamation, deforestation, expansion of farmland, backward farming methods and large-scale commercial forest development. Before the 1970s, the forest coverage rate of Indonesia, Cambodia, Laos and Brunei was as high as 70%, that of Myanmar and Malaysia was 66%, and that of Vietnam, Philippines and Thailand was less than 50%. By 1995, the forest coverage of these countries had decreased significantly, to 55.7% in Cambodia, 41.3% in Myanmar and 47.7% in Malaysia. 60.6% in Indonesia, 22.8% in Thailand and 22.7% in the Philippines. Forest is the habitat of animals. With the decrease of forest area, the habitat of animals and plants also decreases. The rate of net loss is significantly lower than the annual loss of 2.4 million hectares during the period 1990-2000. Despite a net increase in forest area reported at the regional level, the rate of deforestation remains high in many countries. In the past decade, Southeast Asia has suffered the greatest loss of forest area, with a net loss of more than 900,000 hectares a year. However, the rate of net loss is significantly lower than the annual loss of 2.4 million hectares during the period 1990-2000. Overall, the Asia and Pacific region lost 700,000 hectares of forest per year in the 1990s but gained 1.4 million hectares per year between 2000 and 2010. This is largely the result of China's massive reforestation efforts, which saw the country's forest area increase by 2 million hectares a year in the 1990s and an average increase of 3 million hectares a year since 2000. As article 8 of the Forest Law of the People's Republic of China stipulates that the state shall implement the following protective measures for forest resources: (1) implement quota cutting for forests, encourage afforestation, close mountains for forest cultivation, and expand the area covered by forests; (2) to give economic support or long-term loans to collectives and individuals for afforestation and forest cultivation in accordance with the relevant provisions of the state and local people's governments; (3) To advocate the comprehensive utilization and economical use of wood and encourage the development and utilization of wood substitutes; (4) Collect forest raising fees and use them exclusively for afforestation and forest raising; (5) In the departments of coal and paper making, a certain amount of funds shall be set aside according to the output of coal, wood pulp and paper to be used exclusively for the construction of pit timber and timber for paper making; (6) Establishing a forestry fund system. The State shall establish a forest ecological benefit compensation fund to be used for the construction, upbringing, protection and management of protection forests that provide ecological benefits and forest resources and trees with special uses. Forest ecological benefit compensation funds must be earmarked for special purposes and may not be misused for other purposes. Specific measures shall be formulated by the State Council. Bhutan, India, the Philippines and Vietnam also reported an increase in forest cover over the past 10 years. Despite a net increase in forest area reported at the regional level, the rate of deforestation remains high in many countries. In the past decade, Southeast Asia has suffered the greatest loss of forest area, with a net loss of more than 900,000 hectares a year. China, India and Vietnam have all set targets for large-scale reforestation, as well as incentive programs to encourage small farmers to plant more trees. China plans to increase its plantation area by 50 million hectares to 23 percent by 2020. If the current rate of afforestation continues, it may be possible to achieve this goal by 2015. India has set a goal of 33 percent forest and tree cover by 2012. Forests, other woodlands or land covered with trees accounted for about 25 percent of India's land area in 2010, according to the Global Forest Resources Assessment. The area of unknown rows of trees planted and other "trees outside the forest" should be included in this percentage. The government's goal was to restore forest cover to 43 per cent by 2010, and according to information provided to the Global Forest Resources Assessment, this goal has been met.

## 5.7 Suggestions

(1) Strengthening the awareness of forest resources protection The human living environment is increasingly bad, the ecological environment problem has become the focus of globalization. The destruction of forest resources leads to soil erosion, land desertification, poor air quality and even harm to human health. We should realize the importance of forest resources, strengthen the awareness of forest resources protection, the protection of forest resources is everyone's responsibility, starting from ourselves, fundamentally accept and support the forest resources protection policy, dare to report illegal logging behavior, participate in the protection of wild animals and plants. On the basis of not destroying, afforestation can promote the healthy and sustainable development of forestry, mobilize the enthusiasm of the broad masses of people, effectively protect forest resources to the greatest extent, improve the ecological environment, and enable people to live in harmony with nature. (2) Strengthening the construction of forest resources management institutions The management and protection of forest resources should be based on the principle of sustainable development and operation, and rational harvesting should be carried out according to the quality and structure of forest resources. Forest resources management agencies should be established and the management system should be improved. According to the actual situation of forest resources, forest management and protection stations should be set up reasonably, and the management and protection personnel should be trained to improve their management and protection ability and legal awareness of forest resources. We should reasonably formulate quotas for forest cutting, conduct management and supervision over the issuance of cutting licenses in accordance with the Forest Law, ensure that there are laws to follow for cutting with vouchers, supervise the progress and management of cutting, and resolutely prohibit arbitrary cutting. Forestry departments should also adapt to the requirements of the current social development situation, under the trend of rapid development of information, increase investment to improve hardware and software infrastructure, establish a perfect information system, improve configuration facilities, improve work efficiency. The perfect forest resources information management system, standardized management data collection and analysis, improve the level and quality of monitoring, scientific management and protection of forest resources. (3) Strengthening control of diseases and insect pests of trees and protection against forest fires Natural disasters of forest resources mainly have two aspects, one is pests and diseases, the other is forest fires. These two kinds of harm to the forest destruction and loss are huge. As for the prevention and control of diseases and insect pests, the quarantine of quarantine forest plants and the prevention and control of forest diseases and insect pests should be strengthened. The Quarantine Law should be strictly implemented to prevent the introduction of harmful organisms and put an end to the man-made spread of pests. Monitoring and forecasting of forest diseases and insect pests, taking the initiative to prevent disasters and effectively control the scope and harm of diseases and insect pests; On the other hand, the prevention and control of forest fires has always been the top priority of forest resource management. For a long time, the need to constantly, vigorously adhere to the propaganda of fire prevention work, multimedia, multi-faceted personnel into the forest to strengthen the awareness of fire prevention, has been unable to relax vigilance. Implement the fire prevention responsibility of relevant units, control fire source management, carry out regular joint prevention of responsible households, establish and perfect fire monitoring and forecast system, strengthen the allocation of fire prevention equipment, fundamentally control fire sources, timely control when fire occurs, and reduce the loss of forest resources. (4) Improve the utilization rate of forest resources The utilization of forest resources is mainly the development of forestry, and the industrialization of forestry development is its development trend. In the management and management of forestry, we should first cultivate forest resources fundamentally, increase the intensity of forest cultivation, improve the quality of forest resources and improve the ecological environment. On this basis, forestry

industrialization, technological production technology improvement, research and development of new wood processing industry, adjust the direction and structure of wood products. At the same time, the comprehensive development of forest resources, the development of breeding, planting, and related processing industries, in many ways to improve the maximum utilization rate of forest resources.

# **Chapter 6**

# **Invasive Species**

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## **6.1 Section Heading**

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<sup>1</sup>Statement of Contributions– For example, “The chapter was first drafted by Marc Los Huertos (2021). The author received valuable feedback from X, and Y and Z to improve the chapter. Slater revised the chapter in 2022 with suggestions from Cater.” Note: I am still working on the formatting for this to improve it.



# Chapter 7

# Coral Reefs, Ecosystem Services, and Indigenous Peoples

David Chengwen Gorman

## 7.1 Coral Reef Ecosystem Functioning and Interactions

### 7.1.1 Coral Reefs: An Introduction

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.

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 600-800 different coral species. Healthy coral reef ecosystems provide various anthropological benefits, or ecosystem services, to people of all socioeconomic backgrounds. They 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.

### 7.1.2 Coral Functioning

Coral polyps are tiny animals that work together by the thousands to build reef ecosystems. Each coral polyp uses calcium and carbonate ions that have been dissociated in the surrounding water to create calcium-carbonate (limestone) skeletons. During the day, these vulnerable, nocturnal creatures protect themselves by hiding in their limestone skeletons. At night, they extend their many tentacles to feed, using specialized cells called nematocysts to stun their prey before consumption. Coral polyps are part of the family Anthozoa, which includes sea anemones as well, explaining their similarities. 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 important for 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. The shape of these skeletons, while heavily influenced by genetic composition, is also largely dependent on the surrounding environmental conditions to which the coral is subject. In rougher water with stronger waves breaking over the reefs, hard corals tend to create a more robust, stable shape, like a mound or coral flat. In contrast, corals in more sheltered, calmer waters can create complex shapes with intricate branching patterns [CORAL, 2021].

The body of each coral is actually clear; the intricate colors come from single-celled dinoflagellates, or plant cells living inside the corals. This grouping of small, photosynthetic algae living in symbiosis with the coral polyps are generally referred to by their colloquial, zooxanthellae. [NOAA, 2019b]. 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 incredibly slow growing, as they require a delicate balance of nutrients and environmental conditions. Most species only grow between 0.2-1 inch per year. Coral reproduction processes vary by species. Some coral species are hermaphrodites, able to produce both eggs and sperm at the same time. Others are gonochoric and can only produce one of the two gametes. Coral larvae can be formed either inside the polyp body or outside the polyp body, such as during mass gamete ejection events. Coral larvae are released into the water, where they are free swimmers. They first swim to the surface, and then fall back to the seafloor where they must attach to a hard surface, like a rock or preexisting coral skeleton. Once attached, the corals begin dividing and making genetic copies of themselves. They then can begin secreting the calcium carbonate skeleton, which in turn attracts zooxanthellae, and the symbiotic relationship begins [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.

### 7.1.3 Reef Organisms and Trophic Interactions

The species the reef ecosystem largely depends on, or its keystone species, are the coral polyps. 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 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. 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 ecosystems 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 niche is to "clean the coral," allowing normal function to continue. The Parrotfish is a highly targeted, overfished species, and because it fulfills 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 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 the seafloor, creating urchin barrens 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].

### 7.1.4 Necessary Climate and Nutrients

Coral reefs require a delicate balance of nutrients and external conditions, which is easily upset, 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 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 degrees C (68-90 degrees F). This explains the abundance of coral reefs in the tropical, warm climate of Southeast Asia. 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 [Brandl et al., 2019].

FIGURE

### 7.1.5 Southeast Asian Reefs by Country

MAP TABLE

## 7.2 Climate Change and Its Effects on Coral Reefs

### 7.2.1 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 corals as one of the fastest declining species (in terms of diversity and richness) in response to climate change [Almond and Petersen, 2020]. Even all localized reef threats and pollutants were eliminated, the overarching threats of ocean acidification and rising temperatures hold the ability to 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].

Oddly, indigenous groups are some of the most well-adapted and resilient groups in response to climate change as well. Knowledge of specific environments and ecosystems is passed down generationally, creating a plethora of knowledge concerning responses to environmental issues, all which can be used to combat the effects of climate change. This ecosystem expertise and resilience, coupled with their high vulnerability to climate change, creates what some call “The Indigenous Paradox.” Indigenous groups all throughout Southeast Asia are continually ransacked by reef degradation in response to climate change, yet their complex, generational knowledge is vital in combatting climate change and reversing its current narrative. Indigenous peoples offer highly valuable resources concerning reef restoration, which will be discussed further in Section 7.6.3 [Lyons et al., 2019].

### 7.2.2 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. [CORAL, 2021].

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. Theoretically, this makes sense. Sea level rise increases the vertical space a coral can grow in, or the accommodation space. 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. At first glance, this promising result suggests that climate change actually may benefit coral reefs in some way, but that is unfortunately not the case. 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]. Retrospective studies have also found that coral growth rates increased with sea level rise over 16,000 years ago, and then faltered as the sea level became stabilized during the Holocene (current time period, which began 11,700 years ago), but these results cannot be taken as indications of future outcomes. 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].

The negative effects of sea level rise on the coral reef ecosystem are relatively unquantified, yet practically accepted as true based on past events and prospective insight. Rising sea levels 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, causing them to either move inland or to other coastal areas. Many would likely move to other coastal areas to practice similar lifestyles, which would in turn concentrate pressure on reefs not yet affected by coastline degradation. Indigenous groups and other coastal communities are disproportionately threatened by sea level rise, as the already underrepresented groups will be forced off their land now not only by oppressive governments and corporations, but also by nature itself. These threats to coral reefs may seem distant, but they are quickly approaching realities imposed by climate change [Keller et al., 2009].

### 7.2.3 Ocean Warming and Acidification

Climate change has already begun to negatively impact reefs in quantifiable ways that can be observed at the molecular level. Fossil fuel emissions release carbon dioxide into the atmosphere, and a third of that gas is absorbed by the ocean [Keller et al., 2009]. As carbon dioxide dissociates, it releases protons, which when added to the water, lowers the pH, making it more acidic. 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<sub>2</sub> 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 limestone formation. The bicarbonate ion formed by the carbonic acid-carbonate interactions is unusable to corals, thus slowing skeletal growth (see figure for complete chemical process). It is estimated that up to 60% of reefs today persist in waters with inadequate aragonite saturations [Ayala, 2009].

The skeletons built by corals in waters lacking proper carbonate ion concentrations not only form slower but are also weaker and less robust. 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 [Ayala, 2009].

On top of 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 7.4.4. 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]. It is generally agreed that 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 will completely eradicate the coral reefs, with an estimated loss of around 99% of reefs worldwide [Almond and Petersen, 2020].

#### 7.2.4 Coral Bleaching

Coral polyps react to warming water temperatures and other environmental stressors by expelling their algae. If the waters do not cool or the stressor continues to persist, the algae will not come back, and the coral will starve without them. The starved corals crumble into empty, white, lifeless skeletons. This is known as coral bleaching, and it has the potential to destroy entire reef ecosystems in an alarmingly short period of time [Suggett and Smith, 2020].

Most bleaching and mass coral mortality events are driven by heat waves, which have increased with climate change and global warming. The disruption of the coral-algae symbiosis caused by the loss of algal endosymbionts is what causes the corals to pale, as the algae are responsible for coral coloring. Without their symbionts, the corals lose the ability to feed and rapidly starve and die off. Not only does this halt further reef growth, but it also sends negative ecological cascades throughout the ecosystem. Many organisms' habitats are destroyed as the coral, the keystone species and ecosystem engineers, are removed [Suggett and Smith, 2020].

Coral bleaching is the net outcome of complex, multifactorial stressors working at both the cellular and ecosystem levels. At the cellular level, the accumulation of reactive oxygen species, or ROS, triggers signaling cascades prompting corals to expel their zooxanthellae. These ROS are both produced and accumulated in response to environmental changes and stressors. At the ecosystem and environmental 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 accredited with the increasing frequency of bleaching events. The two recent back-to-back bleaching events in both 2016 and 2017 show not only the vulnerability of the coral ecosystem to change, but also how climate change will only make coral bleaching more frequent and of greater severity. Other environmental exacerbators include, but are not limited to, light availability, salinity, oxygen demand, organic nutrient availability, and inorganic nutrient availability. While one of these single factors may not cause a mass bleaching event, they are interconnected and have cumulative effects on the fragile, not-easily-adaptable coral polyps. Each factor also can change how well coral adapts to rapid heat change. Coral bleaching is the result of a complex, dynamic system that global warming negatively affects in multiple ways [Suggett and Smith, 2020].

### 7.3 Unsustainable Fishing Practices

#### 7.3.1 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 food web balance, since macroalgae, without as many fish as predators, grow disproportionately and smother corals. Overfishing 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 [CORAL, 2021].

A major driver of unsustainable fishing practices is the Live Reef Fish Trade, or LRFT, which is precisely as it sounds: selective fish are caught alive and sold as high-priced delicacies. Certain high-commodity fish, like leopard coral reef fish, are targeted and fished for disproportionately, selectively 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” [Fabinyi, 2010].

Many of the practices for catching live fish are inherently destructive. 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].

### 7.3.2 Cyanide and Blast Fishing

The selective catching of live fish is easily accomplished through the use of sodium cyanide, which stuns larger fish to be later revived. While it may sound complex, 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. While larger animals may only be stunned and can later revive, smaller organisms are severely poisoned by the cyanide, as it represents a much larger proportion of their body weight and size. These animals inevitably die, disrupting ecosystem functioning on multiple levels. Cyanide is most often fatal to small fish, invertebrates, corals, and their symbiotic algae [Pearce, 2003].

After just 30 seconds of cyanide exposure, coral becomes stressed and begins to lose its ability to function normally. It is estimated that for every live fish caught with cyanide, a square meter of reef is destroyed. Cyanide fishing is not only used for the LRFT, but also for aquarium trade as well. At the turn of the century, 75% of all aquarium fish coming from Southeast Asia were estimated to be cyanide-caught. It is estimated that around two-thirds of all Filipino reefs are affected in some way by cyanide poisoning [Renaud, 1997].

Despite being banned in both Indonesia and the Philippines, cyanide fishing still persists today. Asia's growing affinity for live fish, with neighboring countries like China and Hong Kong making up the majority of the market, fuels the continued use of cyanide fishing. The Padilla region in the Philippines is responsible for around two-thirds of all live fish exports, exporting up to a ton of fish per day. Many of these live fish are caught via cyanide fishing. The minimal regulations and negligible punishments for cyanide fishing enable this destructive practice to continue. There have been almost no convictions or case files against cyanide fishing only six total have occurred in six years [Pearce, 2003].

#### FIGURE

Blast fishing is another way to stun fish for the live trade harvest. Explosives are detonated in reefs to stun fish, which are then selectively chosen for live trade. Like cyanide fishing, smaller

organisms are often immediately killed by these blasts, and the coral is as well. Because blasts also break the preexisting coral skeletons, both the habitat and entire ecosystem are destroyed. Over half of all Southeastern reefs are threatened by blast fishing practices [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. An examination of craters left behind by blast fishing concluded that even after five years, the rubble and debris left inside the crater was between 5-10 cm deep. This additional sediment can smother both coral and algae, either blocking light and hindering photosynthesis or burning still-intact corals alive. Larger debris and skeletal pieces can also abrade 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. Again, like cyanide fishing, blast fishing is legislatively banned, but this ban is not adequately 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].

### 7.3.3 Economic Drivers and Indigenous Contributions

A group of indigenous peoples deeply impacted but also highly connected to unsustainable reef fishing is the semi-nomadic, boat dwelling communities of Southeast Asia. These maritime communities are reliant on the sea for subsistence, often inhabiting areas of high biomass and biodiversity, as resources are often concentrated there. As a result, many of these communities are situated near coral reefs and rely on them; to them, reef survival means human survival [Hoogervorst, 2012].

One of these groups, the Sama-Bajau, reside mainly in the Philippines and eastern Indonesia. Foods derived from reefs provide a majority of their protein intake, and fishing is a dominant economic sector among the group. Most other economic activities among the Sama-Bajau relate to reefs, as reef reliance supports a wide range of activities, from boat building, to guiding tours, to sea trading. Many groups like the Sama-Bajau have modernized to incorporate stilt houses, giving them more of a sense of community and stability. Unfortunately, many other groups lack government representation, and in turn cannot officially own land areas for settlement. The resulting highly mobile lifestyle deprives these groups of not just landownership, but also healthcare, education, and traditional economic prosperity [Hoogervorst, 2012].

Because of the many factors contributing to indigenous suppression and poor socioeconomic conditions, the vast majority of the reef fishermen are poor and struggle to sustain themselves and their families through traditional fishing practices. One factor of interest is the drop-out rates among children in these indigenous groups. The reef-reliant, seafaring lifestyle is commonly not respected among upper socioeconomic classes, for these indigenous groups are viewed as primitive and uncivilized. 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 overarching issues, such as climate change and local issues (e.g., corporate overfishing and pollution), sustainable fishing practices become less viable. Many Sama-Bajau fishermen, like other indigenous fishermen, have turned to the more lucrative unsustainable fishing practices like blast fishing and cyanide fishing. Driven by the high demand of the LRFT and aquarium trade as well, these destructive fishing practices promise steady, higher payouts than traditional fishing methods. Indigenous participation in these activities is not driven by economic greed, but purely because they lack other alternatives to feed their families. These fishing practices further

degrade reefs, putting indigenous groups in a vicious cycle of reef degradation and economic activity loss. The drivers of many of the previously mentioned unsustainable fishing practices result from a complex system of oppression, especially among indigenous groups of Southeast Asia [Hoogervorst, 2012].

## 7.4 Reefs Pollutants

### 7.4.1 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. Nutrient increase, or eutrophication, can also promote pathogenic growth among corals and lead to coral epidemics. A wide range of human activities contribute to reef pollution, with globalization, population expansion, and development as main exacerbators [Todd et al., 2010].

Marine debris is essentially human trash, which enters the water via boats or from land. Floating trash can bear resemblance to jellyfish and is often consumed by animals, obstructing their gastrointestinal tract [CORAL, 2021]. If not eaten, it also may 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]. 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].

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 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. 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 [CORAL, 2021]. 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].

Another major source of reef contamination is crude oil, which blocks sunlight, smothering and starving reefs. Oil enters the ocean not only through 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 and other solvents are often used for their ability to 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 [Shafir et al., 2007].

#### 7.4.2 Development, Industrialization, and the Agta

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].

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].

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. Much of the Agta lifestyle consists of spearfishing the shallow reefs of their native waters, and as they are 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].

#### 7.4.3 Deforestation and Agriculture

As the 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].

#### 7.4.4 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. 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. 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].

Though the methods of transmission are well-theorized, the exact pathogenic causes of coral diseases are not fully 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. 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, 2019a].

### 7.5 Reef Ecosystem Services

#### 7.5.1 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, Alzheimers, heart disease, viruses, bacterial infection, and more are currently being developed with corals as the centerpiece. Other reef organisms like the seahorse have traditionally been used in alternative medicine [CORAL, 2021]. In 14th century Asia, seahorse extract was used to treat infections and pain, as well as respiratory, circulatory, and sexual problems. The medical contributions of the reefs have long histories, but it is their potential that holds the most promise [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].

### 7.5.2 Food Sources

Despite only making up 1% of the ocean, coral reefs support over a quarter of all fish in the ocean. [NOAA, 2019b]. They are densely populated regions which provide food to people around the globe. It is no wonder six million fishermen a 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 Timor-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 Asia's 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. Thought to be descendants of the Tabon Man (16,500-year-old remains

found 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].

### 7.5.3 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 barrelsevery 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].

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. Cn-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 worlds 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 Tagbanuas 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 7.4.1 [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].

#### FIGURE

##### 7.5.4 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 waves 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].

##### 7.5.5 The Sentinelese People

###### MAKE A BOX

Another Southeast Asian indigenous group in close relation with the reefs are the Sentinelese people of the Indian Oceans North Sentinel Island. This group drew international attention when they killed an American tourist who travelled on their land illegally, and then shot arrows and threw spears at the helicopter sent to recover his body. It is estimated that there are between 80-150 people currently living on the island, and they are one of the last untouched native peoples.

Their sovereignty is protected by North Sentinel Islands 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].

## 7.6 Reef Restoration, Protection, and Conservation

### 7.6.1 Ecosystem Based Adaptations

Coral reefs, in their current state, cannot be restored passively. It is not enough to simply stop the problems and threats corals face; the extent of current degradation cannot be repaired. Active restoration efforts are critical for the future survival of the corals and the coral reef ecosystem. The implementation of ecosystem-based adaptations and formation of marine-protected areas have been two highly successful active restoration efforts. Reef restoration is a complex, dynamic task that requires community involvement, government backing, foreign aid, and restorative projects that are backed by research and driven by science [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. 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].

Another EbA, direct transplantation, involves transplanting broken corals to other locations without first growing them in a nursery. This strategy is often employed after storms, as rough waters and waves may break pieces of coral away from their main structure, and the corals cannot survive without anchoring. Colonies are then relocated to areas with more inhabitable conditions where they are more likely to survive and reproduce. After this more suitable area is identified,

fragmented corals are secured with cement or steel ties. Corals need stable, secure structures, which are achieved either by cementing a colony onto a cement base and then attaching this base to the seafloor with cable ties or by just simply attaching cable ties to corals and then driving them into the seafloor to act as anchors. 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. 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. EbAs 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 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].

## 7.6.2 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].

### 7.6.3 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. These intersectional efforts are vital to reef restoration efforts, as local communities hold extensive ecological knowledge about specific reefs of their area. Intersectional efforts also maintain an environmental justice lens, as both environmental and anthropologic factors are considered in policy making. This protects already marginalized groups like the indigenous people of Southeast Asia, for purely environmental efforts often disproportionately affect the groups more directly reliant on a specific ecosystem. When consulted in policy making, indigenous groups are not only given their deserved voice, but also offer generational knowledge concerning reefs which has been expanded upon for over a millennium. These indigenous groups and local communities also do not share 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 this intersectionality is crucial to maintaining a just, inclusive approach to ecological restoration [Lyons et al., 2019].

Indonesia's Coral Reef Rehabilitation and Management Program, COREMAP, perfectly illustrates this collaborative effort between national government and local communities. Started in 1998, COREMAP began by aiding local community management of coral reefs but has since significantly widened its scope of practice and nationwide impact. COREMAP has successfully implemented over 350 collaborative management plans between local communities and governments, increasing awareness about ocean health and the threats coral reefs face. Through COREMAP, rare and endangered species have been able to rebound and have returned to reefs. 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, clearly illustrating that coral restoration drives economic prosperity [Aquino and Kaczan, 2019].

The national scale COREMAP operates on allows for a wider range of capabilities achievable by purely local-level projects. Their intersectional nature, however, allows for local community voices to be heard and accounted for, and marginalized groups to be represented. COREMAPs involvement with local communities also allows for a better implementation of policies, as the groups involved have personal ties and motivations for restoration. For example, interventions such as the 2004 Blast and Cyanide Fishing ban can only be implemented at the national level but has had issues with implementation and enforcement. National bans and legislation are useless if they are not followed, but because COREMAP promotes community engagement, its projects have been highly successful. It is initiatives like this, backed by both national power and local participation, that are critical to the protection and restoration of the coral reefs [Aquino and Kaczan, 2019].

## 7.7 Coral Reefs: Conclusion

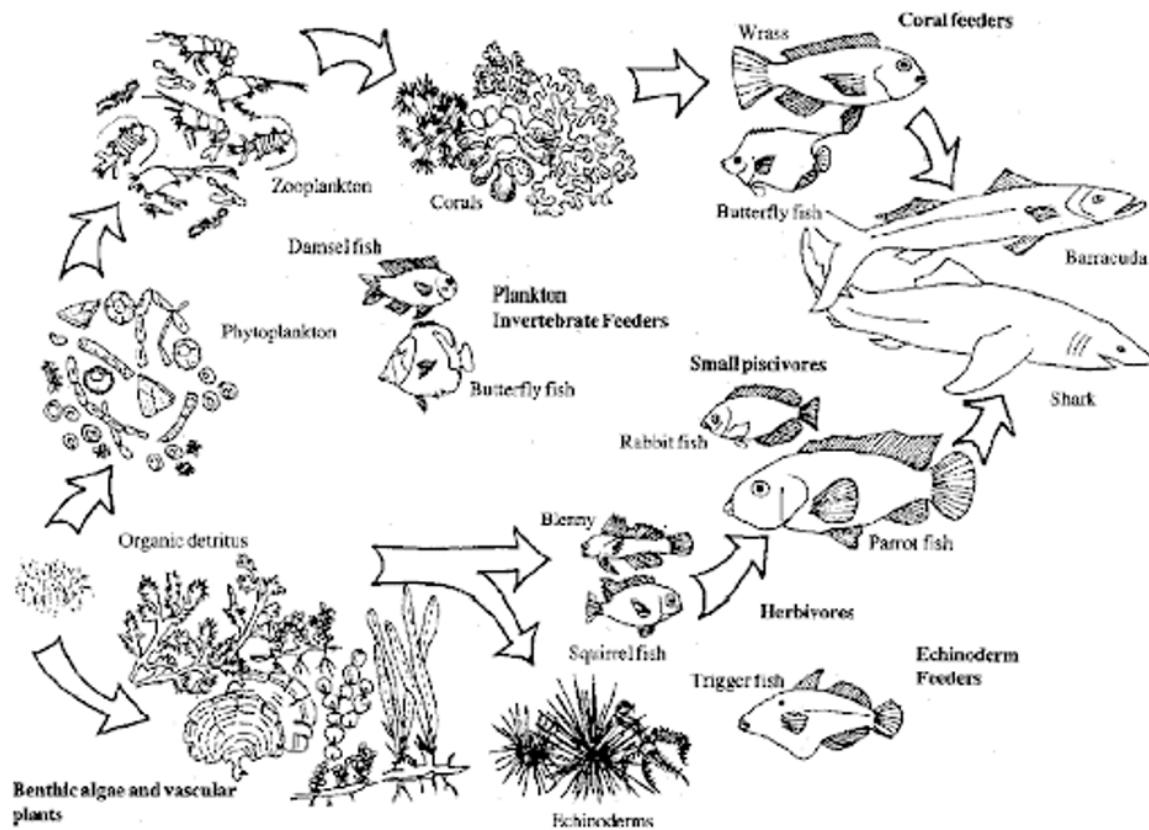
### FIGURE

From localized threats, like unsustainable fishing and pollutants, to global threats 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.

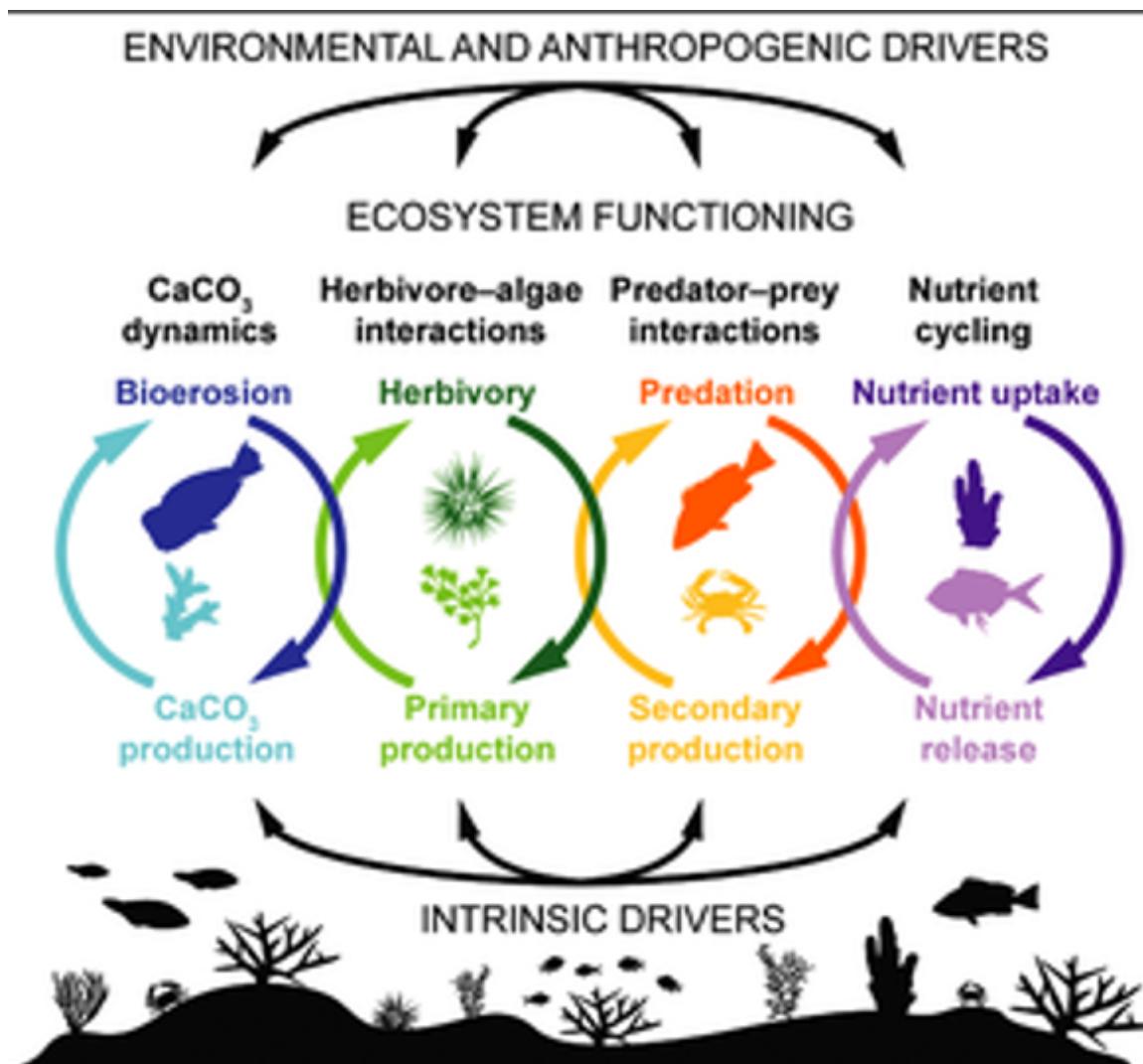
**Table 7.1:** Southeast Asian Coral Reef Size by Country

(a) :Listed are some notable Southeast Asian countries and their respective reef areas. While Indonesia and the Philippines dominate total reef area, many coastal Southeast Asian countries have reefs of their own, all which face similar anthropologic pressures. Southeast Asia accounts for over a quarter of all the worlds coral reefs [Spaldin et al., 2001].

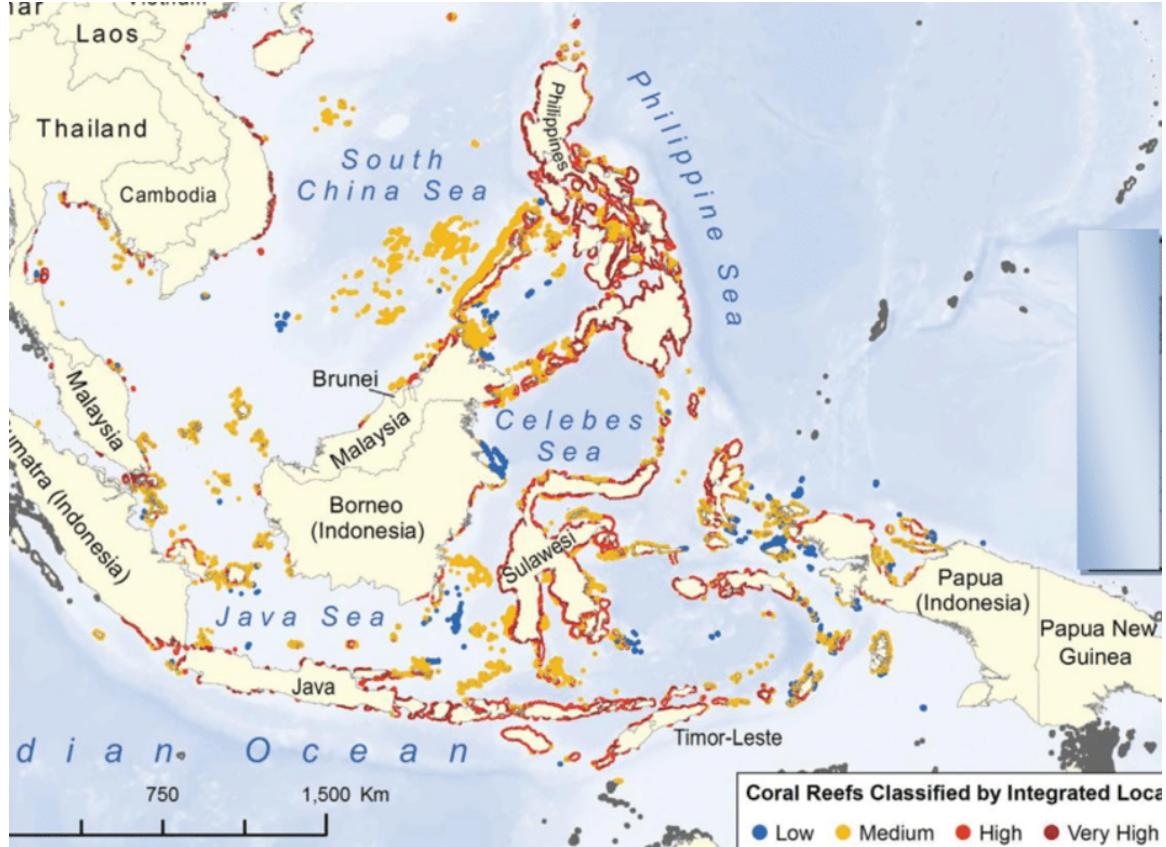
Country	World Reef Area Ranking	Reef Area (sq km)	Percentage of World Total Reef Area (%)
Indonesia	1	51,020	17.95%
Philippines	3	25,060	8.81%
Malaysia	17	3,600	1.27%
Japan	23	2,900	1.02%
Thailand	26	2,130	0.75%
Myanmar	27	1,870	0.66%



**Figure 7.1:** The coral reef food web, 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. These primary producers include seaweed, grass, phytoplankton, and perhaps most importantly, the zooxanthellae coral symbionts. This is the largest group, as only about 10% of the energy in each trophic level is passed to each successive level. 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].



**Figure 7.2:** The above cycles and reciprocal processes are vital for coral growth and survival. The first, blue cycle, 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 second, green cycle, 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, 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, nutrient cycling, or the uptake and release of nutrients among the organisms of the ecosystem. Nutrients must be moved efficiently and effectively in cycles, with a balance maintained between retention and reintegration [Brandl et al., 2019]. Figure from: [Brandl et al., 2019].



**Figure 7.3:** Coral reef locations are relatively limited, as the previously mentioned conditions must be satisfied, yet they can be found in over 100 countries, mainly between the Tropics of Cancer and Capricorn. As seen above on the map, reefs are concentrated in shallow waters surrounding many islands of the Indo-Pacific. Reefs surrounding both Indonesia and the Philippines compose a majority of not only Southeast Asian reefs, but also reefs worldwide. 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].

Condition	Chemical Reaction	Effect
Elevated Levels of Atmospheric $\text{CO}_2$	$\text{Carbon Dioxide} + \text{Water} \rightarrow \text{Carbonic acid}$ $\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$ $\text{H}_2\text{CO}_3 \rightleftharpoons \text{HCO}_3^- + \text{H}^+$ $\text{Carbonate} \rightleftharpoons \text{Bicarbonate}$ $\text{CO}_3^{2-} \rightleftharpoons \text{HCO}_3^- + \text{H}^+$ $\text{Calcium carbonate} \rightarrow \text{Calcium ions}$ $\text{CaCO}_3 \rightarrow \text{Ca}^{2+}$	<p>Lower pH 7.8</p> <p>Thin shells and dead coral</p>

**Figure 7.4:** 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  $\text{H}_2\text{CO}_3$ . The protons of carbonic acid are easily dissociated by the more polar water molecule ( $\text{H}_2\text{O}$ ), thus dissociating and combining to form bicarbonate, or  $\text{HCO}_3^-$ . 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.



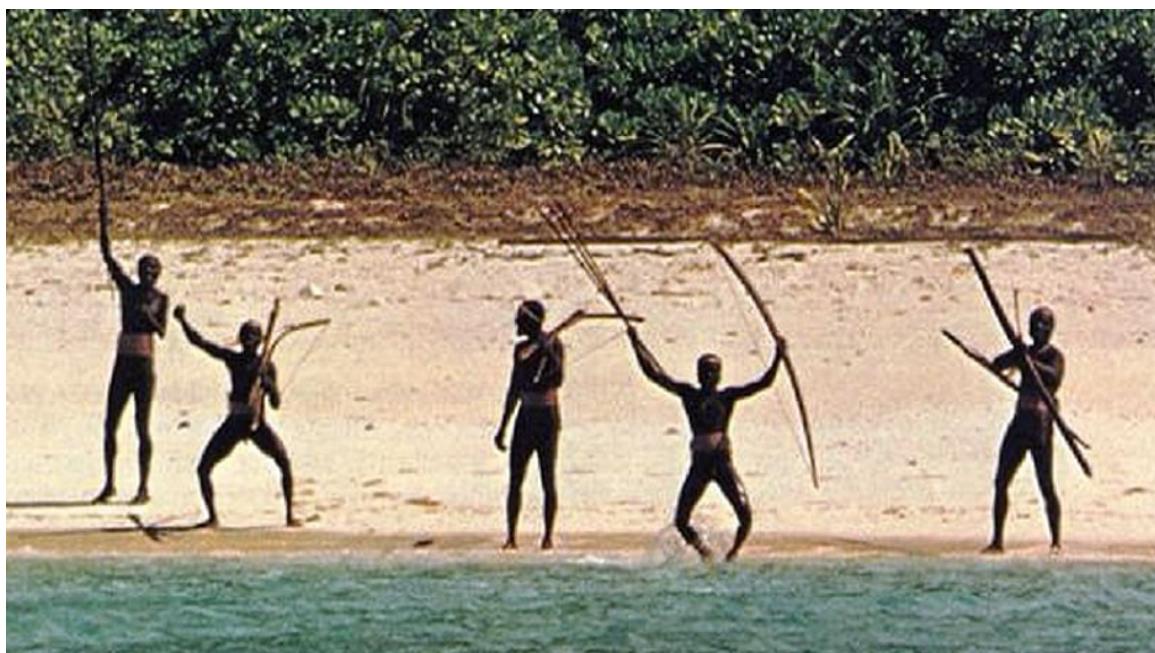
**Figure 7.5:** This above split-image shows the same fire coral before (left) and after (right) coral bleaching has occurred. The vibrant colors on the left image result from the zooxanthellae symbionts, and when the corals expel them, the ghostly white color seen on the right image is observed. This color change is universal across all coral species; only the color of the calcium carbonate skeleton remains after the algae are expelled.



**Figure 7.6:** 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 repurposed. 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.



**Figure 7.7:** :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 diseases 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).



**Figure 7.8:** :The Sentinelese people are pictured above. When this picture was taken, they approached the bank and began making threatening advances towards the cameras direction. The man on the far left throws a spear while the man on the far right readies an arrow. This hostility towards outsiders has allowed to Sentinelese to remain one of the last untouched indigenous groups in the world.



**Figure 7.9:** :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 Philippines government [Capistrano, 2010]. 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].



**Figure 7.10:** :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.



## **Chapter 8**

# **Nuclear Power and Nuclear Waste**

### **8.1 Current and Future Energy Needs**



# **Chapter 9**

## **Air Pollution & Social Justice in Hong Kong**

NEENAH VITTUM

### **9.1 Opening**

### **9.2 A Brief Overview of Hong Kong**

### **9.3 Hong Kong's History**

### **9.4 Air Pollution in Hong Kong**

SO<sub>2</sub>

**Figure 9.1:** caption

## **9.5 Air Pollution and Human Health**

## **9.6 Population Density, Income Inequality, and Housing**

### **9.6.1 Income Inequality and Zoning Laws**

### **9.6.2 Public Housing**

### **9.6.3 Economic Mobility**

## **9.7 Indoor Air Pollution**

## **9.8 Open Spaces and Other Patterns of Environmental In-equity**

## **9.9 Environmental Activism in Hong Kong**

## **9.10 Beyond Hong Kong**

## **9.11 Beyond Hong Kong**

practicing with Nora

# **Chapter 10**

## **Flood Pulse System in East Asia**

KRISTIN GABRIEL

### **10.1 Introduction**

What is the flood pulse system?

Seasonality

Ecosystem Services

Fish stocks

Flooded forests

How the flood pulse system influences the Tonle Sap Ecosystem

Timing of Flood Pulse

Magnitude of Flood Pulse

Duration of Flood Pulse

Influence of flood pulse system on people and their livelihoods

Fisheries

Immigration and emigration

Human Impacts on the flood pulse system

Climate change

Dam development

Case Study: Cambodia and the Tonle Sap



# Chapter 11

## Hydroelectric Dams in East Asia

### 11.1 Former Residents of Balui

The Bakun Dam in Malaysia displaced dozens of Indigenous and local communities. A series of case studies was conducted with the community forcibly displaced to government-controlled Sungai Asap in September 2002. The following quotes are pulled from anonymously interviewed Indigenous village members on comparing the conditions of their original home (Balui) and the resettlement in Sungai Asap. They are translated to English as directly as is possible.

#### 11.1.1 On Survival

"Life has been difficult for us since we moved to this area a few years ago. Now we are running out of means to buy our foodstuffs to pay our water and electricity bills. You just look at the electricity meters up there, supplies have been cut off as we have not been able to settle our electricity bill for months."

#### 11.1.2 On Social Change and Economic Development

"I dont think the Bakun project has brought us social and economic development as claimed by the government. The environment here is just not suitable for us Last time we did not have to worry about our daily consumption because we got everything from the forest. Now everything is so different. No money, no food. Just look at the three acres of farmland allocated to me; it takes me about 20 to 25 minutes by land cruiser to get there. Yes, the government built the road for us but where is the means of transport? A return trip from here (Sungai Kojan) to my farmland in Sungai Asap cost me RM4 (US \$1.05). That is very costly for me."

#### 11.1.3 On Returning Home

[If given the chance, would you return to your original settlement?]

"Of course! [The] former settlement is better. Furthermore, when we are asked to pay for the house installment amounting to RM52,000 (US 13,684), we are "habits" [finished]. Where do we have the means to pay? Makan pun susah [Eating is also a problem]. By then, we have no choice but to go back to the jungle."

## 11.2 Introduction

There exist over 48,000 hydroelectric dams worldwide (WWF Global, 2015) and have caused the forced displacement of between 40 and 80 million people (Hai, 2016). Hydroelectric dams account for 19% of the world's electricity needs, in some countries such as Vietnam, hydropower can cover up to 37% of the country's energy production.

One of the largest ironies of hydroelectricity is the benefactors and recipients of the produced energy. This is a process termed water grabbing. In most cases (specifically with mega dam construction), the produced electricity is either exported to nearby urban cities, or, in the case of regions like Laos, the energy is often exported to different countries altogether. This is in part due to the funders of dams and who facilitates construction. According to the BBC, Prior to the late 1900s (1940 to roughly 1970-1990), dam construction was funded by the World Bank (BBC).

### 11.2.1 The World Bank and Other Funders

The World Bank began funding projects such as The Three Gorges Dam (one of the largest and most notorious hydroelectric dams) as well as the Sardar Sarovar Dam in India, the Chonoy in Guatemala, and the Itaparica hydropower project in Brazil as well as countless others. Beginning in the 1970s, criticism arose about the lack of social protection policies for the local and Indigenous communities that dam construction was impacting. Action was called to both assess, and end the harm caused by the World Bank so the World Commission on Dams was released, outlining the human rights abuses by the World Bank and they withdrew official funding from hydropower projects in the 1990s. Despite this, other corporations have filled the gap in funding, namely actors based in China such as the China Three Gorges Corporation and Sinohydro (Cooke, Nordensvard, Saat, Urban, and Siciliano).

Since the 1990s, there has been a surge in the amount of dams constructed in East Asia specifically, with over 10,000 of them (approximately 28% of all worldwide dam construction) in Asia. Even within that disproportionate 28%, a large number of dams lie in Laos which has been devastated by Chinese foreign investment and funders. Many even refer to Laos as the Battery of [Southeast]Asia. In cases of water grabbing in hydropower in Laos, energy is exported to other countries or urban cities and the Indigenous or local groups who were impacted by dam development are not granted access to the benefits of the dams that uprooted their lives. Many of these corporate projects have failed international guidelines on human rights and Indigenous rights, as well as ecological harms (which are often tied to subsistence and cultural reciprocity). In many cases, the current social protection policies that do exist are lacking and can lead to justification for displacement. For example, relocation schemes enable hydropower companies to write off the harm they are causing to communities under the guise of some form of [insufficient] reparation.

Furthermore, most relocation schemes force Indigenous communities into unideal cramped living conditions with poor infrastructure, sanitation, education, and without the ability to live with traditional modes of livelihood including but not limited to subsistence/agriculture, as well as cultural aspects of tradition such as crafts, styles, and familial structure. This, paired with the fact that in most cases of water grabbing in hydropower construction, the Indigenous communities displaced are moved into or not given access to the electricity their lives were destroyed to create. Instead, many Indigenous groups must find their own way to pay for or generate electricity should they desire it in their community.

Dam	Location/Country	River/Watershed	Reservoir		Energy		Type of Dam
			Volume	Height	Capacity		
<b>Three Gorges Dam</b>	China	Yangtze River	39.3 km <sup>3</sup>	181 m	101.6 x10 <sup>8</sup> MW	gravity dam	
<b>Bakun Dam</b>	Malaysia	Balui River	43.8 km <sup>3</sup>	205 m	2,400 MW	embankment	
<b>Sardar Sarovar Dam</b>	India	Narmada River	5.8 km <sup>3</sup>	139 m	1,450 MW	gravity dam	
<b>Son La Dam</b>	Vietnam	Black River	3.1 km <sup>3</sup>	138 m	2,400 MW	gravity dam	
<b>Hoa Binh Dam</b>	Vietnam	Black River	1.6 km <sup>3</sup>	128 m	1,920 MW	embankment	
<b>Nam Ngum</b>	Laos	Nam Ngum River	4.7 km <sup>3</sup>	70 m	865,000 MW	gravity dam	
<b>Itaipu Dam</b>	Brazil and Paraguay	Paraná River	29 km <sup>3</sup>	196 m	96.6 x10 <sup>8</sup> MW	gravity and embankment	

**Figure 11.1:** Some of the largest or most famous mega dams world wide. The Three Gorges Dam is the largest dam globally and produces the most electricity. Dams in East Asia are beginning to be built with more frequency, but other dams such as the Itaipu and Sardar Sarovar are also notorious for their human rights grievances. Due to the nature of megadams and the amount of space they need, all of the dams in this chart have caused forced displacement of local or Indigenous populations. TO BE ADDED TO AND EDITTED!

## 11.3 Dam Function

Hydroelectric dams hold water in artificially created bodies of water, or reservoirs. To generate electricity, water is released through a turbine which spins a metal shaft (propeller) within the turbine to convert the energy of the flowing water into energy from movement, or mechanical energy (USGS). Because energy cannot be created or destroyed, the hydroelectric dams convert one form of energy (in this case the energy of the moving water), into another (watts to be distributed to a larger electrical grid for purposes such as energy for a households lighting) (U.S. Department of the Interior). This type of turbine that turns moving waters energy into electricity is known as a hydraulic turbine.

Figure 11.2 [I changed the reference name to avoid confusion.

### 11.3.1 Hydroelectric Generators

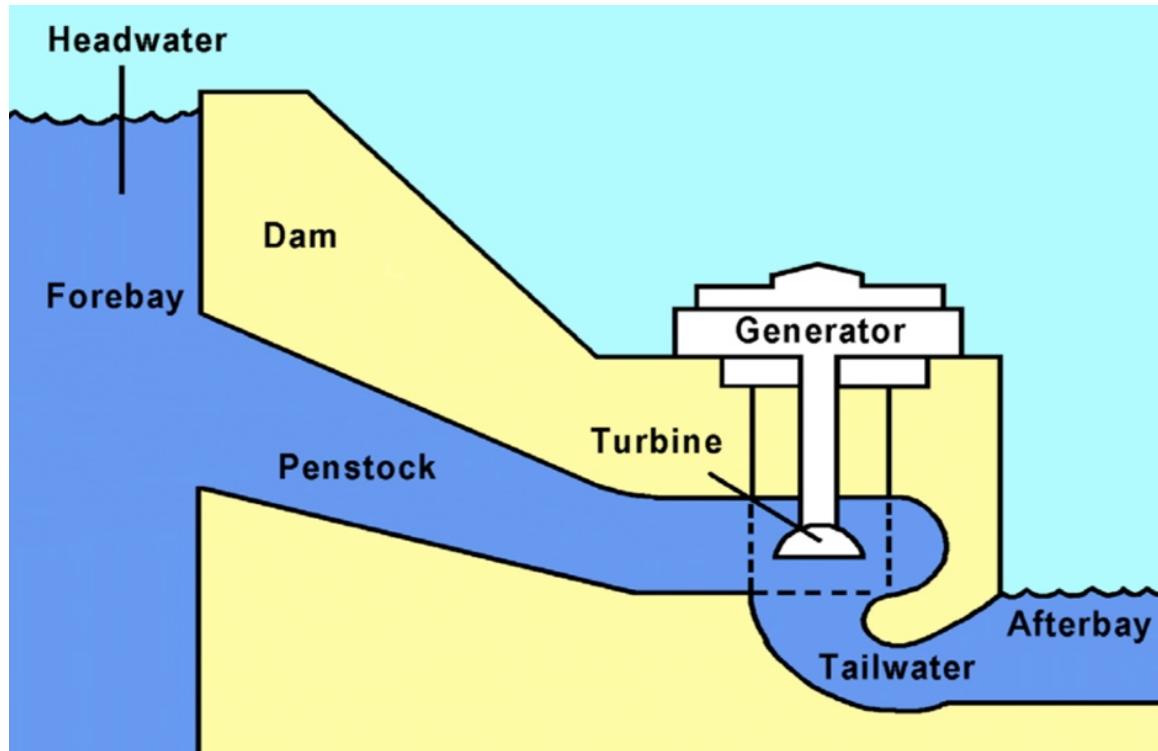
Hydroelectric generators are based on the ideas of Michael Faraday who found that when a magnet moves past materials that allow electricity to flow easily, conductors, the magnet causes electricity to flow through the conductor. When direct currents of electricity are circulated through loops of wire around magnetic steel (electromagnets), poles of electromagnetivity are created (field poles). The field poles are put on the outside of the rotor which is attached to the turbine shaft. When the turned rotates, the field poles move past the conductors and electricity flows, causing an electromotive force, voltage, to develop.

### 11.3.2 Dam Type

There are differences in artificial dam types that impact structure, function, and energy production. Two of the most common dam types in hydroelectric mega dam projects are gravity dams, and embankment dams.

#### Gravity Dams

Gravity Dams are dams that are made of concrete or stone and often hollow. They use the horizontal pressure of gravity to let water fall to create energy. Because they are reliant on gravity, they tend



**Figure 11.2:** USAGE RIGHTS Available TO ALL/public use The reservoir or body of water is often called the headwater. Water travels down to the forebay, then into a sloped area called the penstock where it reaches the turbine then the tailwater is released into the afterbay (which will be lower than the forebay to allow gravity to move the water to generate electricity for the turbine to collect) (Photo and description courtesy of USBR).

to have large heights and require stable foundations to bear the weight of the reservoirs. If reservoirs get overfilled, gravity dams are generally resistant to the over-topping flows of the excess water because they are usually made with concrete which is not impacted by the erosion or scouring from the excess water overflow (Jansen). Depending on the size of the dam and the required energy production capacity, they can range in height, but in general, higher dams will yield more energy production (USSD).

### **Embankment Dams**

Embankment dams are usually made from natural minerals such as soil, sand, clay, rock, or occasionally, industrial waste materials. They can also be filled with either compacted earth (hydraulic fill dams) or rocks (rockfill dams) that are smaller than about 3 inches (USSD). Because of the materials used, embankment dams are generally more susceptible to erosion which means over-topping flows are more of a risk for embankment dams because the excess water can cause erosion of the minerals which puts the dam at risk for collapse or failure because the erosion of the top can cause imbalance of the dam and compromise the structure and the dam could fracture into pieces. Embankment dams are often on some sort of hill or bank with a different levels (high to low elevation) (Jansen).

#### **11.3.3 Energy**

##### **Kinetic Energy**

The size of reservoirs for hydroelectric dams can impact the amount of energy the dam can produce because of the pressure which impacts energy of motion, or kinetic energy. It is the amount of energy from the movement of the water which can be modeled with the equation.

$$KE = 0.5mv \quad (11.1)$$

In this equation, m is the mass of the object and v is the speed. This is important for hydroelectric dams because turbines can be spun through how quickly or strongly water travels in what is termed water flow. The mass of water is 18.015 g/mol and the speed depends on multiple factors, including the amount of pressure in the dam. For example, when using a hose to clean dirt from a surface, when the hose is hardly turned on, the flow is weak and slow. The water flow will not clean the surface very well because of the low amounts of moving energy. A hose turned on to its highest setting has larger amounts of water moving through the same sized hose at faster rates. This means the hose would have high amounts of moving energy and clean the dirt more efficiently. The same applies to hydroelectric dams and how their turbines are propelled to convert the moving energy. The higher speed and pressure means more moving energy which impacts how efficient a dam will be based on size and height. When thinking about a dam with a small reservoir, the amount of water will not create a lot of pressure on the released water, meaning the moving energy is low and the dam will produce fewer amounts of energy. A large dam reservoir will have high amounts of pressure and thus a greater moving or kinetic energy.

##### **Potential Energy**

Similarly, the height of a dam impacts its energy potential. The higher a dam is, the more the water falls and the higher the potential energy is. Potential energy can be viewed as the amount of energy an object has (or has stored) if moved out of its equilibrium position, so when there is a further

height to fall from, the stored or potential energy of the water is greater. This potential energy based on height or gravity can be modeled with the equation

$$PE_{grav} = \text{mass} * g * \text{height} \quad (11.2)$$

In this, the PE grav is the potential energy, m is the mass, g is the gravitational strength (this is generally based on planet in which it will remain constant at about 9.8N/kg on Earth), and h is the height. The mass of water is also consistent at about 18.015 grams/mol on Earth. With this in mind, the gravitational potential energy of water (as is the case of hydropower) is based on the variable of height. The higher the dam, the greater the height, and the greater the potential energy.

### Total Mechanical Energy

There is also a type of energy that is the energy of an object as the result of motion. In essence, it is the stored potential energy and motion energy when moved out of its equilibrium. To model this for falling water (this means we are not calculating the bounce of the object in motion, only the gravitational energy, the equation is

$$TME = PE + KE \quad (11.3)$$

In this, TME stands for the Total Mechanical energy, PE is the potential energy, and KE is the kinetic energy. This means that the most basic way to model the total mechanical energy, or total produced energy, of a hydroelectric dam is dependent primarily on two factors, height of the dam and size of the dam. This is part of the reason that mega dams are favored by development companies they have larger reservoirs and greater heights which allows the dams to produce more electricity, and thus garner larger profits, even though mega dams require exponentially larger volumes and surface areas which requires more local communities to be uprooted and increased deforestation and other ecological consequences.

#### 11.3.4 Megawatts and Electricity Usage

Hydroelectric Dams produce an average of 42 billion kWh (kilowatt-hour) per year. This is enough energy to meet the needs of a developed residential area of about a million people, or 72 million barrels of oil (USBR). To put this into other perspective of just one megawatt is enough energy to power about 10 cars, or 300 homes an hour. Furthermore, part of the reason hydroelectric dams is touted as so efficient is because unlike alternate sustainable energy sources such as solar or wind, hydropower can run at all hours of the day regardless of weather conditions (Clean Energy Authority).

### 11.4 Hazards and Flooding

Another threat posed by the Three Gorges Dam is the impact it has on natural disasters. Due to alterations in the Yangtze's hydrological patterns, sedimentation and saltation of the basin is also altered. As populations were forced to move, many of them moved to areas downstream of the Yangtze river into areas that are now considered floodplains due to the altered hydrology (World Commission on Dams 2000). It was predicted that there would be increased flooding and landslides as a result of the dam construction that has since been confirmed in the 21st century.

There was a documented increase in landslides in the 1990s in the Three Gorges region following dam construction. Of the almost 6,000 kilometers of reservoir shoreline, 5% of it was considered

dangerous and at risk for landslides (Wu 2001). With forced relocation, many people moved into the high-risk shoreline areas, putting them at huge risk for landslides. The increased risk of the landslides is due to the changed siltation and sedimentation which have the potential for loose rocks and sediment (Liu 2004).

Another risk posed by dam construction includes flooding; the alteration of hydrological patterns in the region means that previous flood plains are no longer flooded, and new flood plains are established, sometimes in areas population with humans. Estimates from the Sino-German Center for Research Promotion has documented up to 3,000 people having been killed due to flooding in 1998 as a result of the changed to the Yangtze River Basin due to construction. There also exists the possibility for dam collapse should an earthquake occur, although flooding and landslides are more common (World Commission on Dams 2000).

## 11.5 Three Gorges Dam

Construction of one of the biggest hydroelectric dams, the Three Gorges Dam in the Yichang Hubei Province in China began in 1994 with the aim to prevent flooding, generate electricity, and to allow ocean freighter ship to navigate inland from Shanghai along the Yangtze river basin (Jackson and Sleigh, 2000). The Dam is estimated to have production capacity of 18,600-22,800 Megawatts of hydro powered electricity which accounts for about 10% of all of Chinas energy production (Li 2007).

By 2012, the dams 32 turbine generators were all operational (Britannica). The dams reservoir holds 5.85 trillion gallons of water and is estimated by the dams beneficiaries to eliminate flood related damage for up to a century to protect human development on the banks of a river, or a riparian ecosystem. The dam produces about 84.68 billion kWh of clean energy a year (Wang and Bryant). The water flow on the Yangtze has also deepened by the dam to allow ships to carry commercial goods to and from Shanghai to reduce shipping costs by 35-37% and thus increase profits for large commercial enterprises (Wang and Bryant). The number of people displaced and affected by Three Gorges Dam is highly controversial, with estimates below one million (from the Dams developers) to 10.2 million people in 1996 (Delin and Lijun), and estimates ranging up to 900 million people affected (not displaced) due to disruptions in watersheds upstream or downstream of the dam (Childs-Johnson and Shen 2000).

The local region and population around the dam prior to construction was below the poverty line and reliant on agriculture with dense but patchily populated areas (Delin and Lijun, 2000). Literacy rates were lower than the national average and upon construction of the dam, new townships were created to house the local displaced populations, but many displaced people were forced into urban centers for which they were poorly equipped to find work given their reliance on subsistence farming previously (Cerneia, 2003). 30,000 hectares of farmland that local populations once relied on were flooded and water borne illnesses such as schistosomiasis and other diseases such as tuberculosis and pneumonia become more common in relocation areas due to reduced access to sanitation (Jackson and Sleigh, 2000; Cernea, 2003).

Furthermore, psychosocial impacts on the displaced populations were devastating. The complete forced shift away from traditional livelihoods as well as loss of cultural sites and disintegration of social support networks caused traumatic stress, stigmatization, depression, and inter-community violence as a result of the destruction (World Health Organization, 1999). The Yangtze (a watershed involved in the dam) is known as the sorrow of China due to the millions of lives the dam project has destroyed both through forced displacement, and even death due to natural disasters. (Sino-German Center for Research Promotion 2006).

### 11.5.1 Displacement

One of the common costs of development is displacement of local and Indigenous populations hydroelectric dams are no different. Due to the fact that flood plains are covered in water, the reservoirs themselves take up large amounts of space, and local hydrology is often drastically altered as a result of dam construction, forced displacement is a common result of dam building. Displaced has further implications for even more construction and development for the displaced populations new infrastructure such as hospitals, schools, roads, water irrigation, and electricity needs to be set up for displaced populations. Unfortunately, new infrastructure for forcibly displaced peoples often is insufficient or inadequate to sustain populations.

One measurement of human well-being following construction of the Three Gorges Dam was done my Millennium Ecosystem Assessments (MA) in 2003 by the Millenium Ecosystem Assessment and World Resources Institute. They classify human well-being under five categories: access to basic materials, freedom and choice, health, social relations and social capital, and security (Millenium Ecosystem Assessment (MA) 2003, Table 1). Due to a number of factors, the MA assessment concluded that the Three Gorges Dam does not meet the requirements to be socially responsible and equitable.

### 11.5.2 Schistosomiasis

Snail fever, or schistosomiasis is a disease from parasitic worms called schistosomes. Schistosomiasis causes abdominal pain, diarrhea, bloody stool, or blood in urine (CDC). Schistosomes typically live in freshwater snails which are vectors of the disease. The parasite comes out of the snail in freshwater and humans can become infected from skin contact with the contaminated freshwater (CDC). Snails infected with schistosomes live in freshwater dams such as the Three Gorges Dam (Liang 2002).

Schistosomiasis is found only in certain areas, making it endemic, but along with the construction of hydroelectric dams, it is common that snails become vectors for the disease, and they bring Schistosomiasis from the endemic regions. The dams bring in larger quantities of snails every year, making the disease more common (Zhu). Due to displacement of local populations due to dam construction, this often means influxes of people from schistosomiasis endemic zones enter greater populated areas and this leads to an increase in infections. One of the dams in East Asia that experiences cases of schistosomiasis is the Three Gorges Dam. There is a narrow reservoir attached to the dam that is 1084 km SQUARED which extends into the Jianhan Plain in the Hubei Province and the Chengdu Plains in the Sichuan province both regions are endemic for schistosomiasis (Wang and Zheng 2003).

There are many cases of increased schistosomiasis because of dam construction throughout the globe such as Egypt, Senegal, and other continents such as South America. African snails for example, have thin and lightweight shells that make their dispersal throughout regions especially effective and dangerous (Li and Lin 1998). Following construction of the Diama dam in Senegal, a strain of infection from *S. mansoni* snails occurred due to the stabilized water levels. Inadequate health care services in the area of the Diama dam led to an outbreak infection everyone in the city of Richard-Toll (in the dam region) (Waldstein 1997).

There do exist differences between the case of the Diama dam and that of the three Gorges Dam, including the type of snails in the region, despite this, the Diama dam should serve as a cautionary tale for large dam construction such as the Three Gorges Dam. Healthcare for displaced populations is limited and due to numerous factors, the Three Gorges dam construction poses increased risk for snail dispersal, breeding, and survival. The most common type of snails in East Asian regions such as the Three Gorges Dam is the *O. Hupensis* (Mao and Shao 2018) or *S. japonicum* snail (Jordan

1993). For the purposes of this case study of the Three Gorges Dam and schistosomiasis, the snails referred to are of the *O. hupensis* or *S. Japonicum* variety.

The Center for Disease Control and Prevention (the CDC) observed that schistosomiasis cases occurred frequently in the Three Gorges area after the construction of the dam, with estimates of up to 100,000 cases of infection. If these cases return to their homes from hospitals, the presence of *O. hubensis* in the region could mean their co-existence can lead to increased numbers of infected snails, and later, increased cases in humans. In comparison to other areas of the world, proponents of the Three Gorges Dam argue that there is no correlation between cases of schistosomiasis and the dam, but as evidenced by Zhu and other authors, The Three Gorges Dam may make the region more susceptible to both *O. hubensis* (vectors for the disease), and thus increased cases among humans.

### Temperature

One factor that has the potential to draw snails to the region of the Three Gorges Dam is the ideal temperature for the snails. By using Geographic Information Systems, a study showed with a 95% confidence interval that the compatible range for the snails was 0.9-21.1 C. The Three Gorges regions average temperature is 3.9-18.8 C which is not quite currently compatible with that of the snails. Despite this, because the dam has a greater heat capacity than naturally occurring bodies of water in the area, the average temperatures have the potential to increase in a range from 0.3-1.2 C depending on the season, making the climate changes more compatible with the snails ideal temperatures which may make the region around the dam increasingly ideal for their presence (Peng 2006).

### Breeding Patterns and Resettlement

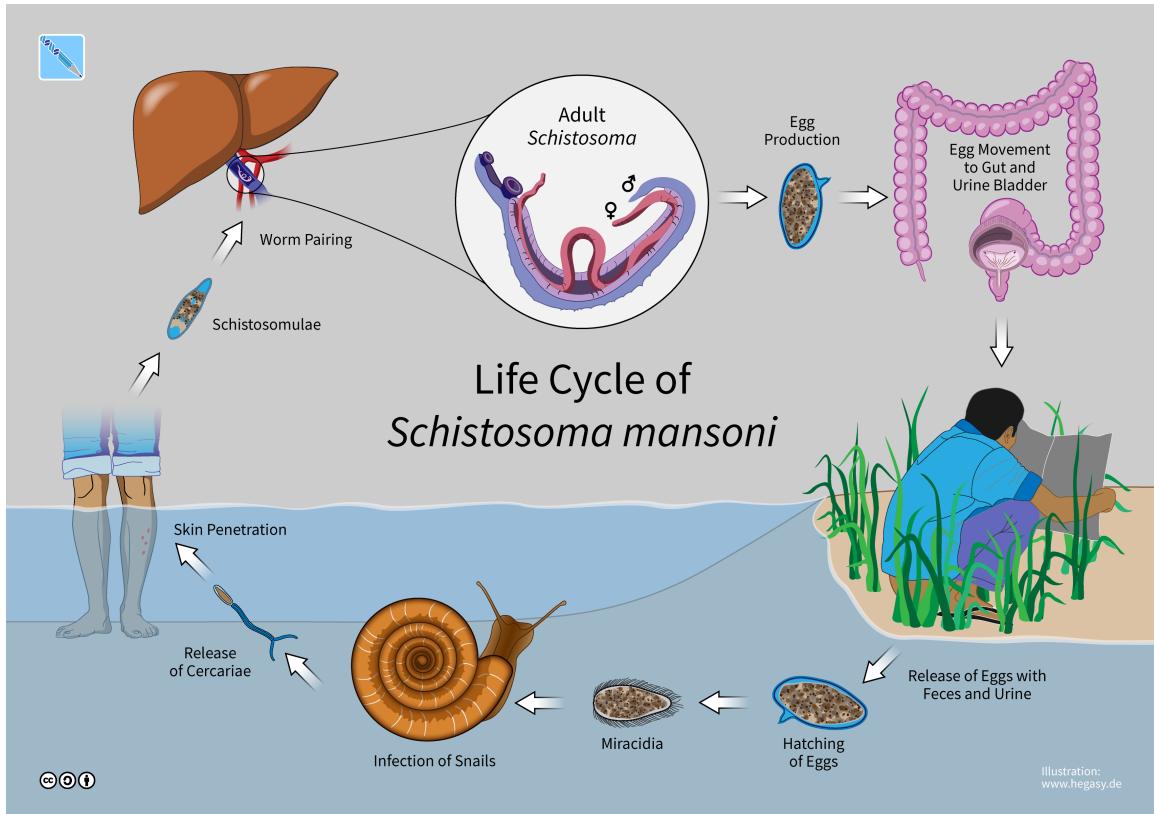
As displacement of millions occurred due to the construction of the dam, migrants resettle their homes often as close to their homes as possible away from the reservoir. This means that slopes or hilly areas near the dam are newly inhabited by farmers and the displaced populations, causing soil erosion in the farmed resettled regions, and it causes increased silt deposits in the Hubei region (recall this is a region endemic to the snails). This causes sedimentation and creation of marshlands in areas such as Hubei which are conducive to snail reproduction (Lai 2000).

Figure 11.3 [I changed the reference name to avoid confusion.]

### Snail Movement

Snails are distributed or dispersed throughout regions in two ways actively and passively (Wu 2005). An example of passive dispersal is snails attaching to ships that move to new areas. Active dispersal can look like snails moving across regions via water currents. Passive dispersal does not necessarily have a limit to potential distance traveled, but through active dispersal, a snail can travel distances of up to 168 kilometers (Zhu 2008). The closest endemic region to the dam itself is 299 kilometers and there have been documented cases of paper-making reeds that snails and snail eggs have lived on which carried the infected snails across large distances into paper factories in the region (Wei 2004). Documented cases such as these imply that the snails could have made their way to the dam from endemic regions through passive dispersal such as the paper-making reeds, or even soil brought into the region that contains snail eggs. Zhu suggests that as the Yangtze River facilitates more merchandise to be brought into the region, there is a greater chance of more infected snails to also enter through passive dispersal.

[MLH: I changed the name of the label to avoid duplicates.]



**Figure 11.3:** USAGE RIGHTS Available TO ALL/public use. This is an image of the lifecycle of schistosomiasis both inside, and outside of the human body. ADD TO THIS CAPTION

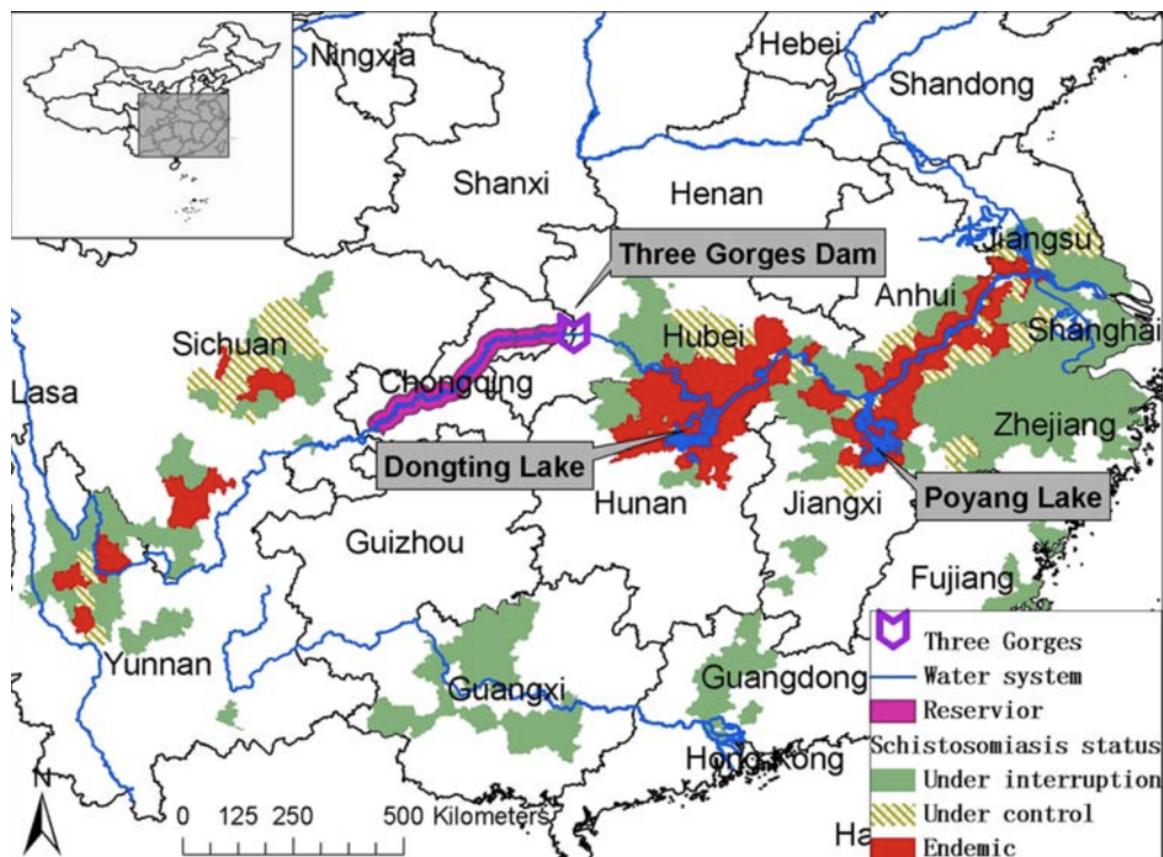


Figure 11.4

### Health Infrastructure

One of the reasons the risk for Schistosomiasis remains high in the Three Gorges Region is because relocated populations are moved into crowded urban areas which make the possibility for outbreaks and spread of disease higher. Furthermore, there is insufficient infrastructure (I.e., Hospitals, clean water, or proper sanitation) to prevent, or treat the disease. Crowded living arrangements with multiple generations forced into crowded housing also does not aid either sanitation, or the prevention of the spread. For this reason, transmission of diseases such as Schistosomiasis is a threat and danger. Other diseases (water borne or otherwise) are also common, including but not limited to hepatitis, pneumonia, diarrhea, and a virus often spread through rodentsHantavirus.

### 11.5.3 Eutrophication

One of the issues with the dam is altered hydrological flows and increased nutrient sedimentation and toxin buildup. The Three Gorges Reservoir is fed by the Yangtze River (among others). There have been shifts in both water flow, and water levels in the Yangtze as a result and it disrupts the aquatic life, including but not limited to the plankton and microbes of the river (Sekiguchi 2002). An excess of nutrients from runoff leading to dangerously low depleted oxygen levels in the water, a process called eutrophication, has occurred in the Yangtze and its tributaries and watersheds. Agricultural practices that were once not harmful are now causing the eutrophication due to the changed water levels and flows (Liu 2002).

Furthermore, industrialization in areas of the Yangtze River watershed has occurred, due in part because of extending urbanization from other areas, as well as urbanization of the displaced populations due to the dam construction. For this reason, the nutrient runoff and toxin runoff associated with industrialization and urbanization has worsened (Zheng 2008). Because of the excess of nutrients associated with eutrophication, there have been increased number of scum and deleterious (dangerous) toxins such as neurotoxins which are a threat to public healththis growth as a result of nutrient excess of nutrient loading is known as cyanobacterial algo blooms (Mei 2003). This buildup of toxins that effects the water quality is especially prevalent in the Three Gorges region because of the amount of subsistence farming that occurs.

Most of the local populations in the Three Gorges regions live rural agrarian lives based on subsistence. Populations along the Yangtze River that do rely on the subsistence farming are also hugely dependent on the river for a water source. As the water quality decreases with eutrophication and the buildup of toxins, the local populations that rely on the water and soil nearby are exposed to the toxins that are caused upstream due to industrialization. The water quality can impact crops and nutritional needs, but also daily life water usage such as washing and cleaning. One of the less deadly diseases is a dietary disease that can cause tooth decay and destruction due to excess fluoride in a water sourcethis is known as fluorosis and is common in subsistence populations who live near the Yangtze river (World Health Organization 1999).

## 11.6 Social Systems and Infrastructure

As a result of millions of people being forcibly relocated, there exists the issue of where to relocate. Some populations move downstream or into regions nearby, maintaining some level of autonomy and subsistence that they had prior to their displacement. Despite having lost often culturally significant lands, this seems to be a better option for many than those who are forced into townships or urban areas such as Chongmingan island city at the mouth of the Yangtze in Shanghai that has been growing in population and size where many displaced populations from the Three Gorges Dam were

relocated to. In these cases, the displaced populations are forced into areas with existing political institutions which causes social unrest, resentment, and discontent among populations who were once primarily autonomous.

Within these townships and urban centers, there often does not exist sufficient living space or housing, education, health care, sanitation, job opportunities, space for subsistence farming/traditional careers, and ironically, energy or electricity. With the loss of 30,000 ha of farming land and government policies to discourage subsistence farming in the region (known as de-farming), malnutrition has increased. Almost half of the resettled populations will not have access or resources to farm and provide subsistence for themselves, driving them away from agrarian jobs into industrial careers (Jim and Yang 2006). This can be detrimental to mental health and personal/individual agency when stripped of the ability to provide for oneself through traditional modes of subsistence (Jackson and Sleigh 2000).

The World Health Organizations reported that the psychosocial effects of the displacement have caused traumatic stress, mental health issues such as depression, and increased violence as a result of the aforementioned. Furthermore, social and cultural networks that were once in place in communities collapsed following displacement in many cases. Communities were split up or simply altered so significantly that the social support that was once available has disintegrated. This too causes mental illnesses such as depression. With a lack of health care system for both physical and mental needs, none of the mental health issues are addressed at a health care level.

### 11.6.1 Food Security

Furthermore, lack of availability of traditional food sources have led to inadequate diets that have documented cases of having caused chronic diseases and ailments (Millennium Ecosystem Assessment (MA) 2005). It would be nave to group all populations impact by hydroelectric dam construction under the same universal or to assume they all rely on the same modes of livelihood, but a large majority of local or Indigenous populations in dam construction regions rely on agrarian lifestyles. Groups such as the community of Long Lawen and neighboring villages in Malaysian Borneo for example rely on agriculture, hunting, and fishing and this is the case with most other villages in numerous villages in East Asia near dams such as the Three Gorges or Bakun dams. For example, Laos or Lao PDR (known as the Battery of Asia because of the number of hydroelectric dams in the country), relies on agriculture for up to 80% of employment and almost a quarter of the country lives at or below the international poverty line (MONROE 2016).

Using Laos again as an example, the threat to subsistence for forcibly displaced or impacted populations. Rural populations in Laos rely on fish for anywhere between 47-80% of their protein intake in their daily diets, often supplemented by carbohydrates and fats from other sources including (though not limited to) crops from farming. This means that when displacement occurs, or when watersheds are altered (i.e., flooding to create reservoirs, eutrophication, or other alterations to water quality), so too is subsistence and traditional food sources are disrupted. This often leads to malnutrition and simply insufficient amounts of food. A case study that briefly illustrates this is that of the Ladakh people. Anthropologist and author Helena Norberg-Hodge did a study of the Indigenous Ladakh people and found that with the introduction of dam construction and western development, the Ladakhis shifted away from traditional subsistence (both forcibly and willingly). In her time with the Ladakh people, she noticed a shift in diet from the agrarian crops produced, to less nutritious options such as instant noodles which are increasingly popular as an affordable food source for Indigenous populations who no longer have access to farmland or fish. This leads to malnutrition as well as psychosocial impacts from a shift away from traditional nutritious food sources for Indigenous and displaced populations.

### 11.6.2 Cultural Sites

Another issue that is posed by the displacement and forced relocation lies in the loss of cultural sites. Estimates of more than 140 villages were destroyed due to the dam and it has been impossible to even count the number of cultural sites lost, as well as their value to communities (Childs-Johnson and Shen 2000). This loss of cultural sites such as traditional alters, ancestral lands, or other culturally significant landmarks, topographical features, homes, burial grounds, and other sites lost to the dam construction is incalculable. It is truly impossible to do an accurate cost benefit analysis when comparing the number of megawatts produced as opposed to the unquantifiable number of cultural sites lost and lives altered.

Entire towns and temples have been flooded by singular dam development. The Three Gorges Dam for example submerged the White Crane Ridgea hydrology inscription–, the original sites of the Zhangfei Templea temple that was removed by archeologists from its original location to prevent it from being completely submerged–, and Dachangan ancient town that was submerged and had to be replicated/rebuilt downstream (Childs-Johnson and Shen).

## 11.7 Vietnam and the Hoa Binh Dam

One of the country's most reliant on hydroelectric energy is Vietnam due to its Riparian ecosystem that makes it ideal for the dams. Between 1995 and 2009, 20 large scale hydropower dams with capacities of more than 100 Megawatts were constructed in Vietnam (Ty, and Westen, 2011). Most of the dams were built in areas populated by ethnic minorities with more than 144 dam investment projects in the Kon Tum and Dak Nong provinces (both rural areas populated with ethnic minorities) (Ngoc Lan, 2008).

Dak Nong for example is located in Vietnam in the central highlands in a mountainous region with generally nutrient rich soils due to high levels of basalt which makes it ideal for farming and many of the people in the Dak Nong province farm coffee, rubber, cashews, sugar cane, and pepper trees. Around 85% of the population lives in rural areas and it is one of the poorest provinces in Vietnam. Furthermore, the Vietnamese government made it a priority to bring electricity to Indigenous and rural communities in 2004 to reach 100% of households by 2020 but these goals were not met. Instead, rampant dam construction has occurred at the expense of the Indigenous populations the Vietnamese government tried [and failed] to bring electricity to and they instead ravaged local ecology in the name of progress and energy (RISIREA).

The dams in this area caused damage to forests and altered river streams and flow speeds, causing sedimentation and erosion which threatened the biodiversity of the rivers and surrounding areas. The 200-kilometer Hoa Binh Dam displaced 58,000 people, 79% of whom belonged to ethnic minority groups including the Muong, Tay, Dao, Thai Trang and Thai Den (Nga Dao, 2010). The dam destroyed 20,800 hectares of farmland, crop fields, and forests which were crucial to traditional production and subsistence practices of the rural poor in the area (Yen, 2003).

The Muong people for example are the second largest ethnic minority in Vietnam and the largest ethnic minority in the Indochina region. They rely on agrarian farming with crops such as rice. They rely on local ecology for subsistence including crops, hunting, and raising animals. They also engage with outside economies to some extent as they gather wood and cinnamon for trade. The destroyed farmland and crop fields were incredibly destructive for the Muong living in the region impacted by the Hoa Binh dam as it stripped necessary farmland and forests necessary for subsistence as well as products to trade (Britannica).

Of the 58,000 people displaced by the dam and surrounding destruction to the ecosystem, clean water, education, healthcare, and other basic human needs were unavailable. Up to 34% of the

displaced population did not have access to clean water, and ironically, 20% of them did not have access to electricity (regardless of the fact that their displacement stemmed from exploitation of their lands to produce electricity for the national grid which they did not have access to). In 2009, poverty rates of the displaced population were 59-60% compared to the national rate of 14%. Primary school completion was also almost 10% lower than the national rate. The Hoa Binhydropower project demonstrates the lack of comprehensive Environmental Impact Assessments (EIA) and sustainable relocation plansallowing for the valuation of profit over human life (Hai 2016).

## 11.8 Long Lawen and Long Liam

Another case study that is important for understanding Indigenous sovereignty alongside the issue of hydroelectric dams is that of Malaysian Borneo, and more specifically, the villages of Long Lawen and Long Liam. Both villages are case studies in which the people protested or refused resettlement and dam construction and they found energy alternatives. This is not to say hydropower development has a happy ending but Long Lawen and Long Liam are arguably more optimistic case studies for the autonomy and advocacy in Indigenous communities.

To begin, Long Lawen set some model of an example for what is called micro hydro projects as termed by Headman Gara Jalong of the village. He has been fighting for many years to protect Long Lawen, often at the cost of imprisonment. In the 1990s, the Bakun company tried to forcibly remove the community of Long Lawen to build a mega-hydropower dam called the Bakun Dam. It is one of the largest dams in Southeast Asia to this day in the rainforest in the Belago District in East Malaysia in Sarawak on the Balui river. The village of Long Lawen lives in this area and their original location was in the way of dam construction. The dam is 14,170 kilometers squared (which for reference, is the size of the entire country of Singaporethis is an extremely large dam). It occupies 12% of Sarawak and its main funder is a Chinese company. During construction of the dam, the company Bakun was practically uninvolved with the relocation scheme which they left to the local government in Borneo. This relocation scheme required the removal of the Long Lawen village and was intended to remove them to a government-controlled site, stripping them of their cultural autonomy and land.

Gara Jalong, as well the community members refused the governments resettlement plan and the community moved independently in a safe area above the dam construction. While an imperfect solution (which already is flawed as Long Lawen should not have been presented with the requirement to move at all), this did allow Long Lawen to remain somewhat autonomous and independent as opposed to moving into the government-controlled resettlement location.

Long Lawen still remains in the rainforest in longhouses with connected apartments for the community members which is the traditional style of residency, and it is not uncommon for the older generation to maintain many of the traditional practices such as stretched long ears, as well as traditional modes of livelihood such as creating forest products and hunting and fishing. It is also common for many members of the younger generation to prefer western fashion or living in a transition very similar to the Ladakh people that we read about in Ancient Futures. Many of them have moved out of Long Lawen but they still visit annually.

In 2000, the Malaysian Senator Banie Lasimbang helped Long-Lawen build a micro-hydro turbine. The science of these micro-dams remains like that of mega-dams (a turbine utilizes gravity to turn and generate electricity), but a key difference is that this micro-hydro power installation was built by, approved by, and desired by the community of Long-Lawen.

Through Senator Banies help, Gara Jalong and the community were able to construct a dam that did not displace them or alter their watershed to detrimental effects. One of the largest ironies

of hydroelectric dams as mega projects by outside contractors is that the local and Indigenous communities they displace almost never receive the benefits of the generated electricity. This is the case with Long Lawen which made the micro-dam so appealing to bring cleaner and arguably better electricity to the village as it was advocated for by the community members themselves.

There are of course limitations to the micro-hydroelectric dams, including but not limited to the amount of energy they produce. For example, during the winter holidays, younger community members and extended family members of the Long Lawen community return home and during this time, the 4-6 kilowatts a day produced by the dam is insufficient for the village. The micro dam was supposed to produce up to 12 kilowatts of electricity a day, but the actual numbers have fallen quite short of those estimates.

Despite the lower energy production than anticipated, the micro dams have been replicated in almost a dozen other villages in the region including Long Liam who also built a micro dam using Long Lawen as an example. The village of Long Liam also ran into issues with their dam, including technical problems. //A feature of hydroelectric dams is a penstock which channels the water towards the turbine, but in the case of Long Liams micro dam, the pathway towards the penstock isn't a straight path which complicated the efficiency of the energy production. While this is technically fixable, it would require manual labor and be difficult to fix without some level of alteration to the ecosystem (notably though, this alteration would be considerably less than any destruction caused by mega dams, and it would be facilitated by the community members). //THIS IS A SUMAMRY OF THE TECH ISSUES COME BACK AND EXPLAIN !

This is not an argument in favor of the mega dams, nor for energy sources such as fossil fuel, just an acknowledgement of the inadequacy of micro dams as a sole energy source for a village. Mega dams are so harmful in both the social aspect, as well as the ecological aspect that micro dams may in fact be a potential alternative to the alternative energy source of mega dams.

Author of the book Ancient Futures, Helena Norberg-Hodge argues for a transition from globalization and globally based economies/development (such as mega dams), towards localization of agriculture, as well as energy production. She advocates for small-scale energy development projects such as micro dams, but explains that when it comes to small-scale projects that truly promote self-reliance, such as village-scale hydroelectric installations or solar ovens and water heaters for the household, the question is immediately asked: Can the people pay? Nuclear reactors and big dams are heavily subsidized, while small scale-technologies based on renewable energy receive no significant support from any major aid agencies (Norberg-Hodge 146-147). There is a very fine line to balance between imposition of western technology and aid. Indigenous communities or villages desire such village-scale installations of hydroelectric dams (or other energy sources), it is the obligation of global aid organizations to subsidize, or even fully fund such projects. I believe this is a place we can begin to remedy some of the harm we have caused given there is desire for it from the community for such small-scale development (although again, this decision would need to be make through Indigenous sovereignty at the community decision making level)

An important part of this desire can be explained by Author John Bodleys proposal for cultural autonomy for Indigenous nations. He says that its purpose is establishing the Indigenous peoples right to self-determination and helping to secure the future of Indigenous cultures in concurrence with their own efforts and desires... 1. to focus international attention on the contemporary situation of Indigenous peoples 2. To pressure governments to respect the internationally recognized rights of Indigenous peoples 3. to provide financial assistance to Indigenous peoples in support of their self-determination struggle (280) which would permit tribal peoples to choose the degree of isolation they want to maintain (295). These ideas of cultural autonomy for Indigenous community is key in the discussion of both mega and micro hydroelectric dams. Part of the reason most hydropower development so radically violates Indigenous rights is because it ignores land rights and human rights

as well as the desires of the Indigenous communities and their right to make decisions for themselves. If village-scale hydropower is an avenue to further explore in terms of electricity generation, it must comply with ideas of cultural autonomy. In other words, any development, even at the micro scale, must permit Indigenous groups to determine the level of involvement and development they would want in their villages.

The alternative energy source of mega dams is far from clean or sustainable both from an ecological standpoint, as well as from a humanitarian point of view. The water-grabbing that occurs in the mega dam development results in clear winners and losers as big construction companies profit off the ecological degradation and human impact of the dams. The displaced populations face loss of culturally important homelands, as well as threats to social systems and modes of livelihood that are clear violations of cultural autonomy and Indigenous rights. We must halt mega dam construction for good and at least attempt to give back autonomy and agency to the Indigenous groups so deeply impacted. In the face of the Climate Crisis, a departure from this avenue of cleaner energy production must not occur, but it is key to ensure hydro power projects are smaller, do not cause displacement, and are done at the behest of the local populations they will impact.

## 11.9 Conclusion



# **Chapter 12**

## **The Political Ecology and Economy of Rice in Myanmar**

LUCAS FLORSHEIM

### **12.1 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 (Wassman et al., 2009). Although specific agricultural adaptations and solutions differ depending on climate and region, several scientists have outlined the general changes that will need to be implemented to sustain food production in the face of the climate crisis. 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, altering crop management practices, implementing resource-conserving technologies (RCTs), diversifying crops, improving pest management, and creating better weather forecasts and crop insurance (Wassman et al., 2009). While there is significant scientific evidence 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). The deltaic regions of Myanmar had an advantage over other rice producing areas as deep-water or floating rice systems were routinely used the countrys 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 election 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. Earlier this year the military of Myanmar, led by General Min Aung Hlaing declared a national emergency and seized control of the country in a coup d'état. The military is now in sole control of the country's operations and infrastructure and has spent the last several months attempting to quell both peaceful protests and armed civilian resistance (Goldman, 2021). The overwhelming majority of Burmese people are in absolute 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 economies 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 current state of Myanmars government on the future of the country's rice production in the era of climate change.

## 12.2 Climate and Rice Production

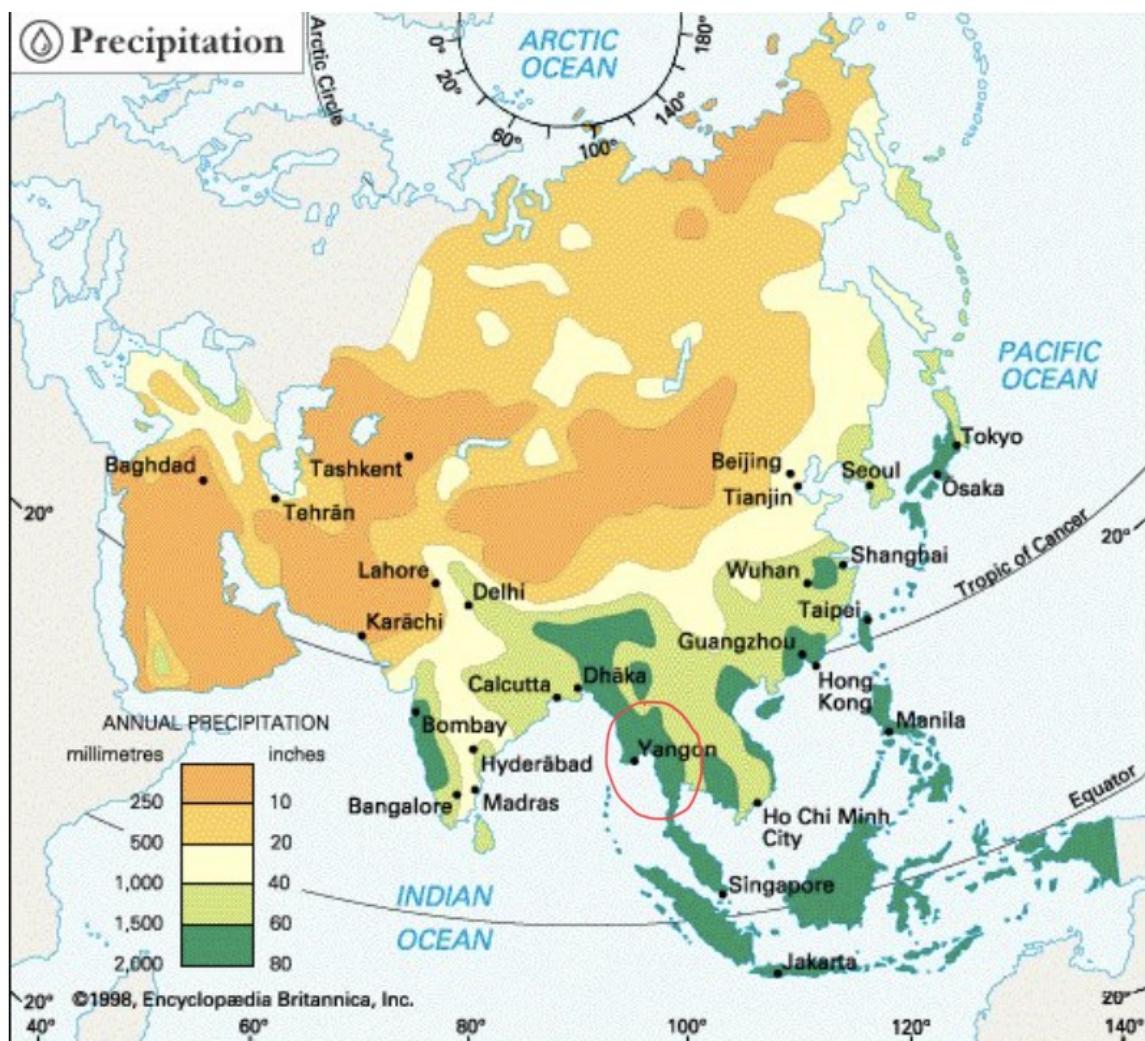
Being one of the largest countries in Southeast Asia, Myanmar experiences several different climates, varying greatly based upon region. The most northern parts of the country feature humid subtropical climate with hot and humid summers and mild winters. The Northeastern part of the country experiences 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.

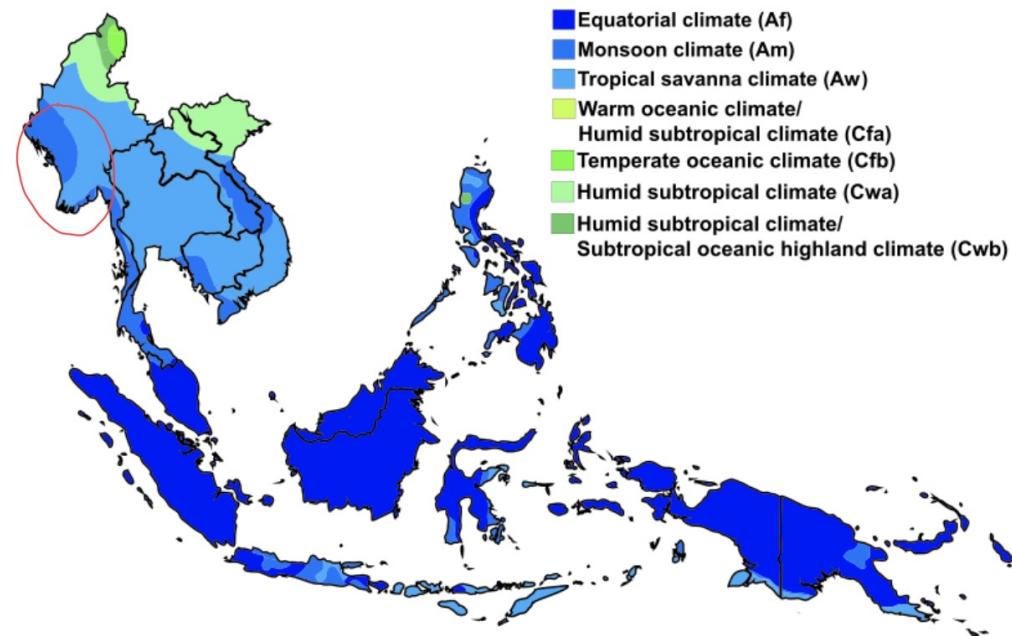
The Irrawaddy delta is responsible for 68% of Myanmars rice production (Brackenridge et al., 2016). River basins and deltas are the most ideal for rice agriculture, as fertile sediment deposited by water, known as alluvial soil, is naturally provided, and monsoon rainfall is prevalent in such floodplains. (Naing et. al, 2008). Rice cultivation in Myanmar relies heavily on deep-water rice production, meaning flooding of up to 100 cm results in increased growth and higher yields.

## 12.3 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 study that revealed that 1 in every 3 families in Myanmar is food insecure and facing problems related to undernutrition



**Figure 12.1:** Average annual precipitation in Asia, the rainfed rice-producing region of Myanmar is circled in red



**Figure 12.2:** Climate Classifications of Southeast Asia, with the rice-producing region circled in red

(Hlaing et al., 2019). Because the majority of the Burmese people work in agriculture, it is important to understand the sources of economic and food insecurities of individuals. In a survey that involved 22 NGOs in Myanmar, it was concluded that hunger in agricultural communities is heavily tied to farmers limited access to markets, land tenure rights, and lagging and ineffective agricultural environments and technology (Elkharouf and Pritchard, 2019). Many farmers do not have the infrastructure to reach sellers or traders and contract-based farming is a relatively new phenomenon as Myanmar liberated their markets in 2011. In addition, complicated land tenure rules often lead to disputes over agricultural land and leave loopholes for Myanmar to seize farmland. Furthermore, lack of access to quality seeds and proper agricultural technology has been economically detrimental to many farming communities.

## 12.4 History of Rice Production in Myanmar

Before the second World War, Myanmar was the world leader in rice production (Kurosaki (Crop choice, farm income article), 2008). While the country has remained among the top 10, rice production became increasingly unstable in the following decades. In the late 1970s Myanmars government sponsored a project called the Whole Township Paddy Production Program (WTTPP) that aimed to extend the agricultural season and increase yields (Naing et. al, 2008). Previously, rice was a monsoon crop with a season that lasted from the end of May until November. The WTTPP introduced new grains classified as high yielding varieties (HYVs) which were intended to completely redefine the limits of the countrys rice production. These HYVs were better equipped to handle closer spacing and fertilizers heavier in nitrogen, as well as more continuous methods of cropping (Naing et. al, 2008). The implementation of HYVs alongside technological advancements in irrigation have both



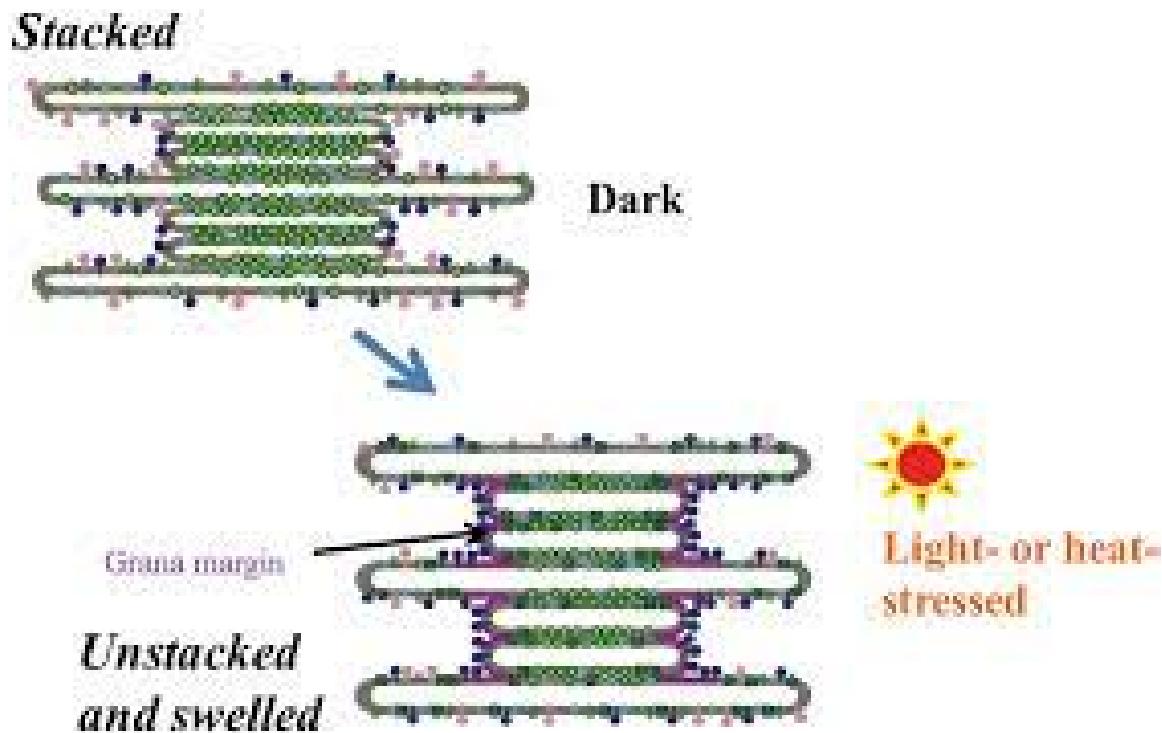
contributed to an extended crop season, as well the ability to plant several crops on the same farm simultaneously, known as multiple cropping (Naing et. al, 2008). While rice production increased in the years immediately following the use of HYVs and launch of WTPP, the growth has since stagnated and increases in yields have not persisted into the 21st century. (Naing et. al, 2008). In addition to government funded programs such as the WTPP, increases in rice production have been attributed to the gradual deregulation of Myanmars economy (Kurosaki, 2008). Myanmars government associated rice production with overall food security, and therefore political stability (Kurosaki, 2008). This association led to continued reforms to expand rice production, some of which involved small steps towards privatization in the agricultural sphere (Kurosaki, 2008). In the late 1980s Myanmars government began to permit farmers to sell surplus crops in private marketplaces. Furthermore, in 2003 the government opened up rice exports to private traders, although private exports remained extremely limited and restricted over the following decade. Throughout the 2000s farmers were obligated to follow three key agricultural mandates enforced by the Myanmar government. Farmers were solely given the right of tillage, meaning they could not lease, inherit, or mortgage their own farmland (Kurosaki, 2008). In addition, farmers were required to meet a quota, which was approximately 20% of the gross yield (Kurosaki, 2008). Lastly, farmers had to follow official policy in terms of crop patterns and farm planning and were in danger of losing their tillage rights if they strayed from the government regulations (Kurosaki, 2008).

## 12.5 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 Thailands 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 the subsequent consequences on the economy. This simulation combined macroeconomic theory, crop modeling, and information from a study by the Asian Development Bank and revealed that the fluctuations 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 Myanmars 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). To understand the future of rice production in Myanmar, it is critical to understand the effects that climate change has on rice production. In this section 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.

## 12.6 Increasing Temperatures

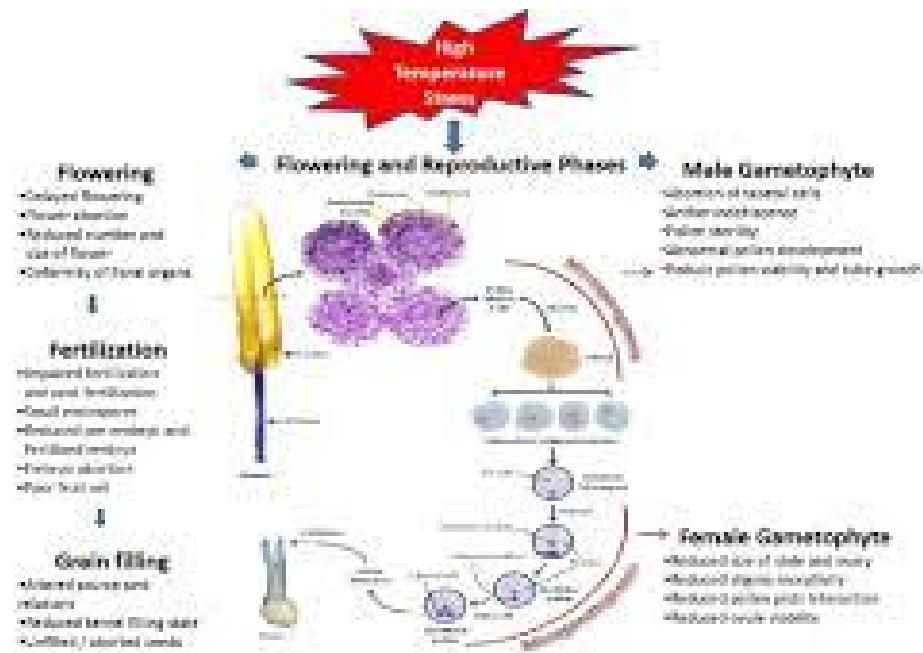
One effect of climate change that has a significant impact on rice production are increasing temperatures. In Myanmar, the warmest months occur directly before monsoon season, from March to June. During these months, the Southern coastal regions of the country experience temperatures well above 36 Celsius (C), which is beyond the critical limits of heat tolerance for rice (Wassmann



**Figure 12.4:** Comparison of an undisturbed (stacked) chloroplast and the swelling of the grana that is induced by heat

et al., 2009). 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., 2009). High heat stresses rice crop during the most vulnerable periods of the plants 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., 2009). 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 its thylakoid stacks, or grana. (Karim et al., 1997), This heat-induced reaction can reduce photosynthesis by over 35% (Oh-e et al., 2007).

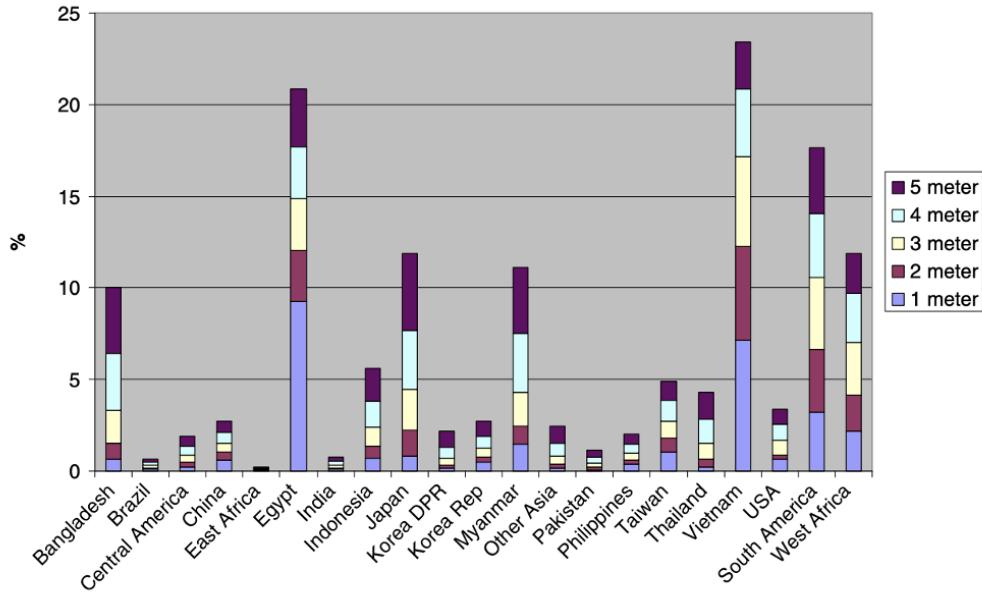
During the reproductive stage the meristem, the tissue on the tips of roots and shoots that is responsible for the production of new cells, begins producing flowers. It is during this phase when rice plants experience spikelet sterility because of high temperatures (R. Wassmann et al., 2009). Spikelet 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 have been shown to greatly decreased 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., 2009). As a result of negative effects that occur at



**Figure 12.5:** 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., 2009.

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).

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 South East Asia. SLR is associated with several environmental issues that are prevalent in Myanmar including coastal erosion, flooding, changed in ground 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 Myanmars available rice cropland and up to an approximately 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.



**Figure 12.6:** Percentage of agricultural land lost under projected SLR for a number of vulnerable countries –Chen et al., 2009.

## 12.7 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., 2018wiki). While rice cannot be grown without adequate levels or rainfall, heavy precipitation and extreme weather result in flooding which has proven to be an increasingly prevalent problem for Myanmars rice farmers over the last 50 years. Flooding is not uncommon in Myanmar, in fact, it is expected and it integral to agricultural practices that help to sustain Myanmars economy. The climate of Myanmar is tropical monsoon, and its flood climate it barotropic, meaning lower winds and less severe storms than other flood climates (Hayden, 1988). Rainfall is usually heaviest during the southwest monsoon (May to October), while the northwest monsoon is associated with a much cooler and drier season (Brackenridge et al., 2016). The average rainfall in the coastal and river-delta regions ranges from 4000-6000 mm annually (Brackenridge et al., 2016). Myanmars unique geomorphology has a large effect on the way in which flooding occurs in the country.

La Nia, the cold phase of the El Nio-Southern Oscillation (ENSO) cycle, heavily influences flooding in Myanmar. The wettest conditions and most extreme weather are often associated with La Nia years in Myanmar. In addition to La Nia, 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

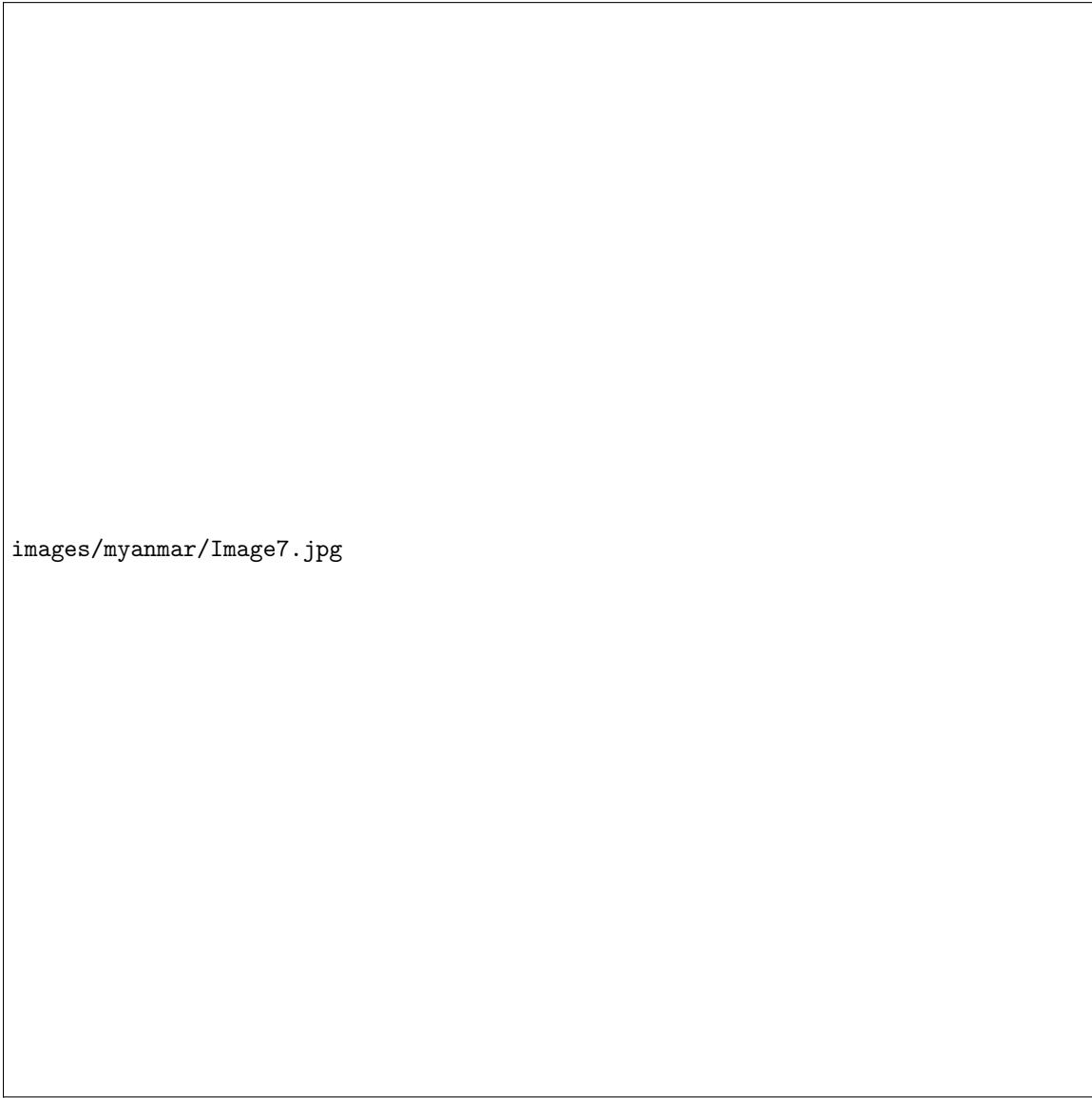
Indian Ocean but acts as an inhibitor to rainfall during monsoon season in Myanmar (Brackenridge et al., 2016). The Pacific Decadal Oscillation (PDO) is also important to consider as its cold phase induced nearly twice the number of tropical storms as during its warm phases (Brackenridge et al., 2016). Weather patterns and seasonal oscillations greatly influence rainfall, flooding, and agricultural planning. Preparing for and predicting 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.

[image file is missing]

## 12.8 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 similar 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 were the Ayeyarwady Delta, the Yangon region, and other parts of Southern Myanmar, which are all prominent rice producing regions in the country. Upwards 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). When Nargis first hit Myanmar, the storm surge flooded approximately 5,200 square km of coastal land 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).

## 12.9 Conclusion



**Figure 12.7:** Inundation along the upper Ayeyarwady river in the state of Kachin during normal winter flow (top), monsoon season flow (middle), and unusual flooding usually tied to extreme weather—bottom



## **Chapter 13**

# **Disasters, Typhoons and Phillipines**

IAN HORSBURGH

### **13.1 What are Typhoons?**



## Chapter 14

# Climate Infrastructure in Vietnam

### 14.1 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

### 14.2 Conclusion

Implications for other places in the region



## **Chapter 15**

# **Waste Management for a Circular Economy**

### **15.1 Life-Cycle**

#### **15.1.1 Collection**

#### **15.1.2 Transport**

Treatment

Disposal

Sectors:

Industrial

Household

Biological

Types of Waste:

Solid:

Liquid

Gaseous waste

### **15.2 Biomimicry**

#### **15.2.1 Circularity**

Examples in Nature

Education:

Teach people to be mindful and live sustainably

Social Psychology Problems and New Approaches:

Sustainability

Incineration & Dumping

Recycle & Reuse

Resource Recovery



# Chapter 16

## Plastic and Packaging in Japan

### 16.1 Introduction and Goals?

Plan: Use Japan's unique plastic packaging as a lens to view plastic waste management. I can bring in benefits of their plastic use, like cultural significance of beautiful wrapping and food safety, and then discuss plastic pollution as a larger issue in East Asia, bringing in examples of blame placing, and of course discussing potential solutions on both international and local scales.

### 16.2 Plastic Pollution and Waste Management in East Asia

#### 16.2.1 Statistics/comparisons

graphs and images will help with perspective

#### 16.2.2 History of plastic waste issues in East Asia

Are specific companies/industries responsible responsible

what kinds of plastic waste are there (sector break down)?

**Where in the world did the ubiquitous usage of single use plastics come from?**

General blame placing/biases/rhetorical

examples of discourse around plastic waste in East Asia. Why does any of this matter(needs its own section)?

Plastic waste trade?

<https://link.springer.com/article/10.1007%2Fs10163-004-0115-0>

<https://www.sciencedirect.com/science/article/abs/pii/S0956053X20305602>

Blame placing through both rhetoric and scientific studies

(this source is a very data based study that concluded that the vast majority of plastic pollution comes from a few sources in Asia/Africa... I want to explore what they might not have taken into account when collecting data)

<https://science.sciencemag.org/content/347/6223/768>

<https://pubs.acs.org/doi/10.1021/acs.est.7b02368>

<https://www.dw.com/en/whose-fault-is-plastic-waste-in-the-ocean/a-49745660> (found the two above studies through this article)

Japan Specific (I need to break these into hierarchies of significance), some sections, the first few will be more data based, the second half will be more rooted in sociological primary sources.

Waste management issue overview

Sector Break Down/ responsible parties in Japan

Impacts of plastic pollution on different groups within Japan

Cultural significance of wrapping

Food safety

Gov action/recycling/current efforts

Activism

Potential solutions moving forward rooted in current activist efforts/respect to culture

<https://www.pnas.org/content/117/33/19844.short>

<https://www.jstor.org/stable/432317?seq=1>

[https://onlinelibrary.wiley.com/doi/abs/10.1002/1099-1522\(200003/04\)13:2%3C45::AID-PTS496%3E3.0.CO;2-%23](https://onlinelibrary.wiley.com/doi/abs/10.1002/1099-1522(200003/04)13:2%3C45::AID-PTS496%3E3.0.CO;2-%23)

# **Part I**

# **Backmatter**



The back matter often includes one or more of an index, an afterword, acknowledgments, a bibliography, a colophon, or any other similar item. In the back matter, chapters do not produce a chapter number, but they are entered in the table of contents. If you are not using anything in the back matter, you can delete the back matter TeX field and everything that follows it.



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