

# 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?

### Creating Professional Typesetting

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 with highly professional looking typesetting.

## 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/ LATEX

### 0.4.1 Latex Book Class

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

### 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.

### 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**, **CALIGRAPHIC**, and **fraktur**. 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 – `tiny`, `scriptsize`, `footnotesize`, `small`, `normalsize`, `large`, `Large`, `LARGE`, `huge` and `Huge`.

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 (/ɛlɛʃɛrtɛk/ LAH-tekh or /ɛləɛltɛk/ 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 TeX distribution such as TeXLive or MiK<sub>T</sub>eX is used to produce an output file (such as PDF or DVI) suitable for printing or digital distribution.

L<sup>A</sup>T<sub>E</sub>X 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. L<sup>A</sup>T<sub>E</sub>X uses the TeX typesetting program for formatting its output, and is itself written in the TeX macro language.”

Use the Verbatim environment if you want L<sup>A</sup>T<sub>E</sub>X 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.)

## Mathematics and Specialized Characters

### Warning: Special Characters

When you use percent and ampersand symbols, hash tags, and other non-standard ASCII characters, L<sup>A</sup>T<sub>E</sub>X will be very uncooperative. L<sup>A</sup>T<sub>E</sub>X 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 symbol, e.g. \\$. See Table 1.

If you want to a superscript (raised to 3rd power), we can create text in math mode, with \$ to start and end the text in math mode, e.g. m<sup>3</sup> is written in L<sup>A</sup>T<sub>E</sub>X as m\$^3\$. A subscript uses an underscore, x\$\_1\$ creates x<sub>1</sub>. If you need more than one character as a subscript or superscript then enclose the content in curly brackets, e.g. x<sup>2c</sup> (x\$^{2c}\$) and t<sub>step</sub> (t\$\_{step}\$).

**Table 1:** Table of Symbols in L<sup>A</sup>T<sub>E</sub>X

Symbol	L <sup>A</sup> T <sub>E</sub> Xcode	Symbol	L <sup>A</sup> T <sub>E</sub> Xcode
&	\&	\$	\\$
"	"	"	"
mg L <sup>-1</sup>	mg~L\\$^{\{-1\}}\$		

### 0.4.2 Creating equations

One of the most powerful parts of L<sup>A</sup>T<sub>E</sub>Xis 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 Current 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).

### 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.

## 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*

## “Child” Rnw Contributions to create a Textbook

To create the textbook, we will each contribut chapters, which are referred to in knitr speak as a ‘child’. For each ‘child’ or chapter, will be a sepreate Rnw fild, but without the need for the preamble, such as the `\begin{document}` and `\end{document}`, which is pretty handy. Then each chapter has the exact same formatting as defined in the root document, which you have to select in the project options.

## 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.] I have created a short cut command to do this with `\red{}`.

## Adding Figures, etc

### Using Rnw Files

To generate R figures, we use R chunks in and Rnw file, where the text is integreated. When we compile into a PDF, the program converts the files into TeX files and then combineds 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).

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

## 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 an example of a pretty good figure, and you can find the code in the 01-guide.Rnw file.

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.

## Using Boxes

### 0.4.3 minibox X

Some text

## 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 repository. 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.



**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.

## Creating glossary words

Not sure why, I haven't been getting this to work yet – stay tuned!

**Definition 5** *This would be used in a glossary entry at the end of the book 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.*

## Custom Environments

For text that we rely on many times, but require odd key strokes and hard to remember code, we can create new commands as shortcuts.

For example, I have created two so far:

\carbon dioxide}, CO<sub>2</sub>

and

\kms, km<sup>2</sup>

# 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 0.4.1. 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

### 0.6.1 Learning L<sup>A</sup>T<sub>E</sub>X

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.

### 0.6.2 Placing figure

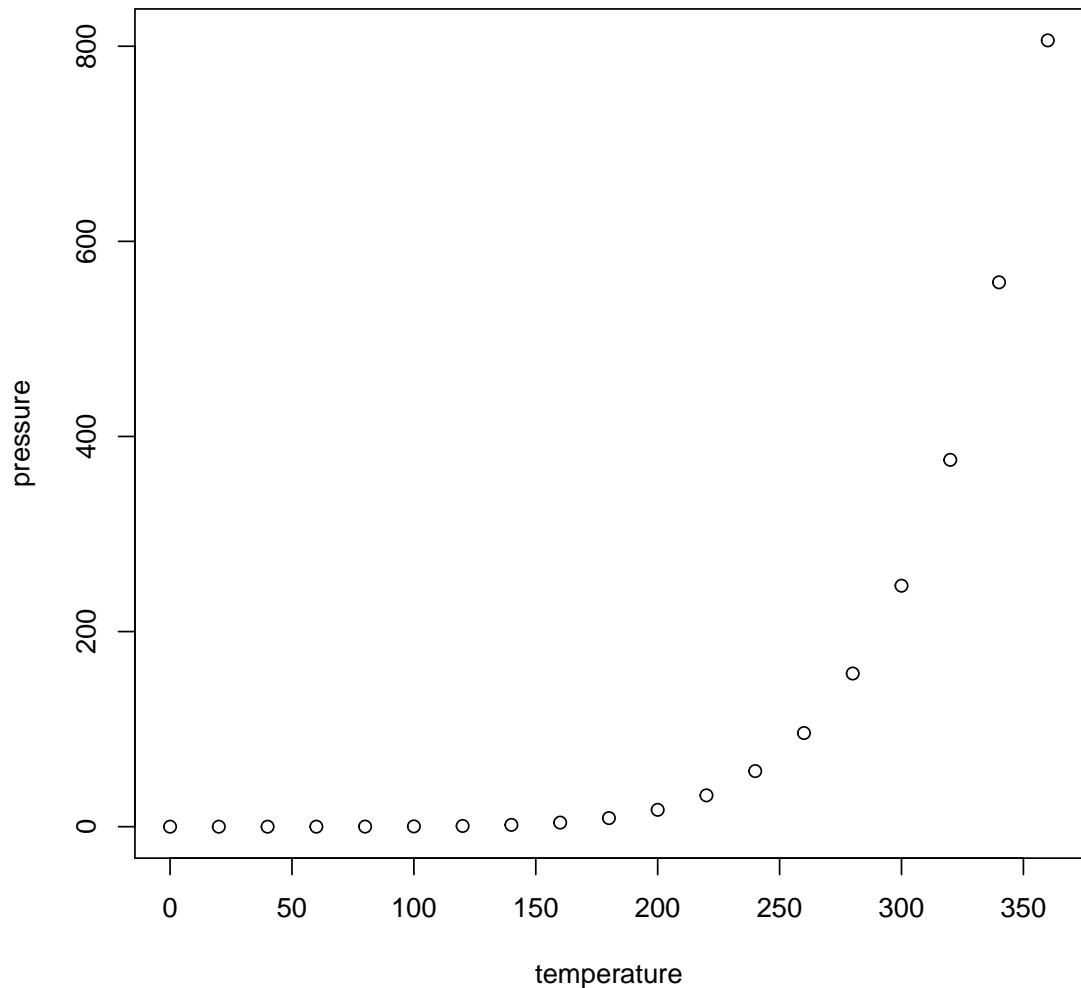
#### R Created Figures

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. \(2017\)](#)).

### 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.

### 0.6.3 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.



# Nora's Practice Sessions

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 marc's EA30e21 branch. - SUCCESSFUL 3. no need to use the "git merge origin EA30e21 "code 4. going to test making a pull request to Marc after saving, committing and pushing to my repo. did it work? 7:45 est YES 7:51 est

## 0.7 Testing Various Push and Pull Options

test commit and pull request

### 0.7.1 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<sub>org</sub> = 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

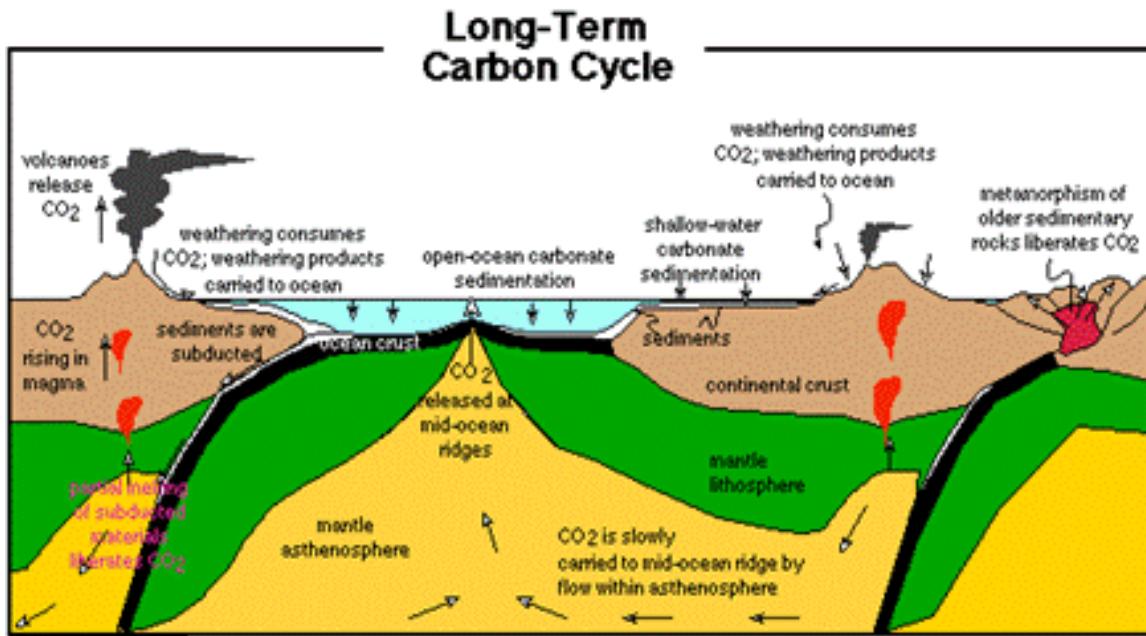
Figure ??

#### 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.

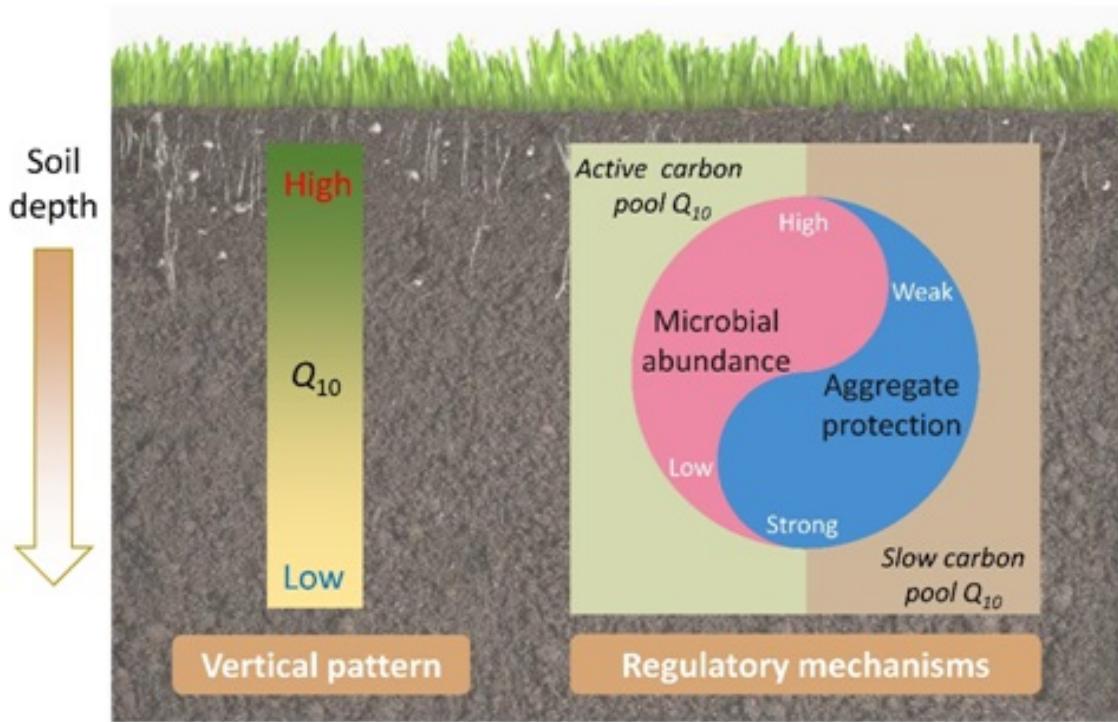
In addition to these microbial biomass and aggregate patterns, the microbes are more sensitive to temperature changes near the surface as measured by Q<sub>10</sub> – the rate of biochemical processes with a 10 degree C increase in temperature. Thus, soil processes, such as respiration, is likely to 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 \(2021\)](#)).



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



## Chapter 2

# Monsoons and East Asia Climates

### 2.1 Temperature Gradients and Latitude

#### 2.1.1 Monsoon – Dominant Climate for SE Asia

Monsoons are identified with copious seasonal rainfall as well as with steady seasonal winds, which reverse their direction in a persistent manner with surprising regularity. The term ‘monsoon’ has its origin in the Arabic word ‘mausim’, which means season. Seamen used this word for many centuries to describe a system of alternating winds over the Indian Ocean and Arabian Seawhich blow from the north-east for six months and from the south-west for the remaining six months. In general, the shift in seasonal wind is about  $120^\circ$ , which is mainly caused by the differential heating of land and ocean. Monsoon winds are most pronounced in the summer season of either hemisphere. The monsoons blow over East Asia, South Asia, Africa, and northern parts of Australia. Recently the presence of a monsoon has also been recognized over south-western parts of North American continent. Overall, about half the tropics or a quarter of the surface area of the entire globe may be defined as having a monsoon climate.

The annual cycle of the monsoon contains two strong components. One is the summer monsoon, which lasts almost from June to September. The second component, the winter monsoon, lasts roughly from December through February. The summer monsoon in southern Asia is a huge climate system in which the Indian monsoon and the East Asian monsoon are the principal constituents.

For millions of people in monsoon regions, monsoon rainfall is the only accessible source of water. If the monsoon fails, people’s lifestyles can be severely disrupted. Accurate prediction of monsoon onset and quantum of monsoon rainfall for a few days up to a season can make a difference between agricultural success and failure. Accurate monsoon forecasts with sufficient lead times are also required for government action and public response. Similarly, prolonged droughts and floods can bring excess hardship to the people in the monsoon region. These may lead to loss of life and property, and a heavy economic burden on the people as well as on the government.



# 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.

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<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 pour 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 pour 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 Darcy's 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

Jeju 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 address this...[Lee et al. \(2017\)](#).



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



# Chapter 4

## 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 [MLH: passive voice] a particularly interesting place to begin analyzing land use change. A study [MLH: is the study itself important or the results? It can be both, but in the intro, I would avoid jumping into studies per se] 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.) (Figure 4.1). Regardless of potential impacts, it cannot [MLH: passive voice] be ignored that the land is changing at a rapid pace. This phenomenon, reflected in Figure 1 [MLH: remove reference?], 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?

As most scholars would agree, we are currently situated in the Anthropocene, [MLH: I like that you appeal to authority, but can you put this in more nuanced way?] or at least an age dominated by the systems of humans [MLH: I like this, start here then define anthropocene]. The supposed "age of man," as described by environmental artist and engineer Natalie Jeremijenko, [MLH: a picture of her work here would be very useful!] 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) [MLH: neat idea, but let's see if we can be more circumspect, and perhaps use evidence then cite this paper?]. In a paper understanding climate change through Qi, et al. [MLH: let's work on references this week] 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 yields a response from the environment that can



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

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,”  
[MLH: open quotes are accent in latex... I fixed this one] in a way progressing from our current practices with radical change, deconstructs power systems, and moreover reimagines our relationship with nature.

“Land use changes”  
[MLH: fix quotes] 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  
[MLH: passive voice] 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  
[MLH: I wonder if this might not be universally agreed upon?] prominent, intersecting issues.

## 4.2 What is Land Use Change?

Simply,  
[MLH: I don't think we need the 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  
[MLH: currently, this is the driver, but that doesn't explain the previous 3000 years before the rise of capitalism and colonialism...], 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.  
[MLH: can we make a graphic for this?] 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 [MLH: how about using authors as subjects?] 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. [MLH: super interesting! nice]

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

Land use change is primarily measured through processes of [MLH: do we need this?] remote sensing. Temporal and spatial data are compiled [MLH: is this the right word?] from aerial photos, satellite images, and various radar sensing systems to be analyzed into topographic maps and more. It [MLH: what is '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. [MLH: nice inclusiveness]

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

Socrates once wrote: "[MLH: quote] 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) [MLH: interesting – a new science is born, in effect, right?]. 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-Félix 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). [MLH: super interesting]

#### 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). [MLH: what were the first uses in Asia?] In 1918, it was [MLH: passive voice] recorded that the French military in particular captured and developed up to 10,000 photos per day from such camera mounts (Moore, 1979). [MLH: you can use moore here as the topic of the paragraph and then don't need to cite him in every sentence] 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). [MLH: as part of war efforts, thus explain why asia didn't have this??] 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). [MLH: and in Russia?]

### 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). [MLH: oh, this is cool, how about some impages for each of these sections above to illustrate what you are talking about?] 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, [MLH: good] 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). [MLH: can we see this image] 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. [MLH: This is great stuff – as a history goes, but I wonder if you could put East Asia in here more... even if the 'subject' of military surveillance (sp?).]

### 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 [MLH: fix apostrophe] 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 land's 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). [MLH: great, and if you can link to SE Asia colonialism too...] 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. [MLH: nation building?] We can see this in the map below (Figure 2) [MLH: ref figure using latex command] on soil erosion rates and vulnerabilities across the globe, dictated by national boundaries. While developing countries are illustrated in red, indicating 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. [MLH: great point – which is a history of advances in Remote Sensing in total...]

Figure 4.2 [MLH: I generally put a tilde in between the ref and Fig because is make a "prettier" spacing]

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, Bennet 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, rationalâ€”a key word in Chinese narratives of development and modernization." [MLH: wow, this is really important! nice job, perhaps make this more prominent?] In other words, while remote sensing may easily be seen as perfectly objective, it in fact requires interpretation and representation, so it too is [MLH: awk] 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 [MLH: à€IJ] help turn policies into self-fulfilling propheciesâ€” (Bennett, 2020). Remote sensing produces entire analyses of landscape that may look à€¥rationalâ€ž or à€¥self-evidentâ€ž; 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.



**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.).

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).[MLH: what were the political reason for this?] 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[MLH: passive voice] 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.).[MLH: great points, let's see if we can make more succinct]

### 4.4.1 An Introduction to Land Use Change

**types of data source??**

perhaps some type of intro to the categories coming... even an illustration might be useful.

#### Soil Classification

[MLH: I suggest we put this in the critical zone chapter and then you can reference that...]

Soil is the combination of biotic organisms and dirtâ€”it 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 particularâ€”proximity to the water table, degree of slope, etc.â€”can help predict the effects of weathering that the soil may take from the other factors.

Rocks and soils at Earthâ€Žs 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 â€œthe process of rock and mineral alteration to more stable forms under the variable conditions of moisture, temperature, and biological activity that prevail at the surfaceâ€ (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.[MLH: I think we can put this in the critical zone chapter and then you can jump into source of impacts... what do you think?]

#### 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.[MLH: what is the percent of land use in monocrops?] 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

[MLH: we can put this in the long and short carbon cycle that I started in the the critical zone chapter] 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.[MLH: can we get a figure for this?]

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 -32% decrease in equilibrium SOC over 23 years, and grassland to cropland similarly resulted in a -36% equilibrium decrease after 17 years. These numbers in particular reflect the relative vulnerability of topsoil to intensive change.[MLH: I think this is super interesting, but we'll need to make a direct connection to earlier sections, remote sensing history, or methods or about critical evaluation of the good and bad in these data...]

##### 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

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.

grasslands can result in a 128% increase in SOC at grasslands 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 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 “[MLH: I fixed opening quote]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 [MLH: let's see if we can make this sentence less complex]. According to some studies, rice production in particular needs to increase an estimated 42% by 2050 to meet rising global demands (Ray, et al.). [MLH: maybe a new paragraph?] 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



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

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 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.[MLH: do these show up in remote sensing analyses?] 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 worldâĂŹrather than interfere with intensive systems, it is meant to work with existing natural systems.[MLH: I have some more resources for this that you might find useful].

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

Figure 4.4

Direct impacts on soil: enhances water infiltration/retention, aeration, structure, porosity âEŠ [MLH: →] 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[MLH: we'll need to describe these a bit more...]

### 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 [MLH: link to remote sensing?]

## 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. [MLH: good place for a map?]

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 [MLH: usually don't think of water as sliding...], 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 [MLH: defin "massive amounts"] 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, [MLH: nomads, I assume?] 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. [MLH: try to avoid relative times..., "in the early part of the 21st Century"?]

### 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, [MLH: how does one look and see this? not obvious to me how..., perhaps with remote sensing?] 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 articleâĂŤwill input figures and explanations of the science here) [MLH: great!]. While



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

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). 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 Korshinsk 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 [MLH: àAIJ] 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.[MLH: could this be in a figure?]

## 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.[MLH: I wonder if you can outline a research project and what imagery one would need to conduct this?]

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

# Chapter 5

## Deforestation

XINLAN CHEN

<sup>1</sup>

[MLH: I added my comments from before, it looks like you didn't get them. Be sure to pull my changes].

### 5.1 Overall

[MLH: not a very descriptive heading...]

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.[MLH: I like this as a start] There are[MLH: let's see if we can avoid passive voice] 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,[MLH: let's see if we can find some data on forest changes over the last 200+ years] and nevertheless, natural is punishing[MLH: interesting, let's see if we can define this] them for that. Over-logging is when the level of deforestation exceeds the self-sustaining state of the ecosystem, leading to desertification[MLH: important concept, let's see if we can define this too]. 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. [MLH: as a road map this intro is very nicely structured]

### 5.2 Damage Done by Deforestation – Example of China

After soil erosion and deforestation[MLH: let's see how we can use the land use chapter as a basis / foundation for this section], 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;[MLH: great, let's see if we can make a figure for this...]

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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.

On rainy days, rainwater is washed directly, carrying the fertile topsoil along with mineral elements into rivers.[MLH: great! and let's see if we can connect to the processed described in the land use chapter so we are not repeating ourselves.] It is [MLH: passive voice]estimated that more than 5 billion tons of soil are washed into rivers in China every year[MLH: how do we know if this it alot or too much?]. The siltation of quicksand[MLH: ?] blocked the channel of the reservoir. Sediment concentration in the Yellow River in China is the highest in the world, and when floods come, water and sand are equally divided. Due to the deposition of quicksand[MLH: I don't think we mean 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.[MLH: to make a paragraph break, just add a line space...]

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.[MLH: can we map the changes?] 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.[MLH: super interesting!] In particular, the destruction of the forest, so that some rare animals lost their breeding base[MLH: let's cite some examples]. 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[MLH: yes, here they are! nice, I wonder if we can get these into the previous sentance?]. There is less oxygen supply when deforestation issue is present[MLH: the atmosphere is 21%, is there any evidence that O<sub>2</sub> is impacted?], consequently there is more carbon dioxide [MLH: how is this created?] and less natural filters [MLH: agreed, but we might need to explain this to our readers]. The ecological environment was forcibly occupied, and the law of ecological circulation was destroyed. The temperature can change, causing unstable changes in the climate.

### 5.3 Overall Losses àÁ§ 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.[MLH: wow! is there a map of this?] Trees are widely used as materials in construction, decoration, paper making, metallurgy[MLH: weird, how?], 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.[MLH: not sure how to interpret this statement..., humans generally do everything to meet their own needs, right? or are you implying something else?]

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[MLH: let's find a better word] of tree stumps. According to government statistics, Thailand's forest cover has almost halved in two decades[MLH: or – One half of Thailand's tree cover had been lost]. In 1961, it still accounted for 53% of China's forest areas, and in 1981, it only accounted for 28%. [MLH: why are we talking about China? I thought this was Thailand] Some experts believe that the actual forest coverage is much less at present[MLH: not sure what you mean]. 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[MLH: but

Thailand is 900,000/day, seems like something is off here], 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.[MLH: huh? all these numbers seem in conflict] 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.[MLH: I suggest we make a table] The large-scale disappearance of forests has caused climate change and the death of wild animals and caused ecological disasters. [MLH: looks like a new topic, should be in a new subsection or paragraph] 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.[MLH: how do we know that?] Another reason for the destruction of forests is that mountain tribes in Thailand still carry out primitive farming.[MLH: new topic] 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.[MLH: and how are they using the forests?] 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. [MLH: new topic] 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.[MLH: yes we need a table to track these. I suggest you create one in word/google docs and then I'll help you create one here] 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.[MLH: this is a great start!, Let's link the deforestation to the market demand and then connect to documented ecological impacts with more specificity and documentation. I think the UN sources are useful, but we need more primary sources.]

## 5.4 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 [MLH: why this state? seems odd] 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[MLH: super interesting, let's get this cited and put in more details]. Soon after the bats took up residence in the trees in the Malaysian orchards, nearby pigs began to get sick – [MLH: probably?? let's put this in more scientific terms, was this tested?] from eating fallen fruit eaten by the bats, and local pig farmers also began to get sick.



example image

## 5.5. DATA PROVING THE DAMAGE OF DEFORESTATION AS A BROADER PICTURE AND POLICY IMPLEMENTED

By 1999, 265 people had severe encephalitis [MLH: this is an important disease, let's define it and the vector] 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 [MLH: interesting, can we learn more about the biology?]. Such infectious diseases are usually confined to wild animals but are spreading to areas [MLH: open areas? or areas where people live?, I am a bit confused] where forests are being cleared rapidly. Human infections [MLH: symptoms?] 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. [MLH: interesting! I wonder if we can find a diagram?] 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 [MLH: define what this means] 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 [MLH: what's this?] viruses, as well as the parasites that cause malaria and Lyme disease. [MLH: maybe a table of diseases and their locations and symptoms?] 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. [MLH: or perhaps did!?] 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. [MLH: good, detail the research results here]

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

[MLH: let's see if we can find a better heading] 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%. [MLH: seems like we covered this already?] 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 [MLH: now I am even more confused...] 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. [MLH: let's make a table and / or plot of the data, better than text!] 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. [MLH:

[let's add some references here] This is largely the result of China's massive reforestation [MLH: back in China? I am pleased by the geographic range, but let's organize it so the reader can follow the trek back and forth with ease] 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. [MLH: new section] 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: [MLH: create numbered bullets] (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. [MLH: paragraph or section?] 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.

## 5.6 Suggestions

[MLH: are these policy suggestions? if so, we need to be more specific and precise –country agency and funding sources while addressing political capacity and will] (1) Strengthening the awareness of forest resources protection

[MLH: read and cite Wenhua, Li. "Degradation and restoration of forest ecosystems in China." Forest Ecology and Management 201.1 (2004): 33-41. and]

[MLH: Cheng, Shengkui, et al. "Spatial and temporal flows of China's forest resources: Development of a framework for evaluating resource efficiency." Ecological Economics 69.7 (2010): 1405-1415. and]

[MLH: Sloan, Sean, and Jeffrey A. Sayer. "Forest Resources Assessment of 2015 shows positive global trends but forest loss and degradation persist in poor tropical countries." Forest Ecology and Management 352 (2015): 134-145.]

The human living environment is increasingly bad, the ecological environment problem has be-

come 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.

[MLH: great start, Xinlan! Now that we have a skelton, let's see if we can add images (use the images/deforestation folder) and let's add citations. I think the paper could use some organization and then we can be more specific in how deforestation is caused and it's consequences, which are mentioned, but could have more detail. I am looking forward to the next version]

## 5.7 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, natural 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.

## 5.8 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 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.

## 5.9 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.

## 5.10 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.

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

Deforestation and long-term destruction of forest resources are the causes of drought and flood disasters. The destruction of forest resources will lead to serious soil and water loss which will lead to the decline of soil fertility, make the land lose its foundation of sustainable development, and aggravate soil drought. At the same time, soil erosion will also increase the rainstorm runoff, resulting in water and river siltation and aggravate the flood. Large area of continuous and high intensity rainfall is the fundamental reason for the occurrence of flood disasters, and the increasingly serious destruction of forest, soil erosion, river siltation, lake shrinkage, collapse, landslide, debris flow and other non-climatic factors also aggravate the formation and development of flood disasters. Debris flow is a kind of serious natural disaster. It carries the amount of sand and stones with the flood from the height of the dump, and has a devastating damage, endangering human beings and their living environment. It is not difficult to find the relationship between debris flow and forest change. Good forest vegetation can restrain the occurrence of debris flow and weaken the disaster of debris flow within a certain limit. Debris flow is a kind of geological disaster caused by heavy rainfall. When it breaks out, it can devastate villages, homes, living transportation facilities and people's

## 5.11. DATA PROVING THE DAMAGE OF DEFORESTATION AS A BROADER PICTURE AND POLICY IMPLEMENT

lives. It is often impossible to prevent.

### 1. Characteristics and causes of debris flow

Debris flow is a sudden collapse of the mountain due to the loss of the protection of the forest and other vegetation on the mountain and the continuous rainfall, the swelling of the forest land, the high degree of weathering of the rock parent material and the comprehensive influence of the slope and slope direction. It mainly occurs in the rainfall concentrated season from July to September, especially in mountainous areas and hilly areas with poor ecological environment and little forest vegetation, which directly causes grave disasters such as buried villages and reservoirs, water hitting and sand pressing farmland, rivers and communication being blocked, as well as a large number of human and animal casualties and missing.

### 2. Measures for preventing and mitigating debris flow disasters

In the areas with poor vegetation protection, mountains shall be closed off and farmland shall be returned to forests. All management measures and economic compensation for the protection and construction of ecological public welfare forests shall be conscientiously implemented, and illegal cutting and felling of trees on public welfare forest land shall be strictly prohibited. It is strictly prohibited to cut up mountains for rock quarrying, destroy forest land, change the use of woodland and other illegal acts, and gradually restore and enhance the protection function of forest vegetation, which is a long-term plan to prevent and reduce the harm of debris flow. We will implement and do a good job in ecological planning.

Forests can improve soil aggregate structure and increase rainwater infiltration rate. The litter layer under the forest surface has strong water absorption capacity, and when its water absorption is saturated, it can slow the runoff and improve the rainwater infiltration rate, so the forest can reduce the slow mountain flood. The roots of forest plants intersect and form a network in the soil, just as steel does to concrete, consolidating the soil together and enhancing its integrity and stability. If there is good forest vegetation in the development period of the gully accumulation body, the effect of the root system consolidating the soil can reduce the scale of the mountain being washed away by the flood and reduce the risk of collapse. Therefore, good forest vegetation can restrain the occurrence of debris flow, reduce the content of soil and sand, and reduce the viscosity of debris flow, so as to reduce the harm of mountain flood debris flow.

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.

## 5.12 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

SOLIEL

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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

## Flood Pulse System of the Mekong River and Tonle Sap

KRISTIN GABRIEL

### 7.1 Introducing the Mekong and Tonle Sap

#### 7.1.1 The River-Lake System

The Mekong River and Tonle Sap Lake function as one of the most important river-lake systems in the world. The river itself runs through six countries: China, Myanmar, Thailand, Lao PDR, Cambodia, and Vietnam (Figure 7.1). The Mekong river is currently ranked as the 10th largest river by volume on the planet, while the Tonle Sap is the largest freshwater lake in Southeast Asia.

Throughout the year, the Mekong River experiences significant flow alterations due to the seasonal monsoon (FIND SOURCE). Because of this, the water level in the Tonle Sap is controlled by the water level in the Mekong main stem.

Because of the unique weather patterns of southeast Asia and connection between the Mekong and Tonle Sap, a unique flood pulse system is created. The flood usually lasts an average of 258 days, or 71% of the year. On average, the flood begins at the end of June, peaks at the beginning of October, and ends in early March, with some variation of course. During the wet season, the Tonle Sap's size expands by about four or five times, and this water then flows into the Mekong during the dry season as its level drops (Evans et al. 2004). This creates a distinctive flow pattern, in which the river's main stem actually flows in opposing directions in the flood season and dry season (SOURCE).

The Tonle Sap ecosystem is also one of the most heavily relied-upon ecosystems in the world. The lake is especially important to those in Cambodia and the lower Mekong Basin; in this area, over one million people depend on the natural resources of the lake . In many areas of the basin, water resources are used intensively at a small-scale local level. However, the Mekong basin is under rapid development, including the construction of large-scale hydropower dams, deforestation, development, and climate change . However, recent research has found that the construction of dams and other development activities may significantly alter the hydrology, and therefore the health, of the ecosystem.

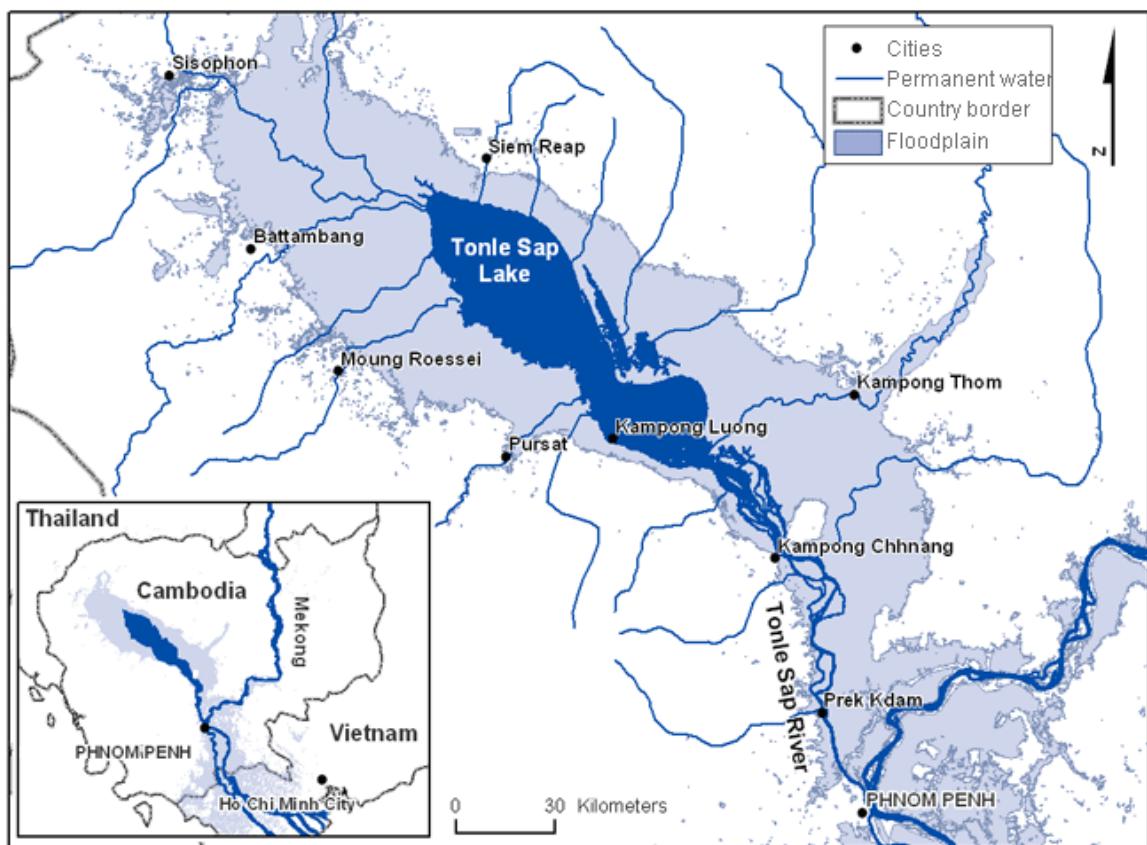


Figure 7.1: Map of Tonle Sap (Source: Wikicommons)

## 7.2 What is the Flood Pulse System?

Scientists who study riverine systems, such as water flow, channel morphology dynamics, and plant and animal organisms have tried to characterize streams to better understand them and make predictions about them.

The Flood-Pulse Concept does exactly this. By acknowledging how rivers can extend well beyond their low flow channels and flood a broad lowlying area on a seasonal basis is a clear pattern of certain rivers, especially those that experience highly seasonal rainfall that is a characteristic of monsoon climates.

### 7.2.1 Habitats in the Flood-Pulse System

The floodplain vegetation is one of the most important elements of the Tonle Sap ecosystem. Because they are inseparable in terms of water, sediment, and shared organic material, rivers and their respective floodplains are considered the same unit, and they work as a combined river-floodplain system. Floodplains are defined ecologically as areas that are periodically inundated by the lateral overflow of rivers or lakes, and/or by direct precipitation or groundwater (The flood pulse concept in river flood-pulse systems). The river-floodplain system comprises a permanent moving-water ecosystem (lotic), a permanent marshy, stillwater habitat (lentic), and the floodplain. Despite many researchers' efforts, it is impossible to apply stable and defined borders between land and water in any floodplain.

### 7.2.2 Organisms

This periodic flooding produces similar anatomical and physiological adaptations in the organisms inhabiting different areas affected by the same phenomenon, and it produces characteristic community structures. The life cycles of organisms in the floodplain are very related to the timing, duration, and rate of rise and fall of the flood pulse system. As an ecosystem, floodplains are very unique because they have both aquatic and terrestrial phases. This leads to specific adaptations among both aquatic and terrestrial animals. For example, aquatic organisms are selected to populate the floodplain at rising and high levels because of the abundance of food. Conversely, terrestrial organisms have adapted to take advantage of the floodplain at low water levels.

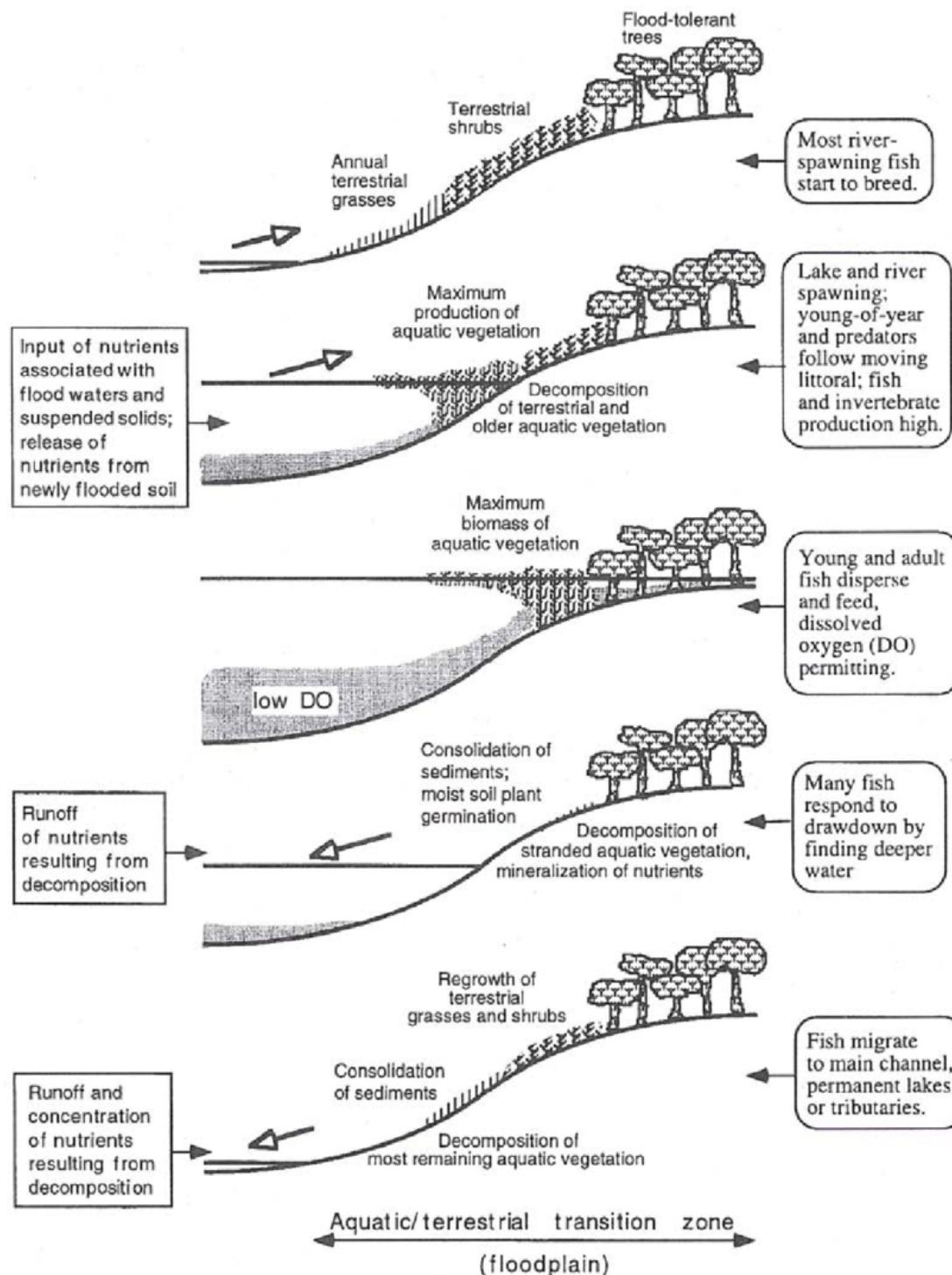
### 7.2.3 Nutrient Patterns

The lateral exchange of nutrients between floodplain and river channel has the most direct impact on the biota of the ecosystem. The floodplains receive all nutrients directly from the main channel; however, because of their differing biogeochemical cycles to the Mekong River and Tonle Sap, the floodplains develop a different nutrient profile (The flood pulse concept in river flood-pulse systems). These nutrients include both organic and inorganic compounds, that can be further divided up into gaseous compounds, dissolved solids, and particulate matter.

### 7.2.4 Hydrology

#### Climate, Monsoons, and the Holocene

@article{penny2006holocene, title={The Holocene history and development of the Tonle Sap, Cambodia}, author={Penny, Dan}, journal={Quaternary Science Reviews}, volume=25, number=3-4, pages=310-322, year=2006, publisher={Elsevier}}



### Ecosystem Productivity

The Tonle Sap ecosystem is widely perceived as an ecosystem with naturally high productivity. The Asian Development Bank even considers the productivity of the lake to be “among the highest in the world”, and this is widely believed to be because of the flood pulse system itself. However, most of the beliefs surrounding the ecosystem productivity of the Tonle Sap actually refer to fisheries production and productivity. Despite fish catch statistics being incomplete and historically unreliable, there has been no research or specific data collected to determine either the primary or secondary productivity of the ecosystem.

Therefore, fish catch data must be used as an indication of ecosystem productivity in this situation. Another powerful indication of the ecosystem’s productivity is the livelihoods that are supported, either directly or indirectly, completely or partially, by the river-lake system.

Because the surrounding communities and other users of the lake’s natural resources are especially dependent on its productivity, the lake’s ability to support these communities’ livelihoods is a robust way of determining its productive capacity. This also makes the ecosystem’s productivity especially important, in that it is not only a key factor of environmental health, but it is also a key determining factor for social equity and economic welfare.

Ask: what is the best way to talk about fish catch data? It seems very all over the place from family fisheries to large scale operations. Would a description/summarization of the data be helpful, or should I just summarize overall findings and trends?

## 7.3 People and the Flood Pulse System

### 7.3.1 Anthropology

The Tonle Sap’s abundance of fish and sustenance has been documented for centuries. It has even been hypothesized that the Tonle Sap’s productivity was the basis for the development of the Khmer Empire: The huge productivity of the Tonle Sap sustained a Khmer empire at Angkor from 802 C.E. until the fifteenth century. (Evans source from this source)

### 7.3.2 Human Impacts on the Flood Pulse System

#### Hydropower Development

#### Climate Change

#### Urbanization and Development

Main focuses: 

- Importance of flood patterns o Not just a diagram, but also math about how floods are measured/work
- Some equations/acknowledgement of hydrology that looks at flood patterns and that can also tie in with the climate change section
- Define lentic and lotic
- Identify groups of organisms that like the different types of organisms
- Then we can link that in the productivity section
- Look at California levee that broke and filled in farmland and the fish were more successful in the flooded zone
- Carbon input and insects in floodplains look at carbon input in lotic zone and lentic as well
- River continuum concept
- Historical development, the flood pulse system was in response to the river continuum concept
- Ignores the lateral movement of water
- This will be helpful in the lotic zone of the river
- Only covers part of the reality
- Flood pulse model only covers part of the reality too. So we need to put them together!!
- Use case studies of specific fish to explain the larger processes going on in the river
- Can even use case studies from north America and Europe and hypothesize about what could be parallel in the Mekong
- Don’t pretend like you

know all the answers, invite questions, and POSE questions → Ecosystem Productivity: tell the reader how fisheries are measured and WHY thatâŽs uncertain o Also define primary productivity and secondary productivity and how thatâŽs measured in real life, like how do scientists figure that out → Look up river culture: an eco-social approach → Values of inland fisheries in the Mekong river basin → Influence of built structures on the tonle sap ecosystem → Civil society and interdependencies chapter on the tonle sap → Ngo doing toilets on the lake, what local ngos are doing → Look at LucasâŽ article → IJDesign With Natureâ† for inspiration → Should I include the Delta in Vietnam?? Food for thought →

Ecosystem Services

Fish stocks

Fisheries

Immigration and emigration

# Chapter 8

## Hydroelectric Dams in East Asia

??

### 8.1 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. [MLH: let's introduce these folks with a more nuanced approach] 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.

[MLH: let's see if the quote blocks look more pleasing... , but also we can use a trick to get rid of

the subsection #s if you want]

#### 8.1.1 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.”

#### 8.1.2 On Social Change and Economic Development

“I don’t 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 [MLH: ... works better for etc] 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.”

### 8.1.3 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.”

[MLH: great intro! I wonder if a map to locate us or some images might be useful?]

## 8.2 Introduction

There exist over 48,000 hydroelectric dams[MLH: this is a measure of dams at a certain height, I suspect?] worldwide (WWF Global, 2015)[MLH: might not be the best source] 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 and some countries such as Vietnam, hydropower can cover up to 37% of the country’s energy production. [MLH: but we started with the island of borneo..., can we circle back to that?]

One of the largest ironies of hydroelectricity is the benefactors and recipients of the produced energy. This is a process termed water grabbing.[MLH: I wonder if we describe the outcome and then give it a name?] 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.[MLH: Bakum is in Borneo so there is a disconnect here with respect to the quotes and Loas] 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).[MLH: let’s see if we can find a better source?]

### 8.2.1 The World Bank and Other Funders

[MLH: let’s back up a bit..., why were dams seen as a critical part of development?] 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.[MLH: add references and details] 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.[MLH: good, very clearly wrote] 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[MLH: passive, let’s make more active] 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 “[MLH: use accent as opening quotes]Battery of [Southeast]Asia.[MLH: use two single quotes for closing quotes]” In cases of water grabbing[MLH: great, I like this term, but let’s put it into a more complex dynamic] 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

**Table 8.1:** 3 column table example, left justified, right justified, and center justified

Header 1	Header 2	Header 3
data 1	data 2	data 3

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 ×10 <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 ×10 <sup>8</sup> MW		gravity and embankment

**Figure 8.1:** Some of the largest or most famous mega dams world wide [MLH: define mega dam]. [MLH: let's create a table in LATEX, I started it for you] 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 [MLH: odd phrase, failures?]. 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!

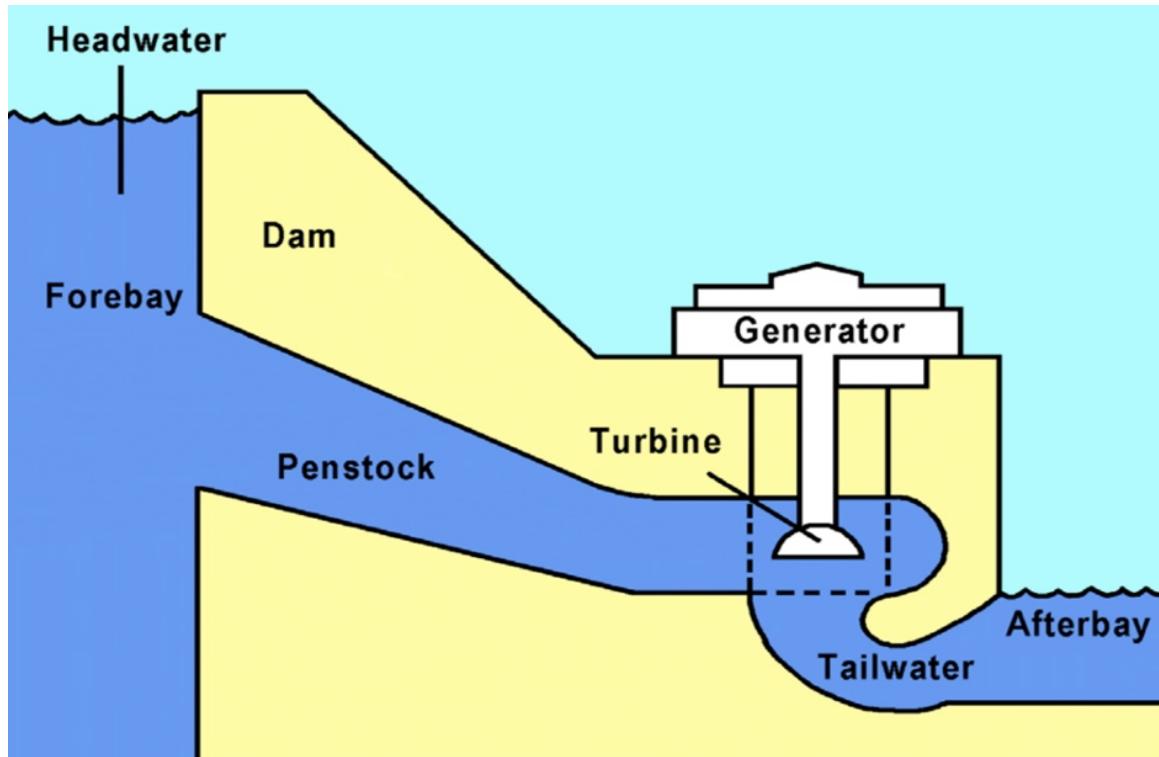
projects have failed international guidelines [MLH: can make a list of these?] on human rights and Indigenous rights, as well as ecological harms (which are often tied to subsistence and cultural reciprocity). [MLH: is this a new paragraph?] In many cases, the current social protection policies that 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 [MLH: I get the word, but I suspect there is a better one] cramped living conditions with poor infrastructure [MLH: define, looks like you list these afterwords, but is ther something missing?], 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 [MLH: need a history of rural electrification]. Instead, many Indigenous groups must find their own way to pay for or generate electricity should they desire it in their community.

[MLH: See Table 8.1].

### 8.3 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



**Figure 8.2:** 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).

larger electrical grid for purposes such as energy for a household's lighting) (U.S. Department of the Interior). This type of turbine that turns moving water's energy into electricity is known as a hydraulic turbine (Figure 8.2) [MLH: I changed the reference name to avoid confusion.]

[MLH: I moved the figure into a directory with your figures to make it cleaner and easier to find, but you'll need to move the rest and change the director]

### 8.3.1 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). [MLH: great place for a figure and some discussion of some physics] 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. [MLH: I generally add spaces to see the section headings, makes no different to pdf]

### 8.3.2 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.[MLH: what about run of the river dams?]

[MLH: did you see the talk on dams on Thurs?, I think it was recorded]

#### 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[MLH: is this the best word?] to create energy. Because they are reliant on gravity, they tend to have large heights and require stable foundations to bear the weight of the reservoirs. If reservoirs get overflowed[MLH: is this the right word?], 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).

### 8.3.3 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. [MLH: cool!]

$$KE = 0.5mv \tag{8.1}$$

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[MLH: why by mole, wouldn't it be clear to make this g/ml or better kg/L?] 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.[MLH: worthy of a hose diagram? ] 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:

$$PE_{grav} = mass * g * height \quad (8.2)$$

[MLH: did you write out mass before or just use m? not consistent with below...] 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)[MLH: what's N? Newtons, but that might not help the reader], and h is the height. The mass of water is also consistent at about 18.015 grams/mol[MLH: ?] 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[MLH: ?] water (this means we are not calculating the bounce of the object in motion, only the gravitational energy, the equation is

$$TME = PE + KE \quad (8.3)$$

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. [MLH: this is GREAT! I wonder if we can find the TME data for a big dam and down how the area flooded correlates in the planning stages? it would be super cool as a graphic! I think :-) ]

#### 8.3.4 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).

[MLH: Okay, I hate adding to this, but after the talk last week I realized we have another driver – electrical demand in the region is SUPER high and growing fast. ADDED to that we need to meet that demand without burning fossil fuels. Are we left with hydroelectric or nuclear? To many yes. That is something we need to engage, I am thinking]

## 8.4 Hazards and Flooding

[MLH: seems out of order with the following section]

Another threat posed by the Three Gorges Dam[MLH: need a transition back to China] 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[MLH: passive voice] 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 populated 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 changes 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).

## 8.5 Three Gorges Dam

[MLH: perhaps this can go after the TME?]

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 China's energy production (Li 2007).[MLH: that's quite impressive! what the GWP for this? do we know?]

By 2012, the dam's 32 turbine generators were all operational (Britannica). The dam's reservoir holds 5.85 trillion gallons of water and is estimated by the dam's 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[MLH: never sure if this is the best word!] 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 Dam's 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).

[MLH: can we get a sense of the area lost by dams? Perhaps another table with impacts? areas, peoples displaced, etc?]

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)[MLH: excellent, and a weird question, did it force them into greenhouse gas producing jobs?]. 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)[MLH: powerful stuff!, give a hint in the intro?]. 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).[MLH: excellent material, but is there peer reviewed literature to discuss this?]

### 8.5.1 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 [MLH: area?], 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. [MLH: has displacement always been the outcome of development or is there evidence that some are wanting to move because of better livelihoods? not your chapter, but it's a question in my head...]

One measurement of human well-being following construction of the Three Gorges Dam was done by Millennium Ecosystem Assessments (MA) in 2003 by the Millennium Ecosystem Assessment and World Resources Institute. They classify human well-being under five categories: [MLH: create a bulleted list] access to basic materials, freedom and choice, health, social relations and social capital, and security (Millennium 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. [MLH: can we rank numerous projects on this scale to show some variance?]

[MLH: need a transition :-)]

### 8.5.2 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[MLH: try to avoid ambiguous pronouns] is common that snails become vectors for the disease, and they bring Schistosomiasis from the endemic regions. The dams bring in[MLH: can we be more precise?] 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[MLH: out of the flooded areas?].[MLH: new paragraph?] 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 km<sup>2</sup>[MLH: I created a short cut to make it easy] which extends into the Jianhan Plain in the Hubei Province and the Chengdu Plains in the Sichuan provinceâ†both regions are endemic for schistosomiasis (Wang and Zheng 2003).

There are[MLH: passive] 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*[MLH: italicize] 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[MLH: passive] 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*[MLH: italicize] (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 â†snailsâ† 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[MLH: I assume there is no real data that we can show?]. If these cases return to their homes from hospitals, the presence of *O. hubensis*[MLH: italics] 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.[MLH: can we make a figure?]

#### 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 [MLH:

is this the subject of the sentence you want to emphasize?] a 95% confidence interval that the compatible range for the snails was 0.9–21.1 $^{\circ}$ C. The Three Gorges region[MLH: a $\tilde{Z}$ ]s average temperature is 3.9–18.8 $^{\circ}$ 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 $^{\circ}$ [MLH:  $^{\circ}$ C depending on the season, making the climate changes more compatible with the snail $\tilde{Z}$ s 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 [MLH: snails?] occurred due to the construction of the dam, migrants [MLH: oh peoples] 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 8.3 [MLH: I changed the reference name to avoid confusion.]

### Snail Movement

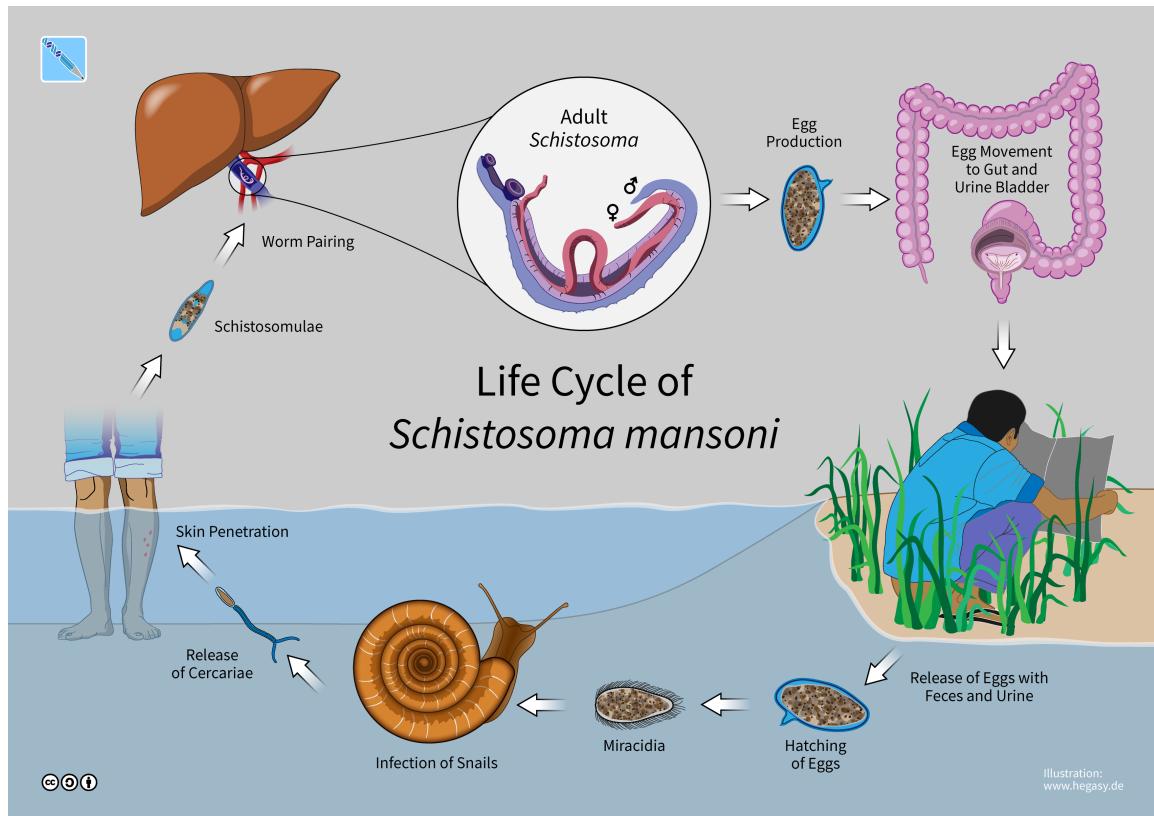
[MLH: in biology we use dispersal...]

Snails are distributed or dispersed throughout regions in two ways $\tilde{Z}$ [MLH: L<sup>A</sup>T<sub>E</sub>X doesn't like this character, I think you need a –]actively and passively (Wu 2005). An example of passive dispersal is snails attaching to ships that move to new areas. Active dispersal can [MLH: 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[MLH: odd number, maybe has been observed or better Zhu (2008) observed...] kilometers (Zhu 2008). The closest endemic region to the dam itself is 299 kilometers and there have been documented cases of[MLH: on?] 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[MLH: passive] 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.]

### 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 [MLH: passive] is insufficient infrastructure (I[MLH: 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[MLH: I wonder if Covid was an issue in this region, seems like vulnerable pop?]. For this reason, transmission of diseases such as Schistosomiasis is a threat



**Figure 8.3:** 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

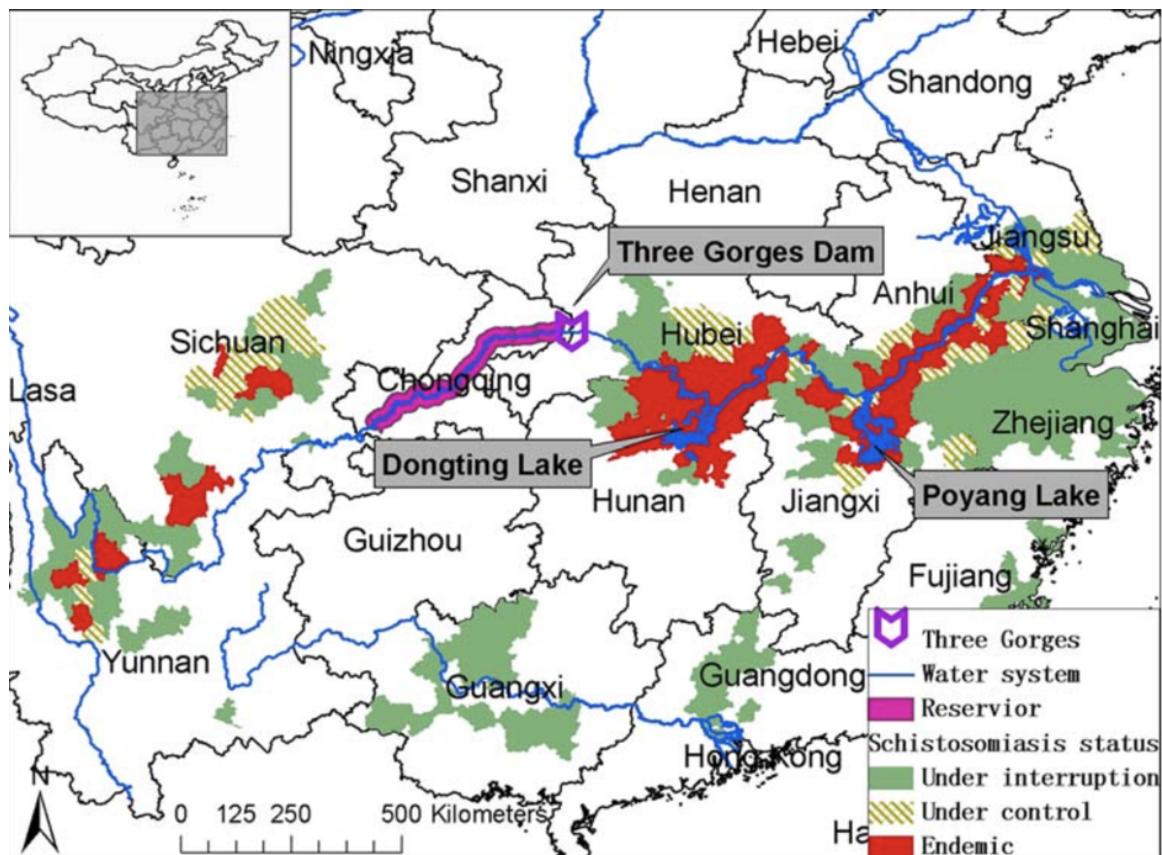


Figure 8.4

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 rodents—Hantavirus.

### 8.5.3 Eutrophication

[MLH: begin with some discussion of eutrophication defining before jumping into cause, throws the reader (me :-)) off a bit to start about flow changes and toxicity...]

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). [MLH: might need to explain this—nothing to do with the dam, or does it?]

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. [MLH: can we map these changes?] For this reason, the nutrient runoff and toxin runoff associated with industrialization and urbanization has worsened (Zheng 2008) [MLH: can we show the data?]. 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 health [MLH: – or –] this growth as a result of nutrient excess of nutrient loading is known as cyanobacterial [MLH: write out] algal 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 source [MLH: – or –] this is known as fluorosis [MLH: doesn't see to fit in well here...] and is common in subsistence populations who live near the Yangtze river (World Health Organization 1999).

## 8.6 Social Systems and Infrastructure

As a result of millions of people being forcibly relocated, there [MLH: passive] 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 Chongming—Tian 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. [MLH: map?] 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 and maintained sovereignty.

Within these townships and urban centers, there[MLH: passive] 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 â€œde-farmingâ€), 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).

[MLH: seems repetitive, perhaps there is a way to make this more precise to make the repetition go away?] 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.

### 8.6.1 Food Security

[MLH: dont' need I think... Furthermore, ]

The 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 naïve 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.[MLH: glad this is back, but wonder if we should integrate more stories so there is a back and forth?] For example, Laos or Lao PDR (known as the â€œBattery of Asiaâ€ 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[MLH: I missed this example?] 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 Ladakhiâ€™s 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.[MLH: super

important, I'd love to see more quantitative data and how folks measure and assess this... , I have no idea how these are estimated and how accurate.]

### 8.6.2 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). [MLH: what are the qualification of the cited article authors?] 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. [MLH: agreed, but let's be more sophisticated in how we discuss this – for example, can you find a source the documents the failure of benefit-costs analyses and cultural values/sites?]

Entire towns and temples have been flooded by singular dam development. The Three Gorges Dam for example submerged the White Crane Ridgeâ€“Ta hydrology inscription–, the original sites of the Zhangfei Temple[MLH: – versus â€“] a temple that was removed by archeologists from its original location to prevent it from being completely submerged–, and Dachangâ€“tan ancient town that was submerged and had to be replicated/rebuilt downstream (Childs-Johnson and Shen).

[MLH: we'll need a transitions and a hint in the intro of the countries you plan to cover]

## 8.7 Vietnam and the Hoa Binh Dam

[MLH: create a reason why we want to know about this] 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). [MLH: again, the history of rural electrification might be good context, many things have been justified by this development goal and the USA is a key part of this]

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. [MLH: good, can you give explicit examples?] 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.[MLH: many migrated to CA!] They rely on agrarian farming with crops such as rice. They rely on local ecology[MLH: ecology is the study of interacting organisms] for subsistence including crops, hunting, and raising animals. They also engage with outside economies[MLH: define] 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).[MLH: maps and better sources?]

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%.[MLH: but what were they before? I can see if they were 80% for the govn't might call it a success...] Primary school completion was also almost 10% lower than the national rate.[MLH: again before?] The Hoa Binh hydropower project demonstrates the lack of comprehensive Environmental Impact Assessments (EIA) and sustainable relocation plans allowing for the valuation of profit over human life (Hai 2016).[MLH: no surprise here, and this might be a good thing to discuss]

## 8.8 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 â€œhappy endingâ€ 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 [MLH: km<sup>2</sup>] (which for reference, is the size of the entire country of Singaporeâ€œ[MLH: !]this 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 government[MLH: â€œ]s 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.[MLH: any maps?]

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 [MLH: passive] 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 [MLH: huh?]. 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 Banie's help, Gara Jalang 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 [MLH: kw/day] 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 Liam's 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 ! [MLH: sound good!]

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. [MLH: very good, let's talk this week about run of the river dams as alternatives] 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 [MLH: oh!], 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 [MLH: might seem to come out of nowhere, right?] 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[MLH: let's talk about voice, I am not sure what is best and don't mind, but let's be intentional about it.] 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 made through Indigenous sovereignty at the community decision making level)

An important part of this desire can be explained by Author John BodleyâŽs proposal for cultural autonomy for Indigenous nations. He says that its purpose is âIestablishing the Indigenous peoplesâŽ right to self-determination and âYhelping to secure the future of Indigenous cultures in concurrence with their own efforts and desires...[MLH: create a numbered list] 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 âIpermit 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.

[MLH: new subsection?]

The alternative energy source of mega dams is far from âIcleanâI or âIsustainableâI 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 âIcleanerâI 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.

## 8.9 Conclusion

[MLH: looks like you have some conclusions above :-) ]

# Chapter 9

## The Political Ecology and Economy of Rice in Myanmar

LUCAS FLORSHEIM

### 9.1 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[MLH: why in caps?] 2050 If certain agricultural adaptations are not implemented (Wassman et al., 2009).[MLH: let's create the citations using citep] 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. [MLH: is this a new paragraph? add a space to make one] 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).[MLH: wow, this is a mouthful and probably needs to be translated...] While there is [MLH: passive voice]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[MLH: uniquely or just recently convoluted?] and political history. [MLH: Did japanese occupation have an impact?] 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 19660s[MLH: :-)], 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 countryâŽs 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

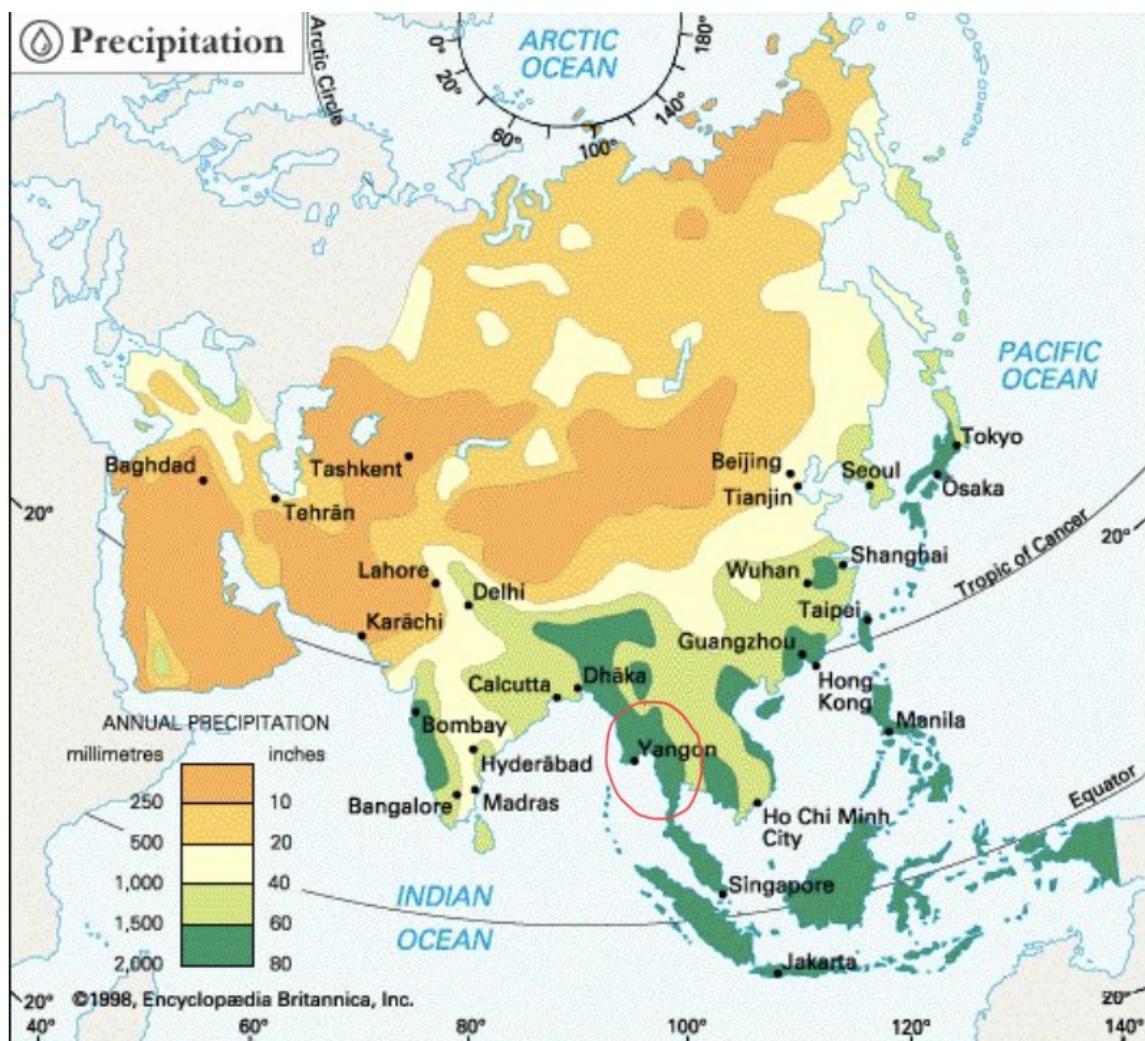
from performing the necessary implementations in response to the agricultural issues posed by the climate crisis.[MLH: as a poorer country, how did it fit into the cold war geopolitics?] Myanmar has made tremendous progress towards democracy in the last 20 years. This progress culminated in a democratically 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[MLH: why?] and to introduce the infrastructure needed to combat the effects of climate change.[MLH: again, why? Is this always the case?] 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 dâŽ[MLH: see how accents and apostrophes are done in LATEX]âltat. The military is now in sole control of the countyâŽs 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[MLH: ?] 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).[MLH: do we want to be more circumspect in case Burmese want to read this? Could get censured?] 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[MLH: why-I think I agree, but it's important to tell the reader of your assumptions here]. 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. [MLH: new paragraph?] 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 MyanmarâŽs government on the future of the countryâŽs rice production in the era of climate change.

## 9.2 Climate and Rice Production

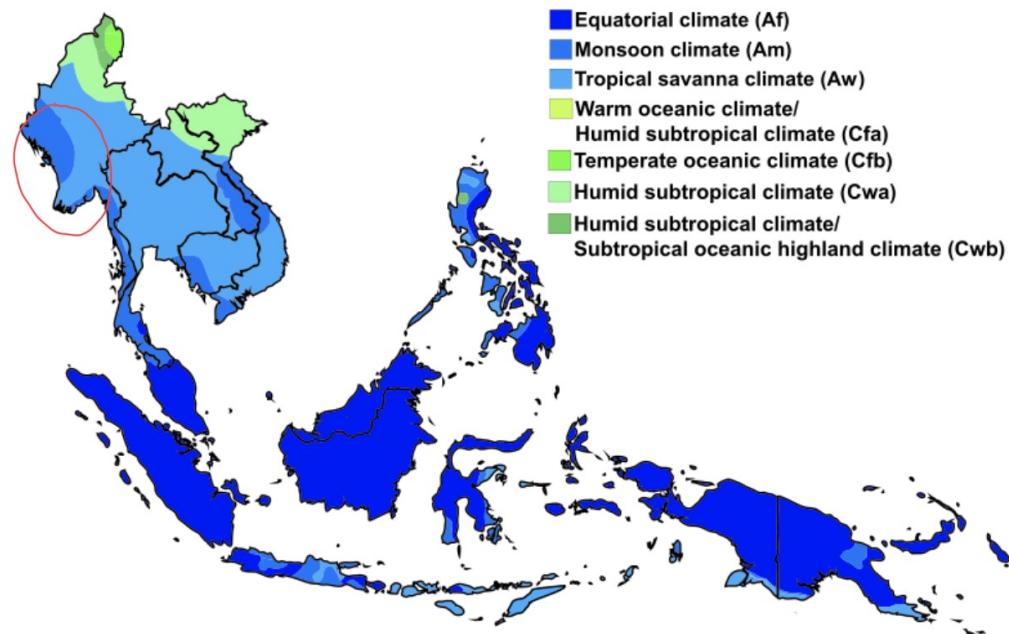
Being one of the largest countries in Southeast Asia, Myanmar experiences several different climates, varying greatly based upon region. The most northern parts of the country feature humid sub-tropical climate with hot and humid summers and mild winters. The Northeastern part of the country experiences 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.[MLH: map of climates?] 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. [MLH: I moved your figured to a subdirectory to help organize them.]

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 MyanmarâŽs 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,[MLH: I wonder if we start with this river as the center stage of



**Figure 9.1:** Average annual precipitation in Asia, the rainfed rice-producing region of Myanmar is circled in red. [MLH: I wonder if we can find /make a figure for just Myanmar?]



**Figure 9.2:** Climate Classifications of Southeast Asia, with the rice-producing region circled in red.  
[MLH: is there a map layer we can use to create maps just of Myanmar?]

rice and the region and see if there are some cultural values associated with the river? Then we can also reference, Chapter 7, which deals with the flood pulse...] is naturally provided, and monsoon rainfall [MLH: we can reference the monsoon chapter here] 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.

### 9.3 Agricultural Production and Food Insecurity

[MLH: I generally add a space in the Rnw file to these stick out better, when the PDF is formed, a space will automatically added..., so it's just so I can see the sections easier...]

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 (Hlaing et al., 2019).[MLH: how was this measured? Could be important, like how is covid measured has policy implications...] Because the majority of the Burmese people work in agriculture, it is [MLH: passive voice]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 farmerâŽs 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[MLH: transportation? cars? roads? I suggest we be more specific?] to reach sellers or traders and contract-based farming is a relatively



**Figure 9.3:** Map of regions in Myanmar [MLH: I multiplied by .5 to make it fit, but it's still pretty pixelated, let's see if we can make a better figure...]

new phenomenon as Myanmar liberated their markets in 2011. In addition, complicated land[MLH: is it worth explaining?] 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. [MLH: what causes these lack of access, is it simply money?]

## 9.4 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 MyanmarâŽs government sponsored a project called the Whole Township Paddy Production Program (WTPP) that aimed to extend the agricultural season and increase yields (Naing et. al, 2008).[MLH: motivated by what do you think?] Previously, rice was a monsoon crop with a season that lasted from the end of May until November. The WTPP introduced new grains classified as high yielding varieties (HYVs) which were intended to completely redefine the limits of the countryâŽs 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).[MLH: nice! I wonder if you can define the fertilizer/spacing changes and what is meant by continuous] 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).[MLH: aha! Let's see if we can create a better transition so the reader knows that the terms will be defined or talk about the process then introduce the term...] 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 MyanmarâŽs economy[MLH: deregulation of what?] (Kurosaki, 2008). MyanmarâŽs government associated rice production with overall food security, and therefore political stability (Kurosaki, 2008). This association led to continued reforms [MLH: for example?] to expand rice production, some of which involved small steps towards privatization in the agricultural sphere (Kurosaki, 2008). In the late 1980s MyanmarâŽs government began to permit farmers to sell surplus crops in private marketplaces.[MLH: sounds like it was a command and control economy like a marxist gov't, is this a good way to read this?] Furthermore, in 2003 the government opened up rice exports to private traders, although private exports remained extremely limited and restricted over the following decade.[MLH: why?] 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).[MLH: sounds like a stifling economy??] 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).[MLH: what are the environmental implications of HYV rice production for the country? air, water pollution? toxicity? etc]

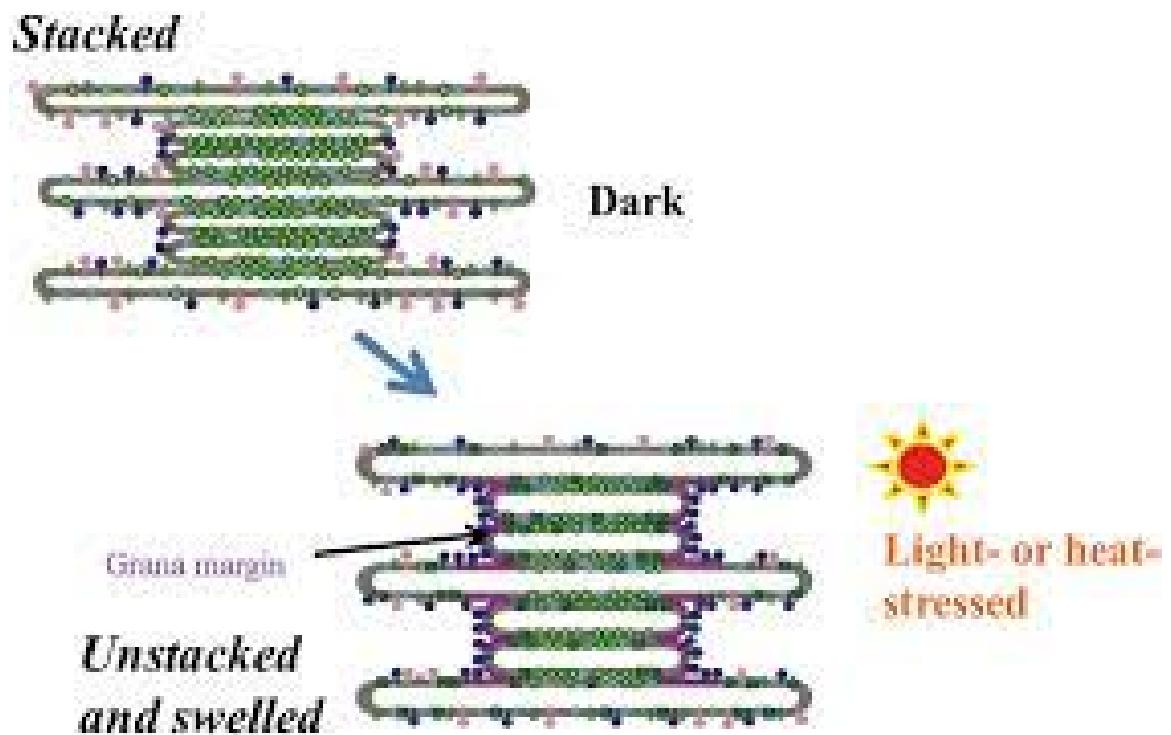
## 9.5 Implications of Climate Change on Rice Production

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 ThailandâŽs 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 MyanmarâŽs 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 [MLH: paasice voice] 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. [MLH: might be too much detail, what does the reader really ned to know?]

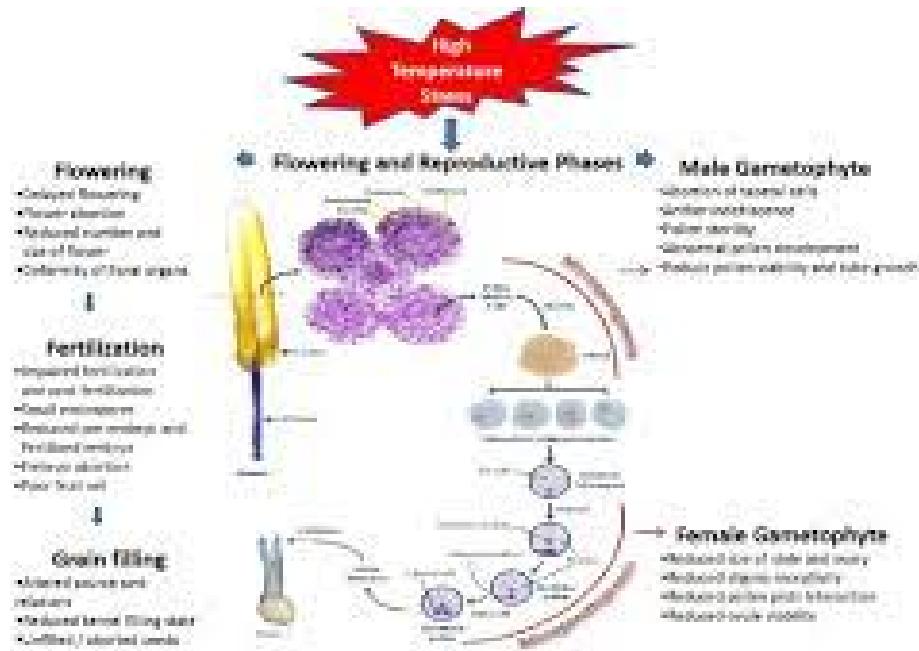
## 9.6 Increasing Temperatures

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 36Â°C [MLH: °] Celsius (C), which is beyond the critical limits of heat tolerance for rice (Wassmann 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°[MLH: added tex com-mond for degree] (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 plantâŽs production cycle. The growth rate of rice increases linearly as temperatures increase from [MLH: 22Â°C to 31Â°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 35Â°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.[MLH: great name!]

During the reproductive stage the meristem, the tissue on the tips of roots and shoots that is responsible for the production of produces [MLH: seems more direct...] 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



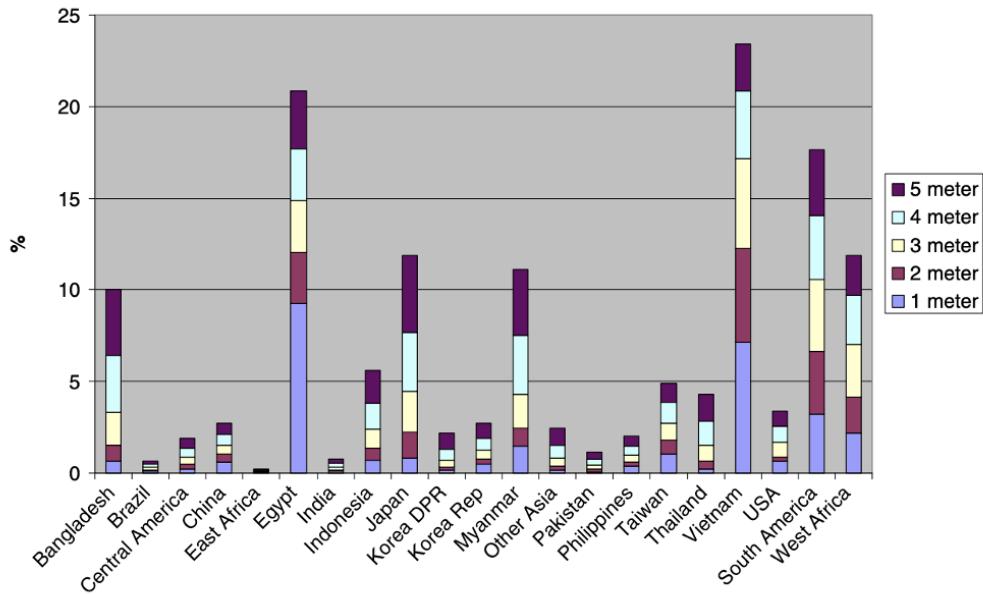
**Figure 9.4:** Comparison of an undisturbed (stacked) chloroplast and the swelling of the grana that is induced by heat [MLH: let's create a better image]



**Figure 9.5:** 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. [MLH: pixelated...]

period, also known as grain filling, high temperatures have been shown to [MLH: can] 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 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 [MLH: 35 °C] (Xiong et al., 2017).

[MLH: new subsubsection?] 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). [MLH: put in an additional space if you want to create a new paragraph] For each meter of SLR, Myanmar is projected to lose 0.85% of its rice cropland (Chen et al., 2009). If long term estimations are correct, a 5-meter increase in sea level could result in a loss of over 6.5% of Myanmar's available rice cropland and up to 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



**Figure 9.6:** Percentage of agricultural land lost under projected SLR for a number of vulnerable countries –Chen et al., 2009. [MLH: can we make this into an R graphic and even better if we had more recent numbers...]

(The World Bank, 2021) meaning the price of a staple food like rice rising could have disastrous implications for the average Burmese person.

## 9.7 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., 2018a&Twihi). 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 MyanmarâŽs rice farmers over the last 50 years.[MLH: new paragraph?] Flooding is not uncommon in Myanmar, in fact, it is expected and it integral to agricultural practices that help to sustain MyanmarâŽs economy. The climate of Myanmar is tropical monsoon, and its flood climate is 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)[MLH: repetitive], 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). MyanmarâŽs unique geomorphology has a large effect on the way in which flooding occurs in the country.

La [MLH: NiÃša], the cold phase of the El NiÃšo-Southern Oscillation (ENSO) cycle, heavily

**Figure 9.7:** 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

influences flooding in Myanmar. The wettest conditions and most extreme weather are often associated with La Niña years in Myanmar. In addition to La Niña, 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)[MLH: explain? or we put this into the monsoon chapter that I started...] 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.

[MLH: image file is missing, I commented out the line]

## 9.8 Cyclone Nargis

Cyclone Nargis was a Category 3 tropical storm that struck Myanmar in May of 2008. [MLH: As low pressure storms, cyclones are similar to typhoon in the western Pacific and hurricanes in the eastern Pacific and western Atlantic. And Cyclone Nargis was particularly destructive to Myanmar??] 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). [MLH: In May 2008, Cyclone Nargis wreak havoc in the Ayeyarwady...?] 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 [MLH: km<sup>2</sup>] 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).

## 9.9 Conclusion

[MLH: this is odd to have the entire thing repeated, not sure why – might be something to work with Nora about.]



# Chapter 10

## The Political Ecology and Economy of Rice in Myanmar

LUCAS FLORSHEIM

### 10.1 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 country's 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 county'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 Myanmar's government on the future of the country's rice production in the era of climate change.

## 10.2 Climate and Rice Production

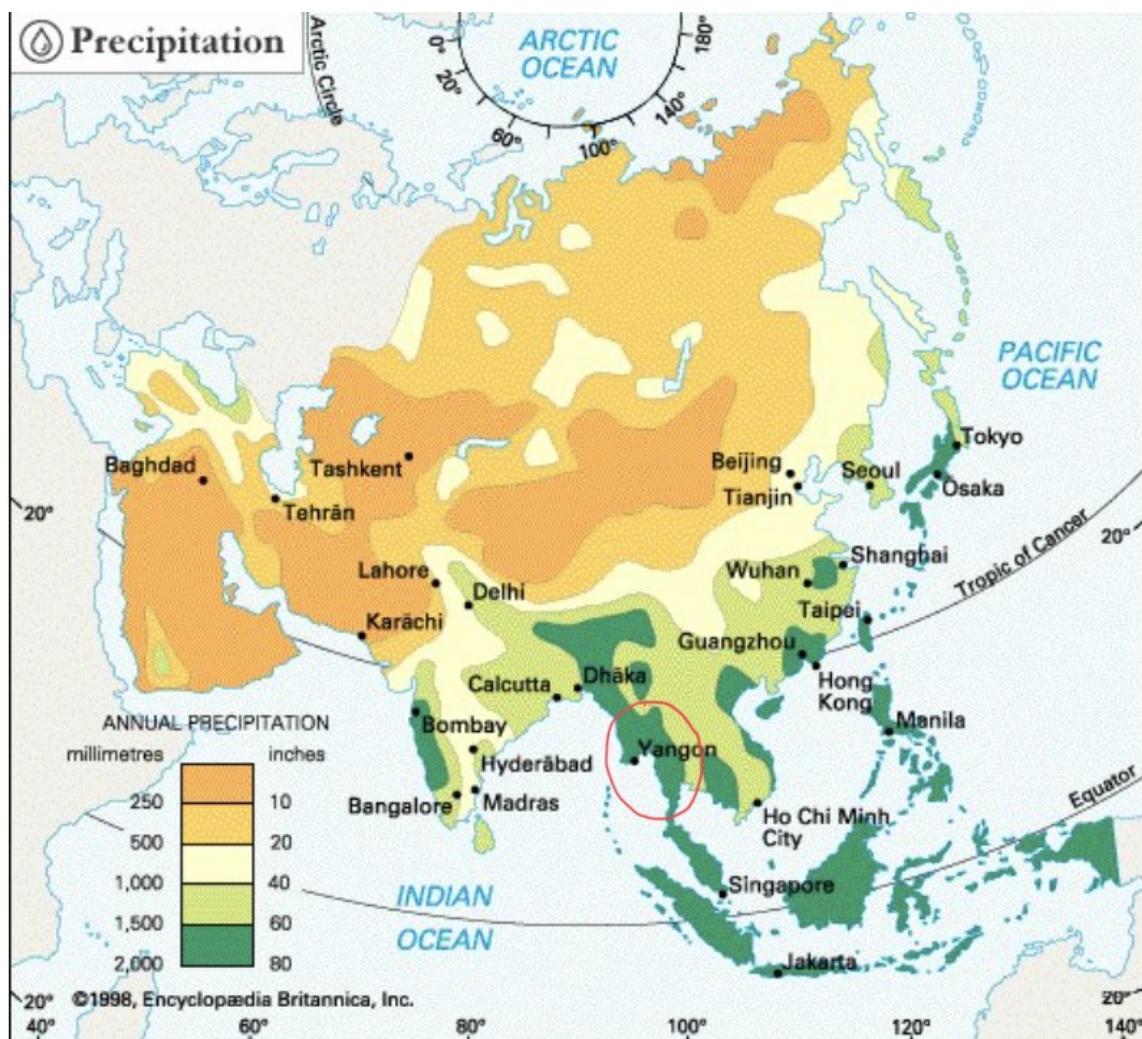
Being one of the largest countries in Southeast Asia, Myanmar experiences several different climates, varying greatly based upon region. The most northern parts of the country feature humid subtropical climate with hot and humid summers and mild winters. The Northeastern part of the country experiences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

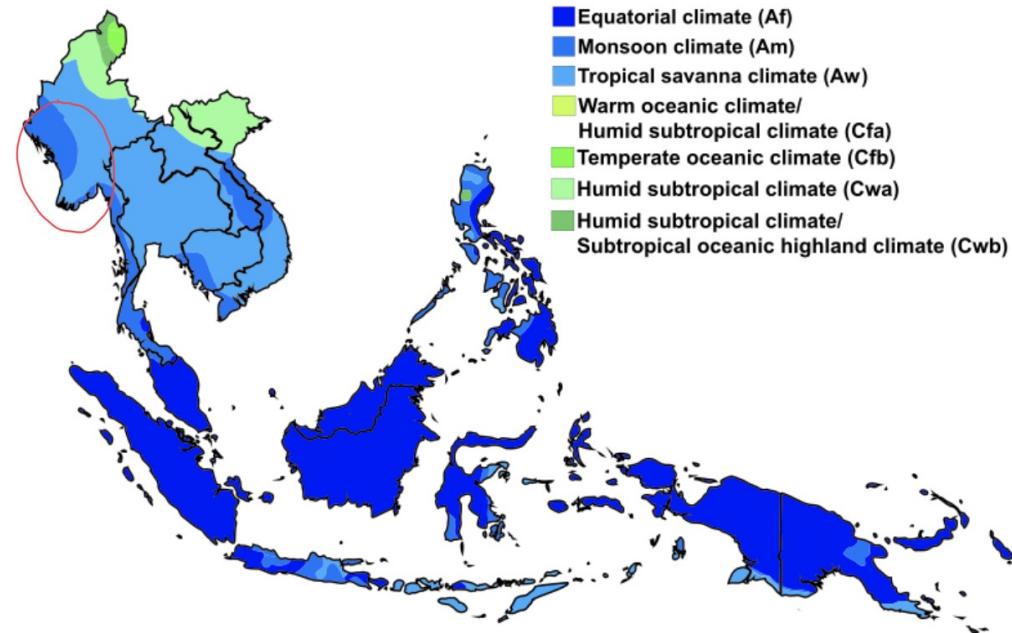
The Irrawaddy delta is responsible for 68% of Myanmar's rice production (Brackenridge et al., 2016). River basins and deltas are the most ideal for rice agriculture, as fertile sediment deposited by water, known as alluvial soil, is naturally provided, and monsoon rainfall is prevalent in such floodplains. (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.

## 10.3 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 10.1:** Average annual precipitation in Asia, the rainfed rice-producing region of Myanmar is circled in red



**Figure 10.2:** 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 farmerâŽs 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.

## 10.4 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 MyanmarâŽs government sponsored a project called the Whole Township Paddy Production Program (WTTP) 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 WTTP introduced new grains classified as high yielding varieties (HYVs) which were intended to completely redefine the limits of the countryâŽs 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



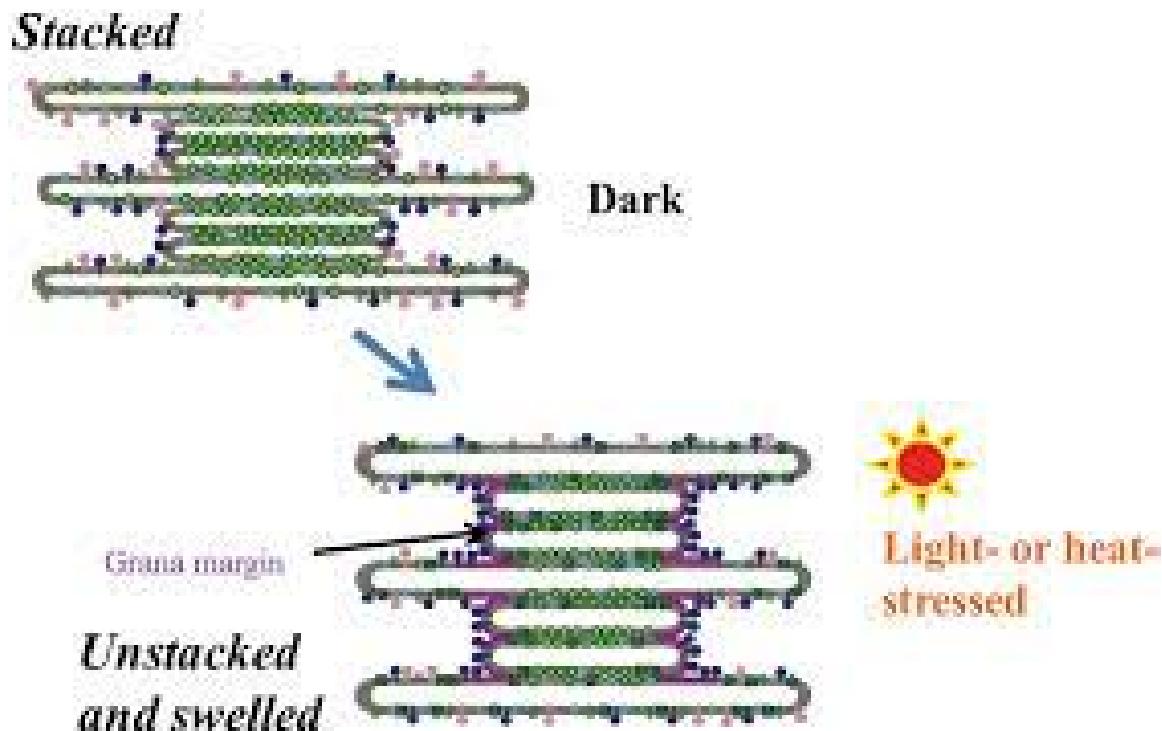
in irrigation have both contributed to an extended crop season, as well the ability to plant several crops on the same farm simultaneously, known as multiple cropping (Naing et. al, 2008). While rice production increased in the years immediately following the use of HYVs and launch of WTPP, the growth 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 Myanmar's economy (Kurosaki, 2008). Myanmar's 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 Myanmar's 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).

## 10.5 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 Thailand's Development and Coordination Center for Global Warming and Climate Change, and the Southeast Asia START Regional Center, an environmental organization founded by the National Research Council of Thailand and Chulalongkorn University, created a regional climate modelling system that could be used to predict changes in precipitation and temperature and 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 Myanmar's agricultural economy, extreme weather and sea-level rise are also expected to have a negative effect on rice production in deltas such as the Irrawaddy River Basin (Furuya et. al, 2013). 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.

## 10.6 Increasing Temperatures

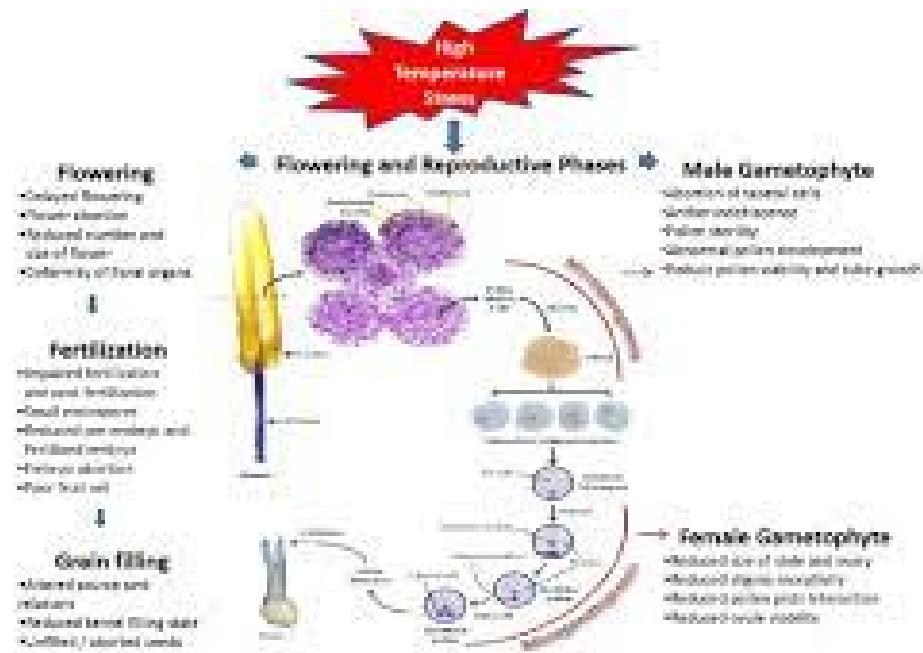
One effect of climate change that has a significant impact on rice production are increasing temperatures. In Myanmar, the warmest months occur directly before monsoon season, from March to June. During these months, the Southern coastal regions of the country experience temperatures well above 36°C,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



**Figure 10.4:** 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  $1^{\circ}\text{C}$  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 plantâŽs production cycle. The growth rate of rice increases linearly as temperatures increase from  $22^{\circ}\text{C}$  to  $31^{\circ}\text{C}$ , 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  $35^{\circ}\text{C}$  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).

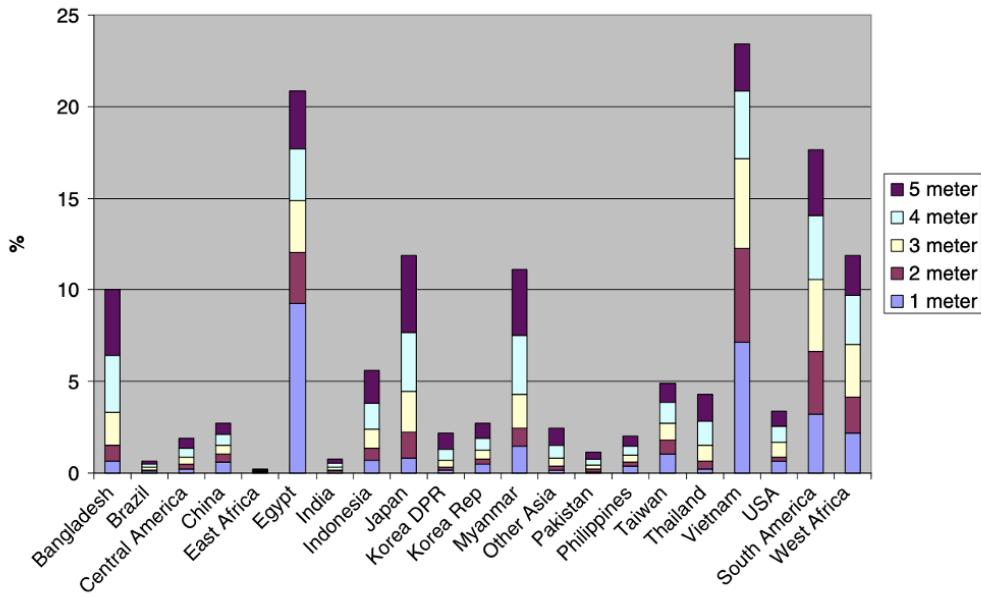
During the reproductive stage the meristem, the tissue on the tips of roots and shoots that is responsible for the production of new cells, begins producing flowers. It is during this phase when rice plants experience spikelet sterility because of high temperatures (R. Wassmann et al., 2009). Spikelet 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 10.5:** 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 Myanmar's 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 10.6:** Percentage of agricultural land lost under projected SLR for a number of vulnerable countries –Chen et al., 2009.

## 10.7 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., 2018a). Although monsoon rainfall is integral to plentiful rice production, excess precipitation and flooding related to tropical storms and monsoons can also be detrimental rice production. For example, floods tied to monsoon rainfall during a La Niña episode in 2003 led to a 14% decline in rice exports the following year (Brackenridge, 2016). 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 Myanmar's rice farmers over the last 50 years. Flooding is not uncommon in Myanmar, in fact, it is expected and integral to agricultural practices that help to sustain Myanmar's economy. The climate of Myanmar is tropical monsoon, and its flood climate is 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). Myanmar's unique geomorphology has a large effect on the way in which flooding occurs in the country. There are two main types of flooding in Myanmar. The first type has to do with the way in which monsoons and tropical storms hit river deltas hard, triggering river plains act as runoff generators (Kravtsova et al., 2009). This first type of flood occurs when extra-local runoff from wetter parts of the delta upstream flows downstream onto drier floodplains (Brackenridge et al., 2016).

In addition to extra-local precipitation flowing downstream, a second type of flooding occurs when local rainfall concentrates on naturally wetter lowlands, which are often the sites of agricultural fields floodplains (Brackenridge et al., 2016). This is known as pluvial flooding. Pluvial flooding is often associated with large-scale rainfall events like monsoons, and other types of extreme weather as they are caused by high levels of precipitation on already saturated soil floodplains (Brackenridge et al., 2016). Myanmar's unique geomorphology greatly influences precipitation and flood patterns throughout the country. Most of the rivers in Myanmar are classified as anabranching (Furuchi et al., 2009). This means that the rivers are made up of multiple channels with divided flows as a result of sediment build-up. As sediment accumulates in riverbeds the flow of rivers is often diverted into smaller channels (Brackenridge et al., 2016). Over the course of a year these small diversions can result in entire segments of rivers to migrate over 100 meters (Brackenridge et al., 2016). Accumulated sediment and diverted channels cause unpredictable river flow which can be a serious flooding hazard. Throughout the 19th and 20th centuries river embankments and levees were constructed in an effort to protect agricultural land from river channel migration (Hajek and Edmons, 2014). In additions to levees and embankments, reservoirs and dams also influence flood hazards throughout the country. When dams and reservoirs were being constructed throughout the 20th century, flood control and mitigation were not considered. Most of these dams were designed to have a spillway feature, a system in which excess water can pass through the dam in a controlled manner when the reservoir is full (Brackenridge et al., 2016). This spillway design is extremely susceptible to flash floods when the mechanism fails. In addition to issues with spillway dams, large hydroelectric dams also pose flood hazards. (Gupta et al., 2009). These dams trap sediment during floods which in turn creates a sinking delta, a phenomenon that occurs when riverbeds erode due to a lack of delivery of sediment and sink, which increase the risk of flood hazards downstream (Svitiski et al., 2009). Innovations like levees and dams have had moderate levels of success, but when these structures are breached during massive floods, damage is worse than it would be otherwise (Brackenridge et al., 2016). These constructions do not allow for much local flood storage or local flood mitigation, so when these systems fail, they fail miserably. While geomorphology and human construction certainly play prominent roles in causing flood hazards in Myanmar factors such as deforestation, mangrove logging, delta subsidence and sea level rise have been identified as other main contributors to what scientists refer to as temporal flood trends (Brackenridge et al., 2016). In the past, flooding has been measured using stationary analysis, a type of flood analysis that relies on the assumption that variables other than time are nonfactors to streamflow (Nonstationarity of Hydrological records- Bayazit 2015). In the last decade, this type of analysis has come under increasing scrutiny as scientist begin to acknowledge the significance of variables that are influenced by climate change. In Myanmar deforestation, especially of mangrove forests, has destabilized coast lines and made deltas more susceptible to storm surges (Brackenridge et al., 2016), small tsunamis of seawater that flood coastal land (Seekins, 2009). Subsidence, the rapid sinking of land as a result of human activity, has made both coastal land and deltaic agricultural flood plains more vulnerable to flooding (Brackenridge, et al., 2016). Futhermore, rising sea levels have increased the frequency of inundation. All of these factors influence flooding temporally, meaning they cause unprecedeted stream-flow inflections and are greatly influenced by climate change.

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

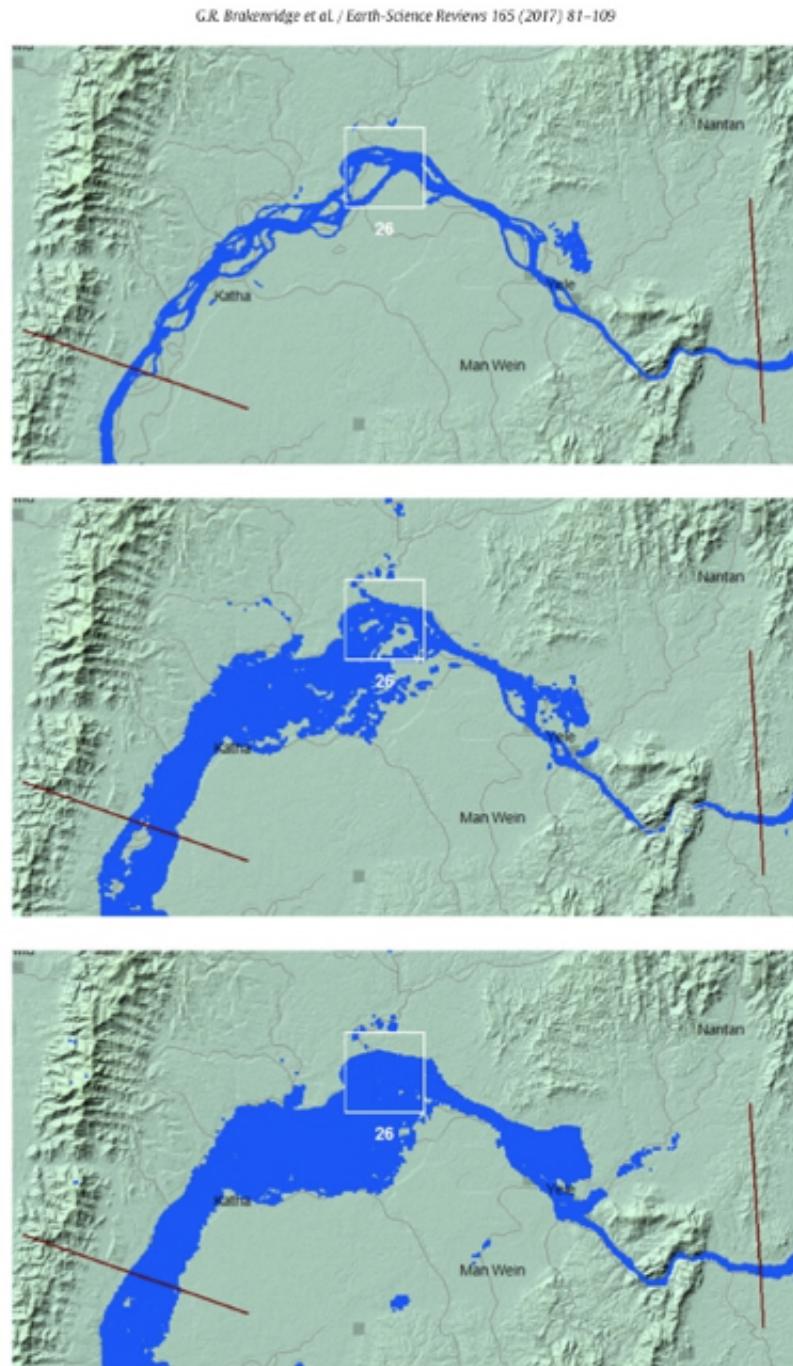
## 10.8 Cyclone Nargis

[MLH: assuming this has some new stuff, starting here]

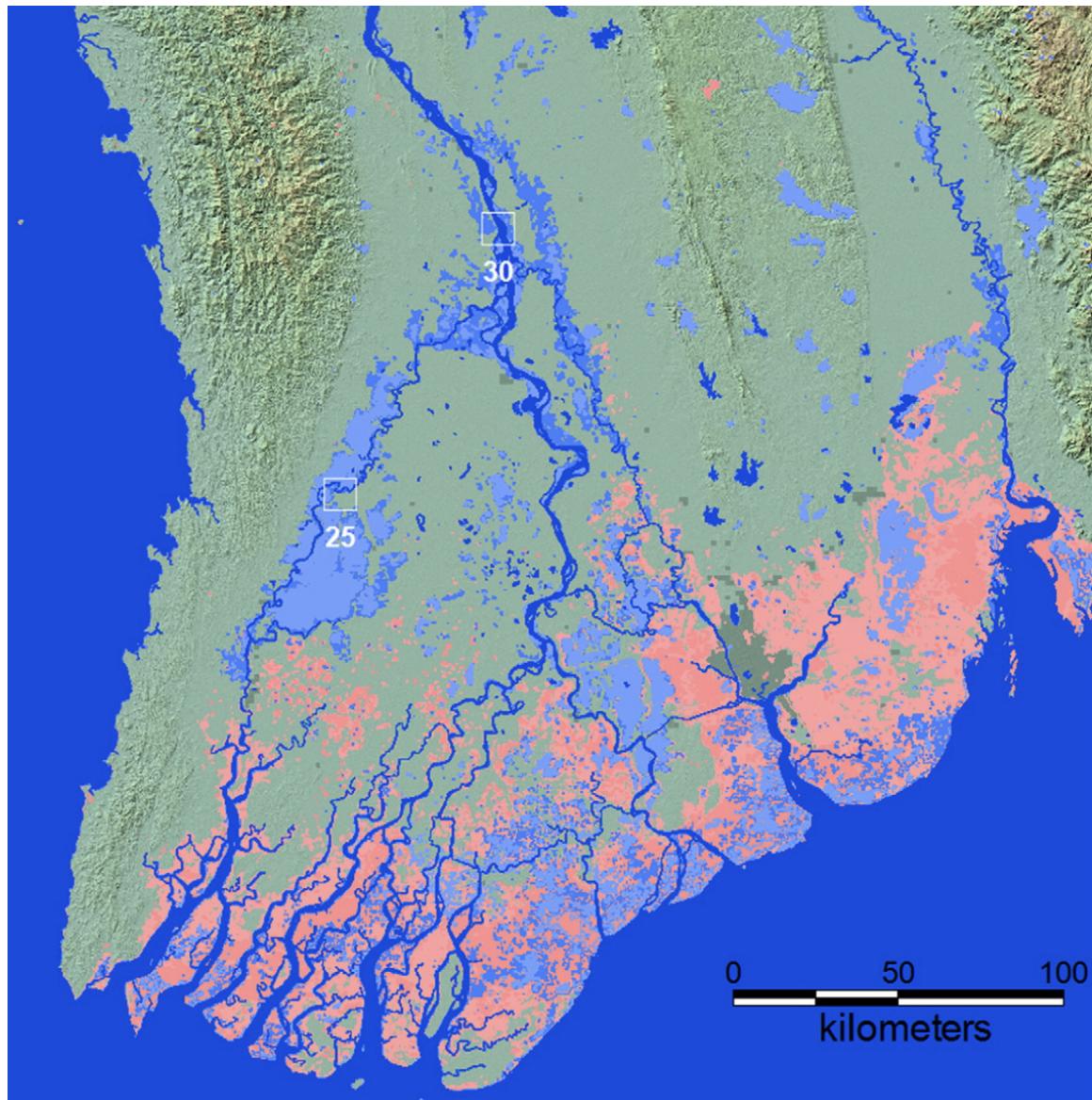
Cyclone Nargis was a Category 3 tropical storm that struck Myanmar in May of 2008. Cyclones are low pressure storms that form in the Indian Ocean and are similar to the typhoons that occur in the western Pacific and the hurricanes that occur in the eastern Pacific and Atlantic (Seekins, 2009). The regions 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[MLH: I wonder if we can get rainfall records to document history of extreme event in this basin?]. 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).

Nargis is significant to this chapter not only because it had a monumental effect on rice production, but also because it is a prime example of the failures of Myanmar's military government to protect the lives and economic interests of its residents. When Nargis first hit Myanmar, the storm surge flooded approximately 5,200 square km of coastal land and low-lying land, contaminating thousands of rice fields with salt water[MLH: map?]. An estimated 404, 858 hectares of cropland were inundated by saline water (Seekins, 2009). The storm took over 24 hours to pass through and hit the country on the Western side first, before concentrating over the Southern deltaic region and moving North (Brackenridge et al., 2016). The nature of this storm path was a significant factor in the degree of destructiveness of the storm as the movement triggered a counterclockwise rotation along the shallow southern seabeds of the country, resulting in maximum winds up to 118 km/hour (Brackenridge et al., 2016).

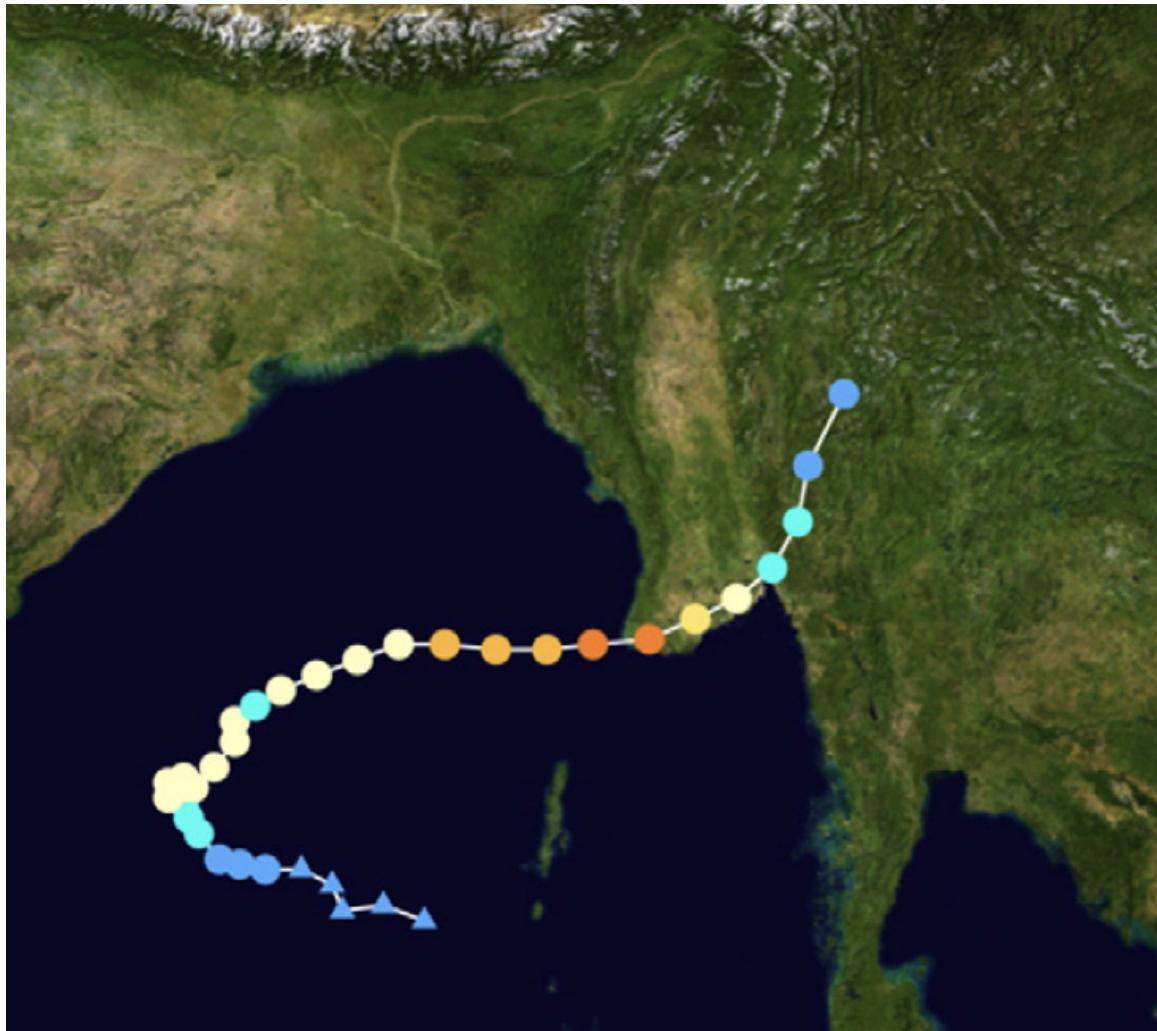
Just like any other major flooding event, population growth, deforestation and human construction were identified as long-term causes of the damage inflicted by Cyclone Nargis (Brackenridge et al., 2016). Although these factors are significant, it is important to consider the role of the government of Myanmar in permitting unsustainable dam construction and deforestation to occur, but it is even more important to analyze the country's disaster response, and to hold the military government accountable for their failures to protect Burmese people. In the days following May 3rd, so much chaos and death ensued that the government of Myanmar stopped counting deaths after the toll reached 138,000 (Brackenridge et al., 2016). Although government officials in Myanmar and weather experts worldwide could predict the areas in the projected path of storm, the government failed to communicate the severity of the storm or highlight evacuation routes to the those living in the communities most affected in the coastal south (Brackenridge et al., 2016). Shortly after the cyclone touched down weak infrastructure was quickly overwhelmed. Storm shelters reached capacity and already damaged roads trapped residents in inundated villages (Brackenridge et al., 2016). Many of the deaths tied to Nargis occurred in the weeks following the storm as people in rural areas did not receive proper aid and began combatting disease and starvation (Seekins, 2009). Cyclone Nargis did not impact all the residents of Myanmar equally. Poor agricultural workers and



**Figure 10.7:** 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



**Figure 10.8:** Inundation as a result of Nargis (red), compared to typical winter hydrology (dark blue) and average maximum monsoon flood events (medium blue). [MLH: It would be great if you can move figures to a directory inside images that I had before.]



**Figure 10.9:** Storm path of Cyclone Nargis

other disenfranchised groups throughout the southern parts of the country bore the brunt of the damage. According to the Post-Nargis Assessment, a project conducted by the Special Association of Southeast Asia Nations (ASEAN), 61% percent of those who died due to Cyclone Nargis and its aftermath were women (Macan-Maker, 2008). Furthermore, thousands of impoverished children were orphaned and had to relocate to cities where they were referred to as "Cyclone Kids." (Seekins, 2009). Many of these children became subject to exploitation in new metropolitan environments, young girls were frequently forced into prostitution and young boys were often recruited into the Tatmadaw, the Burmese armed forces. In the aftermath of the cyclone foreign aid and global responses to the disaster was met with hostility and ignorance by Myanmar's military government. When the United Nations called for over 187 million dollars in relief funds the State Peace and Development Council (SPDC) responded that they would accept foreign aid but wanted absolute control over distributions of supplies and made it extremely difficult for relief organizations to get boots on the ground (Seekins, 2009). As time went on Myanmar's government introduced stricter restrictions on the aid coming into the country. Charity and relief organizations frequently ran into military roadblocks where military forces confiscated food and supplies (Seekins, 2009). The SPDC began facilitating propaganda to discourage organizations from interfering with their response to Nargis. The State-run newspaper "The New Light of Myanmar" declared that the residents of Myanmar no longer needed help obtaining food and supplies because they could get vegetables from the fields and fish and frogs from the creeks (the Irrawaddy, 2008). The corruption and overall inefficiencies that were prevalent in the process of delivering aid remained an issue for different relief efforts and government initiatives throughout the country. The SPDC assigned a government organization called the Union Solidarity and Development Association the task of cleaning up the physical damages to infrastructure in the effected regions. The association quickly devolved into a corrupt and harmful presence in many of the communities they were supposed to rebuild (Seekins, 2009). The occupation of removing debris and repairing structures was often left to be organized by community initiatives (Seekins, 2009)[MLH: when you use the same reference for a whole paragraph, then you might make the subject the "source", so you can highlight the source w/o having to cite very sentence with the same person]. Over the following weeks the international spotlight on the crisis dwindled and food shortages and corruption continued. The Los Angeles Times reported that rice was continuing to be exported out of the country even as thousands of residents of Myanmar were starving domestically (Seekins, 2009)[MLH: get the original citation from the LATimes!]. The SPDC responded by saying the country was attempting to generate revenue while prices were up globally (Seekins, 2009). At first glance the occurrence of Cyclone Nargis may seem like a rarity. Large tropical storms usually do not make landing in the Southern regions of Myanmar, especially compared to regions such as Rakhine, which was hit by severe tropical storms 6 times from 1980 to 2000 (Brackenridge, 2016). This being said, an event as severe as Nargis is projected to reoccur increasingly frequently as the climate crisis[MLH: I don't know why, but not sure how crisis works in this context – seems like crisis on top of crisis, is there a better word?] worsens (Brackenridge, 2016). Nargis was extremely damaging to agricultural production in Myanmar, and rice farms in particular were devastated by the event. Much of the agricultural infrastructure that was constructed throughout the 1980s in an effort to improve rice yield was severely damaged or destroyed by the storm. Paddy Land Development Projects 1 and 2, construction projects supported by the World Bank and the Asian Development Bank that implemented drainage systems, polders and sluice gates were made all but irrelevant due to damage. (Omori et al., 2020).[MLH: begs the question are these projects ever relevant??] Many of the embankments that lined man-made canals or polders were busted as a result of flash floods (Omori et al., 2020). Sluice gates, barriers that are used to control river flow were also overrun in the storm (Omori et al., 2020), The very infrastructure that helps sustain high rates of rice production in Myanmar is clearly extremely susceptible to unpredictable

weather in this era of climate crisis.[MLH: would you say inherantly non-resiliant? be an interesting argument! But perhaps as we discussed today, maybe posing as a question is useful??] Robert Brackenridge, the founder of the Flood Observatory at Dartmouth College, claims that reinforced and sustained flood and sediment management will be necessary to prevent future violent floods in Myanmar(Brackenridge, 2016). Is this sustained management possible considering the political history of Myanmar?

## 10.9 Political History of Rice in Myanmar

## 10.10 Conclusion

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# Chapter 11

## Tropical Cyclones in the Philippines

IAN HORSBURGH

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

### 11.1 Tropical Cyclones in the Philippines

#### 11.1.1 A Storm is Coming

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

#### 11.1.2 Agriculture and Cyclone Vulnerability?

Rural Filipino farmers are vulnerable to tropical storms in part due to their integration into worldwide markets. In particular, famine is often a product of the conditions surrounding access to food. “Famine must be seen not as an absolute scarcity of food in particular regions, but rather as a loss of one’s [MLH: fix apostrophe] entitlements [MLH: does the word have a different meaning than to US uses?] to food and/or the means of subsistence,” writes Warren (2018). As for Filipino farmers, this loss of entitlement goes back to the colonial era. Throughout history, rice has been a staple crop

in the Philippines. Due to the favorable and temperate climate, Fillipino farmers were able to harvest rice twice a year, while simultaneously planting root crops such as sweet potato. When typhoons “created severe food shortages for those who grew rice, these root crops became...the *åÄÝ[MLH: look up how to do quotes and apostroshe's in LATEX, you have it right in some sections..., the problem for me when I cut and paste in to Rstudio]refuge of the poorâŽ*” (Warren, 2018). However, in the nineteenth century, this dynamic began to change. Spanish colonization of the Philippines began in the 1500[MLH: åÄŽ]s, although major agricultural change, especially as it relates to globalization and integration into market economies started in the early 19th century. This began with “the Spanish practice of rewarding the Catholic orders for their conversion efforts with land,” which “turned the church into the largest landlord in the islands” (Ventura, 2016). Spanish catholic landlords then divided up their land, and under this system, “Inquilinos (tenant landlords) paid annual rents for lands they then subdivided among sharecroppers, who often further subdivided their portions, which would be worked by families living in a central town near the fields” (Ventura, 2016). [MLH: any figure could break up the text here] This system was a major step towards the integration of Filippino farming into the global economy, due to the fact that ”as estates commercialized, they increasingly shared management with Chinese-Philippine mestizo businessmen,” who had access to British capital (Ventura, 2016). When America resumed colonial control following their defeat of Spain in the Spanish-American war in 1898, there were a number of changes to this system, but integration into global markets continued. At the beginning of the United StatesâŽ rule,[MLH: super interesting!] the new leadership feigned effort to give farmers independent ownership over their land, but just two years later abandoned this effort, apocryphally citing lack of interest in this initiative by the peasants (Ventura, 2016). Former president William Howard t[MLH: T]aft, the civilian governor of the Philippines from 1901 to 1904, then changed direction entirely, saying that “easing the homestead lawâŽs limitations on corporate ownership to 2,500 acres[MLH: ...is better spacing]...was a much better path to development.” Following this reversion to a similar corporate control as implemented by Spain, “prevailing inequalities of landholding and rural wealth during the Spanish period multiplied under US rule.” Ventura (2016) summarizes the issue, saying that the United StatesâŽ “failure to establish independent homesteads was akin to other alleged shortcomings in hygiene and sanitation, education, and banking, thus justifying the US presence in the islands,” and consequently “ownership for large scale plantation agriculture.” US Civil Service Advisor Roy Franklin Barton talks of the American reforms in the agricultural region of Ifugao, describing how the new “availability of wage labor jobs” makes way for “the introduction of money into the province replacing the old rice currency,” and thus “the integration of a market economy” (Klock, 1995). Thus, Spanish and American policies in the Philippines transitioned the country from local to large scale plantation agriculture.[MLH: add a line if you want a new paragraph] This incorporation into large scale plantation agriculture and world trade had large impacts on the vulnerability of the area to natural disasters, such as typhoons “There is persuasive evidence that peasants and farm laborers became dramatically more pregnable to natural disasters after 1850 as their local economies were violently incorporated into the world market,” writes Davis (2002). “The vulnerability of tropical agriculturalists to extreme climate events after 1870 was magnified by simultaneous restructurings of household and village linkages to regional production systems.” In refuting claims that farmers chose to adopt to this new age agriculture because it provided a better life, Davis argues that åÄIJRecent scholarship confirms that it was subsistence adversity (high taxes, chronic indebtedness, inadequate acreage, loss of subsidiary employment opportunities, enclosure of common resources, dissolution of patrimonial obligations, and so on), not entrepreneurial opportunity, that typically promoted the turn to cash-crop cultivation.åÄÍ[MLH: great quote, need page number] This cash crop cultivation became the primary type of farming in the Philippines by the mid 19th century, and even farmers who still owned land were increasingly “encouraged to plant cash crops of abaca,

copra, tobacco and sugar, and were often forced to sell rice below market prices”(Warren, 2018). By the 20th century,much of the rice still produced by the Philippines was exported to China, while poor Filipinos lived “almost exclusively on imported rice, tubers and corn” (Warren, 2018). Thus, rather than the pre-colonial model of growing rice and root crops, a model that was fairly robust in the face of typhoons, farmers in the colonial Philippines who were encouraged to grow cash crops and buy imported rice, as well as those who now worked plantations for a wage, were left with no money and thus no food when cash crops were wiped out by typhoons. As many cash crops rely on long fertile growing seasons for harvest, and thus were much more easily disrupted by storms, “subsistence farmers, who increasingly chose to cultivate cash crops, counting on a better standard of living,[MLH: can you make a diagram of this? maybe not, just think about it] often found they had no visible means of sustaining themselves, because of the âĂŹeconomic predicamentâĂŹ triggered by typhoons,” writes Warren (2018), again. Thus, in the shift from a diversified to monocrop economy, agricultural, and thus economic disaster became “a fact of life” In sum, as colonial powers such as the United States and Spain implemented policy that shifted Filippino agriculture toward cash crop cultivation within worldwide markets, and away from a local multicrop system, the country became more vulnerable to typhoons.[MLH: really interesting history!]

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

### 11.1.3 Ready or Not

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

[MLH: to reference figure... Figure 11.1, bute needs a better reference name!]

### 11.1.4 Philippine Disaster Mitigation

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

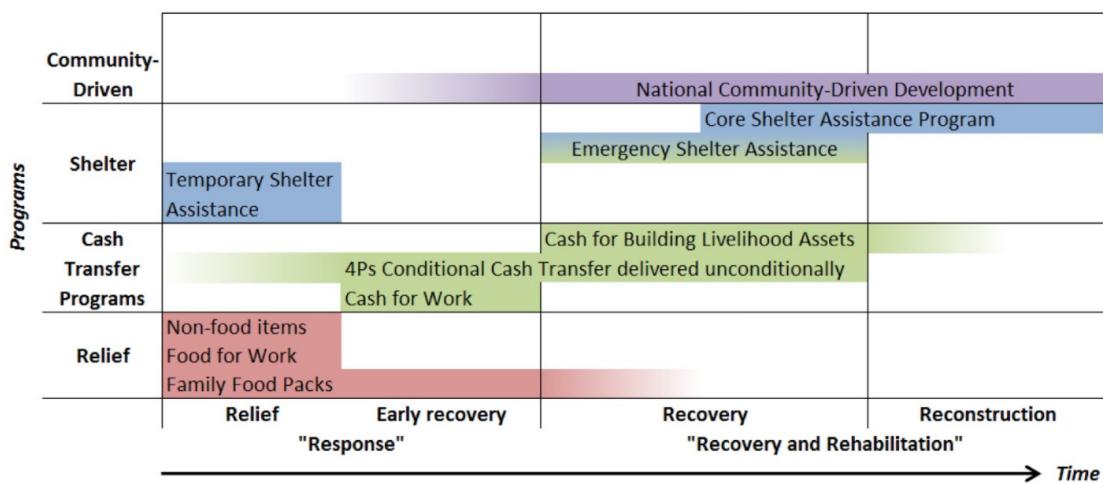


**Figure 11.1:** A Ship is washed ashore in Tacloban City [MLH: let use a more descriptive label remember there are 16 chapters! also need to be one word or hyponated word.]

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

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

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



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

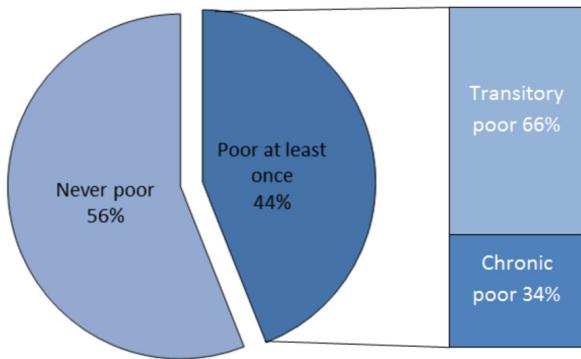
**Figure 11.2:** DSWD Relief Programs

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

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

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

Figure 3: Poverty Status 2003, 2006, and 2009



**Source:** World Bank (2014), Country Partnership Strategy for the Republic of the Philippines for the Period FY2015-2018, p 4

**Figure 11.3:** [MLH: change the reference label to something more descriptive and then we can use a reference in the text.]

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

mitigate the damage caused by future storms, the country must invest in protecting natural features such as mangroves, coral reefs, and coastal dunes, as well as strengthen education programs on tropical cyclones.

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

### 11.1.5 A Changing Game

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

### 11.1.6 Tropical Cyclones and Climate Change

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

To represent how these tropical cyclones operate, climate scientists often employ the Carnot Engine model, a theoretical thermodynamic cycle that provides an upper limit on how powerful a storm can be (Emanuel, 1987). The model depicts fluid [MLH: air is modelled as a fluid, but I wonder if readers will get that? and why?] that performs work (a measure of energy transfer that occurs when an object is moved) on its surroundings while undergoing four stages, the fourth of which returns to the first, making it cyclic. [MLH: is there a figure that shows this? Are there some equations that might demonstrate how the model works? I wonder if we can create a little simulation? <https://www.researchgate.net/figure/Carnot-cycle-Figure-5-Structure-of-a-hurricane-Air-is-cooled-through-convection-1042333>

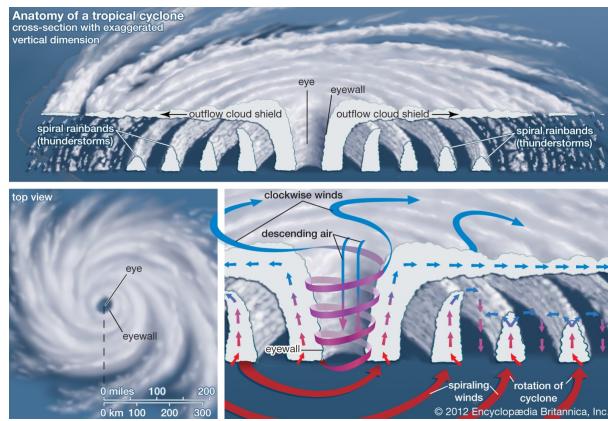


Figure 11.4

[fig1\\_323693275](#) In the case of a cyclone, this fluid takes the form of a mixture of dry air, water vapor, and suspended condensed water, all of which are in thermal equilibrium (the same temperature). However, as the ocean and the atmosphere are in thermal disequilibrium (not the same temperature), the ocean loses heat to the atmosphere by evaporation of water, which has a large heat of vaporization ([Emanuel, 2006](#)). [MLH: this is super interesting and deserves more space if you can figure it out!] The carnot cycle uses this heat flow as an input to estimate the maximum power output that could be produced if the storm was perfectly efficient. Although this perfect efficiency is impossible, the carnot cycle is useful to give an upper bound on storm power, operating as described in figure 10.5.

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

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

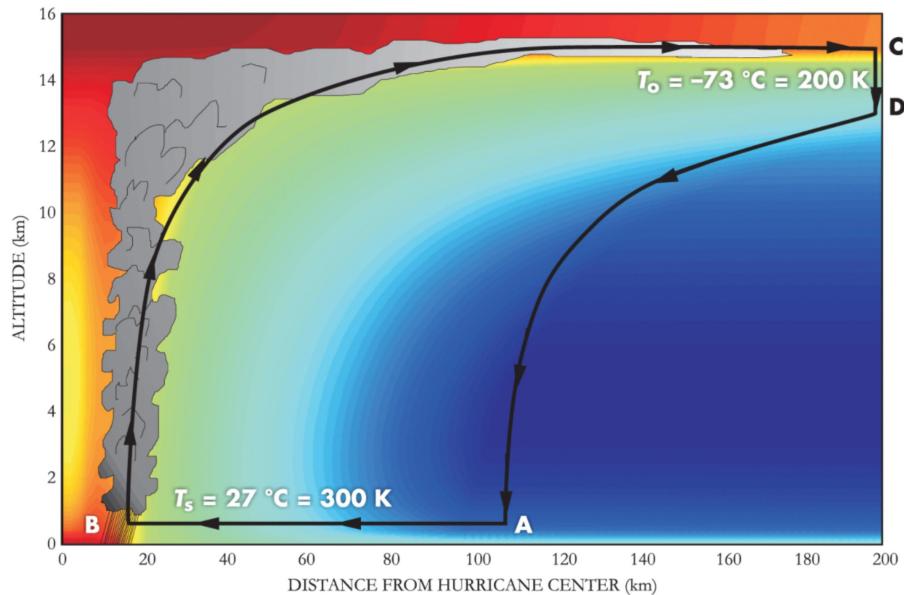


Figure 11.5

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

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

A quick refresher in calculus: the integral represents the area under a curve, so in this case the curve would be a graph of the maximum sustained wind speed of a storm over time (Velocity cubed), and the integral of  $V^3$  would be the area under this curve starting at the beginning of the storm  $t_0 = 0$ , and ending at time  $t$ . This is shown by the 0 and  $t$  at the bottom and top, respectively, of the integral symbol. [MLH: great!, can we create a simulation and show PDI as it relates to  $t$  or  $v$ ?] A simplification of a previous statistic that was problematic as it input data[MLH: what is the input data needed? I assume that  $t$  and  $V$  are not enough?] that was seldom recorded, Emanuel (2005) notes that “this [new] index is a better indicator of tropical cyclone threat than storm frequency or intensity alone.” Because it does well to estimate the damage of tropical cyclones, only requires one input[MLH: but not measured?], and is easy to evaluate, it is often used to represent tropical storm damage. Using PDI to gauge storm intensity, numerous studies conclude that tropical cyclone intensity will increase under climate change (Zhang et al., 2017), (Emanuel, 2013), (Chen et al., 2021). To apply physics to large scale climatological events, scientists use climate models, which divide up the earth’s surface into grid cells, and use complex equations based on fundamental laws of physics, fluid motion, and chemistry to describe how energy and the materials within the grid move through it (NOAA, ???). A visual of this type of model is given in the figure below.

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

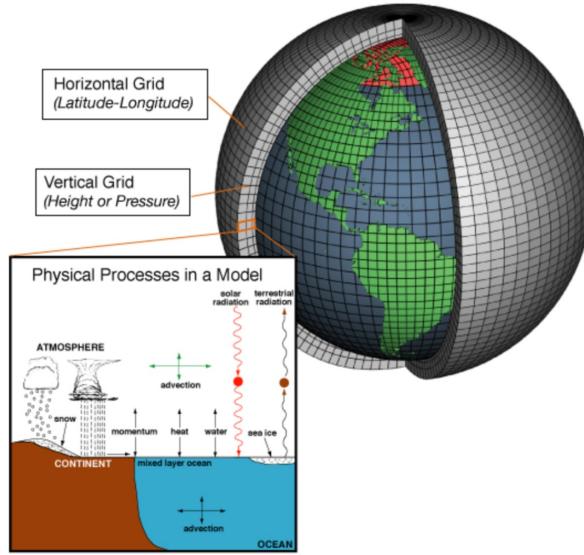


Figure 11.6

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

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

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

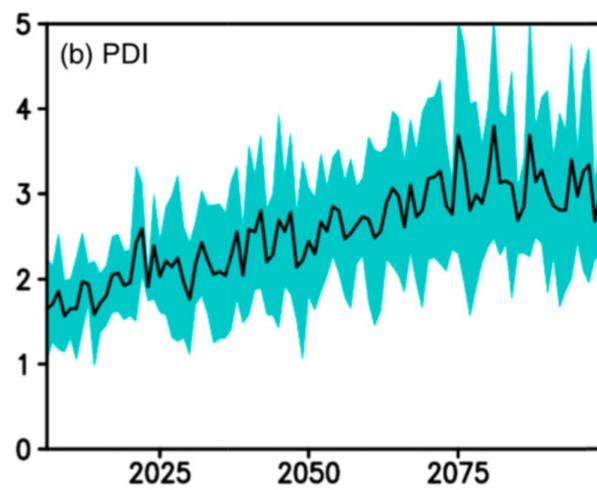


Figure 11.7

## Chapter 12

# Climate Infrastructure in Vietnam

### 12.1 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

### 12.2 Conclusion

Implications for other places in the region



# Chapter 13

## Coral Reefs, Ecosystem Services, and Indigenous Peoples

DAVID CHENGWEN GORMAN

### 13.1 Coral Reef Ecosystem Functioning and Interactions

#### 13.1.1 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. Of these millions, marginalized groups like the indigenous peoples of Southeast Asia are affected disproportionately. Reef destruction will severely harm both the livelihoods and sovereignty of the Sentinelese and other groups like them.

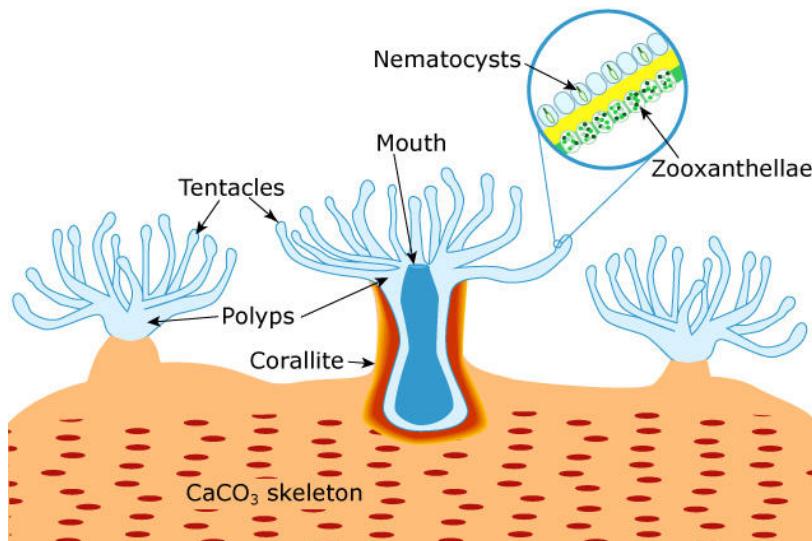
The coral reefs have become vital components of many Southeast Asian, coastal communities and indigenous groups alike. This fragile, colorful marine ecosystem boasts high levels of both biodiversity and biomass, which are vital to both reef survival as well as the millions worldwide dependent on reefs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

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

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

### 13.1.2 Coral Functioning

Coral is composed of tiny animals referred to as polyps. Hundreds of thousands of these polyps work together to build the visible coral structures which comprise reef ecosystems. Each coral polyp uses calcium and carbonate ions that have been dissociated in the surrounding water to create calcium-carbonate (limestone) skeletons (Figure 13.1). 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. These nematocysts are commonly observed on sea anemones, which makes sense, as coral polyps are part of the same family Anthozoa. Most species of coral are extremely slow growing, and the majority grow by less than an inch every year ([CORAL, 2021](#)).



**Figure 13.1:** This simplified diagram illustrates the anatomy of each coral, its skeleton, and symbiotic zooxanthellae relationship. The mouth of each coral polyp is surrounded by tentacles, each full of stinging nematocyte cells. The zooxanthellae inhabit the tentacles, and, along the coral, use the limestone skeleton underneath for protection. Hundreds of thousands of these polyps comprise a single visible coral, all working sharing the same calcium-carbonate skeleton ([NOAA, 2019b](#)).

The majority of corals, and the ones more essential for the construction of the reef ecosystem, are classified as hard corals. These corals are reef-building corals, or hermatypes. They create the calcium carbonate skeletons which support the coral reef ecosystem. 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 stronger, 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 eukaryotic cells called dinoflagellates, more commonly referred to as algae. This grouping of small, photosynthetic algae live inside the coral skeletons and maintain a close, interactive relationship advantageous to both species referred to as symbiosis. The algae symbionts within the corals 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](#))

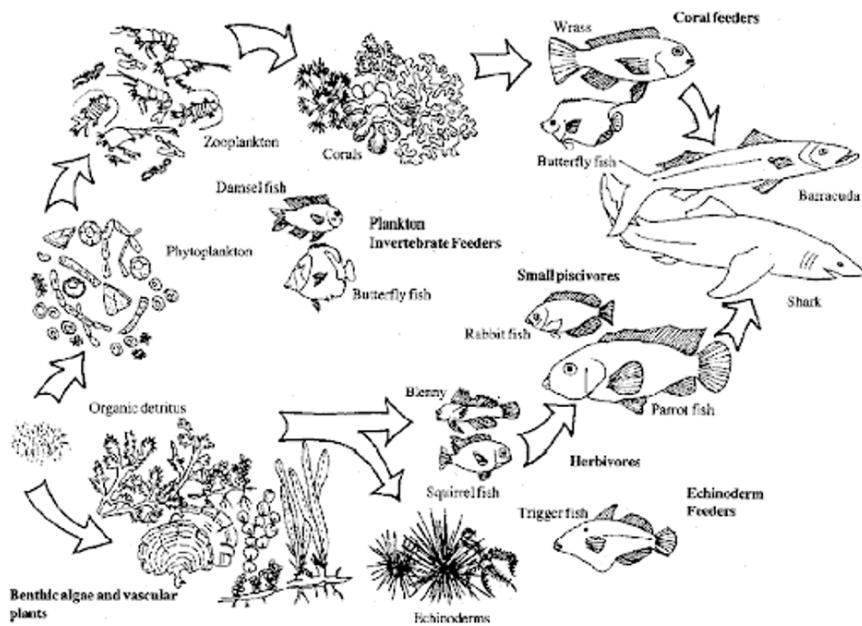
Corals are incredibly slow growing, as they require a delicate balance of nutrients and environmental conditions. Both nutrient influxes and nutrient deficiencies interrupt the coral-zooxanthellae symbiosis, hurting both species. Most species only grow between 0.2-1 inch per year. A reason for this slow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

All coral reproductive processes are affected by the water temperature, time of the year, tidal cycles, and lunar cycles, and they 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. This hard surface provides the polyps with a sturdy base and protection, and the corals can begin dividing and making genetic copies of themselves. They then can begin secreting the calcium carbonate skeleton, which in turn attracts zooxanthellae seeking protection, 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.

### 13.1.3 Reef Organisms and Trophic Interactions

The coral reef food web (Figure 13.2), or the relationship between successive trophic levels of the community, starts as any other food web, with energy being derived from the sun by primary producers via photosynthesis. These primary producers include seaweed, grass, phytoplankton, and perhaps most importantly, the zooxanthellae coral symbiontes. 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 13.2:** Food webs like the one displayed above illustrate the many different feeding interactions within the reef ecosystem. No food web can be completely comprehensive, as the reefs are home to thousands of different species, all interacting with each other. Species may fall into multiple trophic levels depending on their diet and feeding interactions. Food webs like the one shown above provide simplified examples of the feeding relationships and energy transfers within the ecosystem. ([McClanahan and Muthiga, 2016](#)).

A wide range of species in the reef ecosystem depends on coral polyps, thus making them a keystone species. As ecosystem engineers, they provide the entire structure and habitat from many reef-dwelling creatures with their calcium carbonate skeletons. The coral polyps themselves constitute a small percentage of the total biomass of the ecosystem, as the average coral polyp is only around 1.5 cm large, yet their impact is vital to the ecosystem's survival. To the naked eye, observable "coral" includes these skeletons, and the symbiotic algae living within them; the coral polyps themselves make up a significantly smaller biomass percentage as one would perceive.

Many species depend on these coral skeletons for either protection or as hunting grounds. Fish, invertebrate, and other organisms aggregate around these underwater structures, accounting for the ecosystem's dense biodiversity and high overall biomass. Some argue that the Parrotfish is another, secondary keystone species. This herbivorous fish eats algae latched onto the coral skeletons, which blocks sunlight and limits the photosynthetic abilities of the zooxanthellae. In a sense, its mutualistic niche is to "clean the coral," allowing normal function to continue. The Parrotfish is a highly targeted, overfished species, and because it 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 inter-organism 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



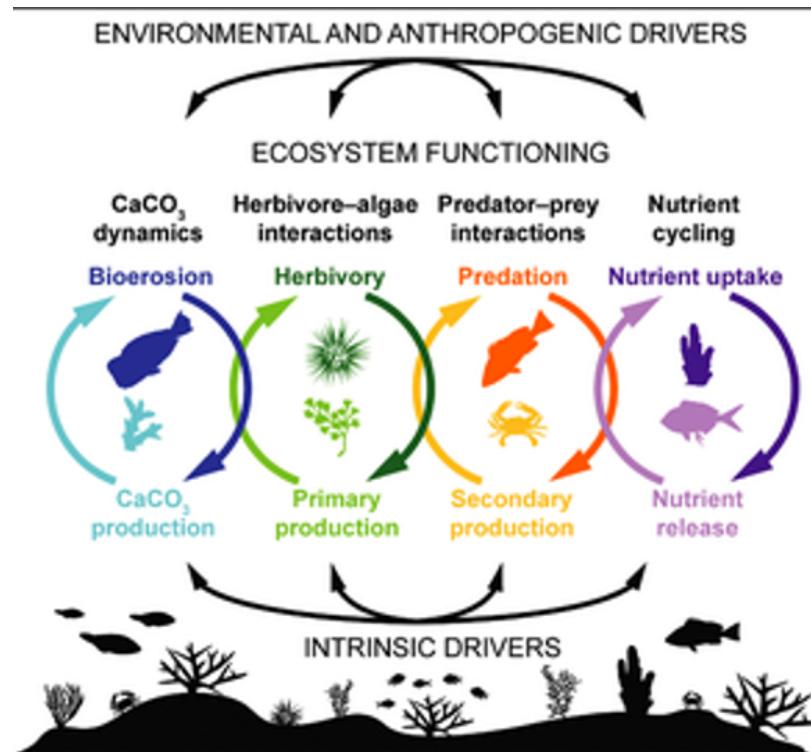
**Figure 13.3:** Pictured above is a seafloor that has been completely overrun by urchins and cannot effectively sustain life anymore. As anthropologic activities influence organism balances within ecosystems, the natural checks and balances systems degrade and certain species may quickly become dominant, seen with the urchins and the creation of these urchin barrens. The simple removal of the urchin's keystone predator, the orange-lined triggerfish, can be enough to cripple entire ecosystems, illustrating the fragile balances within the reef ecosystem ([McClanahan and Muthiga, 2016](#)).

the 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 (Figure 13.3) incapable of supporting life. These predator-prey interactions are disrupted by anthropocentric activities, mainly overfishing. As the fish are removed from the ecosystem at an unsustainable rate, the detrimental grazer effects of the urchins are exacerbated. While negative human influences will be discussed in future sections, this illustrates how interconnected reef species are the delicate equilibrium between them ([McClanahan and Muthiga, 2016](#)).

#### 13.1.4 Necessary Climate and Nutrients

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

The first, blue cycle (Figure 13.4), calcium carbonate dynamics, is directly correlated with the



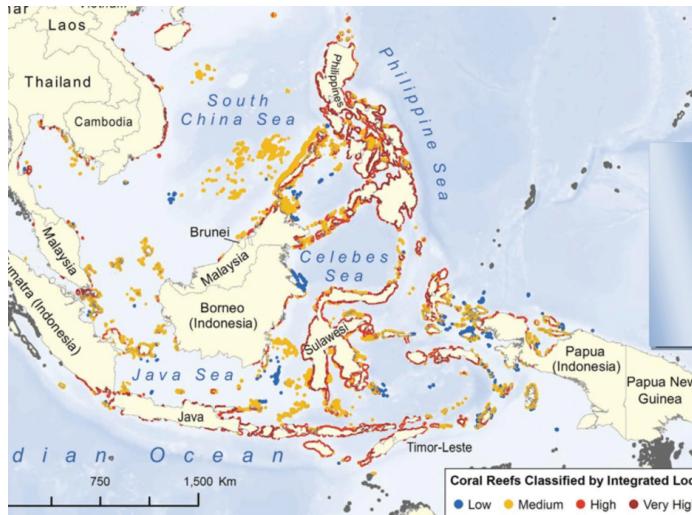
**Figure 13.4:** The above cycles and reciprocal processes are vital for coral growth and survival. They will be further discussed in the following paragraph. Figure from: ([Brandl et al., 2019](#)).

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 (Figure 13.4), herbivore-algae interactions, involves both primary production and herbivory. Photosynthetic organisms transform sunlight into chemical energy, which is then moved up in trophic levels by herbivores. A balance between the two must be maintained to prevent explosive growth of lower trophic levels, which in turn could suppress crucial processes carried out by other organisms in the ecosystem. Predator-prey interactions, the orange cycle (Figure 13.4), also regulate explosive trophic level growth, as successive trophic level limits the prior. Again, the balance keeps the biomass of one species from dominating and smothering other species. The final process driving success within the coral reef ecosystem is the purple cycle (Figure 13.4), 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](#)).

### 13.1.5 Southeast Asian Reefs by Country

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. Many reefs are concentrated in shallow waters surrounding 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 (Figure 13.5). Coral reefs cover 284,300 square kilometers (110,000 square miles) worldwide, yet the overall area of healthy reef is decreasing rapidly ([Spaldin et al., 2001](#)).



**Figure 13.5:** This map not only shows the locations of Southeast Asian coral reefs, but also the relative risk levels associated with each reef. The threat levels are as follows: blue = low, yellow=medium, red=high, maroon=very high. The suggested threat levels describe local threats; global threats like climate change are not accounted for ([Spaldin et al., 2001](#)).

**Table 13.1:** Southeast Asian Coral Reef Size by Country

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%

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. Reefs are spread Southeast Asia accounts for over a quarter of all the worlds coral reefs ([Spaldin et al., 2001](#)).

## 13.2 Climate Change and Its Effects on Coral Reefs

### 13.2.1 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 [13.6.3](#) ([Lyons et al., 2019](#)).

### 13.2.2 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  $16.2 \pm 0.6$  cm rise over the previous 30 years. Of the corals the study surveyed, 86% were under 30 years old, suggesting that the rise in sea level promoted their growth. This phenomenon can be explained by the rise in coral growth accommodation space, as sea level rise increases the vertical space a coral can grow in. As the coral gets closer to the surface, growth is inhibited by temperature, exposure, and sediment, but by increasing the overall depth, growth can occur in a greater area of water. 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](#)).

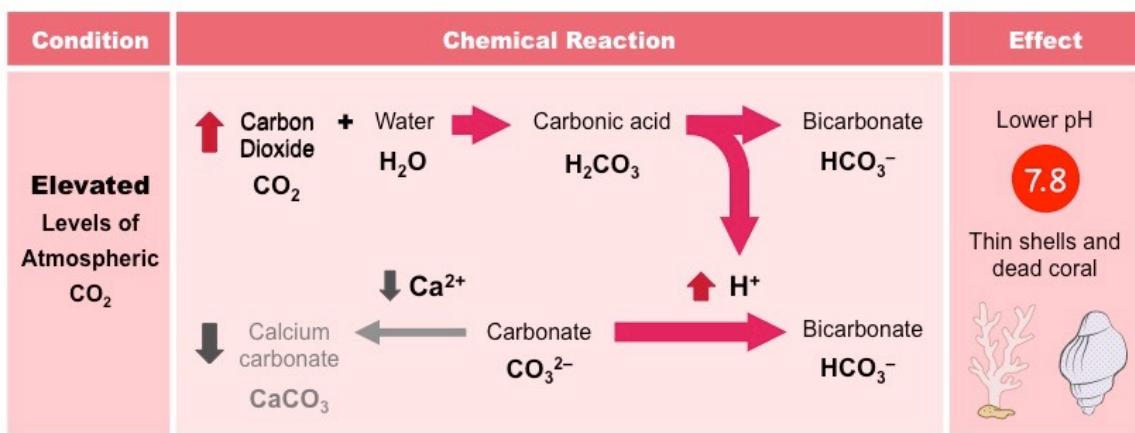
The negative effects of sea level rise on the coral reef ecosystem are relatively unquantified, yet practically accepted as true based on past events and prospective insight. As sea levels continue to rise, they pose risks to coastal regions, with the threat of washing entire communities into the ocean. Such catastrophic events would undoubtedly add sediment and pollutants to the water while also physically damaging corals and other organisms with the marine debris. Community submergence would also displace people groups, 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. The increases storm surge and flooding associated with climate change will most strongly contribute to coastal retreatment. Already, over a million people in over 27 places worldwide have been forced to retreat inward, and this number will only increase incrementally as climate change continues to worsen. ([Sinay and Carter, 2020](#)) 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. As rising sea levels and issues of displacement increase, even benevolent governments struggle to accommodate affected citizens and displaced people groups. These threats to coral reefs may seem distant, but they are quickly approaching realities imposed by climate change ([Keller et al., 2009](#)).

### 13.2.3 Ocean Warming and Acidification

Climate change has already begun to negatively impact reefs in quantifiable ways that can be observed at the molecular level. As greenhouse gases are released and trapped in the atmosphere, they prevent heat escape and also contribute to smog and air pollution. The primary greenhouse gas, carbon dioxide ( $\text{CO}_2$ ), is released in high amounts when fossil fuels like coal and natural gases are burned for energy. Fossil fuel emissions release carbon dioxide into the atmosphere, but a third of the  $\text{CO}_2$  is absorbed by the ocean. The increase in greenhouse gases emissions from fossil fuel burning contributes to both the warming of the planet and the acidification of the ocean([Keller et al., 2009](#)).

As atmospheric carbon dioxide dissolves in the ocean, it reacts with water to create carbonic acid. This carbonic acid then dissociates into bicarbonate, releasing protons in the process. These protons, when added to the water, lower the pH, making it more acidic ([Figure 13.6](#)). Since the Industrial Revolution, a 0.1 pH drop has been observed on the ocean surface, and this drop is expected to increase as global emissions continue and  $\text{CO}_2$  concentrations rise. In more acidic conditions, corals struggle to efficiently create their hard skeletons ([Keller et al., 2009](#)). The carbonate ion saturation, or aragonite saturation, is crucial for skeletal growth, as the carbonate ion is one of the two necessary ingredients needed for 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) Today, up to 60% of reefs 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. The effects of ocean acidification compound on each other. The weaker skeletons stemming from low carbonate ion concentrations cannot adequately protect the



**Figure 13.6:** The above figure outlines the chemical reactions which connect ocean acidification with limestone formation. As carbon dioxide dissociates in the water, it creates carbonic acid, or H<sub>2</sub>CO<sub>3</sub>. The protons of carbonic acid are easily dissociated by the more polar water molecule (H<sub>2</sub>O), thus dissociating and combining to form bicarbonate, or HCO<sub>3</sub><sup>-</sup>. The dissociated protons may also form bicarbonate by reacting with carbonate ions. This chemical reaction removes carbonate ions from the water, which corals need to construct their calcium carbonate skeletons ([Ayala, 2009](#)).

corals, resulting in even lower skeletal production and exacerbating the preexisting consequences of ocean acidification on corals. ([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 13.4.4. Unusually high-water temperatures are the main cause of coral bleaching, and as ocean temperatures continue to rise, mass bleaching events are expected to increase in both frequency and severity([Keller et al., 2009](#)). Ocean warming will have disastrous future effects on coral reefs. In 2018, Intergovernmental Panel for Climate Change, or IPCC, reported that a mere two-degree Celsius rise in temperature could completely eradicate the coral reefs, with an estimated loss of around 99% of reefs worldwide ([Almond and Petersen, 2020](#)).

#### 13.2.4 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. Both species are interdependent and persist in close proximity to each other . They maintain an obligate mutualistic relationship; they cannot survive without each other. The expelling of algae symbionts in response to different stressors is known as coral bleaching (Figure 13.7), 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 this depletion of a singular species shifts the organismal balance of the entire ecosystem. These negative ecological cascades descend throughout the ecosystem. Many organisms' habitats are destroyed as the coral, the keystone species and ecosystem engineers, are removed. The population balances within the ecosystem in turn shift, for the species more directly dependent on corals are disproportionately affected by the bleaching events ([Suggett and Smith, 2020](#)).



**Figure 13.7:** This above split-image shows the same fire coral before (left) and after (right) coral bleaching has occurred. The vibrant colors on the left image result from the zooxanthellae 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 ([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 gained national attention, showing the vulnerability of the coral ecosystem to change on a global scale. These events also demonstrated how climate change will only make coral bleaching more frequent and of greater severity. 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](#)).

## 13.3 Unsustainable Fishing Practices

### 13.3.1 The Live Reef Fish Trade

Unsustainable fishing practices are arguably the most detrimental local practice to Southeast Asian reefs. Over 55% of reefs worldwide are affected by overfishing and unsustainable fishing techniques, and this number is higher in Southeast Asian reefs. Overfishing disrupts trophic interactions, since macroalgae, without as many fish as predators, grow disproportionality and smother corals. An overfishing-driven decline in fish stocks has made fish harder to catch, leading to a shift away from sustainable fishing practices. Unsustainable fishing threatens not only fish stocks and ecosystems, but also local economies and the people that rely on fish for food. The methods currently used to catch live fish, like cyanide fishing or blast fishing, have been incredibly destructive to the coral reefs of Southeastern Asia. Both Indonesia and the Philippines offer textbook examples of unsustainable practices which still persist today, despite efforts to regulate and ban them ([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, kept alive, and later sold. There are two branches of the LRFT: food and ornamental. For the live food fish trade, these live fish are caught and sold as high-priced delicacies. The food trade makes up a majority of the LRFT, as has been continually driven by wealthy Asian countries' affinity for fresh, live fish. 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." The second branch, the ornamental live fish trade, involves the catching of live fish for sale and transport to aquariums worldwide. The vibrant, colorful reef fish are highly desired in aquariums globally, sustaining demand and further fueling the LRFT. ([Fabinyi, 2010](#)).

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

### 13.3.2 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 (Figure 13.8). 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. 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. Around two-thirds of all Filipino reefs are estimated to be 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. In the last six years, only six case files regarding cyanide fishing have resulted in convictions (Pearce, 2003).



**Figure 13.8:** The diver in this picture is cyanide fishing in a Filipino reef. He uses cheap, makeshift gear which can be either made from scrap or 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 (Pearce, 2003).

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 barely enforced. Blast fishing was banned in Indonesia in 1985, yet it still continues today, not only in Indonesia, but also in most other reef-bearing Southeastern countries ([Fox and Caldwell, 2006](#)).

### 13.3.3 Economic Drivers and Indigenous Contributions

A group of indigenous peoples deeply interconnected and dependent upon 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 are not officially recognized and lack legal 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](#)).

## 13.4 Reefs Pollutants

### 13.4.1 Marine Debris and Ocean Contaminants

A significant number of anthropocentric activities contribute to reef pollution. Pollutants can be classified generally in three categories: toxins, sediments, and nutrients. Toxins cause physical harm to corals and other organisms at the cellular level. They can be organic or inorganic and are often found in chemical runoff. Sediments block sunlight and prevent photosynthesis and limit primary production. They also reduce the number of viable locations for coral larvae to attach to, as the loose sediment settles on the previously secure spots on the coral skeleton. Sediment also increases the turbidity of the water, blocking visibility. This can contribute to biodiversity loss, selecting for certain animals which do not primarily rely on eyesight. Finally, nutrients can promote algal blooms which smother corals, or they can disturb organismal balances within the ecosystem, disrupting critical interactions among populations. Excessive nutrient richness, or eutrophication, can also promote pathogenic growth among corals and lead to coral epidemics. A wide range of human activities contribute to reef pollution, 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. (Figure 13.9). Floating trash can bear resemblance to jellyfish and is often consumed by animals, obstructing their gastrointestinal intestinal tract ([CORAL, 2021](#)). 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](#)).



**Figure 13.9:** Plastics and marine debris commonly snag corals and shade them, so that the zooxanthellae cannot adequately perform photosynthesis, and thus starving the corals. Coral engulfed by plastic bags like the one above are highly susceptible to disease, as the plastic bag creates a warm, hypoxic environment that is ideal for pathogen transmission and infectivity. This trash entanglement also may break off chunks of coral, killing entire colonies ([US EPA, 2017](#)).

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

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, substances which reduce liquid surface tension when dissolved, are often used, as they dissolve and break apart large floating sheets of oil into smaller droplets. These dispersants are toxic to coral larvae and can kill large sections of young coral fairly quickly. They also prevent the fertilization of mature eggs and hinder coral maturation, or metamorphosis. Oil contamination and surfactant poisoning are increasing in Southeastern coral reefs, as development has continued to increase in Southeast Asian coastal regions (Shafir et al., 2007).

### 13.4.2 Development, Industrialization, and the Agta People

Many coastal regions in Southeast Asia have seen rapid development in the past couple of decades. This development in itself has negative effects on reefs, as piers and other structures are often

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

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. Despite national legislation ruling against displacement, one Agta group has been involved in a multi-decade struggle, fighting against displacement from their ancestral land, Dimasalansan. They do not legally own the land but instead were given settlement rights in the protected park by the Filipino government. This lack of quantifiable ownership, however, has made it easier for displacement to occur. One standout, displacing developmental project has been the construction of an 82km road through Dimasalansan. This project planned for indigenous displacement, stating that the construction will allow the Agta to adopt “the culture and ways of the (incoming) migrant population” and also that “relocation of livelihood/business and dwelling/camps...shall be formulated.” Developmental projects often justify indigenous displacement by arguing that they are already semi-nomadic and not place-bound, so relocation is relative ([Hagen and Minter, 2020](#)).

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

### 13.4.3 Deforestation and Agriculture

As the aforementioned Agta are continually forced inland, they must find new economic activities to sustain themselves. The most commonly chosen new livelihood is small-scale, swidden agricultural

cultivation. Slash-and-burn technique is used to clear areas for farming, contributing to both deforestation and agricultural issues in the near-coastal forests. Both are contributors of reef pollutants, further harming the already struggling reef ecosystems and the other indigenous coastal groups who still rely upon them ([Persoon and Minter, 2020](#)).

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

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

#### 13.4.4 Coral Diseases

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

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

(Figure 13.9). As certain coral species are more likely to snag plastics than others, plastic-induced pathogens also contribute to biodiversity loss among coral species (Thompson, 2018).



**Figure 13.10:** This picture shows a brain coral that has been infected with black-band disease. The left side of the coral is how healthy coral appears; the right side is diseased. This particular coral disease's name is derived from the black circumferential band in the middle of the coral. As the disease progresses, the band travels along the coral, killing polyps and leaving behind a dying, empty skeleton (seen on the right half of the coral) (NOAA, 2019a).

Though the methods of transmission are well-theorized, the exact pathogenic causes of coral diseases are not well understood. The effects of coral diseases are nevertheless clear. Diseases always present some sort of indicator, including red, black, white, or yellow bands, discolored spots and blotches, or rapid degradation and general tissue loss (Figure 13.10). Coral diseases also cause large coral chunks to slough off, exposing the calcium carbonate skeleton underneath. After the area is exposed, small reef creatures inhabit it, using it for shelter and breeding. This over-colonization thus cannot be regrown with new corals, so instead of only the chunk dying, the entire colony passes with it. Very little treatment is available for coral diseases, as currently, black-band disease is the only treatable disease. Coral diseases pose great threats to reefs, as they are not easily combated and can spread rapidly through entire ecosystems (NOAA, 2019a).

## 13.5 Reef Ecosystem Services

### 13.5.1 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, Alzheimer's, heart disease, viruses, bacterial infection, and more are currently being developed with corals as the centerpiece. One exemplary study conducted by [Tseng et al. \(2013\)](#) found secosteroids and norcembranoids from the coral *Sinularia nanolobata* inhibited carcinogenic skin cell growth in humans. As coral medical research is continually developed, the medical benefits of differing organic compounds in various coral species will likely be discovered. 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](#)).

### 13.5.2 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— $\frac{1}{4}$  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 (Figure 13.11). Thought to be descendants of the Tabon Man (16,500-year-old remains found at 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](#)).



**Figure 13.11:** The 12-15 million indigenous people living in the Philippines make up between 10-15% of the population. 110 groups are officially recognized, yet there are many more who have not been officially recognized by the Philippines' government. Above pictured are the Tagbanua, one of these indigenous people groups of the Philippines. They either spearfish or fish from simple wooden boats like seen above. These boats are used to traverse the shallow reefs and harvest fish, lobster, squid, octopus, and other protein sources. Many other indigenous groups maintain a similar reef-relationship, one consisting of simple fishing practices, and transportation methods ([Capistrano, 2010](#)).

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](#)).

### 13.5.3 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 barrels—every 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. On-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 world's 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 Tagbanua's 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 [13.4.1](#) ([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](#)).

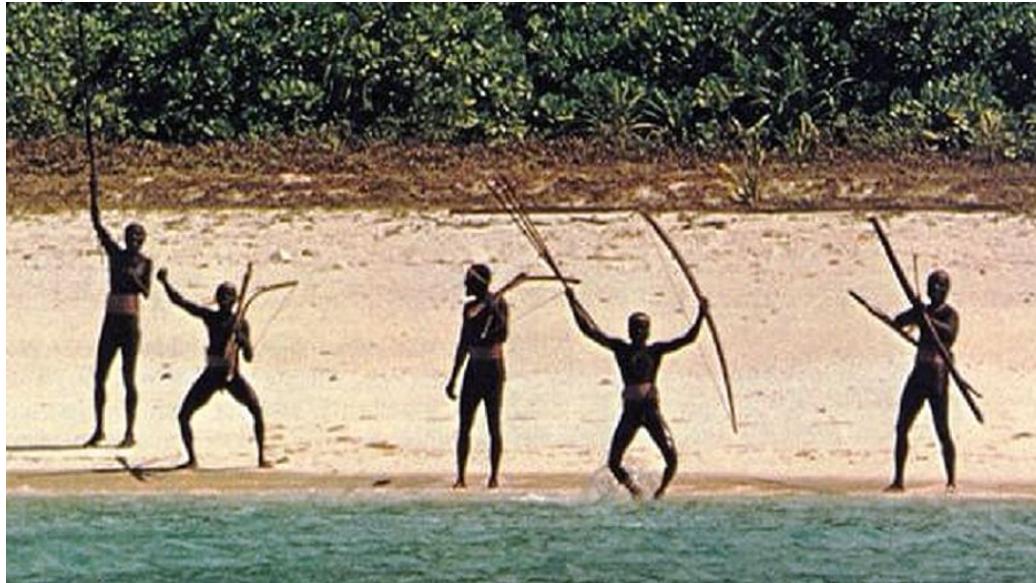
#### 13.5.4 Coastline Protection

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 wave’s 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](#)).

### 13.5.5 The Sentinelese People

Another Southeast Asian indigenous group in close relation with the reefs are the Sentinelese people of the Indian Ocean's 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. The estimated 80-150 people currently living on the island are some of the last untouched native peoples. Their sovereignty is protected by North Sentinel Island's 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](#)).

## 13.6 Reef Restoration, Protection, and Conservation

### 13.6.1 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 reefs 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 (Figure 13.12). During this phase, a hundred colonies can easily become thousands, which are then implanted directly into the reef (Lirman and Schopmeyer, 2021). A newly emerging and highly successful type of coral gardening is microplanning. Newly grown colonies are commonly arranged a few inches apart from each other on a rock-like base and subsequently doused with a growth elixir in a lab. The corals grow up to 25 times faster and connect to form one massive colony, which is then later transplanted into a living reef ecosystem (Morin, 2014).

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 (Figure 13.12). As reef restorative technology has progressed, artificial reef creation has progressed with it. Mineral accretion devices such as Biorock have been very promising and hold great potential. These electrified artificial reefs are essentially metal webs with weak electric current flowing through them, which not only prevents rusting but also causes minerals to precipitate out of the water and collect on the metal. The attached coral colonies can in turn make calcium carbonate skeletons three-to-five times faster than before, as they have an abundance of substrate and easy access to it as well. Mineral accretion devices also protect corals from bleaching and other external disturbances, making them highly effective options for artificial reef promotion. They are expensive and hard to maintain, however. Because of the funding and expertise required, mineral accretion devices are difficult to implement at a local level without an external partner (Scott, 2018).

Reef restoration via EbAs is by no means cheap, but it is a necessary step in coral reef protection and restoration. The benefits far outweigh the costs, for future issues stemming from a lack of coral



**Figure 13.12:** Coral restoration techniques and EbAs often do not fall into a single category but are a mix of multiple. As seen in this picture, this open-ocean coral nursery is also acting as an artificial reef. As the corals are propagated, they will be either transplanted to preexisting communities or remain as an artificial reef, depending on the condition of the reefs in the surrounding water. EbAs must be adaptive to maximize their potential, as the natural world is a dynamic, ever changing system. ([Lirman and Schopmeyer, 2021](#))

reefs will cost more fiscally and harm already struggling populations. EbAâŽs 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](#)).

### 13.6.2 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](#)).

### 13.6.3 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. COREMAP's 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](#)).

## 13.7 Coral Reefs: Conclusion



**Figure 13.13:** Pictured is a healthy Southeast Asian coral reef. Bursting with color and biodiversity, reefs like these support lives for thousands of species, including humans. Reef restoration and protection are crucial to maintaining already thriving reefs like this and also reviving the many degraded reefs of Southeast Asia. Reef conservation will allow these coral reefs to remain rich in biodiversity and continue sustaining the indigenous peoples and coastal communities of Southeast Asia.

From localized threats, like unsustainable fishing and pollutants, to global 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 as well. Pollutants and malpractices must be eliminated, but reefs will also require active restoration efforts, as anthropocentric actions have degraded reefs to the point where they are no longer capable of healing independently. Saving the coral reefs is not saving a few fish species; it is saving millions of organisms and the millions of people who rely on them. Coral reef conservation should not be viewed simply as an ecological issue, but as a complex problem requiring multidisciplinary efforts to achieve success.



## Chapter 14

# Waste Management for a Circular Economy

### 14.1 Life-Cycle

#### 14.1.1 Collection

#### 14.1.2 Transport

Treatment

Disposal

Sectors:

Industrial

Household

Biological

Types of Waste:

Solid:

Liquid

Gaseous waste

### 14.2 Biomimicry

#### 14.2.1 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 15

## Air Pollution & Social Justice in Hong Kong

NEENAH VITTUM

<<<< HEAD

### 15.1 Science of Air Pollution

#### 15.1.1 Overview of the layers of the atmosphere/atmospheric gases

asedfasdf asd fasdf asdf asdf asdf asdf asdf asdf asdf

What part of the atmosphere does air pollution affect?

What is air pollution?

Overview of different types of air pollution

### 15.2 Major Sources → Use as geographical overview

#### 15.2.1 General common sources of air pollution all over the world

#### 15.2.2 East Asian countries/communities and their prominent air pollution sources

Shipping

Traffic Emissions

Commercial and otherwise

Coal

Urban Development

Manufacturing

Other

The transboundary issue and its implications in regulation and politics

Impacts

Human health

Environmental Health

Greenhouse gas emissions and global warming

Both

Visibility

Environmental Justice

Case Study: Hong Kong

The Intersection of Air Pollution and Other Environmental Issues

Many environmental issues are interconnected

Air pollution and deforestation

Air pollution and urbanization/industrialization

Other Issues (To Explore)

Goals/Other Ideas/Questions

Ground information in geography and relevant examples

Incorporate stories and person accounts

slow violence à€š environmental justice issues

Maybe activist or someone who has suffered the issues firsthand

Draw people into the empathy

Use stories and descriptions to describe places

What is the best way to section the chapter? =====

**Figure 15.1:** caption

### 15.3 Opening

### 15.4 A Brief Overview of Hong Kong

### 15.5 Hong Kong's History

### 15.6 Air Pollution in Hong Kong

### 15.7 Air Pollution and Human Health

### 15.8 Population Density, Income Inequality, and Housing

#### 15.8.1 Income Inequality and Zoning Laws

#### 15.8.2 Public Housing

#### 15.8.3 Economic Mobility

### 15.9 Indoor Air Pollution

### 15.10 Open Spaces and Other Patterns of Environmental In-equity

### 15.11 Environmental Activism in Hong Kong

### 15.12 Beyond Hong Kong

### 15.13 Beyond Hong Kong

practicing with Nora »»> be41c24e80529faa7fe0ca3e8da8522beb539373



# Chapter 16

## Unpacking Plastic Pollution and Recycling in Japan

ELEANOR DUNN

→[MLH: this is an example of a right arrow, but I don't recall why I put it in here]

### 16.1 History of Plastic in Japan

[MLH: Great start, Eleanor! Let's see if you can help me with the focus – what are the three main points you want to communicate in this chapter? Yes, three is arbitrary, but let's start there. Use the sections to help you develop that structure and then reflect that in the introduction.]

[MLH: I think the history of urbanization and incineration could be tied... the city is made possible by incineration and waste? or with urbanization, the logic of packaging and incineration was borne (in like 1920?).]

[MLH: I think the Japanese culture values is great and might be able to be used more... but I am not an expert, so let's think about it.]

[MLH: The waste stream includes landfills in most countries, do they no exist in Japan? Can you tell the reader anything about what does recycling mean in the "best case"?]

#### 16.1.1 Introduction

Japan is a unique case study in plastic consumption and pollution in East Asia. Not only is Japan the second largest consumer of single use plastics in the world after the United States citeJohnston 2020 [MLH: here's an example citation that has a key to the bib file (Ref, Year)], but it is also one of the foremost[MLH: how about, "it leads?"] the world... – making it an active verb! recyclers in the world citeMcCurry 2011 with 84 percent of 2018'[MLH: use single quote instead ']'s collected plastic ending up recycled citePWMI 2019. In the face of this impressive percentage, defining what exactly the Japanese government means by "recycling"[MLH: good use of quote symbols!] is significant in revealing the social justice issues associated with this process.

### 16.1.2 Urbanization

Today, 93 percent of Japan's population lives in an urban environment. Japan's rapid urbanization and industrialization began in the late 1800's during the Meiji Restoration. The Meiji government sought to import western industry and technologies and the economy expanded rapidly. Economic growth stalled during the Great Depression.[MLH: perhaps discuss the inter-war period of empire building to support it's economic growth?] After World War Two, Japan's economy boomed once again. The 1960s and 1970s brought particular economic growth. Grocery and convenience stores became ubiquitous, partially due to the importation of US consumer capitalism [MLH: cite]. The "bubble economy" period in Japan was another economic boom from the 80's to the 90's. The late 90s saw the rise of the *Konbini*, a type of convenience store, as well as a shift from reusable containers to single use packaging citeCwiertka 2020. Japan has the third largest packaging market in the world today citeCwiertka 2020. [MLH: nice!]

Waste management became a mounting problem in the face of urbanization.[MLH: perhaps, a long view – global trends in urbanization have...] [MLH: and subsequently, a new problem of where to stick all this waste!] Landfills began to overflow, and illegal dumping caused human and environmental health crises, including the Minamata disease[MLH: explain?] of the 50s citeHCSWM. Japan has the third largest economy in the world despite ranking 63rd citeencyclopedia in land area, creating a situation of high consumption with minimal disposal space, an issue faced worldwide, but exemplified on such a small archipelago. [MLH: passive voice...] It is important to note that a Japanese person throws away half as much garbage as an American citeHarden 2008, so [MLH: could fill in a few blanks here where this blame comes from] despite blame placing rhetoric on East Asian countries for the world's plastic crisis, this issue is global, and more an impact of economic largesse than regional failure.

Figure 16.1

Figure 16.2

### 16.1.3 Cultural Significance of Packaging

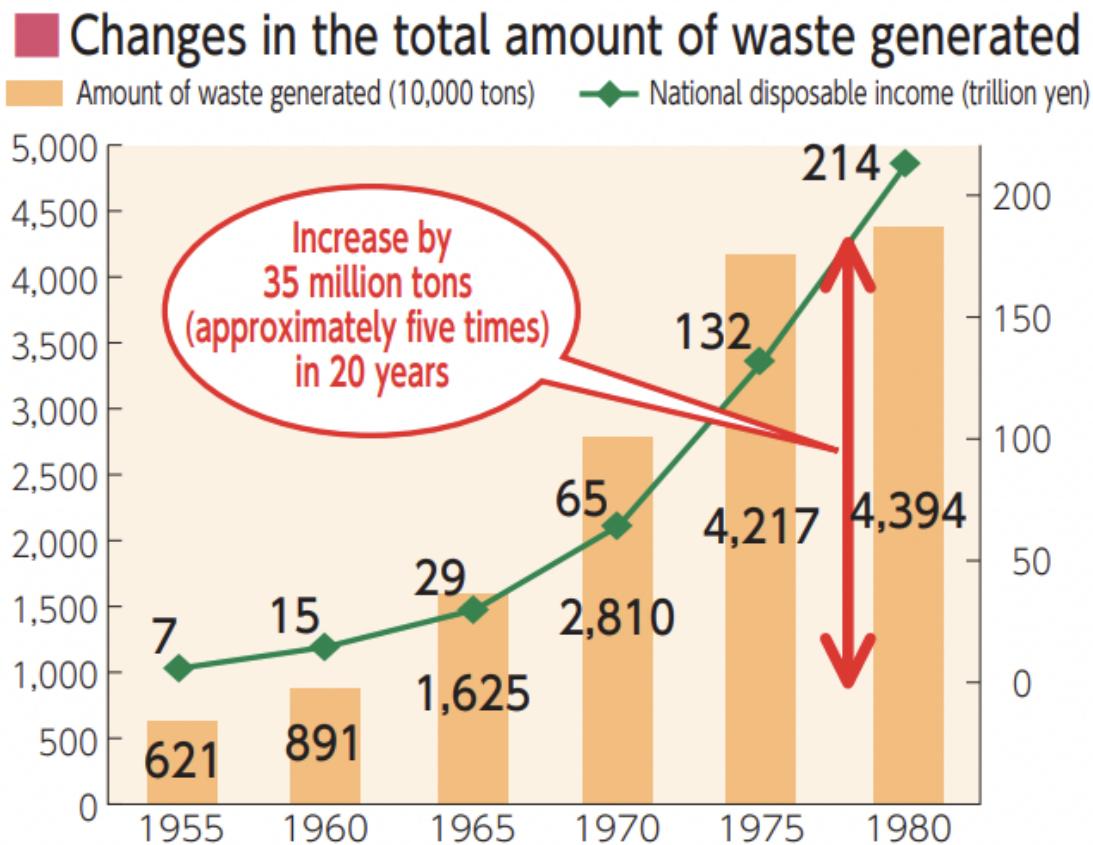
While convenience and food safety are practical reasons for plastic consumption, [MLH: there is–passive voice] historical and cultural significance to packaging in Japan. This section is not offered to proliferate western ideas of hyper traditionalism and exoticism of Asian countries, but rather to create a more complete overview of Japan's plastic consumption.[MLH: nicely stated. Is there a reference you can use to support this statement?]

Aesthetics have always been important to Japanese culture, guiding art and daily practices alike citeSaito 1999. "The allure of the hidden" is a cultural appeal based in indigenous Shintoism and a reason for historic attention to packaging, even before plastic packaging took hold. The tactile experience of opening packages is also significant:[MLH: good place for a quote block (after 50 words?), where the quotation marks are redundant]

[MLH: paraphrase this sentence?, not as compelling as the rest, which is super cool!– There are other examples of choreographing the temporal sequence of our aesthetic experience by spatial design in the Japanese tradition.] For example, both Buddhist temples and Shinto Shrines are wrapped with a series of enclosures, consisting of walls, gates, and vegetation, that regulate our experience of the respective space by offering a progressing sequence of going from the outer to the inner. The glimpse of the inner gradually unfolds as we keep going through the walls and gates citeSaito 1999.[MLH: I can't remember where the citation goes for a long quote...]



**Figure 16.1:** talk about Kobini categories. Source: citewashingtonpost.



Source: Compiled from MOE, Waste Management in Japan (annual editions) and Cabinet Office, National Accounts Statistics (annual editions)

**Figure 16.2:** Consumption and disposal rose with urbanization. Source: citeSMWRT.

[MLH: Thus, ]This quote points to an artistic intentionality [MLH: may influence the consumer products that are...] that can explain why corporations decided to sell products layered in plastic as a culturally based marketing technique[MLH: maybe?]. citeBen-Ari et al. 1990's anthropological study of Japanese wrapping offers that "by carefully wrapping an object, one is apparently expressing politeness [MLH: and ca,?] care for the object, and therefore care for the recipient ". These traditions and cultural sensibilities give more depth to the merchandizing outsiders hypocritically criticize.[MLH: perhaps we can be more nuanced here?] While thoughtful wrapping has roots in traditional Japanese culture, aesthetically pleasing packaging is ubiquitous in the global marketplace, and it'[MLH: regular opening quote here ']s fair to say just about everyone enjoys opening presents.

### 16.1.4 Where is it Coming from? [MLH: heading is abit ambiguous]

Coca-Cola, PepsiCo and Nestle are the largest distributors of plastic in the world citeStatista. The first two companies are based in the United States, and Nestle is based in Switzerland. [MLH: why is this statistics important? Sounds like an important factoid, but needs some framing...]

In 2015, around 71 percent of Japan's domestic plastic demand came from industries, while household demand accounted for 39 percent citeNakatani et al.

I should add more to this but I would think I'll submit the paper I'm basing the section to the call for papers so I can make sure I've understood it correctly. [MLH: :-) also, I wonder if we could make a table of these statistics?]

## 16.2 Problems of Plastic Pollution

This could be a whole chapter on its own, I'll offer a limited overview and someone can add on next year... [MLH: yes, let's see how other chapters engage with this...]

### 16.2.1 Ocean Plastics and Ingestion

What are the human implications of the plastic pollution? Japan is the largest seafood importer in the world, consuming six percent of global fish harvests (Bird 2012). This dietary fact [MLH: becomes dangerous perhaps a bit more nuanced on this] when a study finds that eighty percent of anchovies in Tokyo Bay contain plastic (Denyer 2019). Although researchers have not conclude direct correlation between microplastics in fish and negative health outcomes, some plastics contain endocrine disruptors, which have known negative impacts on human health citeRoyte 2018 such as increased risk of cancer, immune and nervous system interruption, and reproductive issues EPA. [MLH: nicely framed! Let's see if we can make this flow better.]

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

## 16.3 What Does Recycling *Really* Mean?

### 16.3.1 Recycling Laws and Public Cooperation

[MLH: I generally put text in before I put in a figure, text first, then cite the figure... using the figure reference below]

Figure 16.4[h]

### 16.3.2 Incineration

[MLH: Japan was not the first, put in context with a larger, longer history of incineration..., no more than two or three sentances?]

Japan has used incineration for waste management for around eighty years citeSWMRT. In 2009, Japan had nearly 1500 incinerators, 70 percent of which were stoker furnaces, others included fluidized bed furnaces and gasification fusion resource furnaces. [MLH: perhaps a figure to demonstrate this?] Incinerators generate electricity as the burning waste heats up water, turning it into steam. The steam then propels a turbine generator which creates electricity citeEIA 2020.

History of legal systems regarding the development of a sound material-cycle society (post-war period to the present)		
Period	Major issues	Laws enacted
Post-war period to the 1950s	<ul style="list-style-type: none"> <li>Waste management for environmental sanitation</li> <li>Maintenance of a healthy and comfortable living environment</li> </ul>	<ul style="list-style-type: none"> <li>Public Cleansing Act (1954)</li> </ul>
1960s to 1970s	<ul style="list-style-type: none"> <li>Increase in the amount of industrial waste and emergence of pollution problems as a result of rapid economic growth</li> <li>Waste management for environmental protection</li> </ul>	<ul style="list-style-type: none"> <li>Act on Emergency Measures concerning the Development of Living Environment Facilities (1963)</li> <li>Waste Management Act (1970)</li> <li>Revision of the Waste Management Act (1976)</li> </ul>
1980s	<ul style="list-style-type: none"> <li>Promotion of the development of waste management facilities</li> <li>Environmental protection required for waste management</li> </ul>	<ul style="list-style-type: none"> <li>Wide-area Coastal Environment Development Center Act (1981)</li> <li>Private Sewerage System Act (Johkasoh Law) (1983)</li> </ul>
1990s	<ul style="list-style-type: none"> <li>Waste generation control and recycling</li> <li>Establishment of various recycling systems</li> <li>Management of hazardous substances (including dioxins)</li> <li>Introduction of a proper waste management system to cope with diversification in the type and nature of waste</li> </ul>	<ul style="list-style-type: none"> <li>Revision of the Waste Management Act (1991)</li> <li>Act to Promote the Development of Specified Facilities for the Disposal of Industrial Waste (1992)</li> <li>Japanese Basel Act (1992)</li> <li>Basic Environment Act (1993)</li> <li>Containers and Packaging Recycling Act (1995)</li> <li>Revision of the Waste Management Act (1997)</li> <li>Home Appliance Recycling Act (1998)</li> <li>Act on Special Measures against Dioxins (1999)</li> </ul>
2000-	<ul style="list-style-type: none"> <li>Promotion of 3R measures aimed at the establishment of a sound material-cycle society</li> <li>Enhancement of industrial waste management</li> <li>Enhancement of illegal dumping regulations</li> </ul>	<ul style="list-style-type: none"> <li>Basic Act for Establishing a Sound Material-Cycle Society (2000)</li> <li>Construction Recycling Act (2000)</li> <li>Food Recycling Act (2000)</li> <li>Revision of the Waste Management Act (2000)</li> <li>Act on Special Measures concerning Promotion of Proper Treatment of PCB Wastes (2001)</li> <li>Automobile Recycling Act (2002)</li> <li>Act on Special Measures concerning Removal of Environmental Problems Caused by Specified Industrial Wastes (2003)</li> <li>Revision of the Waste Management Act (2003 to 2006, 2010)</li> <li>Small Home Appliance Recycling Act (2013)</li> </ul>

**Figure 16.3:** legal history of waste management legislation in japan. Source: citeSMWRT.

Incinerators are effective at reducing waste volume, an important benefit to a small island nation where many landfills are at capacity citeHarden 20008. Additionally, they generate electricity through the process detailed above, or **thermal recycling**, which is better for the environment than some other forms of steam turbine energy production, like coal burning. Generally, one ton of waste creates as much electricity as one ton of coal citeWatson 2016. [MLH: I suspect the chemicals emitted depend on the feed stock used in the incineration.]

### Health and Environmental Justice

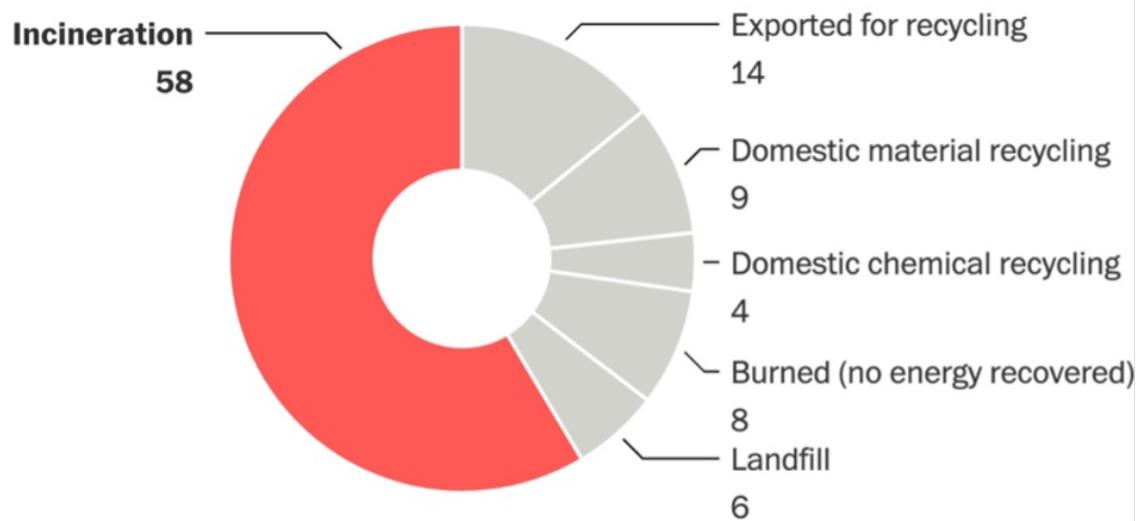
Most studies on the health and social justice implications of incinerating waste include little data[MLH: ‘data’ is a narrow concept, do you mean information?] on East Asia. Generally, older incinerator technologies correlate to adverse health impacts.

Though Japan has replaced most older incinerators in recent years, reducing incinerator related dioxin emissions by 98 percent since 1997 citeSMWRT, not enough time[MLH: when will enough time pass?] has passed for adequate evaluation of possible health impacts of newer technologies citeTait et al.

While demographic evaluations of communities near incinerators in Japan are scarce, in Europe and the United States, incinerators tend to be in areas with minority and lower socioeconomically positioned populations citeMartuzzi et al 2010. As a country that recycles 58 percent [MLH: fig x] of its plastic waste through incineration, the government should continue research and offer transparency about the process of choosing where incinerators will be built and who might have suffered disproportionately from the hazardous incineration technologies of the past.

One of the largest concerns with incinerators is **dioxin** emissions[MLH: sometimes the using the term without some context can be off putting, how about could say something about toxic

### How Japan disposes of discarded plastic (percent)



Source: Plastic Waste Management Institute Japan

SIMON DENYER/THE WASHINGTON POST

**Figure 16.4:** How Japan disposes of discarded plastic. As you can see, most discarded plastic ends up in some recycling category. For the purpose of this chapter, let's unpack the "Incineration" and "Exported for recycling" categories. Source: citeDenyer2017.

chemicals created by incineration] . Between 1997-1998,[MLH: start with the potential impact on the population in the study] a study in Japan found a higher incidence of infant mortality related to congenital birth defects in areas near incinerators with higher soil dioxin levels citeTait et al 2020. Dioxins have a seven-year half-life cite and can persist in soil and the body for multiple times longer cite. Therefore, despite Japan's drastic 98 percent reduction in dioxin emissions since 1997, the harmful chemical compounds are likely still impacting the populations closest to them or who eat food from those areas, even if direct emissions no longer pose a significant threat. Although, a 2005 study in Osaka showed a positive correlation between school incinerator proximity and number of children experiencing "wheeze, headache, [MLH: stomachache], and fatigue" citeMiyake et al. 2005. These problems could also be attributable to ash or heavy metal contamination, two additional byproducts of thermal recycling.[MLH: maybe define these additional impacts into your earlier section?]

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

#### BREAKING THIS UP WITH IMAGE [MLH: :-)]

These contradictions suggest the need for further research into incinerator impacts. A pamphlet published by the Ministry of the Environment, offers that the research and development of more efficient, cleaner incinerators are ongoing, and the government communicates with residents about building plans, negotiating until they have consent cite SMWRT and Harden 2008. Additionally, modern incinerators in cities like Tokyo and Hiroshima serve as tourist attractions and community gathering spaces, featuring swimming pools, fitness centers, and health clinics for the local elderly population. These incinerators are odorless and have tall smokestacks, so that smoke, greenhouse gasses, and trace toxic compounds are expelled above the skyscrapers citeHayden 2008. [MLH: does this seem odd to you?]

While incineration is an effective and evolving way to reduce plastic waste volume while generating electricity and modern incinerators in Japan can seem like a magic solution to crushing waste volume, the human and environmental costs require further investigation. Governmental assurances of safety coupled with contradictory studies of dioxin impacts prove incineration to be a complex environmental justice issue as Japan continues to rely on the process for waste management. Consider this issue with regard to the two dominant theories of pollution: matter out of place and thresholds of harm.[MLH: nice!] Despite the strict emission regulations for "NOx, SOx, smoke, dioxin and other gasses" citeSMRWT, Japan's remarkable incinerators still emit low levels of dioxins and other toxic chemicals. The matter out of place theory would suggest that any amount of contamination from these chemicals in the soil, air, or human body, is unacceptable and should be fought against. The thresholds of harm theory, which generally informs environmental legislation, makes the distinction between "perceived" and "demonstrated harm", basically, that forms of contamination are non-violent until the moment harm is scientifically proven, not anecdotally or psychosomatically.

Although Japan's incinerators are a solution to overflowing landfills and contribute significantly less dioxins than landfill fires citeWatson 2016, they still emit. Any toxic emissions can constitute a slow violence to those living and working nearby, and the full extent of human and environmental impacts of new incinerator technologies will likely not be demonstrable for decades, if ever. Also, the extent to which dioxins and contaminants from past, more unclean incineration, persists soil, food systems, and bodies requires more research so that those impacted can be compensated cite NRDC 2017.

### 16.3.3 The Global Plastic Trade

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

#### “The Recycling Myth”- The Global Plastic Trade and Malaysia

In 2018, GreenPeace Malaysia released a paper outlining the impacts of plastic imports on Malaysia, problematizing recycling as the developed world has come to understand it. Countries like Japan ship their plastic to Malaysia, where it is then sorted into high and low grade. High grade plastics are for recycling, though much of those end up dumped or burned, and low grade, typically single-use items, are slotted for disposal, though as low as 30 percent of all plastics imported to Malaysia end up recycled.

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

A mother from Jenjoram, Malaysia, Fatma, recounts her son’s complaints of the health impacts from unregulated plastic burning: “Mother, it is always hazy in the mornings at my school.[MLH: aŽ] I said, [MLH: aÝ]Oh, itâŽs fine. ItâŽs always hazy, and the haze is from Indonesia.” He said, “No! Every day is hazy[MLH: . . . ]” Since the beginning of the year, my eldest son aged 13 years old-he has this health problem: his eyes are red, itchy and tearing”. Illegal dumpsites can be found near fisheries, contaminating the waters of prawn and other food sources with aluminum levels 300 times higher than the acceptable limit.

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

## 16.4 Conclusion and Moving Forward

### 16.4.1 Mitigation Efforts

#### Ecotowns

[MLH: sort of a response to the ills of urbanization? Super interesting to explore...]

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

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

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

In the ideal situation, the world's wealthiest nations will agree to phase out plastic production in favor of eco-friendly alternatives, whether that's biodegradables, paper, or reliance on reusable packaging. Also to tackle industry, local and national governments must enforce plastic reduction goals, making it more economically attractive for companies to use less plastic.

[MLH: super interesting... can this be linked to aesthetics?]

#### Longterm Goals

Japan[MLH: “]s goals for reducing plastic usage on a national level include a 25 percent reduction in single use plastic waste and 60 percent reuse rate, and 2 megatonne usage of biobased plastic alternatives by 2030 citeNakatani et al. 16.3 demonstrates the history of waste management laws in Japan. Though legal enforcement of these goals in the industrial sector has proven difficult citeNakatani et al 2020. Allusions I have found to these difficulties are vague, but I'm continuing to search and will use evidence from another country to offer potential reasons for this. [MLH: sounds good]

### 16.4.2 In Closing

On an even deeper level, we must continue to ask ourselves what a sustainable future looks like under the capitalist world powers who push consumerism to fill the pockets of the wealthy at the expense of the environment and socially deprived groups who pay the price, typically those in the global south. Is a sound-material society feasible under capitalism? Who has the greatest potential to spark change?

Three of **The 17 Principles of Environmental Justice**, “demand the right to participate as equal partners at every level of decisionmaking, including needs assessment, planning, implementation, enforcement and evaluation”, “affirms the right of all workers to a safe and healthy work

environment without being forced to choose between an unsafe livelihood and unemployment. It also affirms the right of those who work at home to be free from environmental hazards” and “protects the right of victims of environmental injustice to receive full compensation and reparations for damages as well as quality health care” citeNRDC 2017. Should I paraphrase these? In what ways does Japan’s current recycling system fail to fulfill the tenets of Environmental Justice? What uncertainties arise in your attempt to answer that question? Likely many. Those uncertainties are important, and should drive efforts not to accept “recycling” as it stands.

[MLH: this could be useful in the earlier section... then discuss the social justice and various scales, city, nation, and beyond?]



# 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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