

# Irrawaddy River Valley, Delta and Control of Myanmar's Lifeline

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## Abstract

Myanmar is situated in Southeast Asia and bordered in the west by the India, by Bangladesh in the northwest, by China in the north, China (Xizang) in the northeast, by Laos in the east and Thailand in the southeast. Myanmar's forests and wildlife are among its greatest natural treasures. They have been steadily lost to human activities including large-scale deforestation for mining, illegal charcoal production, and booming online wildlife trade. Political turmoil, expanding extractive industries, and diminishing focus on sustainable agriculture are accelerating soil degradation across Myanmar. The primary objectives are to assess the extent and causes of soil degradation in the Irrawaddy River basin and its impacts on agricultural productivity and to assess lessons learned, manage, mitigate, and restore the Irrawaddy River watershed lifeline in Myanmar. The river is still of great importance as the largest commercial waterway within Myanmar. It also provides important ecosystem services to different communities and economic sectors, including agriculture, tourism, and fisheries. Myanmar's military dictatorship signed an agreement for the construction of seven hydroelectric dams in 2007. Environmental organizations have raised concerns about the project's ecological impact on the river's biodiverse ecosystems.

## Keywords

Irrawaddy River, Myanmar, Irrawaddy Delta, Hydroelectric Dams, Watershed Lifelines, Deforestation, Soil Degradation, Evergreen Rainforest

## 1. Introduction

Xizang Autonomous Region in China is well known for being the roof of the world

and the “Third Pole”. It is the third largest source of freshwater in the world, right after the North and South Poles [1]. With so much water in one region, it is little surprise that the more than 6 great rivers from Qinghai-Xizang Plateau feed more than 46 percent of the people of Southeast Asia. Xizang is the location of the headwaters for six of the largest rivers on the Asian continent. These include Brahmaputra [2], Mekong [3], Yangtze [4], Yellow [5], Irrawaddy, and Ganges [2] (via the Bhothe Kosi and Arun). These six great rivers provide water needs to approximately 20 percent of the world’s population [1].

The largest river in Myanmar, the Irrawaddy is the main river, and a source of water for most of the country. It is still unclear as to which side of the border the source of this massive waterway lies, as the headwater area is still in dispute between China and Myanmar. However, its main feeder, the Dulong Jiang, does originate on the Qinghai-Xizang Plateau, in the north of Xizang in Chayu County and runs through Yunnan Province before crossing into Myanmar to join with the Irrawaddy not far downstream from the source.

Myanmar (formerly Burma) occupies an area of 676,578 km<sup>2</sup> in the northwestern part of mainland Southeast Asia. One of the largest nations in this region, Myanmar borders five other nations (India, Thailand, Bangladesh, China, and Laos). Myanmar’s geography is mostly made up of tall mountains, surging river valleys and thick tropical rainforests. The Himalayan Mountain range extends into northern Myanmar. The country’s highest point, Hkakabo Razi, is at an elevation of 5881 m. The mountain ranges of the north mostly run in the north-south direction. The Irrawaddy River system dominates Myanmar. The elevation of the country gradually rises from the sea level at the Irrawaddy and Sittang River deltas to Mount Hkakabo in the north.

A civil war has displaced people and has taken a heavy toll on Myanmar’s rich natural resources. Once seen as a frontier of untapped wealth, including minerals, timber and other valuable resources, these assets are now being exploited to fund the war and to generate profits for a select few. Citizen journalists still inside the country have been uncovering the hidden costs of war. These include deforested hills that poisoned the rivers and displaced communities and lost local conservation efforts.

The Irrawaddy River is responsible for giving the country countless valleys and the massive delta in the south. The low-lying floodplains in the south are ideal for growing crops. Many of Myanmar’s largest towns and cities are located along the banks of the Irrawaddy River including the capital of Nay Pyi Taw. In 2007, Myanmar’s military dictatorship signed an agreement for the construction of seven hydroelectric dams. These dams can generate a total of 13,360 MW, in the N’mai and Mali Rivers, including the 3600 MW Myitsone Dam at the confluence of these rivers. The controversial Myitsone Dam is no longer under construction.

The Mergui Archipelago, located in the south, contains over 800 islands, most of them completely uninhabited. The islands are located just off the southern coast along the Indian Ocean and the Andaman Sea. These bodies of water give Myanmar access to global trade, but this does come at a cost. Each year the nation is

wracked by a series of devastating monsoons. Myanmar is a known “hot spot” in Southeast Asia for mangrove loss from aquaculture, agriculture, and logging.

Regarding the study of the Irrawaddy River Valley and Delta, extensive research has already been carried out and many interesting results have been found. For example, Hedley *et al.* [6] demonstrated the changes in the existing coastline of the Irrawaddy Delta region of Myanmar. They suggested a reasonable balance of the corresponding coastline. Later, Thi *et al.* [7] pointed out that relevant strategies should be considered to ensure durable land use management of the Irrawaddy River Valley and Delta. For their part, Shamsudduha and Panda [8] showed that precise management of the Irrawaddy River valley and delta is necessary so that the southern port cities and important points in the interior are effectively connected to each other. In fact, with the effects of climate change causing variations in river flow and fluvial sediment loads [9], relevant management in the Irrawaddy River Valley and Delta is expected to be a heavy and continuous task. Recently, a comprehensive study by Zhao *et al.* [10] revealed that high temperatures and weakening of the intercontinental environment led to increased drought events in the Irrawaddy River Valley and Delta. They said worse drought situations could occur in the future due to global warming if appropriate countermeasures are not taken. Therefore, it is of utmost consideration to continuously study and monitor the Irrawaddy River Valley and Delta. The primary objectives of this study are to assess the extent and causes of soil degradation in the Irrawaddy River basin and its impacts on agricultural productivity and to assess lessons learned, manage, mitigate, and restore the Irrawaddy River watershed lifeline in Myanmar.

## 2. Study Site

### 2.1. Myanmar

Myanmar is a Southeast Asian country [11] which is situated in the Earth’s Eastern and Northern hemispheres. **Figure 1** shows the location of Myanmar in Southeast Asia. Myanmar (officially, the Republic of the Union of Myanmar) is divided into 7 regions (taing), 7 states (pyine) and 1 union territory (**Figure 2**). With an area of 676,578 km<sup>2</sup>, Myanmar (**Figure 3**) is the 10<sup>th</sup> largest country in the Asian continent and the largest country in Southeast Asia. Located in a mountain-framed spot in north-central Myanmar is Naypyidaw—the capital and the third-largest city of Myanmar [11]. Yangon (Rangoon) is the largest city of Myanmar and located in southern Myanmar. With a population of over 5 million people, Yangon is the most populous city as well as an important commercial center of Myanmar.

### 2.2. Irrawaddy River

Leinbach [12] found “*Irrawaddy River* (**Figure 4**), *principal river of Myanmar (formerly Burma), running through the center of the country. Myanmar’s most important commercial waterway is about 2170 km long. Its name is believed to derive from the Sanskrit term airāvati, meaning “elephant river”. The river flows*



**Figure 1.** Map of East Asia including Myanmar, Pakistan, Nepal, India, and Bangladesh. Photo Credit: World Atlas.

*wholly within the territory of Myanmar. Its total drainage area is about 411,000 square km. Its valley forms the historical, cultural, and economic heartland of Myanmar.”*

*“The Irrawaddy is formed by the confluence of the Nmai and Mali rivers. Both branches rise in the glaciers of the high and remote mountains in northern Myanmar in the vicinity of 28°N. The eastern branch, the Nmai, rises in the Languela glacier on the border with Xizang (China) and has the greater volume of water but is virtually unnavigable because of its strong current. Mali, the western branch, has a gentler gradient and, although interrupted by rapids, has some navigable sections.”*

*“About 50 km south of the confluence is Myitkyinā, the northernmost limit of seasonal navigation by the Irrawaddy steamers. Bhamo, about 240 km south of the confluence, is the northern limit for year-round navigation. Between the confluence and Bhamo, the width of the river during the low-water season varies between 400 and 800 meters. The depth of the main channel averages about 9 m.”*

*“Between Myitkyinā and Mandalay, the Irrawaddy flows through three well-marked defiles (narrow passages or gorges) [13]. About 65 km downstream from Myitkyinā is the first defile. Below Bhamo the river makes a sharp westward swing, leaving the Bhamo alluvial basin to cut through the limestone rocks (Figure 5) of the second defile. This defile is about 90 m wide (Figure 6) at its narrowest and is flanked by vertical cliffs about 60 to 90 m high. About 100 km north of*



**Figure 2.** Map showing location of the Myanmar Provinces. Photo Credit: Encyclopedia of Britannica.



Figure 3. Map of Myanmar showing the location of the Irrawaddy. World Atlas.



Figure 4. Passenger transport boat on the Irrawaddy River, Myanmar. Photo Credit: Encyclopedia of Britannica.



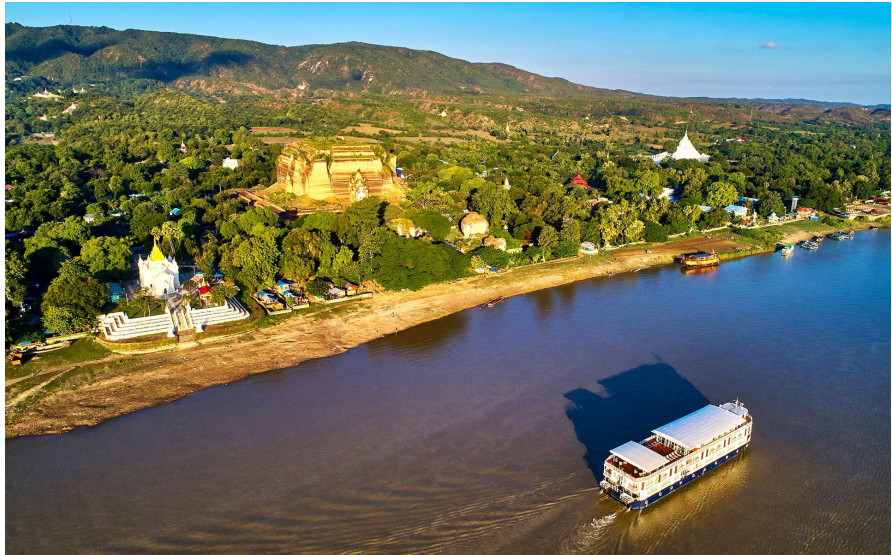
**Figure 5.** Irrawaddy cruise. Photo Credit: <https://www.ar.inspencil.com>.



**Figure 6.** Irrawaddy River. Photo Credit: <https://www.ar.inspencil.com>.

*Mandalay, at Mogok, the river enters the third defile. Between Katha and Mandalay, the course of the river is remarkably straight (Figure 7), flowing almost due south, except near Kabwet [14], where a sheet of lava has caused the river to bend sharply westward. Leaving the third defile at Kyaukmyaung, the river follows a broad, open course through the central dry zone—the ancient cultural heartland—where large areas consist of alluvial flats. From Mandalay (formerly the capital of the kingdom of Myanmar) the river makes an abrupt westward turn before curving southwest to confluence with the Chindwin River. From there the river continues in a southwesterly direction. It is probable that the upper Irrawaddy originally flowed south from Mandalay, discharging its water through the present Sittang River to the Gulf of Martaban, and that its present westward course*

*is recent. Below its confluence with the Chindwin, the Irrawaddy continues to meander through the densely populated dry zone to the vicinity of Yenangyaung, below which it flows generally southward. In its lower course, between Minbu and Prome, it flows through a narrow valley between forest-covered mountain ranges—the ridge of the Arakan (Rakhine) Mountains to the west and that of the Pegu Mountains to the east” [12].*



**Figure 7.** Irrawaddy River with village and temple. Photo Credit: myanmartravel.

### 2.3. Irrawaddy Delta

The delta of the Irrawaddy faces the Andaman Sea and begins about 93 km above Hinthada (Henzada) and about 290 km from its curved base. The sides of the delta are formed by the southern extremities of the Arakan Mountains on the west and the Pegu Mountains on the east [12]. The easternmost stream is the Yangon River. On the left bank of the river stands Myanmar’s largest city, Yangon (Rangoon). The westernmost distributary of the delta is the Bassein (Patheingyi) River. The delta’s relief is low but not flat. The soils consist of fine silt, which is replenished continuously by fertile alluvium carried downstream by the river. The delta surface extends into the Andaman Sea at a rate of about 50 meters per year because of heavy rainfall, soil erosion, sediment transport, and the sediment load of the river [12]. The Yangon River water flow is insufficient to prevent Yangon Harbor from silting up and needing periodic dredging.

### 3. Methodology

This study employed qualitative content analysis and visual data (pictures) to identify themes and insights for developing a master plan that harnesses the Irrawaddy River’s hydropower potential while examining the socio-economic challenges of community resettlement due to new dam constructions. Peer-reviewed papers, reports and case studies on hydropower development, need for fish lad-

ders to sustain fish migration and populations, community resettlement, and socio-economic impacts in the Irrawaddy River Basin among several other themes, were gathered and synthesized to identify best practices. Key metrics such as food security, compensation adequacy, and health outcomes were analyzed to establish a baseline for assessing the potential impacts of proposed hydropower projects. This methodology aimed to ensure that hydropower developments not only leverage the Irrawaddy River's energy potential but also prioritize the well-being and livelihoods of affected local communities. Another objective was to assess the extent and causes of soil degradation in the Irrawaddy River basin and its impacts on agricultural productivity. The river is still of great importance as the largest commercial waterway within Myanmar. It also provides important ecosystem services to different communities and economic sectors, including agriculture, tourism, and fisheries.

## 4. Natural Resources

### 4.1. Climate

Leinbach [12] noted “*The lower Irrawaddy River basin has a humid tropical climate, while the upper river basin has a warm humid subtropical climate. Both climatic zones are dominated by the South Asia summer monsoon, which brings the heaviest rains between May and October. At Yangon, in the lower basin, temperatures range from a January mean of 25°C to an April mean of 30°C; temperatures fall slightly during the summer rainy season. At Myitkyinā, in the upper basin, January temperatures average 18°C and monthly average temperatures peak at 28°C in June. Temperatures decrease with altitude up the basin to the glaciated regions where mean annual temperatures are below 20°C. Precipitation varies across the basin from 150 to 250 cm per year and falls mainly from May to October.*”

### 4.2. Hydrography

Due to monsoonal rains, which occur between mid-May and mid-October, the volume of the Irrawaddy and its tributaries varies greatly throughout the year [15]. Chavoshian *et al.* [16] stated that “*In summer, melting of the snow and glaciers in Northern Burma add to the volume. The average discharge near the head of the delta is between a high of 32,600 m<sup>3</sup> and a low of 2300 m<sup>3</sup> per second. The discharge can be as high as 40,393 m<sup>3</sup> per second in the rainy season. Over a year, the discharge averages 15,112 m<sup>3</sup>. Further North, at Sagaing, shows a 38% decrease in discharge compared to where the river enters the delta, it also silts up around 278 tons of sand every year.*”

As a result of monsoonal rain, the highest amount is recorded in August, the lowest in February. Variation between high and low river water levels is also significant [17]. At Mandalay and Prome, a range of 9.66 to 11.37 m has been measured between low-water level and flood level respectively. This variation in water level makes it necessary for ports along the river to have separate landing ports for

low- and high-water [17]. However, low water levels can cause problems for ports along the river, as in the Bamaw-Mandalay-Pyay sectors, where the shallowest point is 6 meters [18]. Within the basin, the average population density is 79 people/km<sup>2</sup>. For these people, the river supply amounts to 18,614 m<sup>3</sup> per person per year.

### 4.3. Hydrology

Leinbach [12] noted “*The volume of the Irrawaddy and its tributaries fluctuates greatly through the year, chiefly because of the character of the monsoon rains, which occur between May and October, but also because of the rapid melting of snow and glaciers during the summer, which adds still further to the volume. The average discharge of the river near the head of the delta varies between a high of 82,000 and a low of 32,600 m<sup>3</sup> per second; the annual average discharge is 13,000 m<sup>3</sup> per second. The range between high and low water is also great. Annual variations between low-water level and flood level of 9.66 m and 11.37 m have been recorded at Mandalay and Prome, respectively. The lowest water level occurs in February, and the highest in August. In general, from December to March the river varies between the lowest level and 1.5 m above it, while from mid-June to mid-October the river is 6 to 9 m above the lowest level. The river ports therefore find it necessary to have separate high- and low-water landing points*”.

### 4.4. Physiography

The Irrawaddy River bisects Myanmar from north to south and empties into the Indian Ocean through the nine-branched Irrawaddy Delta [15]. The Irrawaddy River arises by the confluence of the N'mai (Nam Gio) and Mali Rivers in Kachin State. Both rivers find their sources in the Himalayan glaciers of Upper Burma near 28°N. The eastern branch, N'mai [19], is the largest and headwaters are in the Languela Glacier north of Putao [20]. The N'mai is unnavigable because of the strong current. The smaller western branch, the Mali River despite a few rapids is navigable. Consequently, the Mali River is still identified by the locals with the same name as the main river [21]. The controversial Myitsone Dam is no longer under construction at the convergence of these rivers.

The town of Bhamo, about 240 km south of the Mali and N'mai river confluence, is the northernmost city reachable by boat all year round. However, during the monsoons most of the river cannot be traveled by boats. The city of Myitkyina lies 50 km south of the confluence and can be reached during the dry season [15].

Leaving this plateau at Kyaukmyaung, the river follows a broad, open course through the central Dry Zone [22]. This large area consists of alluvial flats and was the Bamar people's ancient cultural heartland [23]. From Mandalay (the former capital of the kingdom of Myanmar), the river makes an abrupt westward turn before curving southwest to unite with the Chindwin River. It is probable that the upper Irrawaddy originally flowed south from Mandalay, discharging its water through the present Sittang River to the Gulf of Martaban. The Irrawaddy Rivers present

westward course is geologically recent. Below its confluence with the Chindwin, the Irrawaddy continues to meander through the petroleum producing city of Yenangyaung. Below the city it flows southward. In its lower course, between Minbu and Pyay, it flows through a narrow valley between forest-covered Arakan Mountains [24] to the west and the Pegu Yoma Mountains to the east [25] [26].

#### 4.5. Cultural History

Leinbach [12] found “*the Irrawaddy River, as the principal axis of the old Myanmar kingdom, has shaped the country’s history, settlement patterns, and economic development. As early as the 6th century, the ancestors of the Burmese arrived from the China-Xizang border area. Using the Irrawaddy as a means of transport, they gradually spread onto the Kyaukse plain and became the major power in the rice-growing region of the north. The Burmese fortified the town of Pagan and eventually gained control over the Irrawaddy and Sittang river valleys and the trade routes between India and China. During the 12th century the town supported a flourishing civilization through rice cultivation and a well-developed network of irrigation canals.*”

“*In the 13<sup>th</sup> century, both the Shan and the Mongols defeated Myanmar armies, and the area dissolved into a number of states, though Burmese kingdoms intermittently reunified the Irrawaddy basin. Beginning in the 16th century, European interests set up trading companies in ports along the coast of Myanmar. By 1886 the British had gained control of Burma (Myanmar) and along with-it shipping rights on the Irrawaddy, which also had been sought by the French to gain a direct route to China.*”

“*The British interest was primarily economic, and the opening of the Irrawaddy delta and the rise of the port of Rangoon (now Yangon) eventually paid off in terms of rice exports. As part of this economic and administrative drive, the British formed the Irrawaddy Flotilla Company in 1865 to convey troops, mail, and stores to riverine stations of British Burma. Starting with four steamers, the company had more than 600 vessels in service by 1940. In 1948 the company was renamed the Inland Water Transport Company. Since then, the service network has declined by half, equipment has become antiquated, and scheduling irregular.*”

“*The peoples living on the river’s banks are culturally diverse. On the upper reaches, the Kachin, who practice shifting agriculture, predominate. In the middle and lower basins, the Burmese are the dominant group, cultivating wheat, cotton, and oilseeds in the central dry zone and rice and jute to the south and in the delta region, where rainfall is more plentiful. Also, to the south, and particularly in the delta proper, a considerable minority of Karen and some Indians are to be found among the Burmese majority. In addition, a small number of both rural and urban Chinese are scattered throughout the river’s drainage basin*” [12].

#### 4.6. Major Cities, Towns, and Bridges

The river flows through or past 11 cities [13] including Kyaukmyaung, Mandalay

Sagaing Yenangyaung, Chauk, Myitkyina, Bhamo, Katha, Tagaung, Bagan, Nyaung-U, Pyay, Hinthada, and Pantanaw. Until the construction of the Ava (Innwa) Bridge, a 16 span rail and road cantilever bridge built by the British colonial government in 1934, the only way across the Irrawaddy was by ferry [13]. The bridge was destroyed by the retreating British Army during World War II. It was rebuilt in 1954 after Burmese independence and was the only bridge to span the Irrawaddy until recent times when the government developed a new bridge construction program.

## 5. Discussion

### 5.1. Impact of the Myanmar Civil War on the Environment and Natural Resources

As Myanmar enters its fifth year since the military coup on February 1, 2021, the country has descended into a bloody civil war [27]. The civil war has displaced people and has taken a heavy toll on Myanmar's rich natural resources. Once seen as a frontier of untapped wealth, including minerals, timber and other valuable resources, these assets are now being exploited to fund the war and to generate profits for a select few. Citizen journalists still inside the country have been uncovering the hidden costs of war. These include deforested hills that poisoned the rivers and displaced communities, and loss local conservation efforts.

Myanmar's forests and wildlife are among its greatest natural treasures [28]. They have been steadily lost to human activities including large-scale deforestation for mining, illegal charcoal production, and booming online wildlife trade. While elites and armed groups profit from resource exploitation, villagers have been driven to participate in resource exploitation to survive. Some have turned to illegal logging, poaching and other environmentally harmful activities since jobs are scarce and their farmland was destroyed by war. War has also taken a toll on marine life [29]. Since villagers can no longer access traditional turtle sanctuary areas due to military control the sea turtle populations are in sharp decline. The once-thriving conservation efforts that protected these endangered species have been disrupted, leaving marine ecosystem vulnerable.

### 5.2. Soil Degradation as a Result of Political Turmoil

Political turmoil, expanding extractive industries, and diminishing focus on sustainable agriculture are accelerating soil degradation across Myanmar [30]. Lack of assistance and scientific research and soil degradation following the military coup in Myanmar have severely impacted millions of farmers, whose livelihoods depend on the once fertile land. Many farmers in Sagaing, Myanmar have been farming for half a decade. These farmers and their parents and grandparents had relied on a 2.4-hectare plot of land to grow rice and beans near Meza Creek in central Myanmar's Sagaing Region. Annual flooding has kept the soil fertile, keeping the families afloat.

Things started changing about 10 years ago when the annual monsoon stopped

leading to floods. Their soils degraded and they started using more and more chemical fertilizers to maintain the productivity of their farmland. But it was a losing battle. Their arable land had now dwindled more than half due to degradation, only enough to feed their families. They are currently selling goods to make ends meet for their families, as their income from farming alone is insufficient. Meza Creek flows more than 128 kilometers from the northern Kachin Mountain range through Indaw township into the Irrawaddy River to the south. Half of the essential food needed for the area is sourced from the farms along the banks of this creek. Its water is affected by chemical overuse and an explosion in illegal gold mines, which releases cyanide, arsenic, and other toxic substances into the creek. Farmers believe they degrade agricultural land. Indaw is not the only place experiencing a decline in soil quality and soil productivity. It is occurring in many regions of the country, according to soil scientist Myo Aung [30]. “*Across various regions, we have observed a common deficiency in soil quality. Nutrition is alarmingly scarce,*” he said. “*The availability of essential nutrients such as organic matter, phosphorus, and potassium is notably less.*” The combination of reliance on agrochemicals, a lack of awareness about how to use them correctly, successive governments’ neglect of soil fertility, and a focus on extractive activities like mining and deforestation have been the reasons.

The 2021 military coup has worsened the situation by halting all documented soil conservation and restoration activities while accelerating extractive practices that are harmful to the soil. These changes raise serious concerns about long-term food production in Myanmar, one of the poorest countries in Southeast Asia, where 26% of the population already requires food assistance, according to the World Food Program. Amidst the ongoing full-scale civil war following the coup, there is still no comprehensive remedial plan for soil conservation in Myanmar.

According to Myanmar’s National Action Plan for Agriculture [30] issued in June 2016, problem soil occupies an area of nearly one million hectares—or around 5.3% of the total cultivable land. Around 70% of the population of Myanmar relies on agricultural activities for household income. During the colonial period and subsequent parliamentary era between 1948 and 1962, Myanmar, once known for its fertile land, was one of the leading exporters of rice in the global market. However, this situation has gradually deteriorated due to the mismanagement of successive governments.

Around the 1980s, when Green Revolution initiatives were implemented to increase rice production, the government provided farmers engaging in traditional agricultural practices with free chemical fertilizers. Since farmers did not learn how to use chemical fertilizers systematically, the land became saline and damaged, according to U Thein Soe Min, co-founder and manager of the Greenovator organization, which focuses on agricultural education. “*From there, the disease of dependency on chemical substances started to emerge. It has become so bad that we cannot continue without adding chemical fertilizers or spraying pesticides,*” he said. Currently, Myanmar is only able to export about two million tons of rice and

rice by-products (**Figure 8**) to the global market. Buyers usually purchase Myanmar rice only when there are no other options available, according to Myanmar Rice Federation [30].

Organic farmers from Pyay Township (**Figure 9**) in the fertile plains of the Ayeyarwady River, noted that it has been a considerable time since they witnessed earthworms thriving in the soil of this region. One farmer [30] claimed “*In my youth, I could find those little insects wherever I went. Now, to catch them for fishing, I must venture deep into the woods and search through the mud. If no one is monitoring the situation [of declining soil quality,] it will only get worse.*” According to soil scientists, earthworms are crucial for soil health as they improve aeration, enhance nutrient cycling, support microbial communities, decompose



**Figure 8.** Rafts and water buffalo on Irrawaddy River. Photo Credit: myanmartravel.



**Figure 9.** Homes on Irrawaddy stream bank. Photo Credit: Goddard Photography:iStock.

organic matter and regulate soil structure and pH—making them key indicators of fertile ecosystems.

Government activities related to environmental conservation, including soil conservation efforts, have come to a standstill since the military coup. Before 2021, there were about 11 international organizations collaborating with the Myanmar Department of Agriculture and the Department of Agricultural Research. These organizations were involved in various activities related to maintaining the quality of the country's soil, including data collection, research, awareness-raising, and providing technical and financial assistance throughout the country.

The International Rice Research Institute (IRRI) was one of those [30]. IRRI implemented a project in Myanmar from 2020 to 2022, aiming to reduce the rice production gap and develop a sustainable agriculture system. Collaborating with the local agriculture experts, IRRI provided support to collect soil and water data from across the country to develop indicators for soil health. In response to an email inquiry regarding prospects for this effort, a representative from IRRI replied that it is unable to provide any further information on the matter as it is currently not operating in Myanmar. “*The projects anticipated to benefit Myanmar have ended up being diverted to neighboring countries,*” lamented Ko Soe [30], an agricultural expert who had collaborated with international organizations before the coup. “*Upon reading their annual reports, I feel sorrow for what Myanmar deserves to receive. Much of what we hoped for has regrettably vanished.*”

Agricultural research has been limited within the campus of Yezin Agricultural University in Naypyidaw and nearby areas, where the military government is at its strongest, according to the reports from Myanmar's Department of Agriculture web site. The rest of the country, meanwhile, is being deprived of investment in soil science, technical advice, and services to support food production. To assist local farmers, the parallel and exiled government National Unity Government has appointed agricultural officers in many parts of the country. They have educated residents on the use of sustainable agricultural practices, including farming with organic fertilizers in place of chemical options. However, these alternative methods have not yet led to renewed efforts to restore degraded land, especially when people need to prioritize their safety in the war.

Typhoon Yagi hit northern Myanmar and damaged more than 260,000 hectares of paddy and other crops, according to reports from the Myanmar military and UNICEF. The damaged agricultural lands will require at least three years of adequate support to regain productivity. Without effective implementation of natural resource management, the risks will continue to escalate, one agricultural expert warns. Professor Duncan Boughton, of the International Development Department, Agricultural, Food and Resource Economics at Michigan State University [30], said that Myanmar's agricultural research service was tiny and highly centralized in Yezin, even before the recent crises. Duncan was a resident in Myanmar from January 2016 until the military coup, serving as team leader for the USAID Burma-funded Food Security Policy Project and the UN LIFT-funded Agri-food

Value Chain Development project. He emphasized that rebuilding, expanding, and decentralizing Myanmar's agricultural research system, along with strengthening relationships with private and public extension systems, is essential to reversing soil degradation and enabling agriculture to become a source of rural prosperity and dignified livelihoods. "Myanmar is a net exporter of rice and maize, which are crops that water-scarce neighbors find difficult to produce," Duncan [30] added "Lower supply of these crops due to soil degradation will require that neighboring countries have to pay more to procure them from alternative sources."

### 5.3. Irrigation

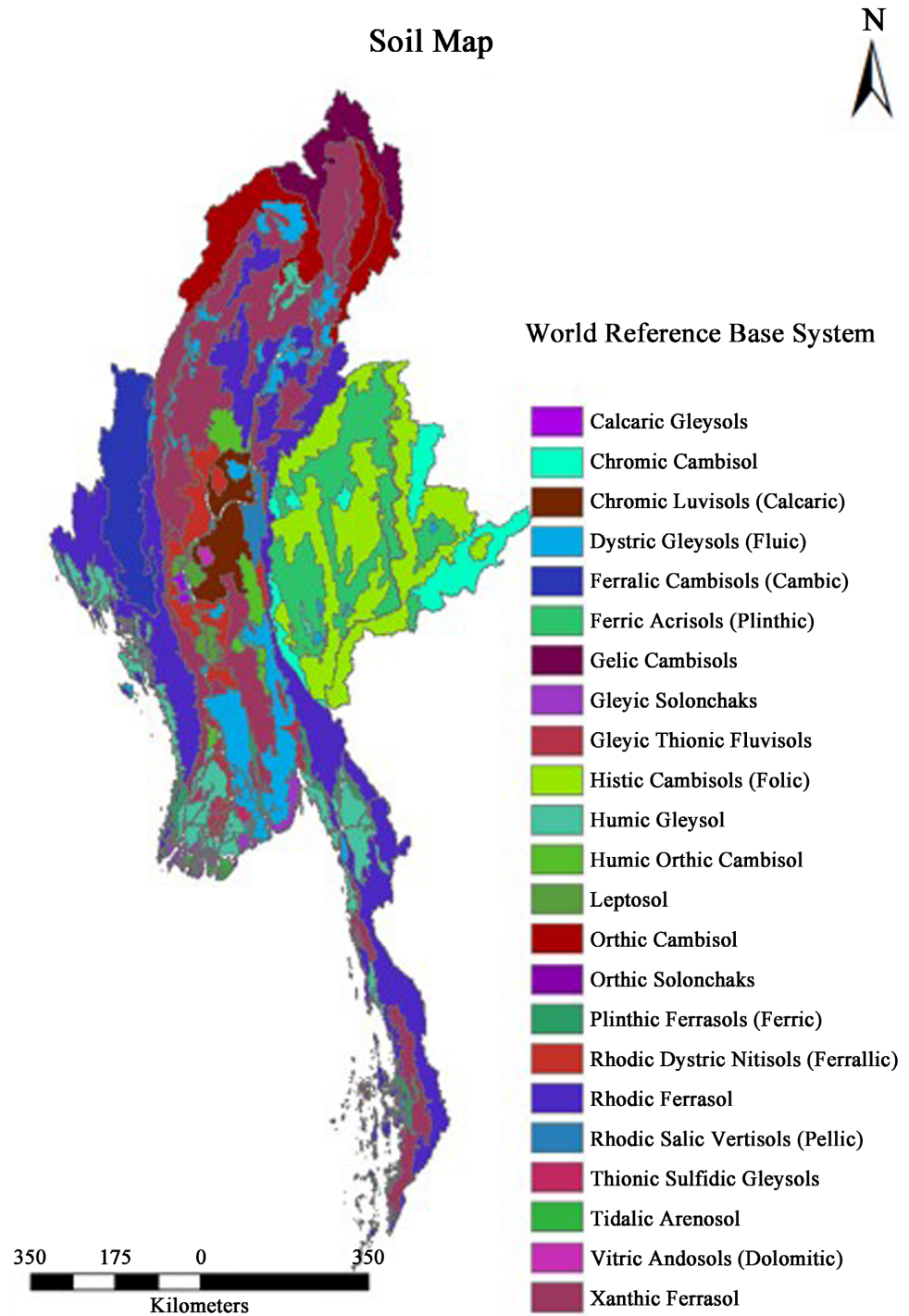
Although the Irrawaddy in the central dry zone has seldom been used for soil irrigation (Figures 10-12). However, its tributary, the Mu River, has been used



**Figure 10.** Irrigation of rice paddies with workers planting the rice in the Irrawaddy Delta. Photo Credit: Encyclopedia of Britannica.



**Figure 11.** Mu Valley irrigation project in the Irrawaddy Delta. Photo Credit: Encyclopedia of Britannica.



**Figure 12.** Soils of Myanmar. Photo Credit: Encyclopedia of Britannica.

for this purpose since the 9<sup>th</sup> century. The Mu Valley Irrigation Project is among the largest in the country [12]. It permits the dry season cropping of corn (maize), wheat, cotton, millet, peanuts (groundnuts), sesame, and other dry crops. About one-sixth of the total rice grown in Myanmar comes from the irrigated areas of Sagaing, Mandalay, and Magwe divisions. The river itself also serves to irrigate the

delta during the dry season.

#### 5.4. Navigation

Leinbach [12] found “*Because the Irrawaddy delta is one of the world’s major rice-growing areas, rice is a major item of commerce on the river. Also transported are other foodstuffs, petroleum, cotton, and local commodities. Teak logs—of which Myanmar is the world’s major exporter—are floated downstream as large rafts. In the delta region, the rice is carried in small boats to local markets, whence it is shipped to Yangon for export.*”

“*The main crossing of the Irrawaddy is the Ava Bridge, which spans the river near Mandalay. Another important bridge crosses the river at Hinthada and connects the western delta with Yangon. The main river ports on the Irrawaddy are, from north to south, Bhamo, Myitkyinā, Mattha, Mandalay, Myingyan, Chauk, Yenangyaung, Minbu, Magwe, Thayetmyo, Prome, Hinthada, and Yandoon. Of these, Mandalay, Chauk, Prome, and Hinthada have good landing facilities. The remaining ports have landing facilities for only one or two barges or lighters, with the vessels mooring alongside the riverbank in most places. Despite Mandalay’s position as the chief rail and highway focus in northern Myanmar, a considerable amount of passenger and goods traffic moves by river. The Chindwin valley has no railroad and relies heavily on river transport. Chauk, downstream from the confluence in the oil-field district, is a petroleum port. Like Mandalay to the north and Prome, about 225 km to the south, it is linked to Yangon by road and rail. Hinthada, near the apex of the delta, is the rail junction for lines leading to Kyangin and Bassein (Pathein). A ferry operates between Hinthada on the west bank and the railway station at Tharrawaw on the east bank.*”

“*Commercial transportation on the Irrawaddy is maintained for about 1300 km: from Hinthada to Bhamo (1080 km) throughout the year but from Bhamo to Myitkyinā (200 km) for only seven months. More than 3200 km of navigable waterways exist in the Irrawaddy delta. On the Chindwin River, transportation is carried on by steam or diesel vessels (Figure 13 and Figure 14) throughout the*



**Figure 13.** Ferry crossing the Irrawaddy River. Photo Credit: Encyclopedia of Britannica.



**Figure 14.** Ferry port on the Irrawaddy River. Photo Credit: Encyclopedia of Britannica.

year up to Homalin—about 640 km from its confluence with the Irrawaddy. Seasonal navigation is carried on into Tamanthi, which is 92 km above Homalin” [12].

## 5.5. The Irrawaddy Delta

Wikipedia [3] noted “*The delta of the Irrawaddy begins about 93 kilometers above Hinthada (Henzada) and about 290 kilometers from its curved base, which faces the Andaman Sea. The westernmost distributary of the delta is the Pathein (Bassein) River, while the easternmost stream is the Yangon River, on the left bank of which stands Myanmar’s former capital city, Yangon (Rangoon). Because the Yangon River [31] is only a minor channel, the flow of water is insufficient to prevent Yangon Harbour from silting up, and dredging is necessary. The relief of the delta’s landscape is low but not flat. The soils consist of fine silt, which is replenished continuously by fertile alluvium carried downstream by the river. As a result of heavy rainfall varying from 2000 to 3000 millimeters a year in the delta, and the motion and sediment load of the river [32], the delta surface extends into the Andaman Sea [33] at a rate of about 50 m per year*” [15].

### 5.5.1. A Mangrove Forest System along the Coast

The Irrawaddy River and its tributaries flow into the Andaman Sea through the Irrawaddy Delta. This ecoregion consists of mangroves and freshwater swamp forests. Because of the river-borne silt deposited in the delta [15] it is an extremely fertile area. The upper and central portions of the delta are almost entirely under cultivation, principally for rice (Figure 11). The southern portion of the is made up of fanlike marshes [34] with oxbow lakes, islands, and meandering streams [35] [36]. The ecoregion transitions into the Burmese Coast mangroves.

Wikipedia [15] stated “*Birds of the delta are both winter visitors and passage migrants including great cormorant (*Phalacrocorax carbo*), a wide variety of Anat-*

*idae*, Eurasian coot (*Fulica atra*), about thirty species of migratory shorebirds, the whiskered tern (*Chlidonias hybrida*), the Caspian tern (*Hydroprogne caspia*), and the brown-headed gull (*Larus brunnicephalus*), which is very common [15]. One of the most numerous wintering shorebird is the lesser sand plover (*Charadrius mongolus*), which occurs in flocks of many thousands along the outer coast of the delta. The wood sandpiper (*Tringa glareola*) and red junglefowl (*Gallus gallus*) are also abundant.”

“In the late 19<sup>th</sup> century, the spot-billed pelican (*Pelecanus philippensis*) nested in huge numbers in south Myanmar. One colony on the Sittaung River plain to the east of the delta was described in November 1877 as covering 300 square kilometers and containing millions of birds. Immense colonies were still bred in the area in 1910, but the birds had disappeared completely by 1939 [37]. Small numbers were regularly reported in the delta in the 1940s, but no breeding sites were located. As of 2010, no pelicans have been recorded, and it may well be that the species is now extinct in Myanmar” [15].

Several species of large mammal occur in the delta, but their populations are small and scattered. Asian elephants (*Elephas maximus*) were once widespread throughout the country with numbers as high as 10,000 animals, but in the last decade numbers have dwindled, partly due to transferring the animals to logging camps [38]. Other species reported to be present include the leopard, Bengal tiger, crab-eating macaque, wild dog, and otters (*Panthera pardus*, *P. tigris*, *Cuon alpinus*, and *Lutra* species) [39]. The Malayan sambar deer (*Cervus unicolor equinus*), Indian hog deer (*C. porcinus*), and wild boar (*Sus scrofa*), which have been reported from all Reserved Forests.

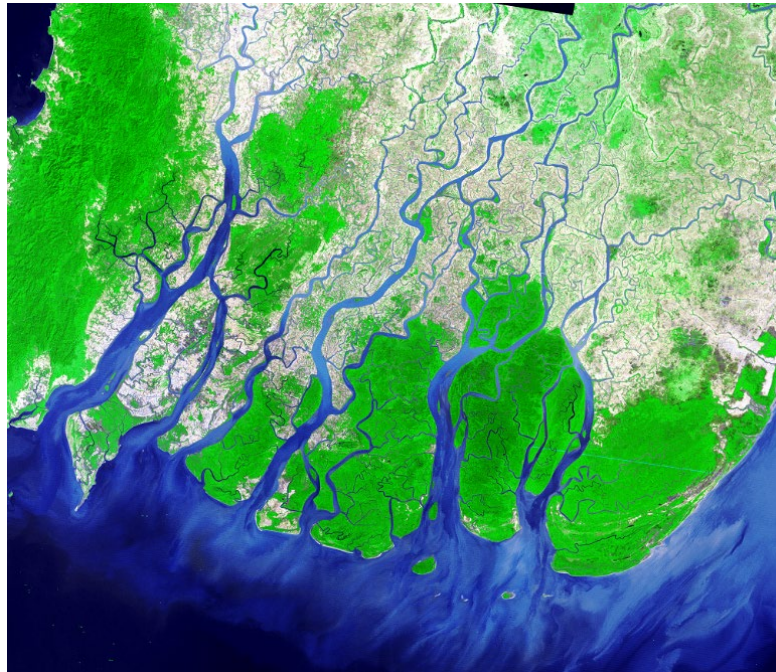
The saltwater crocodile (*Crocodylus porosus*) can be found in the southern part of the delta. It was at this river that a battle between a saltwater crocodile and a tiger was observed that ended with the reptile devouring the tiger [40]. The saltwater crocodile species was formerly abundant in coastal regions, but population numbers have decreased because of a combination of habitat loss, commercial skin hunting, drowning in fishing nets and over-collection of living animals to supply crocodile farms.

Despite recent declines in the sea turtle populations, five species are known to nest in Myanmar at well-known mainland and island beaches known as turtlebanks. These are the olive ridley sea turtle (*Lepidochelys olivacea*), the green sea turtle (*Chelonia mydas*), the hawksbill sea turtle (*Eretmochelys imbricata*), the loggerhead sea turtle (*Caretta caretta*), and the leatherback sea turtle (*Dermochelys coriacea*) [41].

### 5.5.2. Mangrove Forest Deforestation Due to Human Activities

Wang [42] reported “According to Myanmar Environmental Rehabilitation Network the Irrawaddy Delta, the country’s largest remaining area of mangrove forest 83 percent of the mangroves have been lost by 2016 (Figure 15). Myanmar is a known “hot spot” in Southeast Asia for mangrove loss from aquaculture, agriculture, and logging. As one of Myanmar’s most densely populated areas with an

*estimated population of 7.7 million, much of Irrawaddy Delta's tree loss is caused by human beings."*



**Figure 15.** Irrawaddy Delta cleared former forested areas and cultivated fields in 2014. Satellite image. Photo Credit: Encyclopedia of Britannica.

*"What is left of mangrove forests across the delta's expanse of 35,000 km<sup>2</sup> wasn't enough to play the natural role of buffer when the deadly 2008 Cyclone Nargis hit [43]. The sturdy trees have hardy, massive roots that grow in thick mud and partially above ground and are extremely resistant to high winds and flood waters. Had the Irrawaddy Delta mangrove forest been intact in 2008, experts believe that thousands of lives could have been saved. Instead, Nargis killed more than 138,000 people" [42].*

*"When you look at Google Earth, there is only one green area left in Myanmar's Irrawaddy Delta and that is Mein-ma-hla Kyun Wildlife Sanctuary (MKWS)," said Narissa Bax, a Marine biologist for Fauna and Flora International Myanmar [43]. "Irrawaddy Delta is home to one last precious pocket of green. MKWS is an approximately 138 km<sup>2</sup> wetland mangrove reserve located in Bogale Township in Irrawaddy Division."*

*"Mein-Ma-Hla, which means beautiful woman in Burmese, is an area known for its diverse mangrove tree species and saltwater crocodiles. The sanctuary was established in 1986. However, it has been described as one the most degraded mangrove systems or national parks many researchers have ever seen. Poverty among area villagers, a lack of proper management, and agricultural development are all part of the problem" [43].*

In a report published by Fauna and Flora International Myanmar in August 2016, Jean W.H Yong [43], a mangrove consultant with a background in man-

grove plant biodiversity surveys and sustainable agriculture development said “MKWS has highly disturbed mangrove forest vegetation with extant pockets of high mangrove floristic diversity”.

“The report also identified the reasons for deforestation at MKWS and the surrounding area to conversion of land for rice fields (Figure 16), an activity promoted by the government to ensure self-sufficiency in food production, and firewood collection for cooking, shrimp and fish drying, and as commodity to sell at firewood markets at Bogale and Yangon, the biggest commercial hub in Myanmar. MKWS and the surrounding area was all mangrove forest before being converted into rice fields around 40 years ago, and villagers rely on rice farming, fishing, and collecting wood from the sanctuary for livelihood” [43] [44].



**Figure 16.** Forested areas are green in Irrawaddy Delta in 1974. Satellite image. Photo Credit: Encyclopedia of Britannica.

### 5.5.3. How Myanmar’s Gold Rush Threatens Myanmar’s Landscape and Rivers

Cross-border pollution from Myanmar’s gold mining (Figure 17, Figure 18) and deforestation (Figure 19) impacted Thailand’s Kok and Sai rivers, exacerbating flooding and contaminating water with toxic chemicals including cyanide, arsenic, and mercury. These activities, reportedly intensified since 2023 by four Chinese companies, led to ecological devastation, decimating fish populations and threatening the health and livelihoods of 1.2 million people [45]. The September 2024 floods submerged villages (Figure 20) including Peng Kham in Myanmar and Thaton in Chiang Mai with mud-laden water (Figure 21 and Figure 22).

In response, over 700 Thaton residents rallied on March 14, 2025, for the International Day of Action for Rivers, demanding protection of the Kok River. Tests in Mae Ai district revealed alarming arsenic levels (0.026 mg/L, exceeding



**Figure 17.** Loi Kham Mountain is scarred by gold mining operations that started in the early 2000s without minimal cyanide treatment facilities in place. Photo Credit: Shan State Farmers Network.



**Figure 18.** Solution ponds are used to contain or collect the chemical solution—typically cyanide—after it has percolated through gold-bearing ore. Heap leaching, commonly used for low-grade ore, are part of the process where crushed ore is piled onto a large, impermeable pad and irrigated with a cyanide solution to extract the gold. Photo Credit: Mekong Eye.



**Figure 19.** A road through Tanintharyi Nature Reserve (TNR) in southern Myanmar which is one of the largest evergreen tropical rainforest in SE Asia. Photo Credit: TNR Officer/Dawei Watch.



**Figure 20.** Rescuers help an elderly woman evacuate her home in Mae Sai town in Thailand's Chiang Rai province during the historic 2024 flood. The Thai government study indicated that the flood originated from the gold mining activities in eastern Shan State in Myanmar. Photo Credit: Mae Sai Municipality.



**Figure 21.** The Mayor of Mae Sai Municipality in Thailand's northern Chiang Rai province, inspects the mud left behind after the 2024 flood receded. The mud was believed to have originated from a gold mine in eastern Shan State in Myanmar, which borders Chiang Rai. Photo Credit: Mae Sai Municipality.



**Figure 22.** Toxic sediment A farmer in Mong Len township in eastern Shan State near the Thailand border watches as murky water from a gold mine atop Loi Kham mountain floods his rice field. Photo Credit: Shan State Farmers Network.

the 0.01 mg/L safe limit) and mercury (0.076 mg/L, above 0.05 mg/L), linked to cancer and neurological damage. Academics and civil groups petitioned Prime Minister Paetongtarn Shinawatra to negotiate with Myanmar's junta, ethnic forces, and China, proposing a joint panel and water-quality monitoring center.

## 5.6. Economy and Politics

Wikipedia [15] stated “As early as the sixth century, the river was used for trade and transport, and an extensive network of irrigation canals was developed to support agriculture. The river is still of great importance as the largest commercial waterway of Myanmar [36]. It also provides important ecosystem services to different communities and economic sectors, including agriculture, fisheries, and tourism [37].”

“In 2007, Myanmar's military dictatorship signed an agreement for the construction of seven hydroelectric dams, yielding a total of 13,360 MW, in the N'mai and Mali Rivers, including the 3600 MW Myitsone Dam at the confluence of both rivers. Environmental organizations have raised concerns about the project's ecological impact on the river's biodiverse ecosystems. Animals potentially impacted include the endangered Irrawaddy dolphin and the critically endangered Ganges shark.”

“As early as the sixth century, the Bamars were using the Irrawaddy to gain power in the region through trade and transport on the China-India route. By the twelfth century, a well-developed network of canals made for flourishing rice cultivation. Later, the river became a key economic tool of Imperial British interests, who set up trading ports along its shores.”

“Today, the Irrawaddy is still the country's most important commercial waterway. Despite Mandalay's position as the chief rail and highway focus in northern Myanmar, a considerable amount of passenger (Figure 4), goods and food (Figure 23) traffic moves by river. As the Irrawaddy Delta is one of the world's major rice-growing areas, one of the most important goods transported is rice. Teak logs (Figure 24)—Myanmar is one of the world's top exporters—are floated down the river as large rafts (Figure 8). Before it is transported, teak must be seasoned,



**Figure 23.** Fish market. Photo Credit: Encyclopedia of Britannica.



**Figure 24.** Piles of wood can be seen at villages surrounding Mein-ma-hla Kyun Wildlife Sanctuary. Photo Credit: Encyclopedia of Britannica.

*because otherwise it won't float [46]. This happens by girdling, a practice where a deep circular cut through bark and sapwood is made into the heartwood. Other major goods that are transported from the nation's heartlands to Yangon for export are other foodstuffs, petroleum, cotton, and local commodities."*

*"Commercial transportation on the Irrawaddy is maintained for about 1300 km from Hinthada to Bhamo (1080 km throughout the year, but from Bhamo to Myitkyina (200 km) for only seven months). More than 3200 km of navigable waterways exist in the Irrawaddy delta, and there is a system of connecting canals. The Sittang is usable by smaller boats, but the Salween River, because of its rapids, is navigable for less than 160 km from the sea. Small steamers and country boats also serve the coasts of the Rakhine State and Tanintharyi Region. On the Chindwin River, transportation is carried on by steam or diesel vessels throughout the year up to Homalin—about 640 km from its confluence with the Irrawaddy. Seasonal navigation is carried on into Tamanthi, which is 92 km by river above Homalin."*

*"The Chindwin valley has no railroad and relies heavily on river transport. Chauk, downstream from the confluence in the oil-field district, is a petroleum port. It is linked to Yangon by road and rail. Hinthada, near the apex of the delta, is the rail junction for lines leading to Kyangin and Bassein (Pathein). A ferry operates between Hinthada on the west bank and the railway station at Tharrawaw on the east bank" [15].*

### 5.7. Dams

Myanmar's military junta signed an agreement with China Power Investment Corporation in May 2007 for the construction of seven hydroelectric dams along the Irrawaddy, Mali, and N'Mai River in Kachin State [15]. The total planned electric output of all seven plants will be 15,160 MWs of electricity, making it the largest hydropower project in Myanmar, surpassing the 7100 MW Tasang Dam in Shan State [41]. The following capacity (MW) data is available for the following dam locations: Pashe 1600, Lakin 1400; Myitsone 3600; Chibwe 2800; Phizaw

1500, Khaunglanphu 2700; and Laiza 1560. The power generated by the dams will be transmitted to other South-East Asian countries, with most going to China [47]. Other countries targeted for power export are India, Thailand, and Bangladesh.

The largest of the seven, the Myitsone Dam, is located at the confluence of the Mali and N'Mai Rivers at the creation of the Irrawaddy [48]. Although the China Power Investment Corporation is project manager of the Confluence Region Hydropower Projects [49]. Par Confluence Region Hydropower Projects, several companies have been or are currently involved in the preparation, construction and financing of the 3600 MW Myitsone Dam. Asia World Company has a key position, amidst Burmese Suntac Technologies and state-run Myanmar Electrical Power Enterprise, a state-owned utility enterprise responsible for power generation, transmission, and distribution [50].

Chinese involvement comes from China Power Investment Corporation, China Southern Power Grid, Yunnan Machinery Equipment Import & Export Company Changjiang Institute of Surveying, Planning, Design and Research. At least one Japanese company is involved, Kansai Electric Power Company.

### 5.8. Myitsone Dam Controversy

Due to its location and size, construction of the Myitsone Dam (Figure 25) has raised significant sociological and ecological concerns. According to the Irrawaddy Myitsone Dam Multipurpose Water Utilizing Project study, the maximum water level of the reservoir will be 290 m. This makes for a flood zone of 766 km<sup>2</sup>, compromising 47 villages [51].



**Figure 25.** Rendition of the Myitsone dam. Photo Credit: Encyclopedia of Britannica.

Other consequences of the inundation include loss of spawning habitat as fish cannot swim upstream anymore and loss of farmland. The Kachin Development Networking Group, a network of civil society groups and development organizations in Kachin State warn this will lead to a loss of income for fishermen. They

report locals are also worried about the flooding of cultural sites in the flood zone. As with other large dam projects, the Myitsone Dam construction will alter the hydrological characteristics of the river, e.g. preventing sediment from enriching floodplains and river banks downstream, where it usually enriches the riverside food-producing plains [52]. This can affect fertility as far downstream as the Irrawaddy Delta, the primary rice-producing area of Myanmar.

Ecological concerns focus on the inundation of an area that is South Central China biodiversity hotspots and the border of the Indo-Burma and. The Mali and N'mai River confluence region falls within the Mizoram-Manipur-Kachin rainforests and is included in the WWF list of outstanding examples of biodiverse regions [53].

The location of the Myitsone Dam, less than 100 km from a fault line where the Indian and Eurasian tectonic plates meet, raised concerns about its earthquake resistance. Earthquakes in the region, such as the 5.3 magnitude earthquake that struck near the Myanmar-China border on 20 August 2008 [54], prompted Naw Lar, the coordinator of the KDNG dam research project, to ask the junta to reconsider its dam projects [55] [56].

## 6. Summary

The primary objectives were to assess the extent and causes of soil degradation in the Irrawaddy River basin and its impacts on agricultural productivity and to assess lessons learned, manage, mitigate, and restore the Irrawaddy River watershed lifeline in Myanmar. As early as the sixth century, the river was used for transport and trade, and an extensive network of irrigation canals was developed to support agriculture. The river is still of great importance as the largest commercial waterway within Myanmar. It also provides important ecosystem services to different economic and community sectors, including agriculture, fisheries, and tourism.

Since February 1, 2021, Myanmar has descended into a bloody civil war. The civil war has displaced people and has taken a heavy toll on Myanmar's rich natural resources. Once seen as a frontier of untapped wealth, including minerals, timber and other valuable resources, these assets are now being exploited to fund the war and to generate profits for a select few. Citizen journalists still inside the country have been uncovering the hidden costs of war. These include deforested hills that poisoned the rivers and displaced communities and impeded local conservation efforts. Political turmoil, expanding extractive industries, and diminishing focus on sustainable agriculture are accelerating soil degradation across Myanmar. Lack of scientific research assistance and soil degradation following the military coup in Myanmar have severely impacted millions of farmers, whose livelihoods depend on the once fertile land. Many farmers in Sagaing, Myanmar have been farming for half a decade. Annual flooding had kept the soil fertile, keeping the families afloat.

Myanmar's military dictatorship signed an agreement, in 2007, for the construction of seven hydroelectric dams, yielding a total of 13,360 MW, in the N'mai

and Mali Rivers, including the 3600 MW Myitsone Dam at the confluence of both rivers. Environmental organizations have raised concerns about the project's ecological impact on the river's biodiverse ecosystems. The controversial Myitsone Dam is no longer under construction.

The reason for deforestation at MKWS and the surrounding area is conversion of land for rice fields. This activity was promoted by the government to ensure self-sufficiency in shrimp and fish drying, food production, and firewood collection for cooking, and as commodity to sell at firewood markets at Yangon and Bogale, the biggest commercial hub in Myanmar. MKWS and the surrounding area were all mangrove forests before being converted into rice fields approximately 40 years ago. The villagers rely on rice fishing, farming, and collecting wood from the sanctuary for livelihood.

Since 2016, the Irrawaddy Delta, the country's largest remaining area of mangrove forest 83 percent of the mangroves have been lost [42]. Myanmar is a known "hot spot" in Southeast Asia for mangrove loss from logging, aquaculture, and agriculture. As one of Myanmar's most densely populated areas with an estimated population of 7.7 million, much of Irrawaddy Delta's tree loss is caused by human beings. What remains of mangrove forests across the delta's expanse of 35,600 km<sup>2</sup> wasn't enough to play the natural role of buffer when the deadly 2008 Cyclone Nargis hit. The sturdy trees have hardy, massive roots that grow in thick mud and partially above ground and are extremely resistant to high winds and flood waters. Had the Irrawaddy Delta mangrove forest been intact in 2008, experts believe that thousands of lives could have been saved. Instead, Nargis killed more than 138,000 people. Reliable management strategies are needed to ensure accurate long-term exploitation of the Irrawaddy River Valley and Delta without deteriorating the regional environment and natural resources. Undesirable events can thus be avoided, and a sustainable environment can be ensured.

## 7. Conclusion

The civil war has displaced people and has taken a heavy toll on Myanmar's rich natural resources. Once seen as a frontier of untapped wealth, including minerals, timber and other valuable resources, these assets are now being exploited to fund the war. Citizen journalists still inside the country have been uncovering the hidden costs of war. These include deforested hills that poisoned the rivers and displaced communities, and lost local conservation efforts. Myanmar's forests and wildlife are among its greatest natural treasures. They have been steadily lost to human activities including large-scale deforestation for mining, illegal charcoal production, and booming online wildlife trade. Some have turned to illegal logging, poaching and other environmentally harmful activities since jobs are scarce and their farmland was destroyed by war. War has also taken a toll on marine life. Since villagers can no longer access traditional turtle sanctuary areas due to military control the sea turtle populations are in sharp decline. The once-thriving conservation efforts that protected these endangered species have been disrupted,

leaving marine ecosystem vulnerable.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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