Open Journal of Soil Science, 2025, 15(5), 285-319
https://www.scirp.org/journal/ojss
ISSN Online: 2162-5379
ISSN Print: 2162-5360

China's Most Important Navigation and Hydropower Power Lifeline: Yangtze River

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How to cite this paper: Olson, K.R. and Speidel, D.R. (2025) China's Most Important Navigation and Hydropower Power Lifeline: Yangtze River. *Open Journal of Soil Science*, **15**, 285-319.
https://doi.org/10.4236/ojss.2025.155014

Received: April 17, 2025
Accepted: May 16, 2025
Published: May 19, 2025

Abstract

The Yangtze River is the world's 6th largest river, based on discharge volume. From its source on the Plateau of Tibet to its mouth on the East China Sea, the river traverses or serves as the border between 10 provinces or regions. More than three-fourths of the river's course runs through mountains. The Yangtze has eight principal tributaries. The primary objectives are to develop, manage, and maintain the Yangtze River system lifeline. The Yangtze River has some of the world's largest reservoirs and is a major source of livelihood for millions of people. Many factories and cities discharge their waste, including sewage, industrial waste, fertilizers, and pesticides, into the Yangtze River. Pollutants tend to settle in the reservoirs and contain several meters of heavily contaminated muck. The Yangtze River produces more ocean plastic pollution, by far, than any other river in the world. Pollution levels have risen in the Yangtze and tributary rivers and lakes, soil erosion in the middle and upper basins caused by overgrazing and the overcutting of trees has increased silt loads, and land reclamation has reduced surface areas of lakes and wetlands. This article aims mainly to develop, manage and maintain the lifeline of the Yangtze River watershed. It is a great tool to ensure the long-term management of the Yangtze River and its surroundings. This article provides key information that may prove very useful for future related investigations.

Keywords

Yangtze River, China, Grand Canal, Three Gorges Dam, Wuhan

1. Introduction

The Yangtze River is the world's third longest river after the Nile and Amazon Rivers and is the longest in Asia and the People's Republic of China. It is also considered the longest river within the borders of a single nation. The Yangtze River Basin drains about one-fifth of the land area of China. The Yangtze River Basin provides support to approximately one-third of the population of the People's Republic of China. The Yangtze River has some of the world's largest reservoirs and is a major source of livelihood for millions of people.

In the past decades, numerous research studies have been devoted to the study of the Yangtze River watersheds. Understanding the role of anthropogenic activities, extensive dam operation, water withdrawal and irrigation, in the hydrological cycle is critical to support sustainable water management for the Yangtze River Basin [1]. Reservoir operation, irrigation and water withdrawal are main components of anthropogenic activities that play a major role in the natural-social dualistic water cycle [2] [3]. To quantify the impacts of human activities on the water cycle involves employing long-term streamflow data to analyze the impacts of human activities on the water cycle before and after a specific time point [4]. Existing process-based models are insufficiently accurate for fully depicting anthropogenic activities as part of the hydrological cycle [1]. As reservoirs increasingly support irrigation water supplies, irrigation has evolved into a critical component of the water cycle [5]. Globally, approximately 70% of freshwater withdrawals per capita are used for irrigation purposes [6]. In addition to agricultural irrigation, industrial and domestic water uses also consume substantial freshwater resources [7]. Overall, reservoir operation, irrigation and water withdrawal are considered to have exerted remarkable effects on the global water cycle. Most reservoirs are designed with objectives including hydropower and flood control [8], and they also serve as vital water sources for irrigation uses [9].

The primary objectives are to identify themes and insights of a developed master plan that harnesses the Yangtze River's hydropower potential while examining the socio-economic challenges of community resettlement due to new dam constructions and to develop, manage, and maintain the Yangtze River system lifeline. Many factories and cities discharge their waste, including sewage, industrial waste, fertilizers, and pesticides, into the Yangtze River. Soil loss from erosion and sedimentation in the Yangtze River and reservoirs needs to be reduced with the use of conservation practices including no-tillage on sloping croplands and improved vegetation management on both grazing lands and forests. Pollutants tend to settle in the reservoirs and contain several meters of heavily contaminated muck.

In this article, aiming at developing, managing and maintaining the lifeline of the Yangtze River watershed, key information is provided. It is observed that although many research studies are conducted on the Yangtze River, the lifeline of this river is little explored. Due to its considerable importance in assessing the sustainability of rivers, it should be studied for a particular river. It is from this perspective that the lifeline of the Yangtze River watershed is presented, considering different relevant factors. An overall view of the Yangtze River is shown in (Figure 1) and (Figure 2) where the Three Gorges Dam is installed.

Figure 1. View of the Three Gorges Dam and a section of the Yangtze River. Photo Credit: Wadslin Frenelus.

Figure 2. Another view of the Yangtze River conditions where the Three Gorges Dam is installed. Photo Credit: Wadslin Frenelus.

2. Location and Methodology

2.1. Study Site

The headwaters of China's three great rivers, Yangtze, Yellow [10], and Mekong [11], all originate in the Tibet Highlands. Greer and Muranov [12] reported "*Yangtze River* (Figure 3), *is the longest river in both China and Asia and the third longest river in the world, with a length of 6300 km. Its basin, extending for some 3200 km from west to east* (Figure 4) *and for more than 1000 km from north to south, drains an area of 1,808,500 km*^{2} [13]. *The Yangtze is considered the world's 6*th *largest river, based on discharge, with an average discharge volume of 30,166 m*^{3}*/s. From its source on the Plateau of Tibet* (Figure 5) *to its mouth on the East China Sea, the river traverses or serves as the border between 10 provinces* *or regions. More than three-fourths of the river's course runs through mountains. The Yangtze has eight principal tributaries. On its left bank, from source to mouth, these are the Yalung, Min, Jialing, and Han rivers and those on the right bank include the Wu, Yuan, Xiang, and Gan rivers.*"

Figure 3. Elevation map with green being the lowlands and brown the mountain tops. Photo Credit: World Atlas, https://www.worldatlas.com/r/w768/upload/df/c8/0c/tibetan-plateau.png.

Figure 4. Map of Yangtze and Yellow Rivers. Map of the Yangtze River watershed map with cities. Photo Credit: Travel China Guide, https://blankworldmap.net/wordpress/wp-content/uploads/2022/08/Map-of-Yangtze-River.jpg. (This map does not depict the full territorial extent of China, and the islands in the South China Sea are not shown.)

Figure 5. Plateau of Tibet highlands in Himalayas. Photo Credit: Encyclopedia of Britannica.

"*The name Yangtze—derived from the name of the ancient fiefdom of Yang—has been applied to the river mainly by those in the West. Chang Jiang ("Long River") is the name used in China, although it is called Da Jiang ("Great River") or, Jiang ("[The] River"). The Yangtze is the most important river in China. It is the country's principal waterway, and its basin is China's great granary and contains nearly one-third of the national population*" [12].

The lower 2884 km course of the Yangtze River from the city of Yibin to its mouth at Shanghai (**Figure 6**) is named "Chang Jiang" which means "Long River" [14]. The 2308 km stretch of the river from Yibin to its confluence with Batang River is named "Jinsha Jiang" which means "Gold Sands River". The 813 km stretch of the river from Yushu to its confluence with Dangpu River is named as "Tongtian River", while the official headstream of the river is named as "Tuotuo River". During the 1800, the English cartographers named the entire river "Yangtze" which means "child of the ocean".

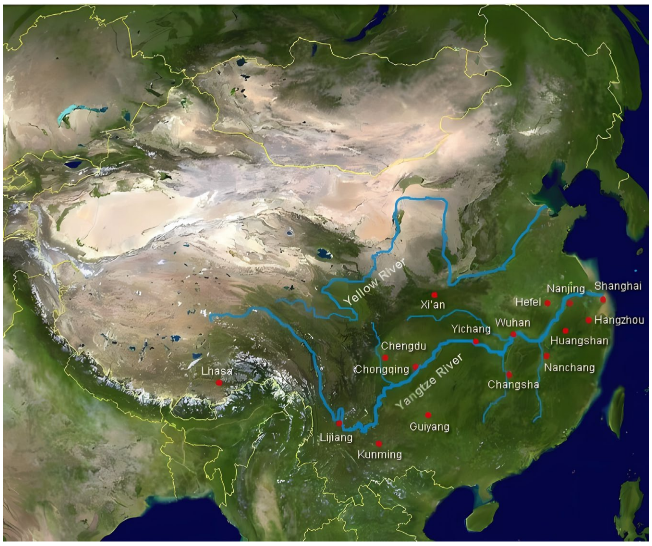

Figure 6. Topography of the Yangtze watershed in Northern China. Photo Credit: Pinterest, https://i.pinimg.com/originals/66/b8/3e/66b83ec5548efd7160556b94263f82a0.gif.

The Yangtze has had a major role in China's history, culture, and economy. For thousands of years, the river has been used for water, irrigation, sanitation, transportation, industry, boundary-marking, and war [14]. The prosperous Yangtze Delta generates as much as 20% of China's GDP. The Three Gorges Dam on the Yangtze is the largest hydroelectric power station (**Figure 7**, **Figure 8**) in the world that is in use [15] [16]. In mid-2014, the Chinese government announced it was building a multi-tier transport network, comprising railways, roads, and airports, to create a new economic belt alongside the river [17].

Figure 7. Electrical generation and water discharge at the Three Gorges Dam. Photo Credit: Pinterest.

Figure 8. Three Gorges Dam and reservoir. Photo Credit: Pinterest.

The Yangtze flows through a wide array of ecosystems and is a habitat to several endemic and threatened species including the Chinese alligator, the narrow-ridged finless porpoise, and also was the home of the now-extinct Yangtze river dolphin (or *baiji*) and Chinese paddlefish, as well as the Yangtze sturgeon, which is extinct in the wild. In recent years, the river has suffered from industrial pollution, plastic pollution [18], agricultural runoff, siltation, and loss of wetlands and lakes, which exacerbates seasonal flooding. Some sections of the river are now protected as nature reserves. A stretch of the upstream Yangtze flowing through deep gorges in western Yunnan (**Figure 9**) is part of the Three Parallel Rivers of Yunnan Protected Areas, a UNESCO World Heritage Site.

Figure 9. Outang Gorge which is one of the Three Gorges Photo Credit: Wikipedia.

The Yangtze River has some of the world's largest reservoirs and is a major source of livelihood for millions of people. Many factories and cities discharge their waste, including sewage, industrial waste, fertilizers, and pesticides, into the Yangtze River. Pollutants tend to settle in the reservoirs and contain several meters of heavily contaminated muck.

2.2. Methodology

This study employed qualitative content analysis and visual data (pictures) to identify themes and insights for a developed master plan that harnessed the Yangtze 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 ladders to sustain fish migration and populations, community resettlement, and socio-economic impacts in the Yangtze River Basin among several other themes, were gathered and synthesized to identify best practices soil erosion and sediment control practices and pollution mitigation. Key metrics such as food security, compensation adequacy, and health outcomes were analyzed to establish a baseline for assessing the potential impacts of completed hydropower projects. This methodology aims to ensure that hydropower developments not only leveraged the Yangtze River's energy potential but also prioritized the well-being and livelihoods of affected local communities. The primary goal is to develop, manage, and maintain the Yangtze River system lifeline.

3. Natural and Cultural Resources

3.1. Geology, Geography, and Soils of the Yangtze Watershed

Greer and Muranov [12] noted "*In its upper reaches, the Yangtze River drains* *across the Plateau of Tibet* (**Figure 10**), *which is still uplifting as the Indian and Eurasian tectonic plates collide. The bedrock is composed of marine sedimentary, igneous, and metamorphic rocks* (**Figure 11**). *Within intermontane basins, thick deposits of sediments of Cenozoic age—i.e., less than about 65 million years old—overlie the bedrock. The Yangtze descends abruptly from the Tibetan Plateau to flow across deeply eroded mountain plateaus composed of Paleozoic and Mesozoic rocks roughly 350 to 150 million years old. In its lower reaches, the Yangtze River flows across basin fills of Cenozoic material about 65 to 25 million years old. These materials are from fluvial sedimentation as the Yangtze has migrated across its lower basin throughout its Cenozoic history*".

Figure 10. Village on the Tibet highlands plateau in Himalayas. Photo Credit: Encyclopedia of Britannica.

The Yangtze River stands at an elevation of 5,170 m and originates from Jari Hill, in the Tanggula Mountain range in the central portion of the Tibetan Plateau. The source of the Yangtze River was discovered in the late 20th century. The Yangtze River flows through 11 Chinese provinces including Qinghai, Tibet, Sichuan, Yunnan, Chongqing, Hubei, Hunan, Jiangxi, Anhui, Jiangsu, and Shanghai. The entire course of the Yangtze River is divided into three parts: the Upper Course, the Middle Course, and the Lower Course [13].

In the Upper Course, the Yangtze flows across the Tibetan Plateau and descends through deep valleys in the mountains, located east of the plateau. The 2nd source of the Yangtze is the Ulan Moron River, which originates from the snowmelt waters on the slopes of the Tanggula Mountain in the southern part of the Province of Qinghai. The Yangtze River confluences with several tributaries and then flows eastward through a large valley. Upon reaching the eastern parts of the Tibetan Highlands, the character of the river changes. At this point, the river's stretch is referred to as Jinsha, where it descends from a high elevation by winding its course to the south of the Bayan Har Mountains and forming a narrow valley. The Yangtze River continues to move in a southeasterly direction through very steep passes

(**Figure 4**). In this region, the Yangtze River flows parallel two other great rivers—the Lancang-Mekong and the Salween-Yellow Rivers.

China is a vast and diverse country with a wide range of soil types due to its varied topography and climate. The soil in China plays a crucial role in agriculture, as the country is one of the world's leading producers of crops such as rice, wheat, and vegetables. In this article, we will explore the different types of soil found in China, their characteristics, and their significance for agricultural production (**Figure 11**).

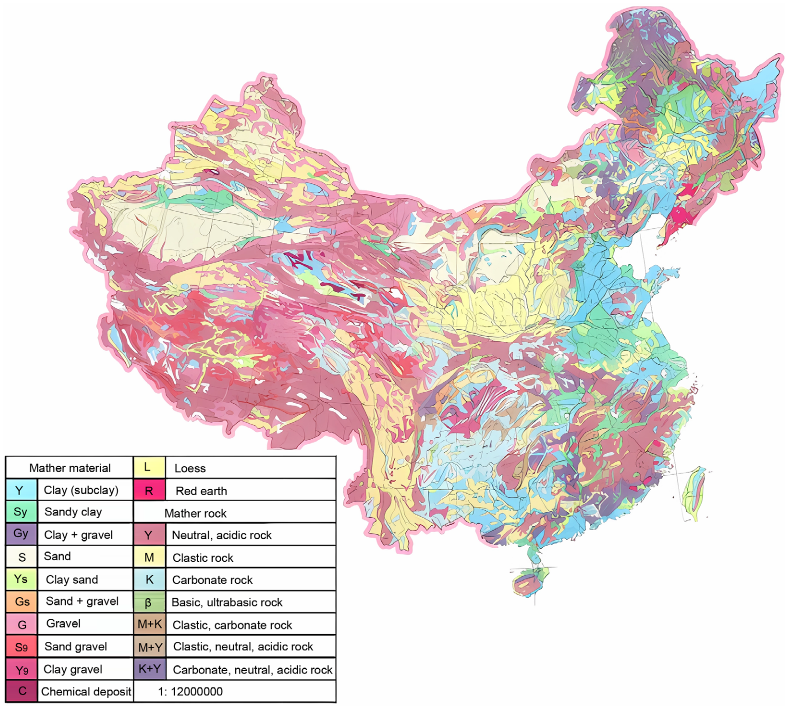

Figure 11. Soil parent material in China. Photo Credit: ResearchGate, https://www.researchgate.net/profile/Gang-Li-79/publication/295173657/figure/fig5/AS:331111499616263@1455954541473/Map-of-soil-parent-material-and-rock-of-China-from-a-book-titled-The-atlas-of-soil.png.

China has a diverse range of soil types, including red, yellow, black, and alluvial soils. Red soil, also known as "hongtian" soil, is found in southern China and is rich in iron oxide, giving it its characteristic red color. Yellow soil, or "huangtian" soil, is prevalent in the northern and central regions of China and is formed from the weathering of loess deposits. Black soil, or "heitian" soil, is found in the northeast of China and is known for its high fertility and moisture retention properties. Alluvial soil, or "tuili" soil, is found along riverbanks and is rich in nutrients due to its deposition of sediment.

Chinese soil is generally characterized by its high fertility, which is conducive to agricultural production. The soil in China varies in texture, pH levels, and nutrient content, depending on the region and climate. The soil in China is subject to erosion and degradation due to factors such as deforestation, urbanization, and improper agricultural practices.

The soil in China plays a crucial role in supporting the country's agricultural sector, which is vital for food security and economic development. Chinese farmers utilize various techniques such as crop rotation, terracing, and organic farming to maintain soil health and productivity. Sustainable soil management practices are essential to ensure long-term agricultural productivity and environmental sustainability in China.

3.2. Physical Features and Geological Evolution of Three Gorges

Due to the lithological conditions of its different regions, the valleys of the Three Gorges are narrow in some areas and broad in others. Most narrow valleys occur in limestone which is relatively hard and resists erosion [13]. However, water can flow along deep vertical fractures, eroding underneath. As the limestone bed is gradually undercut, sections fall into the river along vertical fractures, forming precipitous cliffs. When the river flows through softer sandstone and shale regions, less resistant to erosion forces, the river carves wider valleys.

Greer and Muranov [12] suggested "*There are different theories on how the Three Gorges were formed. Geographers and geologists have generally reached a consensus, believing mountain folding in the east of Sichuan Province and the west of Hubei Province, including the Wu Mountains, were the outcome of the Yanshanian movement around 70 million years ago. The gorges run from southwest to northeast, then turn, and from west to east, with terrain lowering gradually from south to north. The western and eastern parts of the area, between the southern mountains and Bashan Mountain, in the north, are comparatively lower; and in the past, the river flowed to the east through the region. As the crust of the locality continued to rise, the river's erosion intensified, and the Three Gorges were carved*".

Greer and Muranov [12] found "*The upper course of the Yangtze flows across the Plateau of Tibet and descends through deep valleys in the mountains east of the plateau, emerging onto the Yunnan-Guizhou (Yungui) Plateau. Summers there are warm, and the winters are cold. The source of the Yangtze is the Ulan Moron (Wulanmulun) River, which originates in glacial meltwaters on the slopes of the Tanggula Mountains in southern Qinghai province on the border with the Tibet Autonomous Region. From the confluence of this stream with several others, the river flows generally easterly through a shallow, spacious valley, the bottom of which is populated with lakes and small reservoirs. This part of its course lies in the higher regions of the Tibetan highlands*".

Greer and Muranov [12] noted "*The middle course of the Yangtze stretches for about 1010 km between the cities of Yibin in Sichuan province and Yichang in Hubei province. The climate is characterized by hot summers and relatively mild winters, as the high mountains to the west protect the region from the cold north and west winds. Annual precipitation measures between 1000 to 1500 mm, most occurring in summer, and the growing season lasts for more than six months. In* *most of this segment, the river crosses the hilly Sichuan province, where the lower mountains and plateaus connect the highlands of southwestern China with the Qin (Tsinling) Mountains lying between the Yangtze and Huang He (Yellow River) basins. Located in this area is Chongqing, a major industrial center and river port. The river's width is from about 300 to 500 meters, and the depth in places exceeds 10 meters. The current is swift; the banks often are high and steep. The river falls 250 meters in Sichuan, more than 0.2 meters per km of flow."*

Greer and Muranov [12] found "*The lower part of the Yangtze Basin is centered on the extensive lowland plains of east-central China. The region experiences a temperate climate with warm springs, hot summers, cool autumns, and relatively cold winters for the latitude. Monsoons (seasonally changing winds) dominate the weather of the region. In the summer and autumn, typhoons occur periodically. As the Yangtze exits from the Three Gorges Dam* (**Figure 7**)*, near Yichang, it enters a complex system of lakes, marshes, and multiple river channels developed on the plains of plains of Hunan and Hubei provinces. This vast region, lying at elevations below 50 meters, has provided a natural flood-regulation basin in recent geologic history. Three main tributaries (the Yuan, Xiang, and Han rivers) and many smaller ones join the Yangtze in this region where the current slows as the river reaches the plain. Water levels fluctuate considerably between the flood and low-flow seasons. In addition, several large lakes, including Dongting Lake* (**Figure 12**) *and Lakes Hong and Liangzi, also cause considerable fluctuations in water volume. The total area of the lakes, at average water levels, is some* 17,100 *hectares.*"

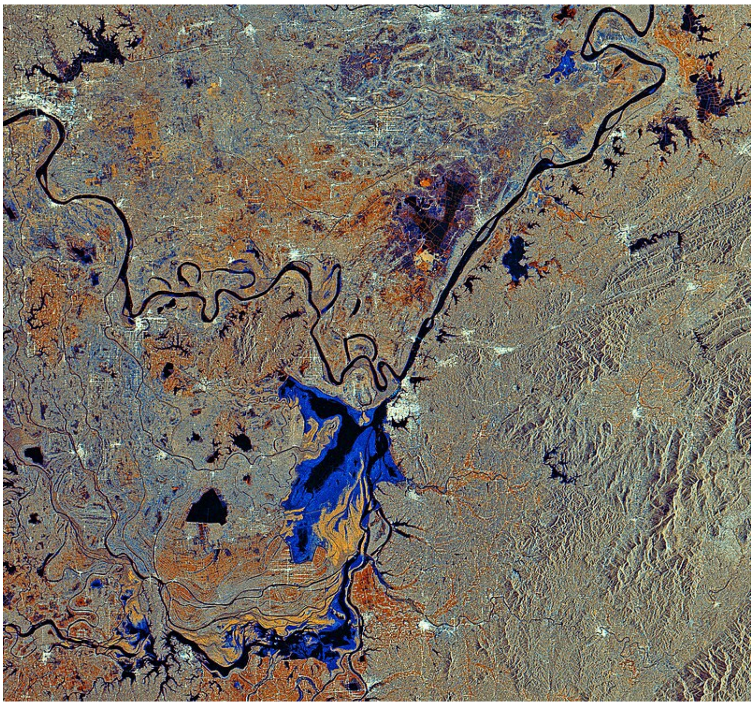

Figure 12. Dongting Lake waters of Central China. Photo Credit: By Ph Envisat satellite Photo Credit: Wikipedia, http://www.esa.int/spaceinimages/Images/2009/07/Waters_of_central_China.

3.3. Jialing River

Jialing River is a river in central China [12]. A tributary of the Yangtze River (Chang Jiang), with the largest drainage area of the Yangtze basin, it rises in the rugged western outliers of the Qin (Tsinling) Mountains in southern Gansu province. It flows south and east into far western Shaanxi province, cuts through the Daba Mountains, and flows southward, in an extremely braided course, into the Sichuan Basin, joining the Yangtze at Chongqing after a course of about 1,190 km. Its upper valley, roughly paralleled by roads and railroads, is the major communications artery between the Wei River basin of central Shaanxi and the cities of the Sichuan Basin. It is navigable by junks in its lower course.

3.4. Yuan River

Yuan River, flows through eastern Guizhou and western Hunan provinces in southeastern China. The Yuan River is about 1,020 km long and rises in the Miao Mountains near Duyun in Guizhou. Its upstream sections are called the Longtou and Qingshui rivers [12]. It becomes the Yuan River after its confluence with its northern tributary, the Wu River, which flows through Zhejiang. It then flows northeast along the western flank of the Xuefeng Mountains in Hunan to discharge into Dongting Lake at Changde which flows into the Yangtze River (Chang Jiang). The Yuan is a major waterway for western Hunan and eastern Guizhou. Large vessels on it can reach Changde, and small steamboats can travel as far as Taoyuan. There are rapids, but shallow-draft junks can reach Hongjiang near the Guizhou border and boats can travel up the Wu River as far as Zhijiang. Although there are highways running through the Yuan Valley, the river is still an important means of transport for the mountainous areas of western Hunan.

3.5. Han River

Greer and Muranov [12] noted "*Han River, one of the most important tributaries of the Yangtze River (Chang Jiang) of China. It has a total length of about 1530 km. The Han River rises in the Shenqiong Mountains, part of the Micang Mountains in the extreme southwestern part of Shaanxi province. Its upper stream is known successively as the Yudai, the Yang, and, below Mianxian, the Mian. At Hanzhong it becomes the Han River. It flows eastward at the foot of the Qin (Tsinling) Mountains, receiving from the north various tributaries (of which the Xun River is the largest) and a number of north-flowing tributaries arising in the Daba Mountains to the south. This upper valley of the Han River is mostly rugged and mountainous, but around Hanzhong is a fertile alluvial basin some 100 km long and 19 km wide. Below Ankang the river cuts through a series of deep gorges and emerges into the central Yangtze basin at Guanghua (Laohekou) above Yunxian in Hubei province.*"

3.6. The Yangtze Delta

The Yangtze Delta (**Figure 13**) begins beyond Zhenjiang. The delta consists of branches, tributaries, lakes, ancient riverbeds, and marshes that connect with the main channel. During major floods, the delta area is completely submerged. Lake Tai, with an area of about 2,410 square km, is notable as the largest of the many lakes in the delta [12]. The width of the Yangtze in the delta, as far as the city of Jiangyin, ranges from 1.6 to 3.2 km; farther downstream the channel gradually widens and becomes a large estuary, the width of which exceeds 80 km near the mouth of the river. Major cities in the delta include Wuxi, Suzhou, and, at the river's mouth, Shanghai (**Figure 14**).

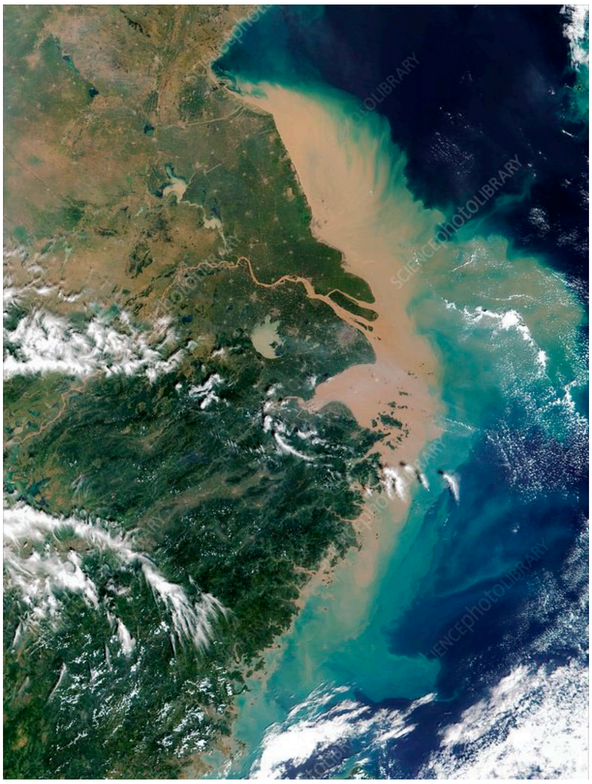

Figure 13. Yangtze Delta. Photo Credit: NASA/Science Photo Library.

Figure 14. Shanghai skyline. Photo Credit: Encyclopedia of Britannica.

Before emptying into the sea, the Yangtze divides into two arms that drain independently into the East China Sea. The left branch has a width of 5 to 10 km and the right branch width is 10 to 25 km. Between the branches is Chongming Island, which was formed over the centuries by the deposit of alluvium at the mouth of the Yangtze. The river depth in places approaches 30 to 40 meters but because of the presence of sandbars decreases to only several feet near the sea at the mouth of the river. The section of the river from the mouth to 400 km upstream is subject to the influence of tides. The maximum range of the tides near the mouth is 4 to 5 meters. The Yangtze Delta is rich in mud and silt and is dominated by fluvial and tidal processes [12].

The present-day bed of the Yangtze in this area is somewhat above the elevation of the plain. Thus, to protect the surrounding region from floodwater, the banks of the main and other rivers are built up. The total length of banks on the Yangtze on which levees have been constructed is about 2740 km. Dams also have been built for flood protection on the shores of several lakes. The Qingjiang Reservoir was built near Dongting Lake (**Figure 12**) for flood protection. The reservoir has a design capacity of 5.5 million cubic meters. The delta is protected from the sea by two gigantic parallel banks that are faced with stone in most parts.

3.7. Hydrology of the Yangtze River

The Yangtze basin is comparatively well irrigated; the yearly average rainfall is about 1,100 mm. Most of the precipitation is brought by the monsoon winds and falls primarily as rain in the summer months [12]. In the mountainous part of the basin, the precipitation is mainly snow. Floods, which result from the monsoon rains in the middle and lower parts of the basin, usually begin in March or April and can occur during the next eight months. In May, the water level decreases somewhat but then sharply increases again, continuing to rise until August, when it reaches its highest level. After that, the water level gradually falls to the premonsoon levels, the decrease continuing through the autumn and most of the winter until February, when the lowest annual level is reached [12].

The annual range of water-level fluctuations is considerable—an average of about 20 meters)—with 8 to 11 meters during years of low water. Downstream from the Three Gorges Dam, the impact of the water-level variation is lessened by the dam itself and by the regulating effect of the lakes. In the delta, tides exert the greatest influence on the water level. Near the city of Wusong, the daily tidal range is 4.5 meters, and the yearly range is 6 meters.

A breakdown of the water volume delivered to the mouth of the Yangtze shows that the highland part of the basin contributes 10 percent of the flow [12]. The remainder of the water in the river is contributed by the middle and downstream parts of the basin, with runoff from the basins of Dongting Lake (**Figure 12**) and Lake Poyang being responsible for about two-fifths of the volume.

Greer and Muranov [12] reported "*Widespread flooding also may take place at shorter intervals. This has been the case since the mid-19th century, as the Yangtze* *basin flooded in 1870, 1896, 1931, 1949, and 1954. Of these, the 1931 and 1954 floods were national disasters. The 1931 flood resulted from heavy, continuous monsoon rains that covered most of the middle and lower parts of the basin. During May and June, six huge flood waves swept down the river, destroying the protecting dams and levees in two dozen places and flooding more than 90,000 square km of land; 40 million people were rendered homeless or otherwise suffered. Many population centers were underwater, including Nanjing and the Wuhan conurbation. In Wuhan the water remained for more than four months, the depth exceeding 1.8 meters and in places more than 6 meters. In the summer of 1954, another powerful flood occurred as the result of monsoon rains. The water level sharply increased and at times exceeded the 1931 flood levels by almost 1.5 meters. Effective flood-control measures developed since the 1930s, however, averted many of the potential consequences of the flood*".

3.8. History of the Yangtze River

The Yangtze River basin is one of the longest-inhabited regions in China. Although much of China's political history has centered around North China and the Huang He basin, the Yangtze region has always been of great economic importance to successive dynasties for its agricultural potential. The Grand Canal (**Figure 15**) was built to transport grain from the Yangtze basin to the great northern capital cities; it is possible that the southernmost portion of the canal was in use as early as the 4th century BCE, and much of it was constructed in the 7th century CE.

Figure 15. Grand Canal. Photo Credit: By EditQ.

Over time, the Yangtze has served as both a political and a cultural boundary. The river now demarcates the provinces constituting South China. The Yangtze was the focus of many imperialist incursions into China in the 19th century and the first half of the 20th, with Shanghai at the river's mouth becoming the main foreign commercial base. Since 1950, the river and its basin have been the focus of much of China's economic modernization.

3.9. People of the Yangtze River

Greer and Muranov [12] noted "*The Yangtze basin contains a significant portion of China's population, but distribution is uneven. The highland area of the river's upper reaches is one of the most sparsely settled regions. The Yangtze Delta has the country's highest population density. Outside the delta, the greatest concentrations of people are in the plains that adjoin the banks of the river and its tributaries in the middle and lower basins, especially in the vicinity of the cities of Chengdu, Chongqing, Wuhan, and Nanjing. These cities are among the largest in China, and Shanghai* (**Figure 16**) *is the country's most populous.*"

Figure 16. Wuhan city skyline at sunset. Photo Credit: lokya.poco.cn.

"*In the highlands of the upper basin, the population consists mainly of ethnic Tibetans engaged in traditional animal husbandry and the cultivation of such hardy grains as barley and rye. The population of the Yunnan-Guizhou Plateau is a mixture of Chinese (Han) agriculturalists and numerous ethnic minorities who combine some farming with herding and hunting. The population of the middle and lower basins becomes progressively more Chinese, although, especially in the middle basin, many other national minorities are represented*" [12].

3.9.1. Yangtze River Populace—Chongqing

This author had the opportunity to observe many of the local populace along the river in both city and village life. During August of 2000, members of the Soil and Water Conservation Society (SWCS) were invited to tour the Three Gorges Dam project and visit with Southwest China University engineers studying the sediment problem anticipated by the new dam. Three days were spent in Chongqing [19]. During the three-day-night stay in Chongqing, this author was able to get out for an unaccompanied run each morning. Observation of the market district was enlightening. Local produce and livestock were brought in early for sale to butchers and street vendors preparing morning and noon meals. It was very well organized. First, the stall floors, covered walkways, then sidewalks were swept. Finally, the street gutters were swept.

Everything, even the swine carcasses was hauled away before the main workday started. These sweepers only worked two hours each morning. They were the same men seen standing around later in the day. Everyone in China, the government, made sure had a job.

During a one-day excursion across a Yangtze River bridge, this author noticed two cab drivers had stopped by a water puddle. They were using the water to wash their cabs. Asking about this, was informed, in Chongqing, all cars must be washed within 24 hours of rainfall to keep the mud from the outlying dirt roads, off the city streets. On our return trip, just where a long, smooth rock slab lay downstream in the middle of the river which had served as one of the old WWII Flying Tigers' landing fields, when this city was called Chungking, we saw a car stopped. The car, a black, large car, was surrounded by a dozen or more policemen. From what we could tell the car owner, was very important, thus the large number of police. His car had been stopped due to not taking time to wash his car [19]. Maintaining order and efficient commerce in the fast moving, hilly, City of Chongqing is apparent in the clean and proper dress, attention to details of the individual's shop or service and general order observed during our visit. While police and military presence was not prominent, indicators in host officials' haircuts, dress and shoes were indicative of the host's normal occupation. During our country trips and views from the boat floating downstream, along nearly every side of the road, the silhouette of a guard could be seen, even deep into the country, the shadow of guards at chokepoints could be observed standing watch on distant passes.

3.9.2. Yangtze River—Middle Course Populace

Our last stop floating down the Yangtze River was at a model village of resettled farmers from the river valley floor upstream of the new dam. Over a million people living (year 2000) in the Yangtze River valley were to be impacted by the raising 100 meters of flood water for the new lake once the dam was completed. The displaced villages were situated on the upper ridgelines above the old bottomland fields. New homes for every participant were built in clean apartments, along with new jobs, and farm fields. We met our local village host in his new apartment. Besides his occupation as a farmer, he was also a blacksmith and was the appointed village spokesman. During our initial discussion of farming methods, he described how the local farmers were educated on new methods. These sessions were held in a local coffee shop, where they could watch the televised farm education programs. One program included herbicide use with products commonly used twenty years earlier in the U.S. We then visited his fields [19].

First, we saw his one mu (a mu in China is one-fifth of a hectare) of citrus seedlings. The propagation of the seedlings in the citrus nursery was under contract with the government. For the other two fields, one mu each, he had more options for what to plant. There was considerable discussion about the stone terrace which leveled this new field. On inspection of the soil and discussion, it was determined that he and his neighbors, had built each new one mu field, by using the topsoil from their bottomland fields. This was accomplished by literally hauling the topsoil, with a tractor-wagon carrying tons of topsoil, from their old bottomland fields. This was mixed with the ridgeline soil, creating a unique mix of glittery, black, sticky, silty material. The soil depth seemed adequate for seedlings and small grains, if watered. We then walked the ridgeline overlooking the sloping hills 200 meters down to the valley floor. The vista was expansive. Below the planned elevated waterline, the terraced, tilled fields stopped. The farmsteads were abandoned, animal pens vacant of any livestock. No one was seen walking or working. But then there was one farmstead situated just below the planned waterline. A hut with a small green garden on one side and a small pen with one sow in a little shed on the other side. I asked our guide what the one farm's story was. Before our group left for this trip, we were informed that our guides would always answer questions, but the questions must be well-formed. The guide told us that the hut belonged to an old woman who had been offered a move to the new apartments. She had refused to make the move. We looked at the two small buildings, garden, and sow's pen, which were below the planned waterline. I asked what was going to happen when the dam was finished. Our guide only gave us a shrug [19]. An unfortunate cost of progress. The Three Gorges Dam was not planned for flood control, irrigation nor navigation, but principally power for Shanghai.

3.10. Economy

The economy of much of the Yangtze basin is focused largely on agricultural production, although inland cities such as Wuhan and Chongqing and the coastal region centered on Shanghai are among China's most important industrial centers. The lower basin and the delta are among the most economically developed areas in the country [12]. Mineral resources include reserves of iron ore near Wuhan and Nanjing and such deposits as coal, copper, phosphorus, gold, oil, and natural gas in Sichuan province.

3.11. Agriculture

The Yangtze basin contributes nearly half of China's crop production, including more than two-thirds of the total rice [12]. The other crops grown are cotton, wheat, barley, corn (maize), beans, and hemp. Of note is the eastern Sichuan province, which its people call the "Land of Plenty." The soil there is extremely fertile, and the climatic conditions are favorable for agriculture. The mild climate also facilitates sericulture (the production of raw silk by raising silkworms). Cultivation is most intensive in the lower basin and delta, where the natural conditions are exceptionally favorable. The growing period ranges from 8 to 11 months, and two or three crops can be harvested annually.

The extensive territory under cultivation in the Yangtze basin—especially for rice—requires man-made irrigation facilities. Even in the highest precipitation areas, severe droughts are experienced, resulting in crop losses. This is explained by the irregular distribution of precipitation over the year, with 60 to 80 percent falling in the summer. Rainless periods sometimes last for six to eight weeks. Irrigation has existed in the Yangtze basin since ancient times, but many modern irrigation projects have been undertaken, the largest being the Three Gorges Dam project.

3.12. Fisheries

Ye *et al.* [20] found "*The Yangtze River and its associated tributaries and lakes abound with fish. The fishing trade is widely developed and is a major livelihood for much of the regional population. Hundreds of species are found in Chinese rivers, the majority inhabit the Yangtze and its tributaries. Some 30 species are of economic significance, especially carp, bream, Chinese perch, gapers (a species of large burrowing clam), and lamprey; the most valuable economically are white and black amur (large members of the carp family), flatfish, and spotted flatfish. Sturgeon is important, the gorges being a favorite spawning area. Farther downstream great amounts of roe can be found, and these are collected and distributed throughout the country for artificial cultivation. The artificial cultivation for trade involves mainly white and black amur, flatfish, and carp.*"

"*As of 2011, 416 fish species are known from the Yangtze basin, including 362 that strictly are freshwater species. The remaining are also known from salt or brackish waters, such as the river's estuary or the East China Sea. This makes it one of the most species-rich rivers in Asia and by far the most species-rich in China (in comparison, the Pearl River has almost 300 fish species and the Yellow River 160 fish species) with 178 fish species are endemic to the Yangtze River Basin. Many are only found in specific sections of the river basin and especially the upper reach (above Yichang, but below the headwaters in the Qinghai-Tibet Plateau) is rich with 279 species, including 147 Yangtze endemics and 97 strict endemics (found only in this part of the basin). In contrast, the headwaters, where the average altitude is above 4,500 m, are only home to 14 highly specialized species, but 8 of these are endemic to the river. The largest orders in the Yangtze are Cypriniformes (280 species, including 150 endemics), Siluriformes (40 species, including 20 endemics), Perciformes (50 species, including 4 endemics), Tetraodontiformes (12 species, including 1 endemic) and Osmeriformes*

(8 species, including 1 endemic). No other order has more than four species in the river and one endemic. The silver carp is native to the river but has (like other Asian carp) been spread through large parts of the world with aquaculture" [20].

The largest threats to the Yangtze native fish are overfishing and habitat loss (such as the building of dams and land reclamation), but pollution, destructive fishing practices (such as fishing with dynamite or poison), and introduced species also cause problems [20]. About 2/3 of the total freshwater fisheries in China are in the Yangtze Basin [21]. A drastic decline in the size of several important species has been recorded, as highlighted by data from lakes in the river basin [20]. In 2015, some experts recommended a 10-year fishing moratorium to allow the remaining populations to recover [22], and in January 2020, China imposed a 10-year fishing moratorium on 332 sites along the Yangtze [23]. Dams present another serious problem, as several species in the river perform breeding migrations. Most of these species are non-jumpers, consequently, the normal fish ladders designed for salmon are ineffective [20]. For example, the Gezhouba Dam blocked the migration of the paddlefish and two sturgeon, [24]-[26] while also effectively splitting the Chinese high-fin banded shark population into two [27] and causing the extirpation of the Yangtze population of the Japanese eel [28]. The Three Gorges Dam has released water to mimic the (pre-dam) natural flooding and trigger the breeding of carp species downstream [29] in an attempt to minimize the effect of the dams. In addition to dams already built in the Yangtze basin, several large dams are planned. These may present further problems for the native fauna [29].

While many fish species native to the Yangtze are seriously threatened, others have become important in fish farming. Many fish species have been introduced widely outside their native range. A total of 26 native fish species of the Yangtze basin are farmed [22]. Among the most important are four Asian carp: grass carp, black carp, silver carp, and bighead carp. Other species that support important fisheries include northern snakehead, Chinese perch, *Takifugu* pufferfish (mainly in the lowermost sections), and predatory carp [20].

3.13. Navigation of the Yangtze River

The Yangtze is the principal navigable waterway of China (**Figure 17**). Along the river for 2,700 km there is intensive cargo and passenger traffic. The river serves as a continuation of the sea routes, binding the inland and coastal ports together with other major cities into a transportation network in which Nanjing, Wuhan, and Chongqing play the leading roles [30]. Motorized junks, other powered vessels, and a small number of sail boats are widely used for transporting cargo. Because of the ship locks (**Figure 18**) at the Three Gorges Dam, large ships of up to 10,000 tons can travel as far upriver as Chongqing. Water routes in the Yangtze basin total about 56,300 km. The Yangtze is joined to navigable stretches of the Huang He and the Huai, Wei, and Hai rivers by the Grand Canal

(**Figure 15**), which is further connected with the seaports of Hangzhou and Tianjin.

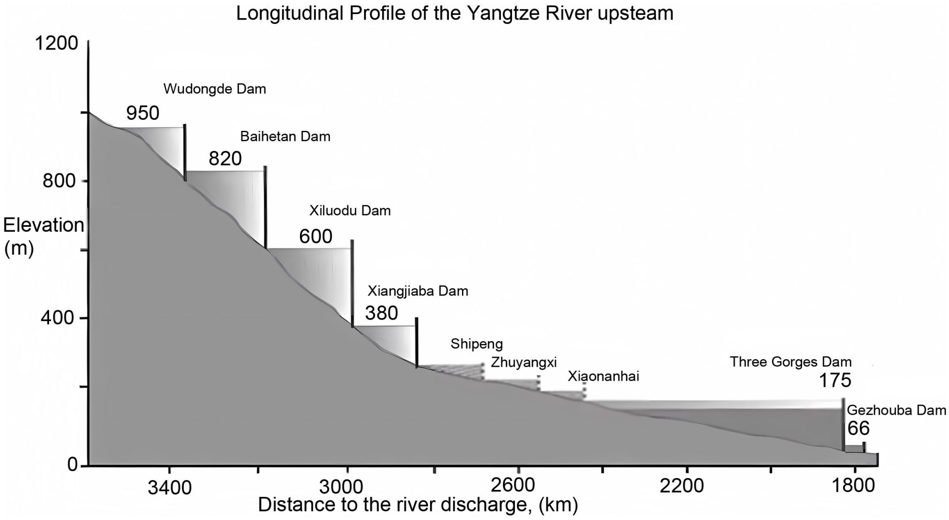

Figure 17. Elevations and sequence of the dams on the Yangtze River. Photo Credit: Road China.

Figure 18. Ship locks on Three Gorges Dam. Photo Credit: Viator.

Headrick [30] found "*Of the several projects undertaken since the 1950s to improve navigation through the gorges region, none has matched the massive Three Gorges Dam project* (**Figure 1**). *Large projects have been undertaken to strengthen and enlarge the levee system. In addition, bridges have been built across the Yangtze at Wuhan, Chongqing, Nanjing, and other cities, improving north-south transport links, and reducing dependence on ferries.*"

"*The Jardine, the first steamship to sail the river, was built for Jardine, Mathe-*

son & Co. in 1835. The China Navigation Company was an early shipping company founded in 1876 in London, initially to trade up the Yangtze River from their Shanghai base with passengers and cargo. Chinese coastal trade started shortly after, and in 1883 a regular service to Australia was initiated" [30].

3.14. Yangtze River Hydroelectric Power

The resources to produce energy from the Yangtze are enormous, although they have not been largely developed. The total potential power is estimated to be more than 200 million kilowatts, representing about two-fifths of the total energy potential of all the rivers of China. Until the Three Gorges Dam project got underway, the most ambitious project completed was the Gezhouba hydroelectric dam above Yichang, which was the first structure to block the flow of the Yangtze. Gezhouba was superseded by the massive Three Gorges Dam project (**Figure 1**, **Figure 2** and **Figure 7**). At the time of the Three Gorges Dam's completion in 2006, it was the largest dam structure in the world. It blocks the Yangtze to create a reservoir that submerges large areas of the Qutang, Wu, and Xiling gorges for some 600 km upstream. The hydroelectric component of the project, which became fully operational in 2012, can generate approximately 22,500 megawatts of hydroelectric power. Many tributaries of the Yangtze that have significant fall and volume—such as the Yalong, Min, and Jialing rivers—and other rivers that are tributaries of Dongting Lake and Lake Poyang also have considerable potential.

4. Human Impact on the Yangtze River Environment

Headrick [30] noted "*Environmental degradation in the Yangtze basin has accelerated with increased economic development since 1950. Pollution levels have risen in the rivers and lakes, soil erosion in the middle and upper basins caused by overgrazing and the overcutting of trees has increased silt loads, and land reclamation has reduced surface areas of lakes and wetlands. However, nothing has had a greater impact than the Three Gorges project. One of the greatest objections critics of the project have made is that it floods an area that is one of the most scenically beautiful in China* (**Figure 19**) *and* (**Figure 20**). *Another concern has been that the changes made to the Yangtze's regime could adversely affect several endangered animal species inhabiting the basin, including the Chinese alligator, the finless porpoise, and the Chinese sturgeon. In addition, numerous towns and cities have been inundated by the reservoir, forcing the relocation of one million people. It is also argued that the buildup of sediment will cause reservoir levels to rise too high to contain floods and that the area-which is highly active seismically and frequently prone to landslides-could be at increased risk for catastrophic dam failure. Furthermore, it is feared that the waters downstream from the dam, now largely free of their silt burden, will tend to erode surrounding banks rather than build them up and may cause much land degradation.*"

Figure 19. Tourist cruise ship passing through the Qutan Gorge one of the Three Gorges. Photo Credit: Photo Credit: Encyclopedia of Britannica.

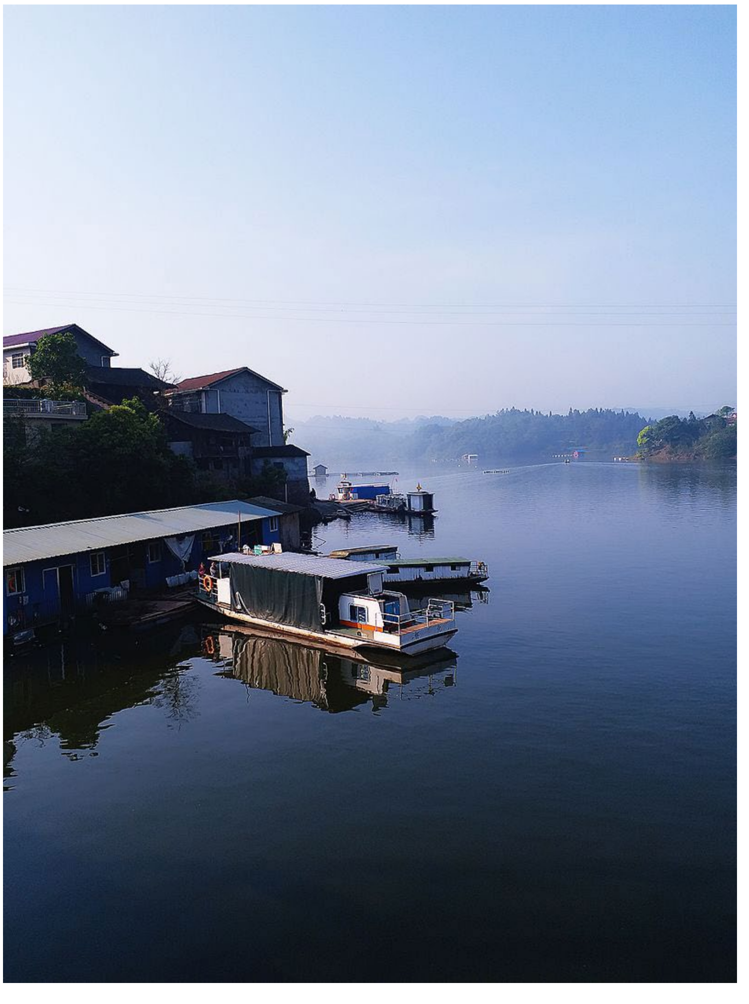

Figure 20. Boats on the Yangtze. Photo Credit: Viator.

4.1. Hydrology, Periodic Flooding, Degradation and Contribution to Ocean Pollution

Tens of millions of people live in the floodplain of the Yangtze Valley. The area naturally floods every summer and is habitable only because of river dikes. The floods large enough to overflow the dikes have caused great distress to those who live and farm there. Floods of note include those of 1931, 1954, and 1998.

The 1931 Central China floods (the Central China floods of 1931) were a series of floods generally considered among the deadliest natural disasters ever recorded, and almost certainly the deadliest of the 20th century (when pandemics and famines are discounted). Estimates of the total death toll range from 145,000 to between 3.7 million and 4 million [31] [32]. The Yangtze flooded again in 1935, causing great loss of life.

From June to September 1954, the Yangtze River Floods were a series of catastrophic floodings that occurred mostly in Hubei Province. Due to an unusually high volume of precipitation and an extraordinarily long rainy season in the middle stretch of the Yangtze River late in the spring of 1954, the river started to rise above its usual level around late June. Despite efforts to open three important floodgates to alleviate the rising water by diverting it, the flood level continued to rise until it hit the historic high of 44.67 m in Jingzhou, Hubei, and 29.73 m in Wuhan. The number of dead from this flood was estimated at 33,000, including those who died of plague in the aftermath of the disaster.

The 1998 Yangtze River floods were a series of major floods that continued from the middle of June to the beginning of September 1998 along the Yangtze [33]. In the summer of 1998, China experienced massive flooding of parts of the Yangtze River, resulting in 3,704 deaths, 15 million homeless, and $26 billion in economic loss [34]. Other sources report a total loss of 4150 people, and 180 million were affected [35]. A staggering 100,000 km^2 were evacuated, and 13.3 million houses were damaged or destroyed. The floods caused $26 billion in damages [35].

The 2016 China floods caused US$22 billion in damages. In 2020, the Yangtze River saw the heaviest rainfall since 1961, with a 79% increase in June and July compared to the average over the previous 41 years. A new theory suggested that abrupt reduction in emissions of greenhouse gases and aerosols, caused by shutdowns during the COVID-19 pandemic, was a key cause of the intense downpours. Over the past decades, rainfall has decreased due to the increase of aerosols in the atmosphere, and lower greenhouse gas emissions in 2020 caused the opposite effect—a major increase in rain. Such a dramatic reduction of aerosols caused a dramatic change in the various components of the climate system. Such a sudden change in the climate system would be very different from changes in response to continuous but gradual policy-driven emissions reductions [36].

Beginning in the 1950s, dams and dikes were built for flood control, land reclamation, irrigation, and control of disease vectors such as blood flukes that caused Schistosomiasis. More than a hundred lakes were cut off from the main river [37].

There were gates between the lakes that could be opened during floods. Farmers and settlements encroached on the land next to the lakes, although it was forbidden to settle there. When floods came, it proved impossible to open the gates since it would have caused substantial destruction [38]. Thus, the lakes partially or completely dried up. For example, Baidang Lake shrunk from 100 square kilometers in the 1950s to 40 square kilometers in 2005. Zhangdu Lake dwindled to one-quarter of its original size. Natural fisheries output in the two lakes declined sharply. Only a few large lakes, such as Poyang Lake and Dongting Lake, remained connected to the Yangtze. Cutting off the links to other lakes that had served as natural buffers for floods increased the damage done by floods further downstream. Furthermore, the natural flow of migratory fish was obstructed and biodiversity across the whole basin decreased dramatically. Intensive farming of fish spread using one type of carp that thrived in eutrophic water conditions and fed on algae, causing widespread pollution. The pollution was exacerbated by the discharge of waste from pig farms as untreated industrial and municipal sewage [37] [39]. In September 2012, the Yangtze River near Chongqing turned red from pollution [40]. The erection of the Three Gorges Dam has created an impassable "iron barrier". The Dam has led to a great reduction in the biodiversity of the river. Yangtze sturgeon uses seasonal changes in the flow to signal when it is time to migrate. However, these seasonal changes will be greatly reduced by dams and diversions. Other animals facing the immediate threat of extinction are the baiji dolphin, narrow-ridged finless porpoise, and the Yangtze alligator. These animal numbers went into freefall from the combined effects of accidental catches during fishing, river traffic, habitat loss, and pollution. In 2006, the baiji dolphin became extinct; the world lost an entire genus [41].

The Chinese government did recognize that the Three Gorges Dam would affect the sediment load downstream. The studies of how to by-pass sediment, captured by the dam, were being conducted by the Southwest China University at Chongqing in 2000. This was the focus of the People-to-People exchange tour with the SWCS group. The Chinese university engineers had developed a working hydrology model which appeared to by-pass some of the sediment. The greatest contribution our group could provide beyond reporting their model's success was in land management to abate soil erosion with better vegetation programs. From our float downstream, the immediate hillsides along the Yangtze where too steep to terrace, were mostly denuded of vegetation. One striking example was the bare ground surrounding and walled enclosure with flush foliage inside [19]. An earlier trip by another soil conservation engineer west of Chongqing, he had observed that all sticks and other fire producing tree litter was picked up as firewood. The lack of tree litter clearly was a limitation to good soil erosion control and impact on the soil's fertility via the loss of protective thatch which results in reduction of mull in the humus.

In 2020, a sweeping law was passed by the Chinese government to protect the ecology of the river. The new laws include strengthening ecological protection rules for hydropower projects along the river, banning chemical plants within 1 km of the river, relocating polluting industries, severely restricting sand mining as well as a complete fishing ban on all the natural waterways of the river, including all its major tributaries and lakes [42].

The Yangtze River produces more ocean plastic pollution than any other, according to The Ocean Cleanup, a Dutch environmental research foundation that focuses on ocean pollution. The 10 Rivers transport 90% of all the plastic that reaches the oceans, the Yangtze River being the biggest polluter by far [43] [44].

4.2. Per- and Polyfluoroalkyl Substances (PFASs)

Many PFAS, such as PFOS, and PFOA are a health and environmental concern because they do not break down via natural processes and are commonly described as persistent organic pollutants or "forever chemicals" [45] [46]. They can also move through soils contaminate drinking water sources and can bioaccumulate in fish and wildlife [4]. Residues have been detected in humans and wildlife [45] [47]-[49]. Only since the start of the 21st century has the environmental impact and toxicity to human and mammalian life been studied. Due to the large number of PFAS, it is challenging to study and assess the potential human health and environmental risks; more research is necessary [45] [50] [51]. According to the United States Environmental Protection Agency, exposure to some PFAS in the environment may be linked to harmful health effects in humans and animals [51]. The International Agency for Research on Cancer (IARC) has classified PFOA as carcinogenic to humans and PFOS as possibly carcinogenic [52]. According to the National Academies of Sciences, Engineering, and Medicine, PFAS exposure is linked to an increased risk of dyslipidemia (abnormally high cholesterol), suboptimal antibody response, reduced infant and fetal growth, and higher rates of kidney cancer [53].

Per- and poly-fluoroalkyl substances (PFASs) are a class of organic compounds in which hydrogen atoms connected to carbon atoms are partially or completely replaced by fluorine atoms. Due to the strong electronegativity of fluorine atoms, the C-F bond energy can reach up to 485 kJ/mol. Making these compounds highly thermally and chemically stable, as well as high resistance against biodegradation processes. Therefore, they have been used to synthesize polymers with surface activity to produce non-stick cookware, aqueous film-forming foams, and water-repelling coatings in food packaging and cloths [54].

Professor Zulin Zhang [54], a senior research scientist at Hutton, recommended testing of the full length of the Yangtze River for emerging chemical contaminants, including PFAS. The Li *et al.* study [55] tested sediments at 38 sites along the 6,300 km-long Yangtze River for 15 types of PFAS. Following textile treatment and food packaging, the next most common source of chemicals was metal electroplating (26.8%), where PFAS is used in the chrome plating process. Fluoropolymer products (16.3%) and coatings (7.4%), used in everything from wiring to coating frying pans or aerospace components, were also identified as significant sources. Professor Zhang [54] found "*Our risk assessment found that the levels of PFAS detected in the Yangtze posed low to medium ecological risks, which points to a need for continuous ongoing monitoring and concern.*"

Li *et al.* [56] noted "*that the urbanization and wealth of an area also appeared to impact PFAS concentrations, with significantly higher levels of the chemicals found in the lower reaches of the Yangtze close to areas of developed industry. Organic carbon, nitrogen, and sediment grain size impacted PFAS distribution. These factors could affect how much PFAS builds up in river sediment. PFAS is a man-made group of more than 12,000 chemicals, including PFOS and PFOA, first used in the 1940s and widely used in household products from frying pans to waterproof jackets. It can be transported via the atmosphere and found around the world. Recent studies have found these chemicals in unexpected places, including the North Pole. Concerns around its links to health issues have led to calls for bans on the use of PFAS, and, to date, a number have been banned, while research is ongoing to find alternatives that can break down more easily*".

4.3. Reconnecting Lakes

In 2002, a pilot program was initiated to reconnect lakes to the Yangtze to increase biodiversity and to alleviate flooding. The first lakes reconnected in 2004 were Zhangdu Lake, Honghu Lake, and Tian'e-Zhou in Hubei on the middle Yangtze. In 2005, Baidang Lake in Anhui was also reconnected [39].

Reconnecting the lakes improved water quality and fish migration from the river into the lake, replenishing their numbers and genetic stock. The trial also showed that reconnecting the lake reduced flooding. The new approach also benefited the farmers economically. Pond farmers switched to natural fish feed, which helped them breed better-quality fish that could be sold for more, increasing their income by 30%. Based on the successful pilot project, other provincial governments emulated the experience and reestablished connections to lakes cut off from the river. In 2005, a Yangtze Forum was established bringing together 13 riparian provincial governments to manage the river from headwater source to Sea [57]. In 2006, China's Ministry of Agriculture made it a national policy to reconnect the Yangtze River with its lakes. As of 2010, provincial governments in five provinces and Shanghai set up a network of 40 effective protected areas, covering 16,500 km^2. As a result, populations of 47 threatened species increased, including the critically endangered Yangtze alligator. In the Shanghai area, reestablished wetlands now protect drinking water sources for the city. It is envisaged that an extended network throughout the Yangtze will cover 102 areas totaling 185,000 km^2. The mayor of Wuhan announced that six huge, stagnating urban lakes including the East Lake (Wuhan) would be reconnected at the cost of US$2.3 billion creating China's largest urban wetland landscape [37] [58].

4.4. Extinct Species

Smith and Xie [59] stated that "*Due to commercial use of the river, tourism, and* *pollution, the Yangtze is home to several seriously threatened species of large animals (in addition to fish): the narrow-ridged finless porpoise, baiji (Yangtze river dolphin), Chinese alligator, Yangtze giant softshell turtle, and Chinese giant salamander. This is the only other place, besides the United States, which is native to an alligator and paddlefish species. In 2010, the Yangtze population of finless porpoises was 1000 individuals. In December 2006, the Yangtze River dolphin was declared functionally extinct after an extensive search of the river revealed no signs of the dolphin's inhabitance.*" [60]

"*In 2007, a large, white animal was sighted and photographed in the lower Yangtze and was tentatively presumed to be a baiji. However, there have been no confirmed sightings since 2004. The baiji is presumed to be functionally extinct currently* [61]*. Baijis were the last surviving species of a large lineage dating back seventy million years and one of only six species of freshwater dolphins. It has been argued that the extinction of the Yangtze River dolphin was a result of the completion of the Three Gorges Dam, a project that has affected many species of animals and plant life found only in the Gorges area* [61]*. Numerous species of land mammals are found in the Yangtze Valley, but most of these are not directly associated with the river. Three exceptions are the semi-aquatic Eurasian otter, water deer, and Père David's deer*" [59].

5. Discussion

5.1. Soil and Agricultural Pollution in Yangtze River Economic Belt

Sun *et al.* [62] used "*Material flow and spatial analysis methods to evaluate and predict the spatial-temporal pattern evolution of agricultural and rural nitrogen (N) flow in the Yangtze River Economic Belt in China from 1949 to 2050 and to analyze agricultural and rural pollution control by environmental measures. The results showed that since the founding of the People's Republic of China, the crop harvest in the Yangtze River Economic Belt has shown an overall upward trend, and the increase in the period from 1979 to 1997 was the fastest, with an average annual increase rate of 3.8%. Since the reform and opening up, N loss (storage) increased from* 50.97×10^8 *kgN in 1978 to* 140.15×10^8 *kgN in 2014, a 2.75-fold increase. In 2015, China began to implement measures to prevent and control agricultural and rural pollution, and N loss (storage) decreased yearly. In 2019, the N loss (storage) decreased by 18.22% compared with that in 2015, but it was still high. Each year,* 113.44×10^8 *kgN was still lost to the atmosphere, water and soil, which was 1.53 times the amount of N harvested with crops. The N loss rate was as high as 60%. Before 2014, N discharge into surface water from agricultural and rural areas in the Yangtze River Economic Belt increased annually, especially after 1978, with an average growth rate of 4.76%, leading to severe nonpoint source pollution.*"

"*With the implementation of the pollution control policy, the N lost to surface water began to show a downward trend in 2015, but it was still 2.17 times higher than the environmental risk threshold in 2019. According to the prediction, under* *the scenarios of the business-as-usual, fertilizer reduction, engineering and rural improvement patterns, the N emissions from the system to surface water in 2050 are expected to be reduced by 25.76%, 45.5%, 30% and 30%, respectively, compared with those in 2019, but will still be higher than the environmental risk threshold. Under the integrated pattern, the N emissions to surface water are reduced to 4.32 × 10^8 kgN in 2050, which is lower than the environmental risk threshold and can achieve the goal of nonpoint source pollution control. A single environmental measure cannot effectively control nonpoint source pollution. It is necessary to promote an integrated pattern to achieve green and sustainable development of agriculture in the Yangtze River Economic Belt*" [62].

In 2006, the Chinese government listed the control of agricultural source pollution and the reduction of chemical fertilizer application into the Outline of the 11th Five-Year Plan for National Economic and Social Development and then adopted a series of measures, including "*One control, two reduction and three basic measures*", which have achieved initial results. In 2019, the Yangtze River Basin eliminated inferior Class V water bodies for the first time. N application and loss have shown an incremental turning point, and N discharge into surface water in 2019 decreased by 19.74% compared with 2015, but it is still at a high level. Agricultural pollution in the Yangtze River Economic Belt is still severe. By depicting the temporal and spatial patterns of agricultural and rural N in the Yangtze River Economic Belt and analyzing the impact of agricultural and rural environmental measures on nonpoint source pollution.

5.2. Industrial Pollution: Heavy Metals in Yangtze River Basin Soils

Understanding the fine-scale spatial distribution of heavy metal contamination is crucial for effective environmental capacity control and targeted treatment of polluted areas. Pang and Wang [63] present the latest dataset on the occurrence of common heavy metals in the soils of the Yangtze River Basin. The dataset was compiled by reviewing peer-reviewed literature published between 2000 and 2020. Rigorous quality control procedures were employed to ensure the accuracy of the data, including the extraction of detailed geographic locations and concentrations of heavy metals. Pang and Wang [63] "*dataset includes 7867 records of heavy metal occurrences (Zn: 1045, Cu: 1140, Pb: 1261, Cr: 980, Cd: 1242, Ni: 649, As: 821, Hg: 729) in the soils of the Yangtze River Basin, distributed at four scale levels: province, prefecture, county, and township or finer. The results indicate that the distribution of heavy metal concentrations is relatively scattered, with higher concentrations in cities and regions with developed industry and agriculture. Cd has the highest exceedance rate (33.90%), indicating significant local contamination. Heavy metals, such as Zn at 11.96%, Ni at 12.63%, and As* [64] *at 9.74%, also exceeded standard levels at certain sampling points. Cr had the lowest exceedance rate of 1.33%*". This updated dataset provides essential information on the status of heavy metals contamination in the soils of the Yangtze River Basin. It can be used for further ecological and health risk assessments and for developing strategies to remediate and prevent heavy metal contamination in the region.

5.3. Land Use Change and Abandonment

Wang *et al.* [65] found "*Farmland abandonment represents the extreme utilization of marginal land and results from the interplay between humans and the environment. In the Yangtze River Delta region of China, a significant economic hub, understanding the landscape patterns and driving mechanisms of farmland abandonment and recultivation land is crucial for regional sustainable development. This study aims to map the extent of farmland abandonment in 2020 and recultivation land in 2021 across the Yangtze River Delta, analyze the landscape patterns of farmland abandonment and recultivation land on multiple scales, and explore their driving mechanisms. Utilizing multi-source data and the Land Use Trajectory Change Method on the Google Earth Engine platform, we classified land use and identified farmland abandonment, fallow land, active farmland, and recultivation land. Spatial statistical analysis was conducted to investigate the distribution and patterns of farmland abandonment and recultivation land at Yangtze River Delta, provincial, and municipal scales. Additionally, a stepwise multiple linear regression model was employed to dissect the main driving forces of farmland abandonment and recultivation land. Results revealed that farmland abandonment in the Yangtze River Delta region exceeded an abandonment rate of 10%, with a reclamation rate in the following year of less than 30%. The spatial distribution of farmland abandonment and recultivation land varied significantly across different scales. On the Yangtze River Delta scale, farmland abandonment was positively influenced by altitude, distance to rivers, and temperature, while recultivation land was positively correlated with night light intensity. At the provincial and municipal scales, the driving forces exhibited scaling effects, with different factors becoming significant. Our findings contribute to a deeper understanding of the complexity and diversity of farmland abandonment in the Yangtze River Delta region.*" The results provide a scientific basis for formulating land use policies, promoting sustainable agricultural development, and ensuring ecological balance. By uncovering the land use status and ecosystem balance influenced by human-environment interactions, this study offers insights into achieving a harmonious coexistence between economy, society, and ecology in the Yangtze River Delta region.

5.4. Soil Conservation for Sustainable Agricultural Production

The Upper Yangtze River Basin comprises a densely populated agricultural region with mountainous and hilly landforms [66]. Intensive cultivation has been extended onto steep hillslopes, which constitute the principal source area for sediment production. Soil conservation on sloping arable lands is thus of utmost priority for persisting sustainable agricultural production and maintaining sound ecosystem services. Although there have been many soil conservation techniques, either promoted by the government or adopted by local farmers, the practiced area was very limited relative to the total area affected by soil erosion. According to Tang [66] "*The four most popular soil conservation measures on sloping arable lands in this region to enhance a broader scale of implementation are hedgerow buffers, sloping terraces, level trenches, and limited downslope tillage*." These practices, although developed from local farmers' indigenous knowledge for productive purposes, have well conformed to our contemporary understanding of soil erosion processes on sloping landscape affected by human disturbances, were of sound suitability to regional manual tillage agriculture and more trade-off-efficient on rill prevention, runoff harvest and nutrient management.

6. Conclusions

The primary objectives were to develop, manage, and maintain the Yangtze River watershed lifeline. The Yangtze River has some of the world's largest reservoirs and is a major source of livelihood for millions of people. Many factories and cities discharge their waste, including sewage, industrial waste, fertilizers, and pesticides [67] [68], into the Yangtze River. Pollutants tend to settle in the reservoirs and contain several meters of heavily contaminated muck. The primary objectives were to develop, manage, and maintain the Yangtze River watershed lifeline. Environmental degradation in the Yangtze basin has accelerated with intensification of agriculture on sloping lands and increased economic development since 1950. The Yangtze River produces more ocean plastic pollution than any other river in the world. Pollution levels have risen in the Yangtze and tributary rivers and lakes, soil erosion in the middle and upper basins caused by overgrazing and the overcutting of trees has increased silt loads, and land reclamation has reduced surface areas of lakes and wetlands. The Environmental degradation in the Yangtze Basin needs to be mitigated since it is no longer a national issue but is starting to affect the ocean, making it an international problem.

In this article, it is shown that millions of people exploit the Yangtze River. The main conclusions drawn from this article are:

- The Yangtze River is filled with several wastes, which generate increased pollutants. The need to effectively manage such wastes and ensure balanced environmental conditions is of utmost consideration.
- Among many existing rivers around the world, the Yangtze River is the number one in terms of ocean plastic pollution. Therefore, environmental deterioration is a huge concern in this river. Although this deterioration hastens economic development in this river, it needs to be reduced or mastered to restore the environmental health of the river and its surroundings.
- A national program to reduce soil erosion and sedimentation is needed to address excessive tree cutting, overgrazing, and cultivation of sloping and eroding lands.
- Drinking water standards, like the WHO standard for arsenic at 10 ppm, need to be established nationally to address forever chemicals and water treatments

methods are needed to reduce chemical levels to below the national standards.

Any solution aimed at effectively managing the Yangtze River should be sustainable. In other words, the lifeline of this river must be sustainably protected to promote an integrated and healthy environment that will be beneficial from all points of view.

Acknowledgements

The authors would like to thank Wadslin Frenelus for his in-depth review, fact-checking, and editing.

Conflicts of Interest

The authors declare that there is no conflict of interest.

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