

Managing Yellow River Watershed Development and Agricultural Use to Reduce the Environmental Impacts of Flooding, Soil Erosion, Siltation and Pollution

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Abstract

The Yellow River flows from the west to the east of China, making a large curve through its northern provinces. As the second-longest river in China, after the Yangtze River, and the sixth-longest river system in the world, it passes through nine Chinese provinces of Qinghai, Sichuan, Gansu, Ningxia, Inner Mongolia, Shaanxi, Shanxi, Henan, and Shandong. The primary objective is to assess the long-term environmental impacts of Yellow River watershed development and agricultural use on flooding, soil erosion, siltation, and pollution. The destruction of forests has turned many grasslands and woodlands into deserts, resulting in the exposure of thick loess. The Yellow River carries an average of 1.6 billion tons of sediment annually. Severe pollution has made one-third of China's Yellow River unusable due to factory discharges and sewage from fast-expanding cities. Due to the global changes generated by floods, such as soil erosion and sediment transport, the development of strategic plans for sustainable watershed management has become an urgent need. However, to achieve this, one of the most important things is to first understand the mechanisms behind these changes. Aiming to properly reduce the environmental impacts of flooding, soil erosion, siltation and pollution, this article describes the management actions for the Yellow River watershed evolution. This paper can serve as a very good reference for similar research studies in the field.

Keywords

Yellow River, Flooding, Silt, Loess, Siltation, Pollution, China

1. Introduction

The Yellow River (Huang He) has flooded about 1593 times, making 26 minor and 9 serious course changes. The Yellow River is yellow because of the great amount of yellow silt suspended in the river. The yellow silt (from loess deposits) mainly comes from China's Loess Plateau. The destruction of forests has turned many woodlands and grasslands into deserts, resulting in the exposure of thick loess. Loess is very loose fine soil, and after long-term erosion by runoff and river water, sediment is carried into the Yellow River, turning its water yellow. It can be said that this is the cost of development from a hunter-gatherer civilization to a farming civilization with a growing population. Severe pollution has made one-third of China's Yellow River unusable due to sewage from fast-expanding cities and factory discharges. The Yellow River Conservancy Commission said 1/3 of the river system is unfit for drinking, industrial use, aquaculture, or even agriculture.

In the past decades, numerous research studies have been devoted to the study of the Yellow River watersheds. For example, Zhang *et al.* [1] found that the regional ecosystems are deeply altered by sediment transport along the Yellow River. It was studied by Kong *et al.* [2] that coastal migration and morphology were strongly changed by sediment loads in the Yellow River. Likewise, the analysis of Li *et al.* [3] shows that by flooding, cold temperatures and lessened precipitations remain evident in the Yellow River watersheds. They also stressed that proper management is needed for the Yellow River watersheds where flood outbreaks are frequent. To protect and manage the Yellow River catchments and their surroundings, adaptive policy countermeasures are proposed by Singh *et al.* [4]. On their side, Yan *et al.* [5] confirmed that in the Yellow River, floods may cause watershed changes and soil erosion which will further disintegrate the affected regional environment. Convinced of the flood-related deterioration, Liu *et al.* [6] stated that functional land should be ecologically improved in the Yellow River Basin. Scheper *et al.* [7] explained that soil erosion caused by floods is a major threat in the Yellow River Basin. Recently, Zai *et al.* [8] pointed out that for regional ecological protection and development, influencing factors and spatiotemporal dimensions should not be ignored for the Yellow River. Despite numerous research studies focusing on the Yellow River Basin, further investigations are still needed. In fact, there is no study yet that focuses in-depth on how to reduce the environmental impacts of flooding, soil erosion, siltation and pollution by effectively managing the Yellow River watershed development and agricultural use. Given the great importance of this river, its environmental impacts are of paramount importance and must be successfully reduced.

The Yellow River needs restoration mitigation to reduce the discharge of waste and sewage that is currently discharged into the Bohai Sea. The primary objective is to assess the long-term environmental impacts of Yellow River watershed development and agricultural use on flooding, soil erosion, siltation, and pollution. The Yellow River carries an average of 1.6 billion tons of sediment annually. Sim-

ilar research studies can use this paper as a very good reference in the field.

2. Study Site

Yellow River, the principal river of northern China, east-central and eastern Asia [9]. The Yellow River is often called the cradle of Chinese civilization [10]. With a length of 5464 km, it is the country's second longest river—surpassed only by the Yangtze River (Chang Jiang) [11] and its drainage basin is the third largest in China, with an area of some 752,546 square km. The Yellow River has an average discharge volume of 2571 cubic meters per second, and a maximum of 58,000 cubic meters per second [12].

The Great Wall of China (**Figure 1**) is a massive fortification that spans thousands of kilometers across the northern borders of China. It crosses several major rivers, including the Yellow River, Yalu River, and Wei River, and these rivers have played an important role in the history and culture of the region.



Figure 1. The Great Wall of China. Photo credit: Wikipedia [9].

The Great Wall of China crosses the Yellow River in several places, and some sections of the wall were built directly over the river to create a barrier against invaders. Several major rivers cross the Great Wall of China, but the most famous of them is the Yellow River, also known as the Huang He. It is the second-longest river in China and is often called the “cradle of Chinese civilization” because it was home to several ancient cultures that thrived along its banks.

Another major river that crosses the Great Wall of China is the Yalu River, which forms part of the border between China and North Korea. The Yalu River is about 795 km and flows through several major cities in China, including Dandong and Hushan. The Great Wall of China crosses the Yalu River near the city of Hushan, and this section is known as the Hushan Great Wall, which is a popular tourist destination and is known for its stunning views of the river and surrounding mountains.

The Wei River is another important river crossing China's Great Wall. It is a

tributary of the Yellow River and flows through the provinces of Gansu, Shaanxi, and Henan. The Great Wall of China crosses the Wei River in several places, the most famous of which is the Huayin City section of the wall.

The river rises in southern Qinghai province on the Qinghai-Xizang Plateau and flows through six other provinces and two autonomous regions in its course to the Bo Hai (Gulf of Chihli), an embayment of the Yellow Sea of the North Pacific Ocean. In its lower reaches, the river is a turbulent, shifting, silt-laden stream that often overflows its banks and sends floodwaters across the North China Plain. Being the “*cradle of the Chinese Civilization*”, the Yellow River is also known by various names such as “*China’s Sorrow*”, “the Ungovernable” etc. Another reason for such a depressing name for the main river system of the country lies in its potential to cause devastating floods.

The Mandarin Chinese word *huang* (“*yellow*”) refers to the fine loess sediments the river carries to the sea. The Yellow River basin has an enormous population—exceeded only by a small number of countries—and the river and its tributaries flow past some of China’s oldest cities.

The Yellow River (Huang He in Mandarin or Huang Ho in defunct Wade-Giles or Hwang Ho) is the second longest river in China (after the Yangtze), and the fifth longest in the world [11]. The Yellow River originates on the Qinghai-Xizang Plateau (Figure 2) and flows through nine provinces from west to east, flowing into the Bohai Sea. It is the “mother river of China”: its basin was the center of Chinese politics, economy, and culture for over 2000 years.



Figure 2. Qinghai-Xizang Plateau [3].

Popov and Greer [12] suggested “*The Yellow River is yellow because of the great amount of yellow silt suspended in the river (Figure 3). The yellow silt (loess) mainly comes from China’s Loess Plateau (Figure 4). The destruction of forests has turned many grasslands and woodlands into deserts, resulting in the exposure of thick loess. Loess is very loose fine soil, and after long-term erosion by runoff (Figure 5) and river water (Figure 6), sediment is carried into the Yellow*

River, turning its water yellow or orange. It can be said that this yellowing of the river is the cost of development from a hunter-gatherer civilization to a farming civilization with a growing population. The Yellow River carries an average of 1.6 billion tons of sediment annually.”



Figure 3. Yellow River bend in highlands. The river water is orange reflecting the sediment load [3].



Figure 4. Discharge (spray) from Sanmexia Dam [4].

“The Yellow River’s middle reaches are about 1200 km long from Inner Mongolia to Zhengzhou, negotiating plains and hills on China’s Loess Plateau region, where huge amounts of sediment are eroded and suspended. In the Loess Plateau, the yellowest (the most sedimented) waterfall in the world is the Hukou (‘Kettle’s Mouth’) Waterfall. Sanjiangyuan (‘Three Rivers’ Origins’) Natural Reserve is in southern Qinghai. The three rivers are the Yellow River, the Yangtze River, and the Lancang River (which becomes the Mekong in SE Asia). It enjoys the moniker

‘China’s Water Tower’ and a richness of landscapes including mountains, glaciers, lakes, and valleys.”



Figure 5. Boats on silted Yellow River [4].

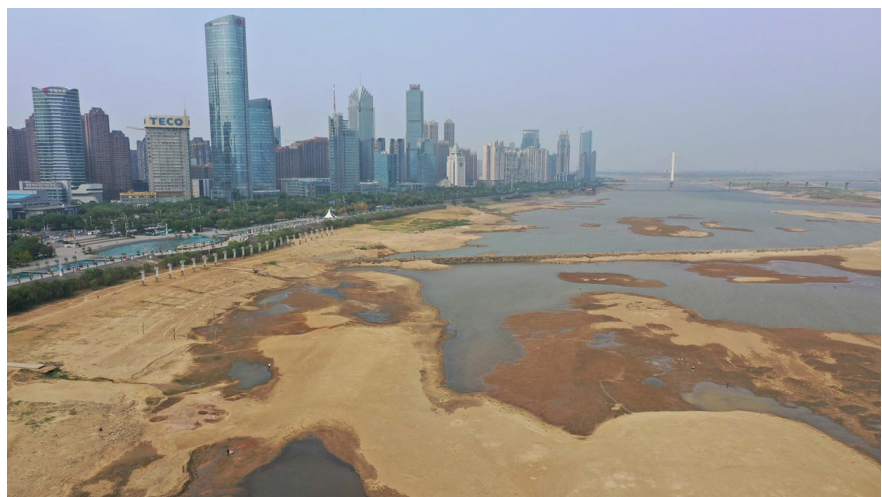


Figure 6. Siltation in Yellow River in dry season near a city [3].

3. Physical Features, Geography and Soils

The Yellow River first formed between 56 million and 34 million years ago during

the Eocene epoch, while the familiar shape appeared around 7 thousand years ago [13]. The Yellow River is divided into three distinct parts: the mountainous upper course, the middle course across a plateau, and the lower course across a low plain [11].

Popov and Greer [12] reported “*The Yellow River carries an average annual volume of about 56 cubic km of water down to the sea, a rate of about 1770 cubic meters per second. The rate can be as much as 2200 cubic meters per second in high-volume years and as little as 600 - 800 cubic meters per second in low-volume years. There also is considerable seasonal variation in its volume. The river has a low discharge rate—eight other Chinese rivers exceed that of the Yellow River—because its basin encompasses large areas of arid or semiarid land, where considerable quantities of water evaporate or are diverted for irrigation. More than half of the basin’s annual precipitation falls during the rainy season (July to October). The average annual precipitation for the entire basin is about 47 cm, but its distribution is highly uneven. In some years the bulk of the river’s volume comes from its tributaries. In the upstream areas, the main source is snowfall in the mountains, with the high-water level occurring in the spring. The highest water levels in the middle and lower parts of the river occur in July and August. Seasonal maximum flows can be considerable: 5350 to 6120 cubic meters per second near Lanzhou, 10,000 cubic meters near Longmen, and 36,000 cubic meters, recorded in 1943 in the lower parts of the river.*”

“*The Yellow River carries along the highest concentration of sediment load of any river in the world (Figure 6), amounting to about 34 kg per cubic meter of water, as compared with 1 kg for the Nile River, 5 kg for the Amu Darya (the ancient Oxus River), and 13 kg for the Colorado River. Floodwaters may contain up to 710 kg per cubic meter of water (70 percent by volume). The river, unimpeded, carried down to the sea about 1.52 billion tons of silt per year, a large part of it loess, which was loose and easily washed away. Other factors contributing to the high volume of silt included the steepness of the slopes, the rapidity of the current, and a lack of forested areas to check erosion. The reservoirs created by dams have allowed increasing quantities of silt to settle out*” [12].

The Yellow River freezes over in parts of its middle section for several months each winter. On the North China Plain near Kaifeng there are 15 to 20 icebound days per year, but farther downstream there are none. Ice jams are broken up with the help of aerial bombardment or sometimes by artillery shelling.

Olson and Morton [14] reported the “*Over time, earthquakes and volcanic activity of the Himalayas altered the mountain drainage southward via steep gorges that appeared about 13 million years ago, and by 8 million years ago formed the present courses of three rivers: the Mekong, Yangtze, and Yellow Rivers, which run in parallel sutures*” [15] [16].

3.1. Upper Course

The Yellow River originates at an elevation above 4600 m in the Bayan Har Moun-

tains, in the eastern Qinghai-Xizang Plateau (**Figure 7**). In its upper reaches, the river crosses two bodies of water, Lakes Ngoring and Gyaring. Those shallow lakes, which freeze over in the winter, are rich in fish and cover an area of about 2000 square km. The Yellow River in that region flows generally from west to east. The broad highlands of the upper course rise 300 to 500 m above the river and its tributary floodplains. The highlands consist of crystalline rocks occasionally visible as eroded outcroppings on the surface. The river enters a region of deep gorges, winding its way first southeast, then northwest around the A'nyêmaqên (Amne Machin) Mountains, where its fall exceeds 2 m per km, and then east between the Xiqing and Laji mountains. Once past the gorges, it leaves the Qinghai-Xizang Plateau near the city of Lanzhou (**Figure 8**) in southeastern Gansu province. That transition marks the end of the upper Yellow River, some 1165 km from its source. The upper course drains a basin covering about 124,000 km². The upper river course consists chiefly of inaccessible, highly mountainous, sparsely populated terrain with a cold climate.



Figure 7. Yellow river with agricultural fields and levees. The river is filled with sediments [4].

3.2. Middle Course

Popov and Greer [12] found “*The middle course of the Yellow River, extending more than 2900 km, consists of a great loop and drains an area of about 60,000 square km. The river first flows northeast for about 880 km through the sandy soils of the northern Hui Autonomous Region of Ningxia and the western Ordos Plateau. It has many rapids, and, in several places, it narrows. The river then turns eastward and flows for another 800 km through alluvial plains in the Inner Mongolia Autonomous Region, in places branching into numerous distributary channels. In that stretch, its fall is less than 9 cm per km, and many channels have been developed over the millennia for irrigated agriculture.*”

“*The Yellow River then turns sharply (**Figure 8**) to the south and flows for about 715 km, forming the border between Shaanxi and Shanxi provinces. The*

river's width usually does not exceed 45 to 60 m in that section, as it cuts through narrow gorges with steep slopes above 100 m in height. The river then gradually widens, notably after receiving the waters of its two longest tributaries the Fen River of Shanxi province and the Wei River of Shaanxi. At the confluence with the Wei, the Yellow River turns sharply to the east for another 480 km as it flows through inaccessible gorges between the Zhongtiao and eastern Qin (Tsinling) mountains. The average fall in that stretch is slightly more than 20 cm per km and becomes increasingly rapid in the last 160 km before the river reaches the North China Plain at the city of Zhengzhou in Henan province.”



Figure 8. Lanzhou city on Yellow River [1].

“Most of the middle course is cut through the Loess Plateau, which extends eastward from the Qinghai-Xizang Plateau to the North China Plain at elevations ranging between 900 and 2100 m. The plateau contains terraced slopes, alluvial plains, and a scattering of peaks sometimes rising more than 450 m above the plateau. The river has cut at least six terraces across the plateau, which rise to more than 500 m above the present river level. The terraces, formed over the past 2.5 million years, provide an important record of landscape evolution and ancient environmental change in the region. The underlying rock systems are covered with thick layers of loose soils, consisting of wind-deposited sand and loess. The loess strata reach thicknesses of 50 to 60 m and in some places as much as 150 m. Through those unconsolidated deposits, the river has cut deep valleys, carrying away huge quantities of surface material, making that region one of the most highly eroded landscapes in the world. The easily eroded loess soil accounts for the instability of the riverbed in the middle basin, where the erosion is considerable, and on the plain, where deposition builds up the channel bed” [12].

3.3. The Lower Course

The Yellow River broadens downstream from Zhengzhou to flow through Shan-

dong and Henan provinces across the North China Plain. The plain is a nearly level, featureless, alluvial fan broken only by the low hills of central Shandong. It was formed over some 25 million years as the Yellow River and other rivers deposited enormous quantities of silt, sand, and gravel into the shallow sea that once covered the region [9]. The plain has been densely inhabited for millennia and has been one of China's principal agricultural regions (Figure 9). The river has changed its course across the plain several times. The region's inhabitants have built extensive systems of levees and irrigation works in an attempt to control the river's flow. The area illustrates perhaps better than any other place on Earth how human activity has combined with natural forces to shape the landscape.



Figure 9. Fields along Yellow River with side channels [4].

Popov and Greer [12] noted “*The lower Yellow River is about 700 km long with an average fall of about 5 cm per km. Along the river are found occasional areas of sand dunes 5 to 9 m high. In general, however, the plain is an area of great floods because the riverbed, built up gradually by sediment deposits, lies above the surrounding land in many places. In the section north of Kaifeng in northern Henan, the low-water level is some 5 m above the surrounding countryside, the mid-water level between 6 and 7 m, and the high-water level is sometimes as much as 9 to 11 m above the land. From Kaifeng to the Grand Canal (Da Yunhe), the levees are lower than farther upstream, rarely exceeding 1 to 2 m in height. Marshes are common. Below the Grand Canal the height of the levees increases to between 4 and 5 m and in some places to 8 m.*”

“*The delta of the Yellow River (Figure 10) begins approximately 80 km from its mouth and spreads out over an area of about 5400 square km. The delta land is marshy, composed of mud and silt, and is covered with reeds. A sandbar at the river's mouth impedes navigation at low tide by boats drawing more than 1.2 meters of water, at high tide the depth on the bar is 2.4 or 2.7 m.*”

“*Until the late 20th century the Yellow River delta was one of the most actively growing deltas in the world, as the North China Plain continued to extend farther*



Figure 10. Yellow River delta. Photo credit: NASA Earth Observatory.

into the Bo Hai (the remnant of the ancient sea now covered by the plain). In the century from 1870 to 1970 the delta grew an average of more than 19 km. Some outlying parts expanded even more rapidly: one area grew 10 km during the period 1949-1951, and another grew more than 24 km in 1949-1952. However, beginning in the 1950s, dam construction upstream—notably the Sanmen Gorge installation in Henan province—began to reduce the silt load that the river could carry to its mouth. By the 1990s, the delta was expanding seaward, but it was also eroding. The Chinese government subsequently took measures to divert the final part of the main stem, so that deposits built up on the north side of the delta.”

“The lower Yellow River has changed course radically throughout its geologic history. The river’s decreased gradient and velocity on the plain cause its suspended silt load to settle. As the riverbed builds up, the stream shifts course to occupy a lower level. In the past four millennia, the river has entered the Yellow Sea at points 800 km apart. From the 3rd millennium BCE to 602 BCE, when it occupied its northernmost course, it flowed near the present-day city of Tianjin and entered the nearby Bo Hai. From 602 BCE to 70 CE both the river and its mouth shifted to a point on the Yellow Sea south of the Shandong Peninsula. From 70 to 1048 the Yellow River shifted to the north, taking up a course near its present bed.”

“From 1048 to 1194 the river course changes occurred farther inland, where the river entered the North China Plain. In 1194 the river occupied a course running to the southern edge of the delta. After protecting dikes were ruptured, a second arm of the Yellow River began flowing south of the Shandong Peninsula. From 1289 to 1324 the river took over the bed of the Guo River and a large part of the Huai River, entering the Yellow Sea well to the south of Shandong. It was stable for more than 500 years, until the 1850s, when it shifted to the north of the Shan-

dong Peninsula, finally settling into its present course.”

“As the Chinese developed agriculture on the plain (Figure 11), they became more adept at building levees to stabilize the channel and protect the inhabitants against the floods brought by shifts in the channel. Tens of thousands of miles of levees have been constructed through the centuries. The overall effect of those structures has been to delay flooding. Because the riverbed has been elevated and confined artificially, levee breaching and channel shifts have become more dramatic and destructive than they otherwise would have been. The few hydraulic engineers who succeeded in decreasing rather than increasing the flood hazard have gained legendary status in Chinese history.”



Figure 11. Ag lands and rice paddies [4].

“Breaks in the levees have been more frequent than course changes throughout history. Such events have triggered cataclysmic floods, notably during the 18th and 20th centuries. Between 960 and 1048 there were 38 major breaks, and 29 more were recorded from 1048 to 1194. In later years, breaches were less frequent due to systematic improvements to the levee system. The slackening of those efforts during the Taiping Rebellion (1850-1864) led to a major river course change between 1852 and 1854. In 1887 the Yellow River burst the levees near Kaifeng and began to flow into the Huai River, but engineering efforts returned the river to its former course in 1889. The flood of 1887 covered thousands of square miles, completely burying many villages under silt. In 1889 another flood destroyed 1500 villages. The next major flood, in 1921, wiped out hundreds of populated places, mainly near the river’s mouth. In the flood of 1933, more than 3000 populated places were submerged and 18,000 people were killed. Other floods occurred in 1938—when the levees were purposely broken near Zhengzhou to delay the advance of Japanese troops in 1949” [12].

3.4. Yellow River Delta

The Yellow River is notable for the large amount of silt it carries-1.6 billion tons

annually at the point where it descends from the Loess Plateau [17]. If it is running to the sea with sufficient volume, 1.4 billion tons are carried to the sea per year. One estimate [9] gives 34 kilograms of silt per cubic meter, as opposed to 10 kilograms of silt per cubic meter for the Colorado [18] and 1 kilograms of silt per cubic meter for the Nile [19].

Its average discharge is said to be 2110 cubic meters per second (32,000 for the Yangtze), with a maximum of 25,000 and minimum of 245 [20]. However, since 1972, it often runs dry before it reaches the sea. The low volume is due to increased agricultural irrigation, increased by a factor of five since 1950. Water diverted from the river as of 1999 served 140 million people and irrigated 74,000 km² of land [21]. The Yellow River delta (**Figure 10**) totals 8000 square kilometers. However, with the decrease in silt reaching the sea, it has been reported to be shrinking slightly each year since 1996 [22].

The highest volume occurs during the rainy season from July to October, when 60% of the annual volume of the river flows. Maximum demand for irrigation is needed between March and June. To capture excess water for use when needed and for electricity generation and flood control several dams have been built, but their expected life is limited due to the high silt load. A proposed South–North Water Transfer Project involves several schemes to divert water from one in the western headwaters of the Yangtze where they are closest to one another. A second using the route of the old Grand Canal rivers and a third another from the upper reaches of the Han River.

4. Results

4.1. Yellow River Flooding

The Yellow River has long been critical to the development of northern China, and is regarded by scholars as one cradle of civilization. Flooding of the river has also caused much destruction, including multiple floods that have resulted in the deaths of over one million people [17]. Among the deadliest were the 1332–33 flood during the Yuan dynasty, the 1887 flood during the Qing dynasty which killed anywhere from 900,000 to 2 million people, and a Republic of China era 1931 flood (part of a massive number of floods that year) that killed 1 - 4 million people [23].

Gascoigne and Gascoigne [24] identified “*The cause of the floods is the large amount of fine-grained windblown silt (eroded loess) carried by the river from the Loess Plateau, which is continuously deposited along the bottom of its channel. The sedimentation causes natural dams to slowly accumulate. These subaqueous dams are unpredictable and generally undetectable. Eventually, the enormous amount of water needs to find a new way to the sea, forcing it to take the path of least resistance. When this happens, it bursts out across the flat North China Plain, sometimes taking a new channel and inundating most farmland, cities or towns in its path.*”

“*The traditional Chinese response of building higher and higher levees along*

the banks sometimes also contributed to the severity of the floods. When flood water did break through the levees, it could no longer drain back into the river bed as it would after a normal flood. The riverbed was sometimes now higher than the surrounding countryside. These changes could cause the river's mouth to shift as much as 480 km, sometimes reaching the ocean to the north of the Shandong Peninsula and sometimes to the south" [24].

Another historical source of devastating floods is the collapse of upstream ice dams in Inner Mongolia with an accompanying sudden release of vast quantities of impounded water. There have been 11 such major floods in the past century. Each flood caused tremendous loss of life and property. Nowadays, explosives dropped from aircraft are used to break the ice dams before they become dangerous [25].

Before modern dams appeared in China, the Yellow River used to be extremely prone to flooding. In the 2540 years from 595 BC to 1946 AD, the Yellow River has been reckoned to have flooded 1593 times, shifting its course 26 times noticeably and nine times severely [21]. These floods include some of the deadliest natural disasters ever recorded. Before modern disaster management, when floods occurred, some of the population might initially die from drowning and many more would suffer later from the ensuing famine and spread of diseases [26].

4.2. Historical Flood Control

The question of how aggressively flooding should be controlled, and whether it should be steered back to its original channels when it migrated, was a topic of controversy in the imperial court. Rival cliques made arguments based on budgetary, technical, and strategic criteria. Geographer Charles Greer [27] identifies “*Two competing schools of thought on how to control the Yellow River. One, which he identifies as Confucian, advocated containing the river between higher levees, thus maximizing the amount of river basin land that could be cultivated. The other, which he associates with Taoism, favored lower levees separated by as much as 5 - 10 kilometers. In one particular long-running debate during the 11th century reigns of the Shenzong and Renzong emperors, when the river repeatedly broke its levees and migrated north and west, officials battled over whether expensive measures should be taken to return the river to its former channels*”. The Shenzong emperor ultimately decreed that the river be allowed to remain in its new course [28].

Crossing the long Yellow River required bridges (Figure 12) which were covered with floodwaters so even floating bridges (Figure 13) were used. Traditional flood control techniques made use of levees, revetments to absorb the energy of the water, overflow basins, drainage canals and polders [29]. Treatises on traditional flood control techniques were written by officials such as Pan Jixun [30], who argued that joining branches of the river increased the water's power and this in turn increased its ability to flush sediment [31]. The difficult situation around the confluence of the Yellow River, the Huai, and the Grand Canal, however, still

led to a major flood of the regional center Sizhou and Pan's dismissal from court. Subsequently, the river's 1680 flood entirely submerged Sizhou and the nearby Ming Zuling tombs beneath Hongze Lake for centuries until modern irrigation and flood control lowered the water level enough to permit their excavation and the tombs' restoration.



Figure 12. Map of the Yellow River crossings [9].



Figure 13. Pontoon bridge [9].

4.3. Recent Floods

Between 1851 and 1855 [21] [32] [33], the Yellow River returned to the north amid the floods that provoked the Nien and Taiping Rebellions. The 1887 flood has been estimated to have killed between 900,000 and 2 million people [34], and is the second-worst natural disaster in history (excluding famines and epidemics). The Yellow River more or less adopted its present course during the 1897 flood [31] [35]. The 1931 flood killed an estimated 1,000,000 to 4,000,000 [34], and is the worst natural disaster recorded (excluding famines and epidemics).

Lary [36] noted “*On 9 June 1938, during the Second Sino-Japanese War, Na-*

tionalist troops under Chiang Kai-shek broke the levees holding back the river near the village of Huayuankou in Henan, causing what has been called by Canadian historian, Diana Lary, a ‘war-induced natural disaster’. The goal of the operation was to stop the advancing Japanese troops by following a strategy of using water as a substitute for soldiers. The 1938 flood of an area covering 54,000 km² took some 500,000 to 900,000 Chinese lives, along with an unknown number of Japanese soldiers. The flood prevented the Japanese Army from taking Zhengzhou, on the southern bank of the Yellow River, but did not stop them from reaching their goal of capturing Wuhan, which was the temporary seat of the Chinese government and straddles the Yangtze River” [36].

Harrell [29] found “In 1954, the People’s Republic of China announced its General Plan to Fundamentally Control Yellow River Flood Disasters and Develop Yellow River Waterworks [37]. It sought to address both flooding risks and to convert rainfall-fed fields of the North China Plain to irrigated agriculture. Construction began in earnest in 1957. From the 1970s to the 1990s, the dry-up trends accelerated, with the Yellow River failing to reach its mouth for an average of approximately 180 days per year in the 1990s. In 1997, the Yellow River did not reach the sea for 226 consecutive days.”

“Due to its heavy load of silt the Yellow River is a depositing stream—that is, it deposits part of its carried burden of soil in its bed in stretches where it is flowing slowly. These deposits elevate the riverbed which flows between natural levees in its lower reaches. Should a flood occur, the river may break out of the levees into the surrounding lower flood plain and take a new channel. Historically this has occurred about once every hundred years. In modern times, considerable effort has been made to strengthen levees and control floods” [37].

4.4. Fish

Li [38] noted “The Yellow River basin is rich in fish, being the home of more than 160 native species in 92 genera and 28 families, including 19 species found nowhere else in the world (endemic).” However, due to habitat loss, pollution, introduced species and overfishing many of the natives have declined or disappeared entirely; several are recognized as threatened on China’s Red List [39] [40]. Dams and their reservoirs have increased the habitat for species of slow-moving and static waters, while it excluded species of flowing waters and prevented the up- and down-stream breeding migration of others.

Xi *et al.* [39] determined “In the 2000s, only 80 native fish in 63 genera and 18 families were recorded in the Yellow River basin. In contrast, introduced fish have risen in both abundance and number of species; only one introduced fish species was recorded in the 1960s when ichthyologist Li Sizhong published his original survey of fish fauna of the region, but by the 2000s there were 26.”

“As typical of Asian rivers, Cyprinidae is by far the most diverse family in the Yellow River basin. More than 85 cyprinids have been recorded in this basin, including species that still are present and species that no longer are present. Other

highly diverse families are the stone loaches (more than 20 species), gobies (c. 15 species), true loaches (c. 10 species) and bagrid catfish (c. 10 species)” [39].

“Fishing remains an important activity (Figure 14), but catches have declined. In 2007, it was noted that 40% fewer fishes were caught in the Yellow River compared to earlier catches [40]. At times fishing is banned do to overfishing. Large cyprinids (Asian carp, predatory carp, Wuchang bream and Mongolian redbfin) and large catfish (Amur and Lanzhou catfish) are still present, but the largest species, the Chinese paddlefish, kaluga sturgeon and Yangtze sturgeon, have not been reported from the Yellow River basin in about 50 years [38] [39] [41]. Other species that support important fisheries include white Amur bream, ayu, mandarin fish, Protosalanx icefish, northern snakehead, Asian swamp eel and others” [39].



Figure 14. Net fishing on the Yellow River photo credit: initiativesrivers.org.

Annual fishing ban has been implemented since 2018, covering the entire Yellow River basin from 1 April to 30 June each year. A total ban of fishing of natural fishes is being implemented in the upper reaches of the Yellow River starting 1 April 2022, covering Qinghai, Sichuan and Gansu provinces, until the end of 2025. For the rest of the basin, the annual ban is extended to a period from 1 April to 31 July.

4.5. Aquaculture

The Yellow River is generally less suitable for aquaculture than the rivers of central and southern China, such as the Pearl or Yangtze rivers, but aquaculture is also practiced in some areas along the Yellow River. An important aquaculture area is the riverside plain in Xingyang, upstream from Zhengzhou. Since the development of fish ponds started in Xingyang’s riverside Wangcun Town in 1986, the pond systems in Wangcun have grown to the total size of 15,000 mu (10 km²), making the town the largest aquaculture center in north China [42].

Two turtle species are native to the Yellow River basin: the Chinese pond turtle and Chinese softshell turtle [43]. Both species—but especially the softshell—are widely farmed for food [44]. A variety of the Chinese softshell turtle popular in Chinese gourmets is called the Yellow River turtle. Nowadays most of the Yellow River turtles eaten in China’s restaurants comes from turtle farms, which may or may not be near the Yellow River. In 2007, construction started in Wangcun, Henan on a large farm for raising this turtle variety. With the capacity for raising 5 million turtles a year, the facility was expected to become Henan’s largest farm of this kind [45].

Yan *et al.* [46] discovered “*The huge, entirely aquatic Chinese giant salamander, a species that has declined drastically due primarily to persecution for food and traditional medicine, is native to the Yellow River and other Chinese rivers. It is farmed in large numbers in several parts of China and genetic studies have revealed that the captive stock mostly is of Yellow River origin. As these often are released back into the wild, the Yellow River type of the Chinese giant salamander has spread to other parts of China, which represents a problem to the other types*”.

4.6. Pollution

On 25 November 2008, Tania Branigan of *The Guardian* filed a report “*China’s Mother River: the Yellow River*”, claiming that severe pollution has made one-third of China’s Yellow River unusable even for agricultural (Figures 15-17) or industrial use (Figure 18), due to factory discharges (Figure 19) and sewage (Figure 20) from fast-expanding cities [47]. After reaching the first major city, Xining, the river is heavily polluted.



Figure 15. Agricultural fields along Yellow River [4].

Despite Yellow River having a central role in the development of Chinese civilization on North China Plain, flooding and constant rerouting of the river have also caused many great disasters to population along the river [48]. It is also known as a River of Disaster, with the disaster brought by the river said as history

of disaster in the development of Chinese civilization [49], and the management of Yellow River have been a great political trouble to various Chinese dynasties throughout the history since ancient time [50].



Figure 16. Workers in agricultural field [3].



Figure 17. Agricultural lands on floodplain with escarpment [4].



Figure 18. Industrial skyline with pollution in Yellow River [9].



Figure 19. Coal mine and drainage into Yellow River through pipes [9].



Figure 20. Trash in Yellow River [9].

5. Discussion

The erosion, transport and redeposition of sediments shape the surface of the Earth and affect the structure and function of ecosystems and society [51]. The Yellow River was once the world's largest carrier of fluvial sediment, but its sediment load has decreased by approximately 90% over the past 60 years. The decline in sediment load is due to changes in water discharge and sediment concentration, which are both influenced by regional climate change and human activities. An attribution approach to analyze 60 years of runoff and sediment load observations

from the traverse of the Yellow River over China's Loess Plateau—the source of nearly 90% of its sediment load. Landscape engineering, terracing and the construction of check dams and reservoirs were the primary factors driving a reduction in sediment load from the 1970s to 1990s, but large-scale vegetation restoration projects have also reduced soil erosion from the 1990s onwards [51]. Since the existing dams and reservoirs can trap sediment declines in the future, erosion rates, use of conservation and no-till practices, on the Loess Plateau will increasingly control the Yellow River's sediment load.

The Yellow River Basin faces enormous challenges related to sustainable water management in agriculture as driven by both drought and flood. Zhang *et al.* [52] collected “64 articles across the Basin to improve our understanding of agricultural water management needs and demonstrate efficacies of management practices to improve the water management. The articles present exciting research on regional soil water storage and dynamics, soil moisture conservation in rain-fed agriculture, crop water demand, irrigation effects, water-nutrient coupling, water management and soil salinity, soil and nutrient losses, groundwater science and management. Findings of studies revealed: 1) the importance of mulching, drip and negative pressure irrigation, water and nutrient coupling (i.e., fertigation) in achieving both crop production and environmental protection objectives; 2) emerging research for better understanding of regional water resources and allocation of the water resources among different agricultural land uses and cropping systems, new approaches for conserving water and soil and mitigating soil salinity, system-level integrated rainfall and irrigation management, and improved knowledge on groundwater quantity and quality management, and 3) need of future research to understand processes and efficiencies of management practices in variable landscapes and cropping systems and variable and changing climates, and system-level linkages and analyses of water balance—soil water availability and conservation—water and soil losses—agricultural and environmental sustainability”.

Microplastic pollution has attracted worldwide attention. Compared with the status quo of microplastic pollution in marine environments and other major rivers and lakes, the relevant data on the Yellow River Basin is limited. The abundance, types, and spatial distribution characteristics of microplastic pollution in the surface water and silts of the Yellow River Basin were reviewed [53]. Meanwhile, the status of microplastic pollution in the national center city and Yellow River Delta wetland was discussed, and the corresponding prevention and control measures were put forward. The data collected in this study [53] showed that the spatial distribution of microplastic pollution in silts and surface water of the Yellow River Basin increased from upstream to downstream, especially in the Yellow River Delta wetland. There are obvious differences between the types of microplastics in surface water and silt in the Yellow River Basin, which is mainly related to the materials of microplastics. Compared with similar regions in China, the microplastic pollution levels in national key cities and national wetland parks in

the Yellow River Basin are in the medium to high degree, which should be paid attention to. Plastic exposure in various ways will cause a serious impact on aquaculture and human health in the Yellow River beach area. To control microplastic pollution in the Yellow River Basin, it is necessary to improve the relevant production standards, regulations, laws, and improve the engineering degradation capacity of plastic waste and biodegradable microplastics.

The Yellow River basin, an area of extreme water scarcity, has faced significant challenges in water quality management due to rapid social and economic development since the 1980s. Yu *et al.* [54] analyzed “*the water quality evolution over nearly 40 years, focusing on primary pollutants like chemical oxygen demand (COD), ammonia nitrogen (NH₃-N), and permanganate index (COD_{Mn}). In the 1990s, sections of the river were severely polluted, with some areas failing to meet the lowest national standards. In 2000, 32% of the river water was classified as inferior Class V. However, enhanced water resource management and stricter pollutant regulations introduced after 2000 have significantly improved water quality. By 2010, water quality reached its nadir, with 16% of water classified as inferior Class V and 25% as Class IV–V. By 2020, water quality showed marked improvement, with a significant reduction in segments classified as inferior Class V and Class IV–V. Recent years have seen water quality stabilize, with COD meeting Class I standards and NH₃-N and COD_{Mn} meeting Class II standards based on national criteria.*”

Yu *et al.* [4] noted “*discrepancies in water quality between the mainstream and tributaries of the Yellow River. While the mainstream generally maintains good water quality, many tributaries remain severely polluted. In 2022, 85% of the water in tributaries was classified as Class I to III, 12.3% as Class IV to V, and only 2.7% as Class V. However, all water in the mainstream reached Class I–III, with 86% achieving Class II and 14% achieving Class I. A detailed analysis of the Huayuankou section over the past three decades shows a general decline in pollution indicators. Seasonal water quality fluctuations, correlated with flow rates and temperatures, were observed, often exhibiting normal distribution patterns. These findings underscore the effectiveness of sustained pollution control and the need for continuous, adaptive management strategies to improve and maintain water quality in the Yellow River basin.*”

Ming *et al.* [55] found “*The intensification of human activities in the Yellow River Basin has significantly altered its ecosystems, challenging the sustainability of the region’s ecosystem assets. This study constructs an ecosystem asset index for the period from 2001 to 2020, integrating it with human footprint maps to analyze the temporal and spatial dynamics of ecosystem assets and human activities within the basin, as well as their interrelationships. Our findings reveal significant improvement of ecosystem assets, mainly attributed to the conversion of farmland back into natural habitats, resulting in a 15,994 km² increase in ecological land use. Notably, 45.88% of the basin has experienced concurrent growth in both human activities and ecosystem assets, with ecosystem assets expanding at a*

faster rate (22.61%) than human activities (17.25%). Areas with high-quality ecosystem assets are expanding, in contrast to areas with intense human activities, which are facing increased fragmentation. Despite a global escalation in threats from human activities to ecosystem assets, the local threat level within the Yellow River Basin has slightly diminished, indicating a trend towards stabilization. Results highlight the critical importance of integrating spatial and quality considerations into restoration efforts to enhance the overall condition of ecosystem assets, especially under increasing human pressures. Our work assesses the impact of human activities on the dynamics of ecosystem assets in the Yellow River Basin from 2001 to 2020, offering valuable insights for quality development in the region, may provide a scientific basis for general watershed ecological protection and sustainable management in a region heavily influenced by human activity but on a path to recovery”.

6. Summary and Conclusions

The primary objective was to assess the long-term environmental impacts of Yellow River watershed development and agricultural use on flooding, soil erosion, siltation, and pollution. The destruction of forests has turned many grasslands and woodlands into deserts, resulting in the exposure of thick loess. Loess is very loose fine soil, and after long-term erosion by runoff and river water, sediment is carried into the Yellow River, turning its water yellow. The Yellow River carries an average of 1.6 billion tons of sediment annually.

The Yellow River has flooded about 1593 times, making 26 minor and 9 serious course changes. The Yellow River is yellow because of the great amount of yellow silt suspended in the river. The yellow silt (loess) mainly comes from China's Loess Plateau. The destruction of forests has turned many grasslands and woodlands into deserts, resulting in the exposure of thick loess. Loess is very loose fine soil, and after long-term erosion by runoff and river water, sediment is carried into the Yellow River, turning its water yellow. It can be said that this is the price of development from a hunter-gatherer civilization to a farming civilization with a growing population. Severe pollution has made one-third of China's Yellow River unusable due to factory discharges and sewage from fast-expanding cities.

The Yellow River Conservancy Commission surveyed more than 13,493 km of the river in 2007 and said 33.8% of the river system registered worse than “level five” according to the criteria used by the UN Environment Program. Level five is unfit for drinking, aquaculture, industrial use, or even agriculture. The report said waste and sewage discharged into the system last year totaled 4.29 billion tons. Industry and manufacturing made up 70% of the discharge into the river with households accounting for 23% and just over 6% coming from other sources. The Yellow River Conservancy Commission said 1/3rd of the river system is unfit for drinking, aquaculture, industrial use, or even agriculture. The Yellow River needs restoration mitigation to reduce the discharge of waste and sewage that is currently discharged into the Bohai Sea. Effective mitigation plans are necessary to

combat the environmental impacts of flooding, soil erosion, siltation and pollution in the Yellow River watershed development and agricultural use.

It can be said that this is the cost of development from a hunter-gatherer civilization to a farming civilization with a growing population. Severe pollution has made one-third of China's Yellow River unusable due to factory discharges and sewage from fast-expanding cities. The Yellow River Conservancy Commission said 1/3rd of the river system is unfit for drinking, aquaculture, industrial use, or even agriculture. The Yellow River needs restoration mitigation to reduce the discharge of waste and sewage that is currently discharged into the Bohai Sea. Sustainable restoration will be a priority. In this sense, how to adequately reduce flooding of this river should also be considered. Hence, special attention should be paid to the effective management of floods caused by the development of the Yellow River watershed and how to adequately reduce such floods.

Future research will focus on determining effective mitigation plans that are necessary to combat the environmental impacts of flooding, soil erosion, siltation, and pollution in the Yellow River watershed development and agricultural use. Thus, sustainable management of these environmental effects will lead to sustainable health of the Yellow River watershed development and efficient agricultural utilization.

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Conflicts of Interest

The authors declare that there is no conflict of interest.

References

- [1] Zhang, L.J., Wang, L., Cai, W.J., Liu, D.M. and Yu, Z.G. (2013) Impact of Human Activities on Organic Carbon Transport in the Yellow River. *Biogeosciences*, **10**, 2513-2524. <https://doi.org/10.5194/bg-10-2513-2013>
- [2] Kong, D., Miao, C., Borthwick, A.G.L., Duan, Q., Liu, H., Sun, Q., Ye, A., Di, Z. and Gong, W. (2015) Evolution of the Yellow River Delta and Its Relationship with Run-off and Sediment Load from 1983 to 2011. *Journal of Hydrology*, **520**, 157-167. <https://doi.org/10.1016/j.jhydrol.2014.09.038>
- [3] Li, T., Li, J. and Zhang, D.D. (2020) Yellow River Flooding during the Past Two Millennia from Historical Documents. *Progress in Physical Geography*, **44**, 661-678. <https://doi.org/10.1177/0309133319899821>
- [4] Singh, D.K., Xu, M., Singh, N. and Lei, F. (2021) Perspectives on Emerging Pressures and Their Integrated Impact on Large River Systems: An Insight from the Yellow River Basin. *Journal of Environmental Management*, **298**, Article 113423. <https://doi.org/10.1016/j.jenvman.2021.113423>
- [5] Yan, X., Liu, J., Rühland, K.M., Dong, H., He, J. and Smol, J.P. (2022) Human Deforestation Outweighed Climate as Factors Affecting Yellow River Floods and Erosion on the Chinese Loess Plateau Since the 10th century. *Quaternary Science Reviews*,

- 295, Article 107796. <https://doi.org/10.1016/j.quascirev.2022.107796>
- [6] Liu, J., Wang, J. and Tan, Y. (2023) Spatiotemporal Pattern and Influencing Mechanism of the Flood-Regulating Ecosystem Service Capacity and Demand in China's Yellow River Basin, 2000-2020. *Journal of Hydrology: Regional Studies*, **45**, Article 101312. <https://doi.org/10.1016/j.ejrh.2022.101312>
- [7] Scheper, S., Liu, C., Xin, Z., Ran, L. and Alewell, C. (2024) Soil Loss and Sedimentation Rates in a Subcatchment of the Yellow River Basin in China. *International Soil and Water Conservation Research*, **12**, 534-547. <https://doi.org/10.1016/j.iswcr.2023.11.008>
- [8] Zhai, G., Ren, P., Zhang, R., Wang, B., Zhang, M., He, T. and Zhang, J. (2025) Evaluation of Land Ecological Security and Driving Factors in the Lower Yellow River Flood Plain Based on Quality, Structure and Function. *Scientific Reports*, **15**, Article No. 2674. <https://doi.org/10.1038/s41598-024-84906-y>
- [9] World Atlas (2024) Yellow River. <https://www.worldatlas.com/rivers/yellow-river.html/>
- [10] New World Encyclopedia (2024) Yangtze River. https://www.newworldencyclopedia.org/entry/Yangtze_River/
- [11] China Highlights (2024) Yellow River (Huang He River): World's Muddiest River. <https://www.chinahighlights.com/yellowriver/>
- [12] Popov, I.V. and Greer, C.E. (2025) Yellow River. Encyclopedia Britannica. <https://www.britannica.com/place/Yellow-River/The-lower-course/>
- [13] Mostern, R. and Horne, R.M. (2021) The Yellow River: A Natural and Unnatural History. Yale University Press. <https://doi.org/10.12987/9780300263114>
- [14] Olson, K.R. and Morton L.W. (2018) Water Rights and Fights: Lao Dams on the Mekong River. *Journal of Soil and Water Conservation*, **73**, 35A-41A. <https://doi.org/10.2489/jswc.73.2.35A>
- [15] Clift, P.D., Carter, A., Campbell, I.H., Pringle, M., Nguyen, V., Allen, C., Allen, C.M., Hodges, K.V. and Mai, T.T. (2006) Thermochronology of Mineral Grains in the Red and Mekong Rivers, Viet Nam: Provenance and Exhumation Implications for Southeast Asia. *Geochemistry, Geophysics, Geosystems*, **7**, Q10005. <https://doi.org/10.1029/2006GC001336>
- [16] Fenton, C.H., Charusiri, P. and Wood, S.H. (2003) Recent Paleoseismic Investigations in Northern and Western Thailand. *Annals of Geophysics*, **46**, 957-981.
- [17] Wikipedia (2024) Yellow River. https://en.wikipedia.org/wiki/Yellow_River/
- [18] Olson, K.R. and Lang, J.M. (2021) The Disappearing Colorado River: Historic and Modern Attempts to Manage the Lifeline of the United States Southwest. *Open Journal of Soil Science*, **11**, 538-566. <https://doi.org/10.4236/ojss.2021.1111027>
- [19] Olson, K.R. and Kome, G.K. (2024) Review and Analysis of Africa's Lifelines: The Nile River and the Aswan High Dam. *Open Journal of Soil Science*, **14**, 741-764. <https://doi.org/10.4236/ojss.2024.1412036>
- [20] Tregear, T.R. (1965) A Geography of China. Routledge.
- [21] The New York Times (2007) China's Yellow River, Part 1.
- [22] China Daily (2005) Yellow River Delta Shrinking 7.6 Square Kilometers Annually.
- [23] White, M. (2012) The Great Big Book of Horrible Things: The Definitive Chronicle of History's 100 Worst Atrocities. W. W. Norton & Company.
- [24] Gascoigne, B. and Gascoigne, C. (2003) The Dynasties of China. Perseus Books Group.

- [25] Strategy Page (2011) The Ice Bombers Move Against Mongolia. <https://www.strategypage.com/htmw/htpeace/articles/20110329.aspx#gsc.tab=0>
- [26] World Health Organization (2011) Flooding and Communicable Diseases Fact Sheet. *Weekly Epidemiology Record*, **80**, 21-28.
- [27] Davis, M. (2011) Late Victorian Holocausts: El Nino Famines and the Making of the Third World. Verso Books.
- [28] Lamoroux, C. (1998) From the Yellow River to the Huai, Chapter 15 in Elvin and Ts'ui-Jung, *Sediments of Time*. Cambridge University Press, 556-571.
- [29] People's Daily (2000) Yellow River Upstream Important to West-East Power Transmission.
- [30] Pietz, D.A. (2015) *The Yellow River: The Problem of Water in Modern China*. Harvard University Press. <https://doi.org/10.4159/harvard.9780674736108>
- [31] Elvin, M. and Ninghu, S. (1998) The Influence of the Yellow River on Hangzhou Bay since AD 1000, Chapter 10 in Elvin and Ts'ui-Jung, *Sediments of Time*. Cambridge University Press.
- [32] Grousset, R. (1959) University of California Press.
- [33] Tsai, S. and Shan H. (1996) SUNY Series in Chinese Local Studies: The Eunuchs in the Ming Dynasty. SUNY Press.
- [34] International Rivers Report (2007) Before the Deluge. Wayback Machine.
- [35] Needham, J. (1986) *Science and Civilisation in China*. Volume 1: Introductory. Cambridge University Press.
- [36] Lary, D. (2004) The Waters Covered the Earth: China's War-Induced Natural Disaster. In: Selden, M. and Alvin, Y.S., Eds., *War and State Terrorism: The United States, Japan, and the Asia-Pacific in the Long Twentieth Century*, Rowman & Littlefield 143-170.
- [37] Harrell, S. (2023) *An Ecological History of Modern China*. University of Washington Press. <https://doi.org/10.1515/9780295751702>
- [38] Li, S.Z. (2017). *Fishes of the Yellow River* (in Simplified Chinese). Ocean University of China Publishing House.
- [39] Xie, J.Y., Tang, W.J. and Yang, Y.H. (2018) Fish Assemblage Changes over Half a Century in the Yellow River, China. *Ecology and Evolution*, **8**, 4173-4182. <https://doi.org/10.1002/ece3.3890>
- [40] Watts, J. (2007) A Third of Fish Species Killed in Yellow River. *The Guardian*.
- [41] Zhao, Y., *et al.* (2020) Species Diversity and Conservation of Freshwater Fishes in the Yellow River Basin. *Biodiversity Science*, **28**, 1496-1510. <https://doi.org/10.17520/biods.2020191>
- [42] Sino Cultura (2024) A Masterpiece Unveiled: The Legacy of "A Thousand Li of Rivers and Mountains". <https://sinocultural.com/blogs/all-blogs/a-masterpiece-unveiled-the-legacy-of-a-thousand-li-of-rivers-and-mountains-by-wang-ximeng/>
- [43] Van Dijk, P.P., Iverson, J.B., Rhodin, A.G.J., Shaffer, H.B. and Bour, R. (2014) *Turtles of the World. 7th Edition: Annotated Checklist of Taxonomy, Synonymy, Distribution with Maps, and Conservation Status*. IUCN/SSC Turtle Taxonomy Working Group. <https://doi.org/10.3854/crm.5.000.checklist.v7.2014>
- [44] Shi, H., Parham, J.F., Fan, Z., Hong, M. and Yin, F. (2008) Evidence for the Massive Scale of Turtle Farming in China. *Oryx*, **42**, 147-150.
- [45] Zhongyuan Net-Zhengzhou Dailey (20009) Xingyang Started to Build the Largest

- Yellow River Turtle Breeding Base in Henan Province.
https://web.archive.org/web/20140222032909/http://www.zynews.com/town/2007-07/24/content_459017.htm/
- [46] Yan, F., Lü, J., Zhang, B., Yuan, Z., Zhao, H., Huang, S., Wei, G., Mi, X. and Zou, D. (2018) The Chinese Giant Salamander Exemplifies the Hidden Extinction of Cryptic Species. *Current Biology*, **28**, R590-R592. <https://doi.org/10.1016/j.cub.2018.04.004>
- [47] Branigan, T. (2008) One-Third of China's Yellow River 'Unfit for Drinking or Agriculture'. Factory Waste and Sewage from Growing Cities Has Severely Polluted Major Waterway, According to Chinese Research. *The Guardian*.
- [48] Cheng, L. and Brown, K. (2009) *Berkshire Encyclopedia of China*. Berkshire Publishing Group.
- [49] Olson, K.R. and Frenelus, W. (2024) Environmental and Human Impacts of Lancang-Mekong Mainstem and Tributary Dams on China, Laos, Thailand, Myanmar, Cambodia, and Vietnam. *Open Journal of Soil Science*, **14**, 555-605. <https://doi.org/10.4236/ojss.2024.1410029>
- [50] Duyvendak, J.J.L. (1939) The True Dates of the Chinese Maritime Expeditions in the Early Fifteenth Century.
- [51] Wang, S., Fu, B., Piao, S., *et al.* (2016) Reduced Sediment Transport in the Yellow River Due to Anthropogenic Changes. *Nature Geoscience*, **9**, 38-41. <https://doi.org/10.1038/ngeo2602>
- [52] Zhang, Y., Yang, P., Liu, J., Zhang, X., Zhao, Y., Zhang, Q. and Li, L. (2020) Sustainable Agricultural Water Management in the Yellow River Basin, China.
- [53] Sun, Z.L., Sun, L.Q. and Wang, B. (2023) Microplastic Pollution in the Yellow River Basin: Current Status and Control Strategy. *Water, Air, & Soil Pollution*, **234**, Article No. 30. <https://doi.org/10.1007/s11270-022-06038-1>
- [54] Yu, Z., Sun, X., Yan, L., Yu, S. Yong, L. and Jin, H. (2024) Analysis of the Water Quality Status and Its Historical Evolution Trend in the Mainstream and Major Tributaries of the Yellow River Basin. *Water*, **16**, Article 2413. <https://doi.org/10.3390/w16172413>
- [55] Ming, L., Wang, Y., Liu, G., Meng, L. and Chen, X. (2024) Assessing the Impact of Human Activities on Ecosystem Asset Dynamics in the Yellow River Basin from 2001 to 2020. *Scientific Reports*, **14**, Article No. 22227. <https://doi.org/10.1038/s41598-024-73121-4>