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Review article

ENVIRONMENTAL CHALLENGES OF THE NORTHERN INDIAN PLAINS AND THEIR IMPLICATIONS

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ABSTRACT

The Northern Indian Plains are facing severe environmental challenges that threaten the health and well-being of millions of people in the region. Deforestation, soil degradation, water pollution and scarcity, and poor air quality are some of the major environmental issues that require urgent attention. Deforestation in the region has resulted in the loss of biodiversity, soil erosion, and reduced water availability. Soil degradation is another major issue in the region, resulting from unsustainable agricultural practices, overuse of chemical fertilizers, and erosion caused by deforestation. It has also reduced soil fertility, resulting in lower crop yields and reduced agricultural productivity. Using chemical fertilizers and pesticides has also led to water pollution, affecting the health of people and animals who rely on these water sources. Water scarcity and pollution are major challenges in the region, with many people having limited access to clean and safe drinking water. The pollution of water sources due to industrial and agricultural activities has further compounded the problem, leading to waterborne diseases and various health issues. Finally, air pollution is a major environmental challenge in the Northern Indian Plains, with high levels of particulate matter and other pollutants affecting people's health in the region. Burning crops, vehicular emissions, and industrial activities contribute to poor air quality, leading to respiratory illnesses, cardiovascular disease, and other health issues. This study aims to provide a comprehensive overview of the mentioned environmental challenges in the Northern India Plains by utilizing contemporary literature and evidence-based research to establish its findings.

Keywords: *deforestation, soil degradation, water pollution, air pollution, India, plains*

INTRODUCTION

The Northern Indian Plains, also known as the Indo-Gangetic Plains or Hindustan Plains, is a vast alluvial plain in northern India, extending from the Indus River in the west to the Brahmaputra River in the east. The region has been shaped by the interplay of geology, climate, and human activities over millions of years and is mainly made of sedimentary deposits of the Indus, Ganges, and Brahmaputra Rivers. It is well known for its rich soil, abundant water resources, and diverse vegetation, making it a vital ecological and econom-

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ic resource for this part of the world (Shaw, 2018). The Himalayan ranges are closely linked to the Northern Plains of India, as they played a vital role in shaping the region's geography through the accumulative processes of mighty rivers that descend from the highest parts of the mountains, thus creating the world's most extensive lowlands. Due to the combination of fluvial and glacial erosion that erodes material from the highest parts of the world but also high areas in the south of the peninsula (in which case it is only fluvial erosion), accumulative deposits in the Ganges and Brahmaputra valleys have a depth of up to several tens of meters (Srivastava et al., 2015). As for the climate characteristics, this region experiences a subtropical monsoon climate, with hot summers, cool winters, and heavy rainfall during the monsoon season, and the ranges of the Himalayas represent a major relief obstacle for the movement of air masses, limiting the movement of summer monsoon winds to the north (Shaw, 2018). As the summer monsoons bring vast amounts of precipitation, it was on the southeastern slopes of the Himalayas that the highest amount of rainfall in the world was recorded so far (Cherapunji, 1861 - 26,471 mm) (Koutsoyiannis, Papalexiou, 2017). Besides favorable climatic conditions, the agricultural productivity of the Hindustan Plains is due to the abundant water supply from the Ganges and its tributaries, which supports the cultivation of rice, wheat, sugarcane, and other crops. The region is also known for its rich biodiversity, with various flora and fauna in its numerous wetlands, forests, and grasslands (Walsh, 2006).

The physical setting of the Northern India Plains region also played a significant role in the social and economic development of India, Pakistan, and Bangladesh. The lowlands have a rich cultural and historical heritage, shaped by the intense mixing of different races, cultures, and religions throughout history. It is home to over 800 ethnicities who speak more than 1500 languages, making it one of the world's most ethnically and linguistically diverse areas (Phillips, Gritzner, 2003; Nakassis, Annamalai, 2020). Today, the main characteristic of the population in the Hindustan Plains is its size, with over 700 million inhabitants living in an area of 1,152,200 km2 and an average population density of approximately 630 people per square kilometer, which is significantly higher than the population density in other parts of the world (Hobbs, 2016). However, certain parts of the Indus Valley lowlands are less populated compared to Bihar and Bangladesh, with a population density of over 1,000 inhabitants per square kilometer (Chandrasekhar, Sharma, 2015). The dynamic interaction between natural resources and transitional characteristics of the Northern Indian Plains has been instrumental in shaping the region's social, ecological, and agricultural development over time. However, the region is currently facing many environmental challenges, such as deforestation, soil degradation, groundwater depletion, and pollution, which pose a significant threat to its ecological and agricultural systems. Besides mentioned, air pollution is one of the most significant environmental threats and health risks. It is caused by various human-made factors that are intertwined with the physical environment.

This research paper aims to present a comprehensive overview of the most significant environmental challenges in the Northern India Plains. The study utilizes contemporary literature and evidence-based research to establish its findings.

RESEARCH AREA

The Northern Indian Plains comprise a vast region, spanning from the Himalayas in the north to the Vidhya mountains in the south. These mountain ranges not only serve as natural boundaries but also significantly influence the climate of the region. They act as a protective barrier against the cold winds from the north and are a vital source of moisture-laden winds during the monsoon season, bringing essential rainfall to the region. The region is predominantly flat, with an average elevation of 200 meters above sea level, and the landscape is dominated by fertile alluvial plains formed by the deposition of sediment carried by the Indus, Ganges, and Brahmaputra rivers (Shaw, 2018). The Northern India Plains has always been a region of favorable conditions, resulting in a high population density throughout history. Presently, the region comprises three countries, India, Pakistan, and Bangladesh, among the most heavily populated nations globally (Figure 1).

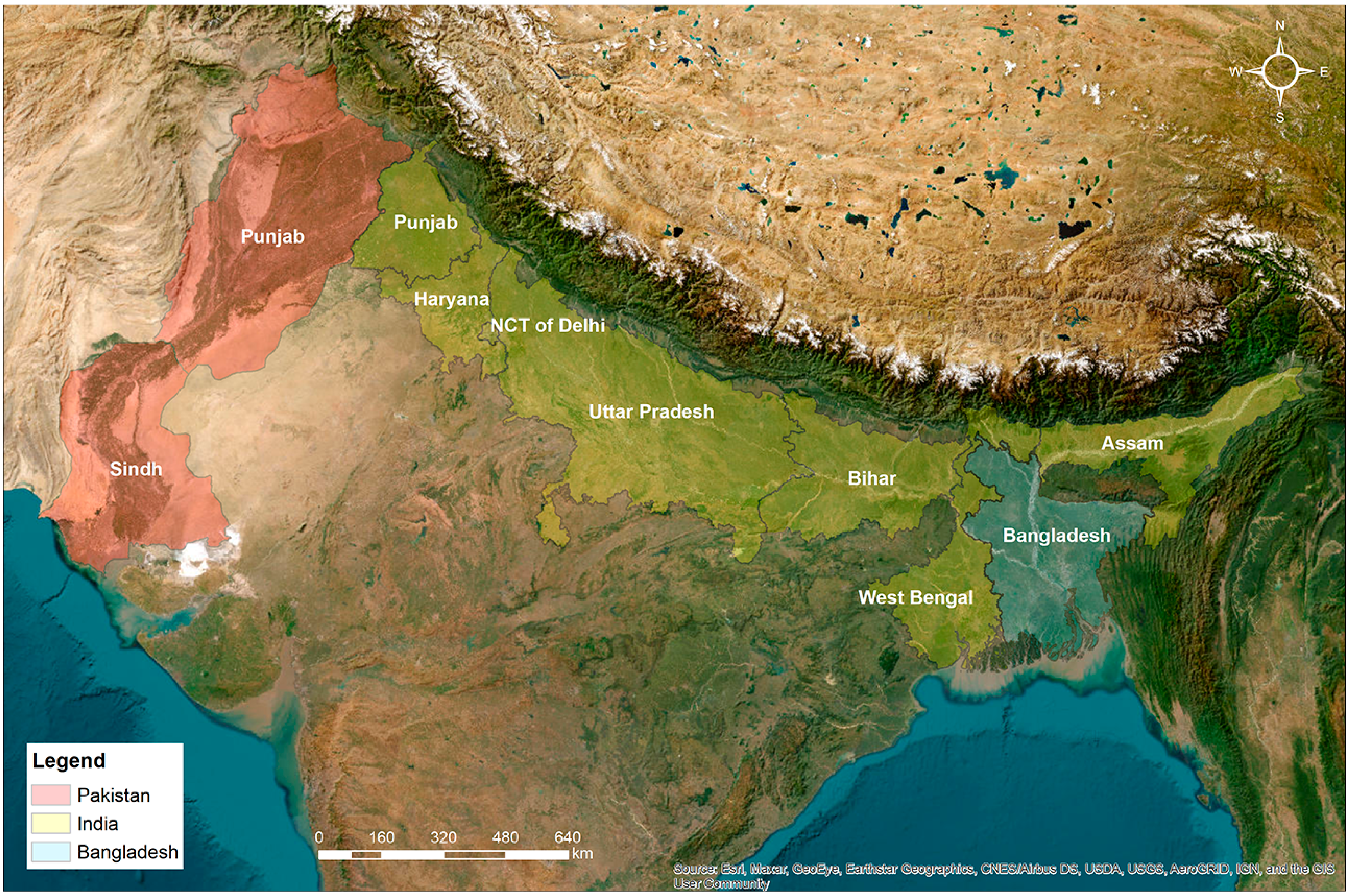

Figure 1. Research area and administrative entities
Source: Dajana Bjelajac

The study area encompasses several administrative entities within the Northern India Plains, including provinces, districts, and countries. Figure 1 depicts the administrative boundaries that closely resemble the natural boundaries of the research area. For example, Sindh and Punjab (figure 1, red color) are two of the four provinces in Pakistan. Punjab is the largest province in terms of population, covering around 25.8% of Pakistan's total land area and housing approximately 60% of the country's population. Sindh, on the other hand, covers around 17.7% of Pakistan's total land area and has a population of about 22% of the country's total population. Therefore, combined, Sindh and Punjab cover around 43.5% of Pakistan's total land area and are home to over 80% of the country's population (Pakistan Bureau of Statistics, 2017). As for India, Punjab, Haryana, the National Capital Territory (NCT) of Delhi, Uttar Pradesh, Bihar, West Bengal, and Assam are all states in Northern India Plains (Figure 1, yellow color). Punjab, Haryana and NCT of Delhi are the smallest of the seven states, covering around 3% of the land but encompassing 6% of the population. On the other hand, Uttar Pradesh is the largest state in India, covering approximately 7.3% of the country's land area and housing around 16.5% of the country's population. Bihar covers around 2.8% of India's land area and has a population of about 8.6% of the country's total population. West Bengal covers about 2.7% of India's land area and has a population of approximately 7.5% of the country's population. Finally, Assam covers around 2.4% of India's land area and has a population of about 2.6% of the country's total population. Together, these seven states cover approximately 18.5% of India's total land area and are home to over 41% of the country's population (Census India, 2011). Compared to the previous countries, most of Bangladesh's territory (Figure 1, blue color) lies within the Northern India Plains (97%), with the majority of the population of more than 165 million.

ENVIRONMENTAL CHALLENGES OF NORTHERN INDIA PLAINS

The Northern Indian Plains, the Indo-Gangetic or Hindustan Plains, have experienced considerable environmental changes over the past few decades, affecting the region's ecological and agricultural systems. The causes of these changes are complex, involving the interplay of geology, climate, and human activities over a long period. Therefore, this paper will focus on the most significant environmental challenges in the region that are currently impacting the local population, such as deforestation, soil degradation, water resources challenges, and air pollution.

Vanishing Green: Exploring Forest Cover Loss and Deforestation

One of the most significant environmental changes in the Northern India Plains is the loss of forest cover. Deforestation has been a long-standing problem in the region, mainly due to agricultural expansion, fuelwood collection, and urbanization. According to a study by FAO (2015), the forest cover in the Northern India Plains decreased by 2.14 million hectares between 1990 and 2015, with an annual deforestation rate of 0.17%. The study also found that the average tree cover in the region is only 7.1%, significantly lower than the national average of 23%. Pakistan is among the countries with the most forest deficiencies globally, where the deforestation rate ranges from 0.2% to 0.5% per year, the highest globally. As a result, the forest cover has been reduced from 3.59 million hectares to 3.32 million hectares, with a mean annual reduction of 27,000 hectares (Hassan et al., 2016; Qamer et al., 2016). Certain authors, such as Siddiqui and Afsar (2004), used satellite images from Landsat TM to assess changes in forest cover and found that the riverine forests of Sindh have been severely degraded, with a decline in forest cover from 17.2% in 1977 to 2.2% in 2000. Forest decline's primary cause was anthropogenic activities such as grazing, agriculture, and fuelwood collection.

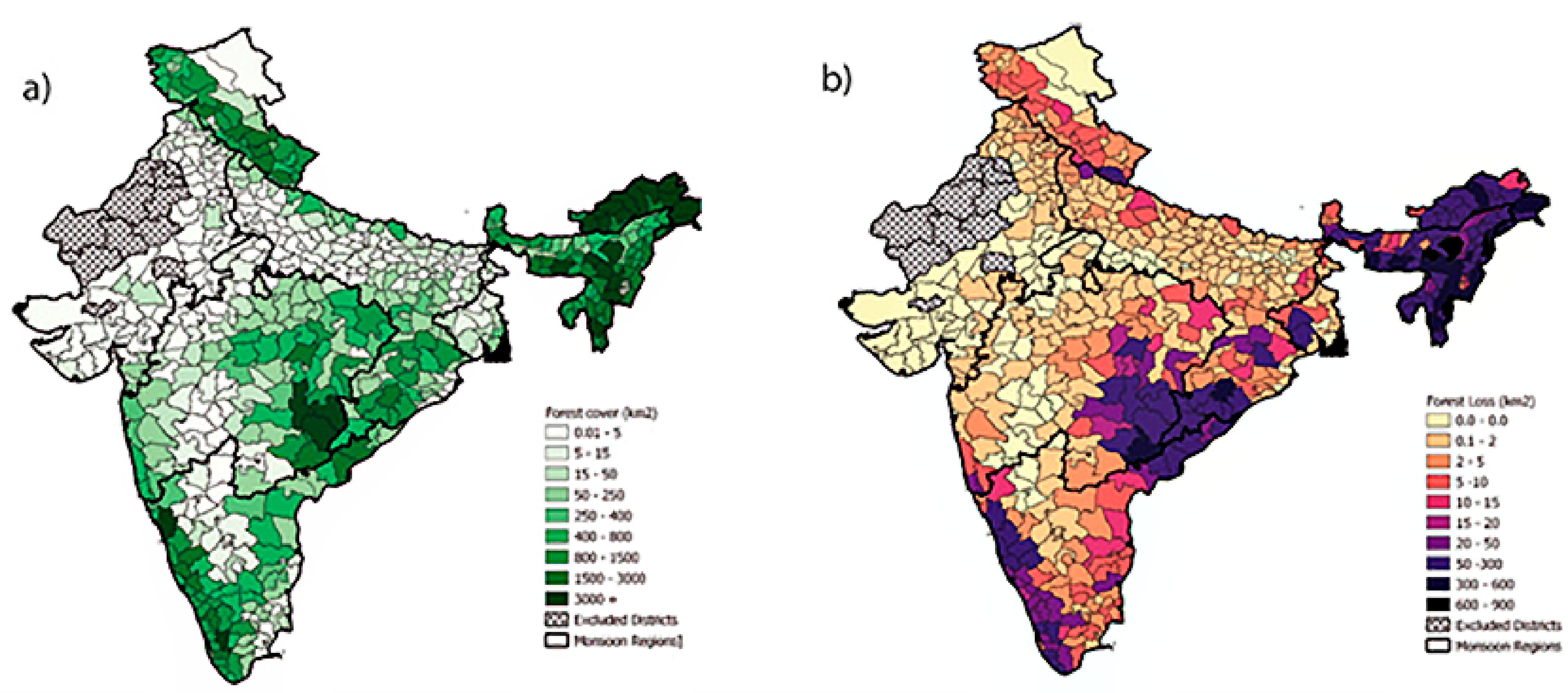

Figure 2. Forest cover changes: a) forest cover in 2000, b) forest lost over 2001-18 in km²

Source: Haughan et al., 2022

Tropical forests in India have also rapidly declined in recent years, with the highest rates of forest loss recorded in the Northeast region, particularly in the states of Assam and West Bengal (Figure 2). According to a study by the Forest Survey of India (2019), Assam lost around 43,000ha of forest cover between 2017 and 2019, bringing the total forest cover down to 28,016 km². Similarly, West Bengal lost approximately 33,000ha of forest cover during the same period, bringing the entire forest cover down to 12,189 km² (Forest Survey of India, 2019). Agricultural expansion, logging, and biotic pressures are some of India's main drivers of deforestation (Kumari et al., 2019; Haughan et al., 2022). As for Bangladesh, according to Global Forest Watch (2022), from 2001 to 2021, Bangladesh lost 214.000 ha of tree cover, equivalent to an 11% decrease in tree cover since 2000 and 108 Mt of CO_2 emissions. It is especially important to emphasize cover changes in Sundarbans mangrove forests, which are critical in protecting coastal areas from the devastation caused by flooding, cyclones, or storm surges in Bengal Bay. For example, according to Rafikul Islam et al. (2021) study, forest cover in the Nijhum Dwip protected area (in the southern part of Bangladesh) decreased by over 42% from 1990 to 2020, endangering more than 30,000 people and numerous protected animals.

In conclusion, deforestation has been a long-standing problem in the Northern India Plains, Pakistan, and Bangladesh, primarily due to agricultural expansion, fuelwood collection, and urbanization. The loss of forest cover has resulted in severe environmental consequences such as soil degradation, reduced water availability, and increased carbon emissions. In addition, reducing forest cover has endangered local communities and wildlife, particularly in the Sundarbans mangrove forests. Therefore, urgent action is necessary to address the issue of deforestation and promote sustainable forest management practices to ensure the well-being of the environment and the communities that rely on it.

Causes and Consequences of Soil Degradation

As a region that heavily relies on the soil's fertility, another significant environmental change in the Northern India Plains is soil degradation. It has become a widespread problem due to intensive cultivation, overuse of chemical fertilizers and pesticides, or unsustainable land management practices. Salinization is one of the leading causes of soil degradation in Sindh and Punjab, reducing its fertility and overall productivity. According to a study by Malik et al. (2021), the salinity levels in the soils of Punjab province have increased significantly in the past few decades due to over-irrigation, poor drainage, and inadequate soil management practices. The authors used remote sensing data to map land use changes and soil salinity levels in the study area, finding that the total area affected by soil salinity increased by 43% during the study period. Another example is a study carried out by Aslam et al. (2015), where results showed that about 44% of the Nara Canal Command Area in Sindh was affected by waterlogging and salinity, varying degrees of severity. The study also identified the leading causes of these problems, including poor drainage, inadequate irrigation management, and high groundwater levels.

Waterlogging and salinity problems have been associated with soil degradation in the entire region of Indo-Gangetic Plains, but for Uttar Pradesh, Punjab, and Maharashtra, burning of crop residues for cooking, heating, or simply disposal is one of the biggest causes of soil organic matter decline (Bhattacharyya et al., 2015). On the other hand, the Brahmaputra basin is an example of a highly heterogeneous watershed with a complex topography and frequent occurrence of floods due to the dynamic monsoon rainfall regime cover. In such a unique physiographic setting, erosion processes play a more critical role in soil degradation in the Assam region. According to the State Disaster Management Plan (2013), Assam lost about 7% of its land to river erosion over the past 50 years. In general, soil degradation is a severe environmental problem that affects many parts of India, and numerous papers are searching for causes and providing mitigation measures, particularly for West Bengal (e.g., Das, Sarkar, 2016; Mahala, 2019), Bihar (e.g., Kamur et al., 2016; Bahadur, Praveen, 2022), Uttar Pradesh (e.g., Saxena et al., 1991; Sanjay, Singh, 2020), Haryana (e.g., Chauhan, Rani, 2019), and Punjab (e.g., Aulakh, Sidhu, 2015). When it comes to Bangladesh, according to the study by Mohsin Ali et al. (1997), the soil fertility status declined from 1967 to 1995 due to intensive cultivation, improper nutrient management, and low organic matter content in the soil. The results indicated that soil pH levels have decreased, and organic matter content and availability of essential plant nutrients (e.g., nitrogen, phosphorus, and potassium) have declined in most agroecological zones of Bangladesh. Another study (Ali, 2006) shows how shrimp farming in Bangladesh can also contribute to soil degradation, increasing soil salinity, acidity, and other content. After prime quality rice fields were converted into shrimp farms from 1985 to 2003, rice production was drastically reduced, and aquatic and non-aquatic habitats inherent in the rice ecosystem were destroyed.

In general, soil degradation severely affects the environment and human well-being. It leads to a decline in soil quality, reducing agricultural productivity and causing food insecurity. It also contributes to water pollution and loss of biodiversity, as soil microorganisms and invertebrates play an essential role in the ecosystem's functioning. Therefore, addressing soil degradation is crucial for maintaining sustainable agricultural production and ensuring food security while preserving the environment for future generations, especially for regions such as the Northern India Plains (Bhattacharyya, 2015).

Water Crisis: Examining Shortages, Pollution, and Groundwater Depletion

The Northern India Plains also faced significant changes regarding **water resources**. The region is home to several major rivers, including the Ganges, Brahmaputra, and Indus, the primary water sources for irrigation, drinking, and industrial use. However, overuse of groundwater and surface water resources, inefficient irrigation practices, and inadequate water management has led to water scarcity and depletion.

Groundwater accessibility is a significant determinant of poverty and welfare in Pakistan, where irrigated agriculture's sustainability is jeopardized by the rapid decline of groundwater levels and the simultaneous increase in the salt content of pumped groundwater (Qureshi et al., 2010a; Qureshi et al., 2010b). According to a Pakistan Water Partnership (PWP) study, the country faces an impending water shortage crisis, threatening food security due to its rapidly growing population. The per capita surface water availability has dwindled from 5,260 cubic meters per year in 1951 to approximately 1,000 cubic meters in 2016. Furthermore, this amount is projected to decline even further to around 860 cubic meters by 2025, indicating a shift from being "water-stressed" to becoming a "water-scarce" country. It is important to note that the minimum water requirement to avoid water scarcity's food and health implications is 1,000 cubic meters per capita per year. As the most populous and agriculturally important province of Pakistan, Punjab is expectedly to face several water resources challenges, including the over-extraction of groundwater that has resulted in declining water tables, water quality degradation, and socioeconomic consequences, particularly for farmers (Nasir et al., 2021). In addition to population growth, it is also important to mention the "build-up area" growth of around 8% between 1990 – 2020, which had the most significant detrimental impact on water quality (Hussain et al., 2023). Like Punjab, Sindh is the second largest province in Pakistan, with a population of over 47 million, facing water scarcity, over-extraction of groundwater, and water pollution. The situation is even worsened by the effects of climate change, such as increased temperatures and unpredictable rainfall patterns, which will likely affect water availability in the future. In addition, the discharge of untreated industrial and household waste into the Indus River and other bodies of water has led to water pollution, making it unsuitable for drinking and irrigation. The findings of Memon et al. (2010) reveal that most hand pumps, wells, and municipal water supplies in the southern part of Sindh were contaminated with pathogenic bacteria such as E. coli and other pollutants like nitrates, chlorides, and total dissolved solids (TDS). The high degree of contamination signals a shortage of safe drinking water in the area, which may result in various health complications like diarrhea, typhoid, and cholera.

As for the Ganges Plains, there are numerous studies related to the water quality, starting from the study by Chander et al. (2023) in SW Punjab (India), where results show the groundwater in the study area is unsuitable for drinking and irrigation purposes due to high levels of fluoride and uranium, as well as high levels of total dissolved solids and salinity. The concentrations of these contaminants exceed the permissible limits, which can pose severe health risks, including cancer and fluorosis. Similar findings have been previously published by Sahoo et al. (2022), where research shows that shallow groundwaters (<60 m) are more contaminated with uranium compared to deeper depths (>60 m), and the primary source of contamination is geogenic, but anthropogenic and climate-related factors may also contribute. Besides the presence of toxic matter in the water resources of Punjab (e.g., Krishan et al., 2021; Singh et al., 2020), researchers also investigated the depletion of the groundwater table, finding that the groundwater depletion in certain areas increased from 30% in 2000 to more than 75% in 2019 (Figure 3) (Sidhu et al., 2021).

It is important to emphasize that the Punjab region covers only 1,5% of India, but it is well-known for its agriculture and rural development, producing 35.5% of wheat and 25.5% of rice. However, as mentioned before, this region is significantly irrigated, with the number of tube wells increasing from 0.19 million in 1970 to 1.48 million in 2019. Shifting from canal irrigation to tube well irrigation has resulted in a change from

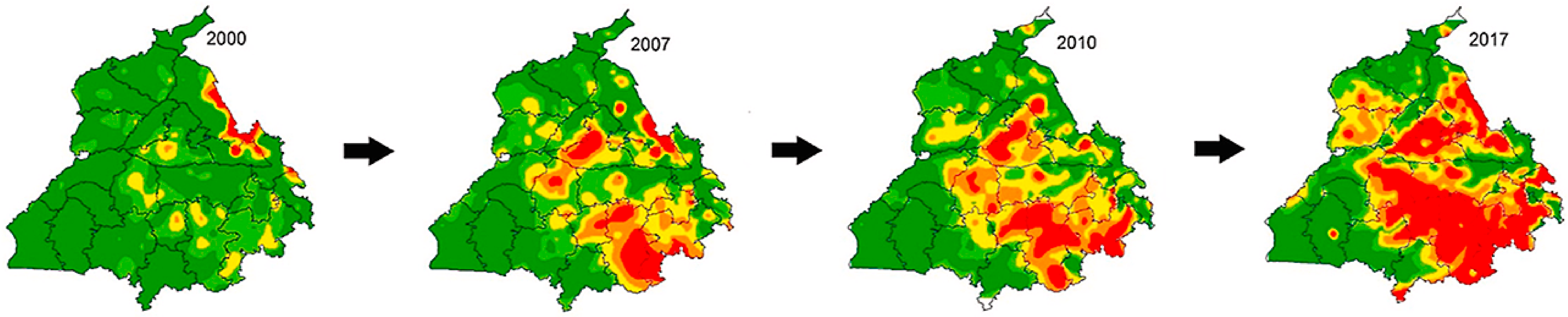

Figure 3. Depletion of groundwater table (red and yellow color symbolising the intensity) in Punjab over the years
Source: Sidhu et al., 2021

wheat-maize cropping to a rice-wheat cropping pattern, leading to groundwater exploitation and an annual fall in the groundwater table in central Punjab from 20 cm/year (1973-2001) to 100 cm/year (2000-06) (Singla et al., 2022). Similar studies can be found for all the countries located in the Ganges Plains and even Assam. Most of them are related to water quality in Haryana (e.g., Kumari et al., 2007; Singh et al., 2007; Rout, Sharma, 2011; Ali et al., 2018; Duggal et al., 2017; Duggal et al., 2021), Uttar Pradesh (e.g., Goyal et al., 2022; Shukla et al., 2020; Idrees et al., 2020), Bihar (e.g., Kumar et al., 2016; Thakur et al., 2021; Xu et al., 2021) and West Bengal (e.g., Patra et al., 2023; Biswas et al., 2023), or to groundwater fluctuations and agricultural consequences (e.g., Sharma et al., 2022; Guchhait et al., 2023). Besides water quality challenges and contaminations (Chetia et al., 2010; Bora, Goswami, 2017), Assam faces the additional challenge of sedimentation in its rivers and reservoirs, which reduces water storage capacity and negatively impacts hydropower generation (Saikia, Mahanta, 2021). According to the study "Water and Agriculture in India" (GFFA, 2017), compared to its 18% share of the world's population, India has only 4% of the world's freshwater, with 80% of it used for agriculture due to an increase in population and changing lifestyles. Due to inadequate storage methods, insufficient infrastructure, and improper water management, the utilization of available water is limited to only 18-20%, and despite receiving an average of 4,000 billion cubic meters of precipitation annually, only 48% of it is used in India's surface and groundwater bodies. In contrast, the country's annual rainfall of approximate-

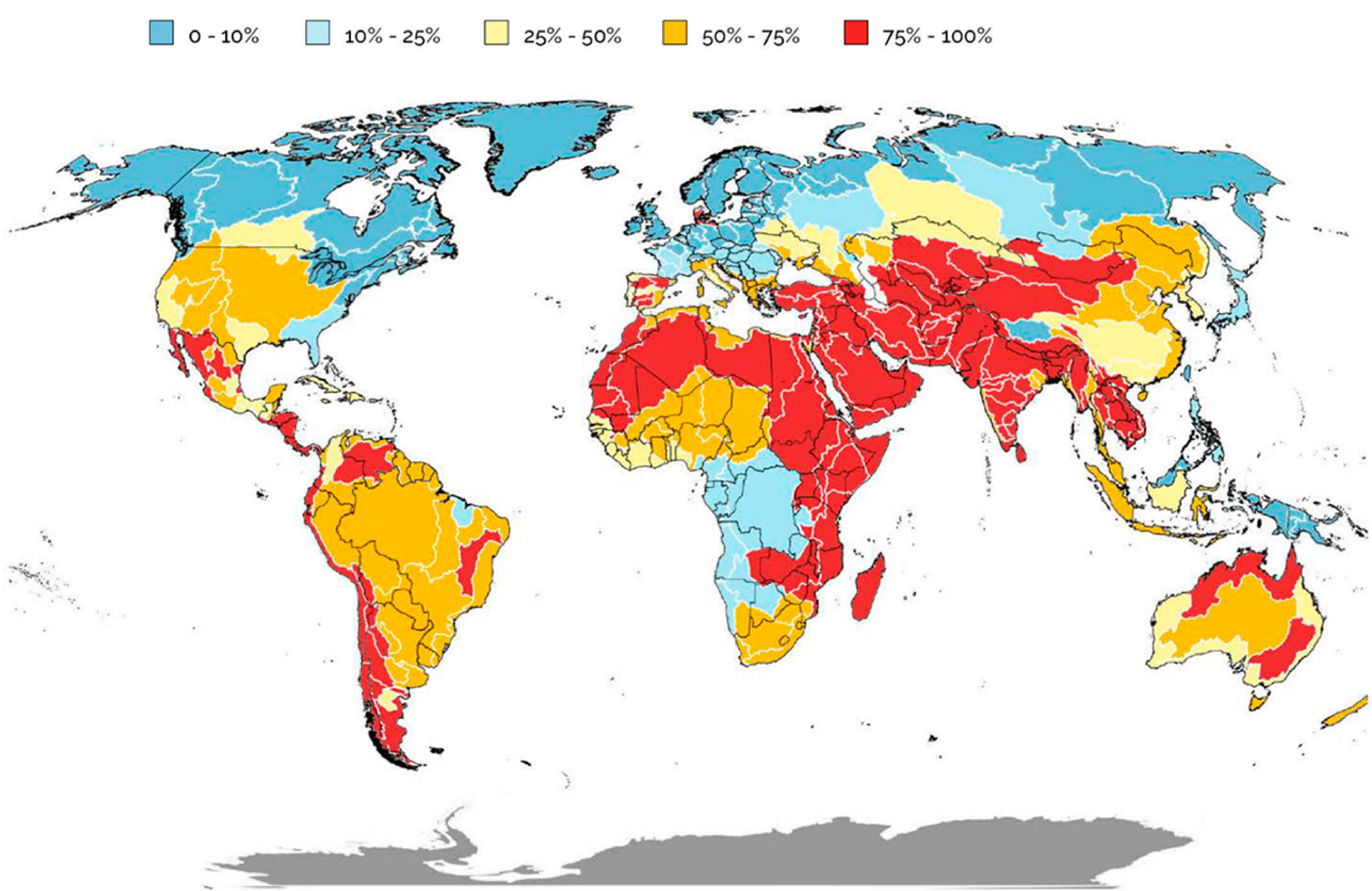

Figure 4. Level of water stress due to the agricultural sector by basin (2018)
Source: Food and Agriculture Organization of the UN and UN Water

ly 1183 mm is mostly received in a short span of four months during the monsoon season, resulting in runoff and requiring investments in irrigation for the rest of the year.

Despite abundant water resources in Bangladesh, this country also faces a severe water pollution crisis due to anthropogenic sources. Both surface water and groundwater sources are continuously being contaminated with various organic and inorganic pollutants, including toxic trace metals and coliforms. As groundwater is the primary drinking water source for most of the population, the elevated presence of arsenic throughout the country poses a significant health risk (Khalid Hasan et al., 2019; Rahman et al., 2022; Anik et al., 2023).

The water scarcity, depletion, or contamination in Northern India Plains has continually worsened over the past 50 years. According to Figure 4, the entire research area has a high level of water stress, meaning that water demand exceeds the available amount during a certain period or when poor water quality restricts its use. The major factors contributing to the decline in water availability are the overuse of groundwater and surface water resources, inefficient irrigation practices, and inadequate water management. Pakistan, in particular, has been facing an impending water shortage crisis, threatening its food security due to its rapidly growing population, especially in Sindh and Punjab. Likewise, every country within the Ganges and Brahmaputra Plains has contaminated fresh water in various degrees, mainly uranium, and arsenic. The degradation of the water resources in the area has resulted in substantial repercussions for both the ecosystem and the populace's health. Additionally, the pollution has negatively impacted aquatic life, causing the disappearance of various fish species and other organisms from the rivers and wetlands. The environmental and social implications of water scarcity and depletion are significant. It results in decreased agricultural productivity, leading to food insecurity and poverty. The situation further exacerbates conflicts over water resources and adversely affects public health, as many communities depend on polluted water sources.

Polluted Air: A Threat to Health and Environment

In the last few decades, air pollution has emerged as one of the most crucial challenges that humanity is confronting, leading to harmful effects on both human health and ecosystems (Dastoorpoor et al., 2019). According to the HEI (2019) and the World Bank (2016), air pollution is now considered the fourth or fifth most significant global risk factor for mortality, and in 2016, approximately 4.2 million deaths worldwide were attributed to ambient air pollution (WHO, 2018). Air pollution is attributed to various pollutants that cause adverse health effects, including carbon monoxide (CO), sulfur dioxide (SO_2), particulate matter (PM_{10}, $PM_{2.5}$), nitrogen dioxide (NO_2), and ozone (O_3) (WHO, 2019). In developing countries, air pollution and associated health challenges have a more significant impact, as Smith (2002) noted. Specifically, in low and middle-income countries, indoor air pollution from the combustion of biomass-based fuels results in a premature death toll of about 3.8 million annually, with two-thirds of these fatalities occurring in Asia and Africa (Yamamoto et al., 2014).

Petrol and diesel fuels commonly used in vehicles are responsible for releasing various air pollutants. Petrol combustion releases a range of pollutants such as volatile organic compounds (VOCs), carbon monoxide (CO), heavy metals, and ammonia (NH3). On the other hand, diesel combustion emits nitrogen oxides (NOx) and PM2.5 particulate matter. Unsurprisingly, India is one of the countries struggling with air pollution, and the transportation sector is considered the primary cause (Gurjar et al., 2008). Its urban population increased from 10% to 28% from 1901-2001, leading to more vehicles (from 0.3 to 159.5 million from 1951-2012), traffic congestion, and wrong road infrastructure growth (Mishra and Goyal, 2014; Gurjar et al., 2016). According to estimates, trucks and lorries are responsible for the largest vehicular emissions in India. However, diesel-fueled heavy and light-duty vehicles also significantly contribute to overall vehicular emissions. (Guttikunda, Kopakka, 2014; Guttikunda, Mohan, 2014). The best example is Kolkata, where the primary source of air pollution is road dust (61%) and vehicles (21%), but dust can also be accompanied by construction activities or dusty weather/climate (Gurjar et al., 2016). In addition to transportation, household and commercial burning of fuels like wood, coal, and kerosene for cooking, heating, and lighting, and the burning of crop residue after the harvest season are also significant contributors to air pollution in countries located in the Ganges Plain (Chawala, Sandhu, 2020; Saxena et al., 2021; Khanal et al., 2022). This is especially pronounced during October and November after harvest residue burning in Punjab and Haryana, leading to extremely hazardous air pollution (Khanal et al., 2022). Khanal et al. (2022) found that pollutants can even be transported to Kathmandu and higher elevations, primarily through the river valleys, during particular wind conditions. Balakrishnan et al. (2019) confirmed the hazardous nature of air pollution, finding that this pollutant was responsible for 1.24 million deaths in India in 2017, accounting for 12.5% of the total deaths (51.4%) in people younger than 70. The North Indian states of Uttar Pradesh, Haryana, Delhi, Punjab, and Rajasthan had the highest ambient particulate matter pollution rate that year.

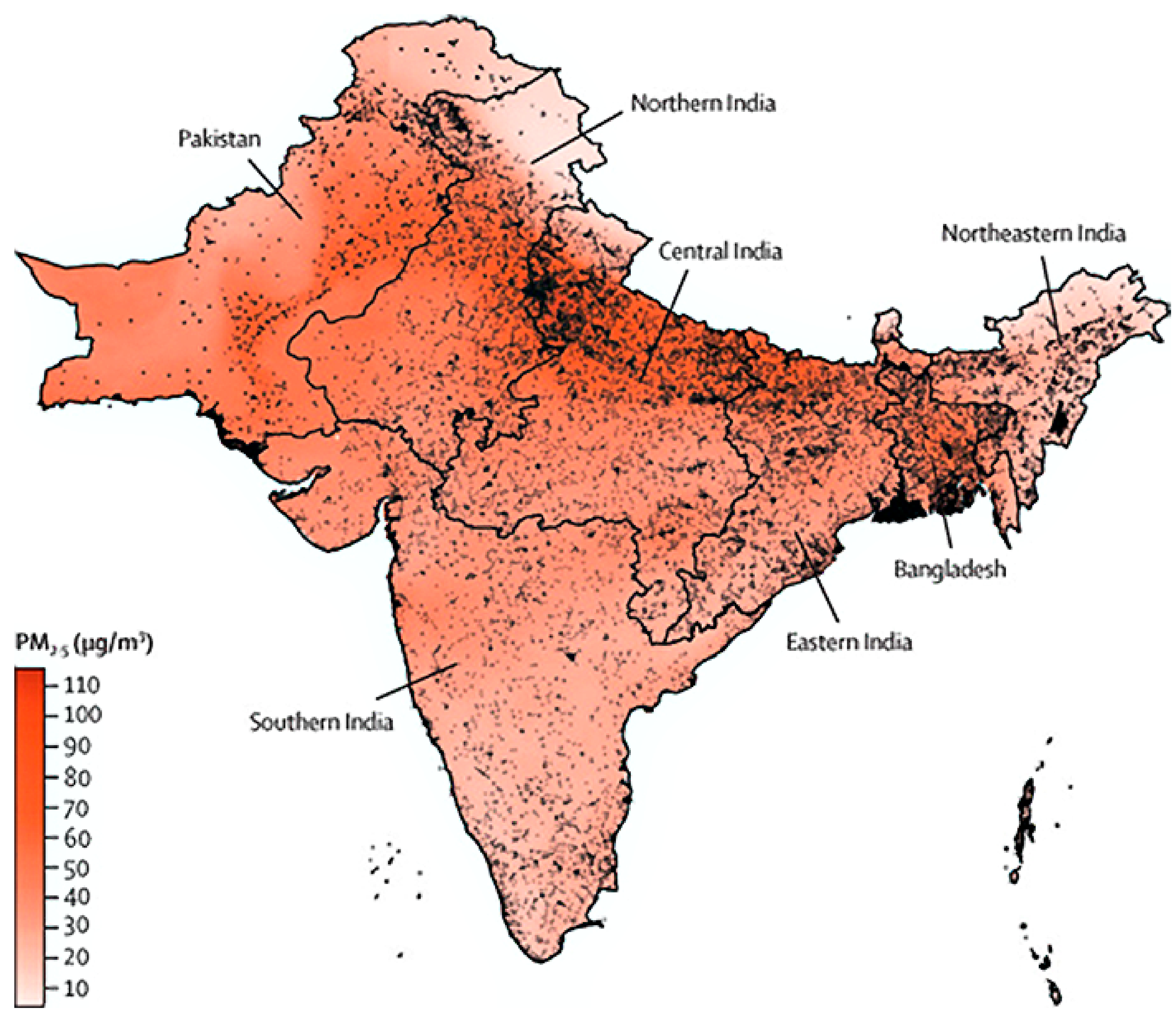

Figure 5. Long-term average $PM_{2.5}$ from 1998 to 2016
Source: Tao Xue et al., 2021

According to Figure 5, most countries within the research areas have extremely high air pollution values. In addition to the aforementioned causes of air pollution, another significant factor must be addressed due to its scale and cross-border characteristics. The Central Pollution Control Board (CPCB) has identified India as a nation that hosts seventeen categories of polluting industries, putting it in the league of industrialized countries (Anwar et al., 2021). The identified industries include oil refineries, smelters for aluminum, copper, and zinc, thermal power plants, cement and fertilizer factories, pesticide production facilities, and petrochemical units (Gurjar et al., 2016). To meet the rising demand for electricity in the country, thermal power plants, which account for 74% of the country's energy mix, use coal combustion as a fuel source. From 1973 to 1997, thermal power plants and the petroleum sector were responsible for over 25% and 40% of total emissions, respectively (TERI, 2001).

The same can be said for Pakistan, where in October 2019, Lahore was ranked as the second most polluted city with an Air Quality Index of 188 (Anwar et al., 2021). According to Mehmood et al. (2021), air pollution, particularly PM2.5, significantly affects hospitalization rates for respiratory and cardiovascular diseases in megacities such as Lahore. The study also finds that the effect of air pollution on hospitalization rates is stronger for females and children and that the effect is more pronounced in winter months. In Dhaka, Bangladesh, particulate matter (PM) has also been identified as the most harmful air pollutant to public health and the environment among the measured criteria pollutants. Fine particles with aerodynamic diameters less than 2.2 μm, of anthropogenic origin, and primarily from transport-related sources, make up 30-50% of the PM10 mass in Dhaka, depending on the location (Begum et al., 2013).

CONCLUSION

The Northern India Plains have undergone substantial environmental transformations, which encompass deforestation, soil degradation, alterations in water resources, and air pollution. The rapid decline of tropical forests in India, particularly in the Northeast region, has been a cause for concern due to their critical role in protecting coastal areas from natural disasters. The primary drivers of deforestation in the region include agricultural expansion, biotic pressures, and logging. Bangladesh has also experienced significant tree cover loss, endangering the lives of thousands of people and protected animals. As for soil degradation, one of the leading causes of it in Punjab and Sindh is salinization, resulting from poor drainage, over-irrigation, and inadequate soil management practices. Soil degradation is prevalent in other regions of India as well, such as Uttar Pradesh, Maharashtra, and Assam, where burning crop residues, erosion processes, and river flooding cause it. This problem is also observed in Bangladesh, where intensive cultivation and nutrient mismanagement are leading causes of soil degradation. Soil degradation leads to a decline in soil quality, reducing agricultural productivity, causing food insecurity, and contributing to water pollution and biodiversity loss. Northern India Plains are home to several major rivers, which are the primary water sources for irrigation, drinking, and industrial use. However, the overuse of groundwater and surface water resources, inefficient irrigation practices, and inadequate water management has led to water scarcity and depletion. This situation is worsened by the effects of climate change, such as increased temperatures and unpredictable rainfall patterns, which will likely affect water availability in the future. In addition, groundwater accessibility is a significant determinant of poverty and welfare in Pakistan, where irrigated agriculture's sustainability is jeopardized by the rapid decline of groundwater levels. The per capita surface water availability has dwindled from 5,260 cubic meters per year in 1951 to approximately 1,000 cubic meters in 2016, indicating a shift from being "water-stressed" to becoming a "water-scarce" country. The situation is similar in Sindh, where the over-extraction of groundwater, water pollution, and the effects of climate change have resulted in water scarcity and contamination. Studies related to water quality in the Ganges Plains reveal that water resources are contaminated with toxic matter and depleted, affecting the health of the population and jeopardizing agriculture and rural development. Air pollution's detrimental impact on human health and ecosystems should be emphasized. This problem is caused by a range of air pollutants, such as carbon monoxide, sulfur dioxide, nitrogen dioxide, particulate matter, and ozone, resulting in millions of premature deaths worldwide, especially in countries with low and middle-income economies, including India, Pakistan, and Bangladesh. The transportation sector, particularly heavy-duty vehicles, is considered the primary cause of air pollution in India. Household and commercial burning of fuels like wood, coal, and kerosene for cooking, heating, and lighting and the burning of crop residue after the harvest season are also significant contributors to air pollution in countries located in the Ganges Plain. Industrialization in India has led to seventeen different polluting industries, including thermal power plants, which account for 74% of the country's energy mix and use coal combustion as a fuel source. Pakistan is also facing severe air pollution problems, with Lahore ranked the second most polluted city in the world in October 2019. Air pollution, particularly $PM_{2.5}$, significantly affects hospitalization rates for respiratory and cardiovascular diseases in megacities such as Lahore, with a stronger effect on females and children, particularly during winter. Dhaka, Bangladesh, faces a similar situation, with particulate matter (PM) identified as the most harmful air pollutant to public health.

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