Chapter– 2

LITERATURE SURVEY

2.1 General

Wetlands are the fundamental landscape on the Earth's surface, work as an ecotone between the aquatic and terrestrial ecosystems (Winter, 2001) and make them a unique hydrological unit (US-EPA, 2008). The distinguishing characteristic of a wetland is the close contact between the water surface and the ground surface. According to the Ramsar treaty, wetlands encompass natural or human-made areas such as marshes, fens, peatlands, or bodies of water. These areas can be either permanent or temporary, with stagnant or moving water, and may have fresh, brackish, or saltwater. Additionally, the definition extends to marine water that is less than six meters deep during low tide. The wetlands associated with rivers and streams are categorised as riverine wetlands, and they keep high ecological importance among all wetlands. The understanding of the process of evolution of riverine wetlands, the evaluation of major controlling factors (e.g., geomorphology, hydrology, changes in climate, and alterations in land use) and demarcation of 'hotspots' are very important for the development of sustainable management planning of wetlands. Undoubtedly, riverine wetlands provide indispensable ecological services; apart from that, they also play a vital role in the development of floodplains through the hydrological process. They create and manage runoff, actively interact with groundwater, reduce the severity of floods and drastically change the water cycle (Bullock and Acreman, 1999; Burt, 1995; Carter, 1986; Bradley, 1996; Gala and Young, 2015; Hunt et al., 1996; et al., Winter 2003; Acreman and Holden, 2013). Riverine Wetlands are often situated in regions characterised by low-energy conditions, such as flat terrains, where water flow tends to occur at a slow pace and flood flows can stored (US-EPA, 2008; Orme,1990). The flat topography of the wetlands facilitates the storage of a significant amount of water since the surface area of the wetlands expands and shrinks in response to fluctuations in the water level. Therefore, wetlands serve as a regulator of hydrological variability. An extensive study of wetlands has been done in the aspects of their ecological and hydrological importance (Cui et al., 2009; Keddy, 2010; Kingsford, 2000; Steinfeld and Kingsford, 2013; Tockner and Schiemer, 1997; Tockner et al., 1999; Acreman and Holden, 2013;

Brinson, 1993; Bullock and Acreman, 1999; Cole et al., 1997; Dawidek and Ferencz, 2014; Drexler et al., 2004; Kotze, 2000; US-EPA, 2008). The evolutionary process and the mechanism of riverine wetlands still need to be studied in many river systems.

2.2 Evolution of riverine wetlands and its classification

Fluvial processes in the floodplain develop a diverse array of topographic features and floodplain waterbodies (Mitsch and Gosselink, 2000) that result in backwater swamps (Hupp, 2000; Lewin and Ashworth, 2014), shallow scoured topography features at channel bends site and deep scours at confluence sites (Singh 1996; Best and Ashworth, 1997).

One of the most important fluvial processes in floodplains is river avulsion. River avulsion refers to the natural process where a river shifts or alters its existing course and adopts a new pathway along the nearby floodplain (Slingerland and Smith 2004). This process left the pre-existing river as an abandoned channel (paleochannel), which may be a single-channel meandering pattern with ox-bow lakes, meander scar and floodplain wetlands (Collins, et al. 2003). Depending on the shape, size, hydrology, and degree of sedimentation, these topographic features converted into lakes or wetlands with time and become the most significant and ecologically important ecosystem of the floodplain environment (Latrubesse, 2012; Mertes et al., 1996; Paira and Drago, 2007; Sinha et al., 2017a,). The river avulsion process has created several ox-bow lakes and abandoned channels in the Amazon and Parana Rivers system (Mertes et al., 1996; Paira and Drago, 2006; 2007). Almost 90 % of the sinusoidal waterbodies in the Parana floodplain have evolved from the river avulsion processes and now exist as abandoned channels (Paira and Drago, 2007). Later, these fluvial waterbodies gradually change their morphology and function depending upon the dynamic nature of the fluvial system (Paira and Drago, 2007; Panday et al. 2022). Within the Amazon River system, there has been a notable occurrence of fast channel migration, leading to the formation of an intricate system of compact lakes and islands with streamlined features. These lakes have emerged as a consequence of the abandonment of meander lakes (Mertes et al., 1996). The Murray-Darling River system of Australia has many abandoned meanders of fluvial origin converted into riverine wetlands (Roberts et al., 2000). The avulsion process in the USA's rivers, such as the

Trinity, Lower Brazos and Sabine Rivers, also creates riverine wetlands that have fluvial origin (Heitmuller, 2014; Phillips, 2008; Phillips and Slattery, 2008). The abandoned meanders in the floodplain of the Sabina River and the interfluve of the Burhi Gandak and Baghmati Rivers have a larger dimension than the current Sabina River (Phillips, 2008; Singh and Sinha 2020). The Macquarie River system displays the phenomenon of river avulsion, resulting in abandoned channels that evolve into creeks and riverine wetlands (Ralph and Hesse, 2010; Yonge and Hesse, 2009). The river's dynamic behaviour generates depressions through fluvial scourings, like ox-bows and abandoned meanders. Over time, these depressions undergo expansion due to various erosional processes and ultimately transform into riverine wetlands (Tooth and McCarthy 2007; Tooth et al., 2007). The rivers in the Gangetic Plain show an avulsion process due to tectonic activity, normal fluvial processes or base-level changes, demonstrating a wide range of channel patterns (Singh 1996; Jain, et al. 2022; (S.S, et al. 2022). The channel pattern of a river depends on the discharge, slope, types and size of the river, sediment loads, etc. (Leopold and Wolman 1957; Ferguson, 1975; Jain, et al. 2022). The interfluves in the Gangetic plain show various river channels and abandoned channel belts, ponds, lakes, and sand ridges (bhur). The river channels may carry sand, mud, or highly sinuous decaying channels that do not transport significant sediment. All these geomorphological features are also shown in the interfluvial zone of the Ganga and Sai rivers, i.e., a series of numerous underfit rivers, abandoned channels in meandering patterns and associated ox-bow lakes, meander scar and floodplain wetlands.

Table 2.1 Shows the Proposed classification of 'riverine wetlands', waterlogged areas and other water bodies (after, Sinha, et al. 2017b)

Level-1	Level-2
Riverine wetlands	Floodplain lakes: Large bodies of standing water of considerable depth, occurring in natural depressions, usually far from the active stream and fed by precipitation a s well as ground water table.
	Oxbows and scroll lakes: Fluvial geomorphic features left behind by the meandering river channels and filled with water; easily identifiable due to their signature shapes. Usually, the oxbows are deeper than the scroll lakes.
	Marshes and swamps: Along the length of rivers in plains, water accumulates to a very shallow depth (e.g. in crevasses), wherever there is a change in speed of running water, leading to formation of marshes and swamps
Waterlogged areas	Natural waterlogged: These are seasonally-fed, inundated and generally low-lying areas in close proximity to rivers/ streams.
	Anthropogenic waterlogging: These are area s under waterlogging caused by surface and sub-surface run-off blockage induced by anthropogenic activities.
Other water bodies	River/stream: All the rivers and streams comprise this category.
	Drainage/canals*: These are man-made canals lined or unlined, easily identifiable due to their perfect linear shape.
	Lakes*: Large water bodies with average depth greater than 2 m.
	Tanks, ponds and reservoirs: All constructed water bodies in urban a s well as rural settlements, easily identifiable due to their sharp boundaries.
	Artificial wetland s*: Aquaculture ponds and paddy fields

*Although these sub-classes are not present in the study area, they have been included to make a general classification scheme rather than one specific to the study area.

2.3 Wetland: hydrology and function

The wetlands originate as a result of the interplay between climate and geomorphology, while hydrological factors primarily sustain their continued existence. Consequently, among all the influencing factors, hydrology is widely acknowledged as the "primary factor" responsible for shaping and sustaining specific wetland types (Brinson, 1993; Mitsch and Gosselink, 2007). Additionally, hydrology has been utilised to gauge and evaluate the processes and functionalities of wetlands (Cowardin et al., 1979; Howard-Williams, 1985; Carter, 1986). The primary natural geological processes responsible for the formation of wetlands are the evolution of river floodplains, tectonic uplift/subsidence etc. These processes are responsible for both hydrological changes as well as geomorphic changes in the landscape. Wetlands often arise as a subsequent or tertiary outcome of landscape processes. They are also dynamic entities, much like any other natural ecosystem, and as they develop and mature, they constantly transform, shifting from one form to another. They modify themselves both from inside and outside and, therefore, are susceptible to being formed and lost over time (US-EPA, 2008). Hydrology plays a critical factor in the process of the formation of wetlands, and hence, a comprehensive understanding of wetland hydrology is necessary for the assessment, quantification, and comprehension of processes and functions of wetlands (Cowardin et al., 1979; Howard-Williams, 1985; Carter, 1986). Moreover, the water chemistry and hydrologic regime exhibit significant influence from the intricate interplay between precipitation, groundwater, and surface water (Koerselman, 1989). Wetlands have sponging characteristics, as they collect and hold water during high precipitation and release it during periods of low precipitation (Bucher et al., 1993). Wetlands carry out various roles, including purifying the environment and sustaining water quality (Mitsch and Gosselink 2000). They enhance floodwater retention, control soil erosion, and contribute to wildlife habitat (Thomas and Nisbet 2007; Acreman and Holden 2013; Dai et al. 2018; Liu et al. 2018; Singh and Sinha 2019a; Waltham et al. 2019). Wetlands also have additional hydrological effects, such as preventing recharge, increasing floods, and decreasing low flows (Bullock and Acreman, 1999). The term "wetland" does not always imply that the land is perpetually flooded. In this particular instance, the appropriate terminology would be "submerged land" or "flooded land" rather than "wetland". This suggests that the land undergoes a period of wetness followed by a period of dryness or exposure to air (Tiner, 2016). Hydrology is the main factor distinguishing wetlands from other flooded water bodies (NRC, 1995). A quantitative study is necessary to understand the hydrology of any wetlands (Boeye and Verheyen, 1992). The hydrology of a wetland is not constant; it varies spatially and temporally (Tiner, 2016), and therefore, spatiotemporal studies are required for the hydrological assessment of wetlands. Insufficient data and research on the causal factors leading to the degradation and depletion of wetlands, especially in economically disadvantaged nations, have significantly hindered the effective execution of sound wetland management approaches (Acreman et al., 2007). Nevertheless, readily accessible satellite datasets such as Landsat and Sentinel-2 can effectively address this deficiency.

2.4 Wetland degradation

Roughly 4 to 6% of the Earth's land area is believed to be covered by wetlands (Junk et al., 2013). As with other vulnerable physical features, wetlands are one of the most threatened landforms on Earth because they are degrading and vanishing quickly, causing a loss of geo- and bio-diversity. Most wetlands, especially urban wetlands, are declining in size, depth, shrinkage, water volume, fauna, flora, water quality, silt deposition, and geo-hydrological and ecological functional characteristics. Its area and ecology are also declining. Encroachment, landfilling, change of wetland to agricultural/industrial/commercial/residential land, overuse of wetland resources, heavy fishing, and pollution dumping have all led to wetland degradation. Wetlands lose their functions and values with their loss (Mitsch and Gosselink, 2000). The quantity and quality of wetlands in the world are continuously decreasing. Therefore, the benefits from the ecological services offered by wetlands to civilisation are reducing (Gardner et al., 2015). Wetlands have undergone significant changes in their location, extent, and biological well-being due to conversion and loss, which altered wetlands' size and biological health (Junk et al., 2013). In the majority of the countries, vast wetlands have been eliminated.

Wetland deterioration is progressing in heavily populated areas like Western Europe and parts of China, as well as in nations facing water scarcity like Australia and those with strong agro- industries like the United States. For almost 200 years, the U.S. has lost almost 50% of its wetland resources due to dyking, draining, filling, urban/industrial growth, or declining freshwater inflow/input (Fluet-Chouinard, et al. 2023). While agriculture intensification, groundwater depletion, and overuse of fertilisers and herbicides threaten European wetlands, the USA loses 1% of its total wetlands every two years, with fresh water wetlands accounting for 95% of this loss. Botkin and Keller (2000) state that freshwater flow has decreased by 50%, and up to

90% of freshwater wetlands have disappeared. Wetland devastation endures across much of the world due to land-use planning that is unfavourable to wetlands, often accelerating the rate of destruction (Junk et al., 2013). Recent estimates suggest that global wetland coverage decreased by approximately 64 to 71% throughout the 20th century, and this trend of wetland loss and decline is still ongoing worldwide.

Among the wetlands, the riverine wetlands (wetlands associated with rivers and streams) keep high ecological importance among all wetlands. They are present throughout the river basin, spanning from the upper reaches to the floodplains and extending to the coastal areas (Amenu and Mamo 2018). Today, riverine wetlands worldwide endure stress from human-caused disturbances to watershed surfaces, hydrology, and waste discharge. On a global scale, vast wetland complexes within river catchments are often transformed into farmland through extensive drainage for intensive agriculture (Hefting et al., 2013). Typically, wetlands have been viewed as wastelands that may be turned into beneficial systems such as agriculture, forestry, livestock, aquaculture, home building, and infrastructure (Junk et al., 2013). Afework et al. (2015) highlight that the conversion of riverine wetlands to agricultural land is propelled by a lack of understanding regarding the social, economic, and ecosystem benefits of riverine wetlands, coupled with the rising demand for agricultural land due to population growth and degradation of upland regions. The reduction and degradation of wetlands result in the loss of essential ecosystem services for people. A crucial approach for promoting wetland conservation efforts and understanding water body hydrodynamics lies in extensive and thorough monitoring as well as detailed mapping of wetlands over an extended period (Liu et al. 2014; Zhao et al. 2020).

In India, the study of wetland degradation has been done on many wetlands. The Directory of Indian Wetlands (1993) provides a comprehensive account of the geographical distribution, geomorphological features, hydrological dynamics, biological attributes, and environmental significance of wetlands throughout several regions of India. The National Wetland Atlas 2011, compiled by the Space Applications Centre (SAC), identified and charted a total of 757.06 thousand wetlands in India. These wetlands collectively cover an area of 15.3 million hectares, making up about 4.7% of the nation's entire geographical area. Among these, inland wetlands account for roughly 69% of the overall area, coastal wetlands make up approximately 27%, and other wetlands (less than 2.25 hectares) constitute around 4% of the total area. Indian wetlands face several manmade challenges in addition to natural deterioration. Their water supplies are being cut off, invasive and foreign species are being introduced in these habitats, and they are being overexploited for resources and uncontrolled recreational activities. They are also being encroached upon for urbanisation and agricultural usage. Climate change also contributes to their decline. A new guideline from the Indian Environmental Ministry (MoEF&CC, 2019) highlights how wetlands degradation has negatively impacted human ecological and socio-economic well-being. Abbasi (1997) has made reference to the Ousteri freshwater lake located in Pondichery City, as well as the meteorology and quality of water in the Chilika Lake, in his publication named 'Wetlands of India' - Volume I and Volume II, respectively. The increasing reduction in size of the Ousteri Lake can be attributed to encroachments and siltation. Due to rising population density, the water distribution area has been shrinking at an accelerated rate in recent years. The erosion of the catchment region surrounding the Chilika Lake is resulting in the shallowing of the lagoon due to the substantial deposition of clay, silt, and sand and the reduction in the water's surface area. Misra et al. (1988) have provided a comprehensive analysis of the environmental and natural dangers present in the vicinity of Chilika Lake.

In recent decades, many waterbodies have dried up due to draining water for agriculture or been polluted by chemical fertilisers and pesticides from agricultural fields, solid wastes, and domestic wastewater. North Bihar's rural drinking water is poisoned. The enormous silt input is also reducing lake depth. Kuwan Lake in North Bihar deposits 3.8 cm of silt annually. Silt influx improves soil productivity and makes people demand more land than water (Singh, 2000). India has no wetland management policy or plan. The Ramsar Convention has several gaps and is simply a "paper tiger" that leaves wetlands to the government. Gopal (2000) noted that rising water demand and pollution were destroying wetlands. The delicate ecosystem of Ladakh's Chunglung wetlands is suffering from human meddling. In a few decades, the new colony turned suitable terrain into agricultural fields and diverted brooks to irrigate them. Tourism, domestic livestock development, and local illiteracy are the biggest obstacles to Ladakhi environment protection. The Uttar Pradesh Bhumi Sudhar Nigam has a World

Bank- funded initiative to recover wastelands in Etawah and Mainpuri districts for agriculture. In wetlands and agricultural regions, the Saras bird nesting season has begun. Although the project aims to help local farmers, it threatens human and avian populations.

In the case of my study, in the interfluvial zone of the Ganga and Sai Rivers, the spatial and temporal monitoring of riverine wetlands, which are on the verge of being lost, is very necessary. This vital information about these diminishing wetlands is missing, which, if obtained, can inform plans for water reserve development and eco-restoration for wetland conservation in the interfluvial zone of the Ganga and Sai Rivers.

2.5 Chemical characterization of soil

Wetlands around the globe are experiencing significant ecological deterioration as a result of heightened agricultural water shortages, climate change, environmental pollution, and several other human-induced disturbances (Lagos, et al. 2008; Cvetkovic and Fraser, 2011). The wetlands suffering from degradation due to water deficiency become affected by soil salinisation. The soil within a wetland ecosystem plays a crucial role by supporting, retaining, and regulating water and nutrients. Additionally, it serves as a growth medium for plants and mitigates the detrimental impacts of toxins (Benitez et al., 2006). The form and functioning of wetlands significantly impact the alterations in soil quality. Hence, soil plays a crucial role as a biogeochemical regulator that significantly impacts water quality, plants, animals, and agricultural products through various physical, chemical, and biological processes (Snakin et al., 1996). Nevertheless, a comprehensive evaluation of soil degradation has indicated that around 13% of the land, encompassing both wetlands and non-wetlands, across the Asia and Pacific area has experienced deterioration. In recent times, a multitude of scholarly investigations have been conducted to examine the impact of soil characteristics on the growth and development of wetland flora and microorganisms inside the Yellow River Delta. The evaluation of salinity in the soil and simultaneously their reclamation and management for practical agricultural use have undergone significant reorientation in recent years. This shift may be attributed to the research undertaken at the Regional Salinity Laboratory in Riverside, California, U.S.A. The initial proposal made by Scofield in

1941 posited that the primary elements contributing to detrimental impacts on plant-soil-water interactions were the concentration and composition of salts present in soils at the field moisture content. This idea has since been extensively developed in the United States to evaluate the salt condition of soils and its potential impact on plant growth. In studying saline and alkali soils, soil researchers utilise data from the concentration of salts in saturation extracts of soils and their composition. According to (Zhang et al. 2007), the soil salt concentration was identified as a significant determinant of halarch succession. In their study, Xiong et al. (2008) found a strong correlation between the distribution of several wetland vegetation communities and soil salinity and pH. However, they did not notice any correlation between the distribution of these communities and total phosphorus, total nitrogen, and organic matter in the soil. According to research conducted by (Nie et al. 2009), the levels of total bacteria and hydrocarbon degraders in bulk soils were predominantly influenced by the soil's salinity and water content. The accumulation of nutrients and contaminants in soil over time provides a comprehensive record, making soil chemistry values a more reliable indication of the study site compared to surface water chemistry values. Nevertheless, a limited body of research has specifically examined the alterations in soil characteristics and soil health pre- and after wetland degradation.

In the region of Uttar Pradesh, of the Gangetic alluvium, where agricultural activities are highly concentrated, a significant portion of the land is adversely impacted by the existence of saline substances. The salty and alkali plains found within the State of Uttar Pradesh are commonly referred to as mar lands by the local population. It is estimated that approximately 2.1 million acres of uncultivated land in this state can be attributed to the presence of alkali in diverse forms. Crop yields on this type of soil are poor, and agricultural production is not economically viable. However, a significant part of this soil exhibits moderate salinity or alkalinity and is not yet completely unsuitable for cultivation. Therefore, the reclamation of such land holds significant economic significance. The highest levels of salty and alkali soils are seen in the central and north-western regions of the state, as well as in districts located on the left bank of the river Ganges. There is a significant lack of analytical data pertaining to salty and alkali soils found in the Indian Gangetic alluvium region. Ongoing research has been conducted on these soils in the aforementioned facilities since 1936. Agarwal and Yadav

(1954) supplied limited data on farmed alkali and saline soils in the alluvium of Gangetic Plain in Unnao District. Similarly, Agarwal and Yadav (1954) provided isolated data on the same topic for the Hardoi District. Agarwal and Yadav (1954) have lately provided a description of the saline soils found in the Gangetic riverain plains near Hastinapur. Nevertheless, the already accessible data has proven to be insufficient since it fails to provide a comprehensive understanding of the extent to which soil salinity or alkalinity impacts the management or enhancement of certain soil conditions. This data is crucial for their investigations. This study seeks to fill the gap in data availability regarding saline and alkali soils in the Indian Gangetic alluvium. It provides analytical information on these soil types within Uttar Pradesh, aiming to assess their salinity levels and potential for reclamation.

2.6 Restoration of river

The rejuvenation of a river is contingent upon the restoration of lost and damaged components within its ecosystem, as well as the enhancement of hydrological, geomorphological, and biological processes within the degraded watershed (Wohl et al., 2005). Efforts have been undertaken globally to restore rivers that have been extinct (Friberg, et al., 2016; Bedarkar, et al., 2018). The re-establishment of river channels and riparian zones in floodplains, along with the reintroduction of water, sediment, and solute inputs to the rivers, can potentially facilitate the identification of the historical catchment area of a defunct river and enable the determination of discharge within the former river basin (Bennett et al., 2011). Modelling has the capability to yield comprehensive hydrologic regime data, encompassing critical aspects such as watershed runoff and sediment load, etc. A relevant model discussed is the Soil & Water Assessment Tool (SWAT), designed to function at the scale of local watersheds up to river basins. Its primary objective is to replicate surface and groundwater quality and quantity, forecasting likely environmental impacts stemming from land use alterations, land management approaches, and changes in climate (Arnold et al., 1998).

River restoration initiatives have been undertaken in India for several rivers, such as the Ganga Action Plan (GAP), National River Conservation (NRCP), and Sabarmati Riverfront Development Project (SRFDP), by both governmental and non-governmental organisations (Bedarkar, et al., 2018). In the region of Uttar Pradesh, India, specifically within the interfluvial zone of the Ganga River and Sai River, there are remnants of a river's channels in the form of multiple winding underfit rivers, accompanied by ox-bow lakes and meander scars. The effort for the rejuvenation of these river's channels has been made at the local level with the support of villagers in 2011, and their effects have also been noticed by the local people in the form of soil moisture increase in water level and agriculture. However, the scientific approach has not been applied till for the rejuvenation of these river's channels, and also no government support has been given.

2.7 Wetland conservation and management in India

Wetlands are one of the most threatened landforms on Earth. Agricultural / industrial / commercial / residential encroachment degrades and vanishes continuously, shrinks the size and depth of wetlands and causes loss of water volume, fauna-flora, water quality, and hydrological and ecological functional characteristics. At present, globally, wetlands cover about 6.4% of the earth's surface, of which 15% belongs to floodplains (Ramsar, 2011)

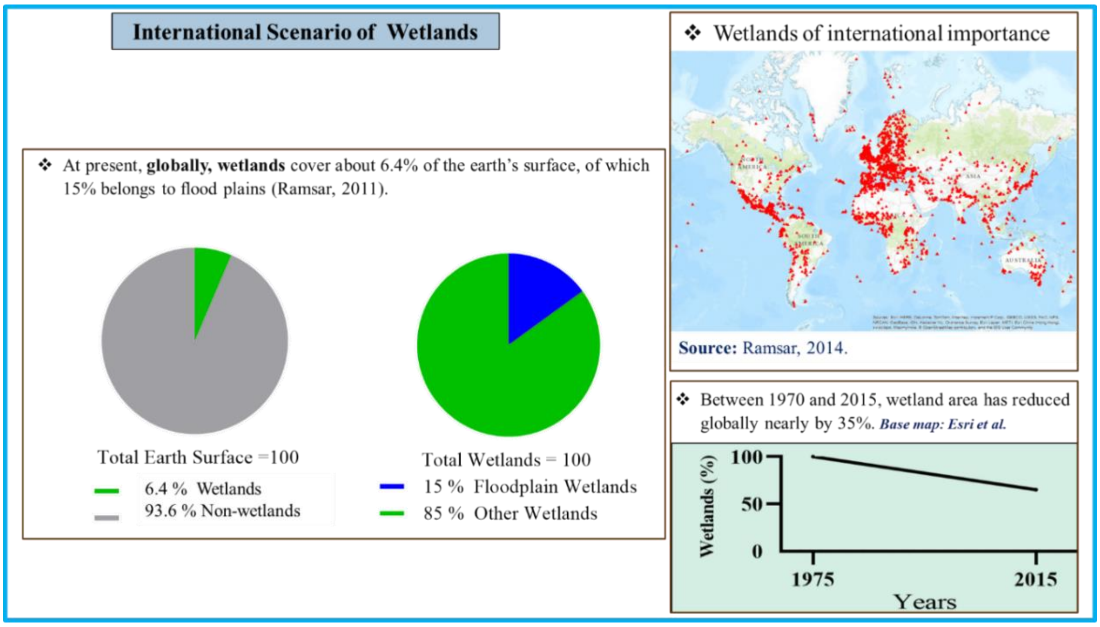

Fig.2.1 International Scenario of wetlands

As per 2022, total of 231,195 wetlands have been mapped in India, which cover 4.86 % of the total country's geographical area (Space Application Centre (SAC,2011)). Out of total wetlands (100%), 69.23% of the area is covered under inland wetlands and 30.77% of the area covered under coastal wetlands. India losing wetlands at the rate of 2–3% each year (SAC 2011; Bassi et al. 2014). Over the last century, India has lost about 50% of its wetland resources. In India at present the food plain wetland encompasses about 5542.13 km2. In India, the Ganga and Brahmaputra River basin has extensive floodplain wetlands covering an area of 3500 km2 (Handbook of Fisheries and Aquaculture, 2011). In Uttar Pradesh, they cover about ±1520 km2 (Pathak et al., 2004).

India is a participant in the Ramsar Convention on Wetlands. The primary objective of the Ramsar Convention is to promote the preservation and sustainable utilisation of wetlands at both local and national levels while also fostering international collaboration. This purpose is aimed at making a significant contribution to the global pursuit of sustainable development. Wetland International, a global non-governmental organisation dedicated to the preservation and rehabilitation of wetland ecosystems, is actively engaged in conservation efforts inside India. The National Wetland Conservation Programme (NWCP) was established in the fiscal year 1985-1986, primarily focusing on the preservation and efficient management of Ramsar wetlands. In 1993, the National Lake Conservation Plan (NLCP) was established as an extension of the NWCP, with the specific objective of addressing the lakes that have been affected by human activities. Nevertheless, before 2006, there was a notable absence of clear governmental support for wetlands (Bassi et al., 2014).

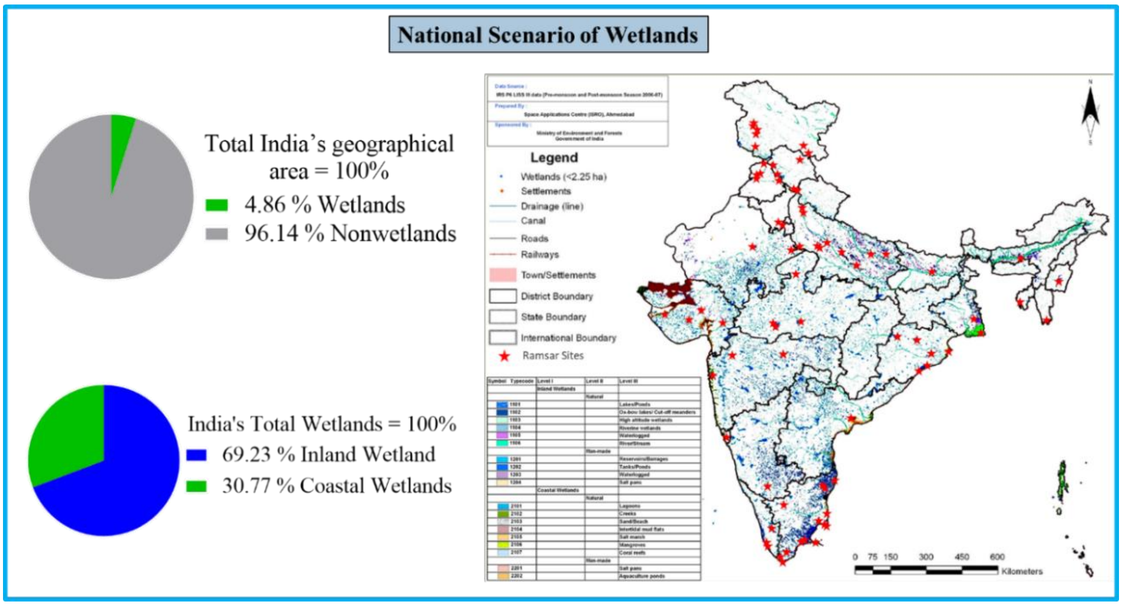

Fig. 2.2 National Scenario of Wetlands

The majority of management policies implemented were derived from the commitments outlined in the Ramsar Convention, as well as various legal instruments including the Indian Fisheries Act of 1857, the Indian Forest Act (1927), the Wildlife Protection Act (1972), the Water Prevention and Control of Pollution Act (1974), the Marine Zones Act (1976), the Water Prevention and Control of Pollution Act (1977), the Forest Conservation Act (1980), the Coastal Zone Regulation Notification (1991), and the Wildlife Protection Amendment Act (1991). In 2006, the National Environmental Policy (2006) acknowledged the ecological significance of wetlands. This policy further acknowledged the absence of a legal framework in India for the notification, conservation and management of wetlands, apart from the obligations outlined in the Ramsar Convention. The aforementioned acknowledgement ultimately prompted the central government to officially declare the Wetlands Conservation and Management Rules (2010). The wetland regulation included a provision for the establishment of a Central Wetlands Regulatory Authority (CWRA) and Expert Group on Wetlands (EGOW) to regulate and examine the management of the newly notified wetlands (Bassi et al., 2014). Also, in the year 2010, a special tribunal, the National Green Tribunal (NGT), was created in India to handle cases related to environmental issues. In July 2016, the NGT gave an important ruling that the CWRA should conduct monthly meetings with all states as well as union territories of the country to identify and notify the wetlands and to maintain a common wetland management framework. Before this order, CWRA had met only thrice since 2010. In the year 2013, the NWCP and the NLCP were merged to make the 'National Plan for Conservation of Aquatic Ecosystems' (NPCA) (PIB, 2013). The NPCA had the mandate to employ an interdisciplinary and comprehensive approach to the holistic preservation and rehabilitation of lakes and wetlands. Additionally, it was assigned the task of revising the Wetlands (Conservation and Management) Rules, 2010. The execution of the NPCA schemes is overseen by the National River Conservation Directorate (NRCD) within the Ministry of Environment, Forests and Climate Change (MoEF&CC).

2.8 Wetlands Conservation and Management Rules, 2017

The task of reviewing the Wetlands Conservation and Management Rules from 2010 was delegated to the National Plan for Conservation of Aquatic Ecosystems (NPCA). As a result, the Ministry of Environment, Forests, and Climate Change (MoEF&CC) formally introduced the updated 'Wetlands Conservation and Management Rules of 2017' in September 2017. The key rationale behind these rules is elucidated in this section to maintain their intended sense and explanations.

The new rule defines the wetlands and associated entities as:

a) A wetland is defined as a region encompassing marshes, fens, peatlands, or water, regardless of whether it's natural or manmade. It can be either temporary or permanent and includes both static and flowing water, with variations in salinity from fresh to brackish or saltwater. This definition also covers marine areas with a depth of less than six meters at low tide. However, it excludes river channels, paddy fields, artificially constructed water bodies or tanks intended for drinking water, and structures explicitly built for aquaculture, salt production, recreation, and irrigation purposes.

b) Wetland complexes refer to a combination of two or more ecologically and hydrologically connected wetlands, which may also encompass their connecting channels or ducts.

c) The prudent utilisation of wetlands involves preserving their ecological characteristics by applying an ecosystem-centred approach within the sustainable development framework.

d) "Zone of influence" refers to the portion of the wetland or wetland complex's catchment area where developmental activities can lead to detrimental alterations in ecosystem structure and ecosystem services".

The above-proposed regulations will be applicable to specific wetlands or wetland complexes, namely:

i. Wetlands are classified as 'wetlands having international importance' according to the Ramsar Convention.

ii. wetlands identified by the Central Government, State Government, and Union Territory Administration. However, it is important to note that these regulations will not be applicable to wetlands located within areas governed by the Indian Forest Act (1927), the Wild Life Protection Act (1972), the Forest Conservation Act (1980), the State Forest Acts, and the Coastal Regulation Zone Notification, 2011, as amended periodically.

As per the recently implemented regulation, the limitations pertaining to activities conducted inside wetland areas are outlined as follows: (1) The conservation and management of wetlands must adhere to the 'wise use' principle established by the Wetlands Authority. (2) The following activities should be prohibited within the wetlands: (i) Any kind of encroachment which converts a wetland into non-wetlands (ii) establishing new industries or expanding existing ones. (iii) engaging in the manufacture, handling, storage, or disposal of specific types of waste as outlined in various rules. (iv) dumping solid waste. (v) releasing untreated waste and effluents from various sources. (vi) constructing anything permanent, except for boat jetties within a specified distance from the mean high flood level. (vii) engaging in poaching.

The new regulation mandates the decentralization of wetland management, requiring states and union territories to create individual State Wetland Authorities. Central authorities now play a limited role, primarily focusing on monitoring state-led wetland management operations. State authorities bear the responsibility for wetland identification, notification, and administration.

The National Wetland Committee (NWC) has been designated as the successor to the CWRA in the recently implemented regulation. Nevertheless, the National Wetland Committee (NWC) just assumes an advising function within the comprehensive framework for wetland management in the nation. The National Wetland Committee (NWC) has several functions, including offering advice to the Central Government regarding suitable policies and action plans for the conservation and prudent use of wetlands. The NWC is responsible for creating norms and guidelines for the comprehensive management of wetlands based on the principle of wise use. Moreover, it oversees the enforcement of these regulations by the Authority. Additionally, the NWC provides recommendations to the Central Government concerning proposals from State Governments or Union Territory Administrations for the removal of prohibited activities, as outlined in sub-rule (2) of rule 4. The committee also suggests wetlands for designation as of international importance under the Ramsar Convention and transboundary wetlands for notification. Furthermore, the NWC assesses the progress in the integrated management of Ramsar sites and transboundary wetlands and offers guidance on collaborations with international agencies regarding wetland-related matters. Finally, the NWC gives advice on any other matter, either independently or as referred by the Central Government.

2.9 Research Gap

Among all wetlands, riverine wetlands keep high ecological importance. A maximum of the study of riverine wetlands has been done regarding their environmental and hydrological significance. However, research with the aspect of geomorphological study, evolutionary process and the mechanism of riverine wetlands still needs to be studied in many river systems. The tract of riverine wetlands in the interfluvial zone of the Ganga and Sai Rivers are ecologically and environmentally indispensable and valuable. The designation of two wetlands as Ramsar sites makes the long interfluvial stretches a vibrant ecosystem. (i) The extraction, delineation, and mapping of these riverine wetlands have not been carried out yet. A study of the evolutionary process and the geological mechanism of their formation is still missing.

(ii) An analysis of spatial and temporal changes in these riverine wetlands, which are on the verge of being lost in the interfluvial zone of the Ganga and Sai Rivers, also needs to be studied, which, if obtained, can provide vital information about the diminishing of these wetlands and plans for water reserve development and eco-restoration for wetland conservation can be developed. (iii) The characteristics of the soil are the function of nutrients in the ground, climate conditions and chemical constituents. The effect of deterioration of wetlands on the chemical characteristics of soils has not been documented for the study area. (iv) Efforts towards restoring the river with a focus on the revival of associated riverine wetlands are still inadequate. A model for reviving all the hydro geomorphological features (underfit rivers, paleochannels, oxbow lakes, meander scars, etc.) in the interfluvial zone of the Ganga and Sai Rivers in Uttar Pradesh, India, can offer insights into a river basin assessment, measurement, and appraisal of hydrological elements which consequently facilitate for the reconstruction of riverine wetlands.