Chapter– 1

INTRODUCTION

1.1 General

Wetlands are hydrological landscape units which are permanently or seasonally flooded with water and have distinct flora and fauna. They perform multiple functions such as environment cleansing and maintaining water quality (Mitsch and Gosselink 2000), improving retention of floodwater and controlling soil erosion (Thomas and Nisbet 2007; Acreman and Holden 2013; Dai et al. 2018; Liu et al. 2018), and providing habitat for wildlife (Singh and Sinha 2019a; Waltham et al. 2019). Broadly, wetlands are classified as riverine (river), marine (ocean), estuarine (estuary), palustrine (marsh), and lacustrine (lake) (Cowardin 1979). The wetland systems associated with the rivers or streams are considered as riverine wetlands. They generally occur in the floodplain and globally significant hydrogeomorphic environmental unit.

1.1.1 River avulsion and Riverine wetlands

River floodplains are among the most dynamic landscapes where the geomorphic features are continuously changing in terms of their shape and structure (Ţuţuianu, et al. 2021, Zacchary, et al. 2017)). River avulsion is one of the most common and natural processes responsible for the development of these geomorphic features in the floodplain. In this process, rivers divert/shift from their established path and follow a new course on the adjacent flood plain (Slingerland and Smith 2004; Tooth, 2018). The major factors which are responsible for river avulsion are climatological conditions, tectonic activity, and geomorphological factors in the past (Jones and Schumm 1999; Schumm 1972, 1977; Dury 1964, 1965; Singh and Sinha 2019b; Singh and Pandey 2014; Wang et al., 2018; Singh et al. 2010; Quiroga, et al. 2017). The major geomorphic features resulting from the river avulsion are underfitted rivers, abandoned channels in a meandering pattern, associated ox-bow lakes, and meander scars (Collins, et al. 2003). These fluvial scours and abandoned channels left behind by the river avulsion process provide negative relief in a dynamic fluvial system, and erosional processes (cut and fill) working on a local scale turn the narrow and deep fluvial scours into wide and shallow wetland systems which are called riverine wetlands

(Brinson, 1993; Mitsch and Gosselink, 2007; Singh and Sinha, 2019a). These riverine wetlands are significant in the study of hydro- geomorphology, fluvial process and landform evolution in the floodplains (Smith and Pain, 2009; Smith et al., 2011; Esfandiary and Rahimi 2019; Gautam et al. 2022c; Lewin 1978; Charlton 2007). They also reveal the history of floodplain activities, prior paleoclimate conditions, fluvial depositional environment and the evolution of these geomorphic features, which are eventually converted into riverine wetlands (Ethridge and Schumm 1 977; Bridge 1985; Singh et al., 2010, Singh 2019).

1.1.2 Riverine Wetlands and its Degradation

Riverine wetlands are a category of wetlands confined within floodplains and associated with rivers or streams (Cowardin 1979). Among all types of wetlands, riverine wetlands hold relatively higher ecological value and are more environmentally delicate. They necessitate proactive conservation approaches (Mitsch and Hernandez 2013; Costanza et al. 1997). Over time, these riverine wetlands have diminished in numerous regions due to drought conditions, declining groundwater levels, and various human activities such as agriculture, urbanisation, and industrialisation (Misra 2011; Lemly et al. 2000; Namaalwa et al. 2013; Russell et al. 2020; Wang et al. 2019; Kalura, et al. 2021). As per IUCN (1996), anthropogenic activities in the form of damming and agriculture are the main cause of the loss of half of the world's wetlands (Moser et al., 1996, McAllister et al., 2001). In alluvial plains, encroachment, sediment accumulation, reduced water inflow, and alterations in drainage patterns significantly contribute to the degradation of wetlands (Ladhar, 2002). This has led to the loss of many shallow riverine wetlands (less than 2 m in depth), the drying up of smaller streams, and the imminent threat of losing interdependent ecosystems in larger rivers. The degradation of micro- climatic conditions (moisture, temperature, winds, etc.) in riverine wetlands poses a risk to their existence (Prigent et al. 2012; Hu et al. 2017; Schneider et al. 2017; Ortmann-Ajkai et al. 2018). Encroachment by expanding populations and declining groundwater levels are key factors in riverine wetlands degradation (Davis and Froend 1999; Central Pollution Control Board (CPCB) 2008; Liu et al. 2014; Zhao et al. 2020, Maheshwari, 2023; Maheshwari and Pinto 2020).

1.1.3 Impact of Degradation of Riverine Wetland on soil's quality in adjoining area

Degradation of wetlands affects the soil, water, and vegetation collectively, as these are the primary constituents of a wetland ecosystem. Their interaction is important for optimum functioning, water quality and growth of flora and fauna (Ehrenfeld et al., 2005; Jiao et al., 2014; Snakin et al., 1996). Soil is a vital component of wetland ecosystems because it may sustain, retain, and regulate water and nutrients. Soil also provides a substrate for plant development and mitigates the negative impacts of pollutants (Benitez et al., 2006). The form and functioning of wetlands can significantly change the soil quality. Thus, the degradation of wetlands can adversely affect the soil's chemical properties and, consequently, the vegetation's productivity (Reddy et al., 2013; Hong et al., 2017; Feher and Hester, 2018; Karppinen et al., 2020; Wu et al., 2020). Change in the chemical constituent of degraded wetland soil changes the soil's chemical properties, which adversely affects the soil in terms of dispersion of soil, reduction in hydraulic conductivity and increased erosion susceptibility, which consequently provides unfavourable conditions for the plant's growth (Fitzpatrick et al., 1994; Rengasamy and Sumner, 1998; Hanay et al., 2004; Fan et al., 2012; Singh et al. 2022; Hameed et al. 2021; Srivastava et al. 2014).

1.1.4 Reconstruction of Riverine Wetlands

The restoration of riverine wetlands is crucial for conserving the wetland ecosystem in floodplains and addressing interlinked issues of soil degradation. This entails the revival of rivers, from which the riverine wetlands eventually evolve or are converted into a river-wetland corridor (Wohl et al. 2021). The function of a river depends on the hydrologic and geomorphic processes. A river may have maintained its function, although it is not preserved in a simplified and attractive form. In this situation, the revival of the compromised river can be done with improvement in the hydrological, geomorphological and ecological processes of its degraded watershed (Wohl 2005; Wohl et al., 2005). Efforts to restore an extinct river have been made worldwide (Friberg, et al. 2016, Bedarkar, et al. 2018; Dieras et al., 2013; Piegay et al., 2023). It can be possible by reconnecting the river channels, adjacent riparian zones in the floodplains, contributions of the water, solute and sediment to the river system, consequently finding out the old catchment area of the extinct river and the discharge in the old river basin (Bennett et al., 2011). Modelling has the capability to furnish comprehensive insights into the hydrologic regime, encompassing crucial aspects such as watershed runoff, hydrology, and sediment load (Pandey, et al. 2021; Gunjan, et al. 2023). One of the models in consideration is the Soil & Water Assessment Tool (SWAT), which operates at a local watershed-to-river basin scale and is employed to forecast the potential environmental consequences resulting from land use, land management practices, and climate change. This model is utilised for simulating surface and groundwater quality and quantity (Arnold et al., 1998).

1.2 Riverine Wetlands in India

The Gangetic Plain is one of the most extensive floodplains in the world (Singh 1996; Singh 2004), which encompasses numerous riverine wetlands in the form of various hydrogeomorphological features. Most of the wetlands in the Gangetic Plain are riverine wetlands. Several of these riverine wetlands are considered as Ramsar sites due to their ecological and environmental importance. One of the remarkable characteristics of riverine wetlands is that they offer seasonal habitat to many migratory birds, which come in flocks of hundreds of thousands for breeding and nurturing their young. These riverine wetlands also provide a migratory stopover habitat, making an important transnational chain worldwide. These riverine wetlands undergo frequent shifts, self-burial, or accretional phases (natural diminution), influenced by factors like neo-tectonism, climatic changes, etc., resulting in spatio-temporal variations. The increasing population in the Gangetic Plain may also witness the rapid disappearance of these wetlands due to human intervention, primarily landcover conversion, to meet various development needs. Comprehensive and long-term monitoring, coupled with detailed mapping of riverine wetlands, holds the key to supporting conservation efforts and understanding water body hydrodynamics. They also provide guidance for the water resource development plans and eco-restoration initiatives, contributing to wetland conservation across the entire Ganga basin. Unfortunately, crucial information about the depleting riverine wetlands that are on the brink of extinction in the Gangetic Plain is currently unavailable. In the adjoining area of degraded riverine wetlands, a momentous development of salt in the soil can be observed in the form of patches in the whole Indo-Gangetic plain (Agarwal and Yadav, 1954). About 2.34 Mha of land in the Indo-Gangetic Plain is affected by salt (Bhardwaj et al., 2016; Mandal et al., 2017; Singh et al., 2017a). The variation in the soil's chemical properties can be the most significant indicator for changing the particular type of ecosystem (Srivastava et al., 2015; Aliat et al., 2016; Ye et al., 2020; Lopes et al., 2021). Thus, the analysis of heterogeneity in soil properties can provide an understanding of pedogenesis, climate change, landscape change and correlation with riverine wetlands degradation (Bhardwaj et al., 2019).

1.2.1 Wetlands in the interfluve of the Ganga and Sai Rivers

In the interfluvial zone of the Ganga and Sai Rivers, a tract of riverine wetlands can be seen in the form of hydro-geomorphological features, i.e., underfit rivers, abandoned channels in meandering patterns and associated ox-bow lakes and meander scars. The identification, delineation, mapping, and connectivity of these tracts of riverine wetlands in the form of hydro- geomorphological features have not yet been done. A thorough spatio-temporal analysis of the riverine wetlands is vital for conserving and restoring Rivers within the interfluvial region of the Ganga and Sai Rivers. In the interfluvial zone of the Ganga and Sai Rivers, salt development in soil can be observed as white-coloured barren soil with sparse vegetation spread in the adjoining areas of Riverine wetlands. However, no study has been done on white-coloured barren soil with the aspect of correlation with the degradation of riverine wetlands. Revival of a river can facilitate the reconstruction of riverine wetlands in the floodplains (Wohl et al. 2021). Efforts towards restoring the river with a focus on the revival of associated riverine wetlands are still inadequate. A model for Reviving the riverine wetlands 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.

For the study and reconstruction of quaternary riverine wetlands in the Gangetic floodplain, **the interfluvial zone of the Ganga and Sai Rivers** has been selected as a representative study area and a detailed investigation of riverine wetlands in this area have been carried such as their delineation and mapping, spatio-temporal analysis, impact of wetlands degradation on soils quality of adjoining area and model for their reconstruction.

1.3 Research Objectives

The interfluvial zone of the Ganga and Sai Rivers is characterised by the tract of riverine wetlands in the form of hydrogeomorphological features (i.e., underfitted rivers, abandoned channels in a meandering pattern, associated ox-bow lakes, and meander scars) in the upper reaches of the currently existing Bakulahi River. The connectivity of these riverine wetlands may play a vital role in understanding a correlation with the currently existing Bakulahi River. The whole tract in the interfluvial zone of the Ganga and Sai Rivers is ecologically and environmentally indispensable and valuable, as the two riverine wetlands have been designated as Ramsar sites. The increasing population results in encroachment towards the wetland and causes degradation of the wetland ecosystem. The presence of salt-affected soil in the adjoining area of the riverine wetlands motivates us to find a correlation between Wetland degradation and the deterioration of the chemical characteristics of the soil. A model for reviving these hydro-geomorphological features can give an idea about the reconstruction of riverine wetlands.

Therefore, the objectives of the study are:

1. To extract, delineate and map the riverine wetlands in the form of hydro-geomorphological features in the upper reaches of the currently existing Bakulahi River and determine the correlation with the Bakulahi River.
2. To analyse the spatio-temporal changes in the areal extent of the riverine wetland in twenty years.
3. To analyse the chemical characterization of soils in the adjoining area of riverine wetlands in the Ganga and Sai Rivers interfluvial zone.
4. To prepare a model for the revival of the Bakulahi River using SWAT, i.e., to delineate the watershed, and to assess all hydrological component. To prepare a model using SWAT, revive hydro-geomorphological features in the study area, delineate the watershed, and assess the Bakulahi River's hydrological component.