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Water Bodies mapping and monitoring using high-resolution satellite images

Mapeo y monitoreo de cuerpos de agua usando imágenes satelitales de alta resolución

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ABSTRACT

Recent developments in satellite optical remote sensors have led to a new age in surface water monitoring. Several methodologies have been developed to identify water bodies using the various spatial, spectral, and temporal properties. Surface water observation is a functional necessity for ecological and hydrological processes. Recently anticipated satellites with enhanced spectral and spatial resolution sensors might lead to broader remote sensing techniques for evaluating and monitoring water bodies. Remote sensing data integration, GPS, and GIS technology are powerful tools to monitor and analyse water bodies. Remotely sensed data could be utilized to construct a geographically positioned permanent database to give a baseline for future comparisons. For many environmental applications, surface water body mapping and monitoring are crucial. This research examines surface water detection, extraction, and monitoring with optical remote sensing, particularly progress within the recent decade. Satellite image delineation of the water body remains challenging due to sensor resolutions, cloud presence, low-albedo surfaces, topography, and atmospheric circumstances in metropolitan locations. This study shows the utility of high spatial resolutions satellite images are suitable for mapping and monitoring surface water bodies, even minor water systems. The suggested technique distinguished water from other land cover features with precision and time. The integrated use of remotely sensed data, GPS, and GIS will allow consultants and natural resource managers to construct management plans for several applications for the management of natural resources.

Keywords: Remote sensing, GIS, GPS, Waterbody, High spatial resolution.

RESUMEN

Los desarrollos recientes en los sensores remotos ópticos por satélite han dado lugar a una nueva era en el control de aguas superficiales. Se han desarrollado varias metodologías para identificar los cuerpos de agua utilizando las diversas propiedades espaciales, espectrales y temporales. La observación de aguas superficiales es una necesidad funcional para los procesos ecológicos e hidrológicos. Los satélites recientemente anticipados con sensores de resolución espacial y espectral mejorados podrían conducir a técnicas de teledetección más amplias para evaluar y monitorear masas de agua. La integración de datos de teledetección, GPS y tecnología GIS son herramientas poderosas para monitorear y analizar cuerpos de agua. Los datos de detección remota se podrían utilizar para construir una base de datos permanente posicionada geográficamente para proporcionar una línea de base para futuras comparaciones. Para muchas aplicaciones ambientales, el mapeo y el monitoreo de masas de agua superficial son cruciales. Esta investigación examina la detección, extracción y monitoreo de aguas superficiales con teledetección óptica, particularmente los avances en la última década. La delimitación de imágenes satelitales del cuerpo de agua sigue siendo un desafío debido a las resoluciones de los sensores, la presencia de nubes, las superficies de bajo albedo, la topografía y las circunstancias atmosféricas en las ubicaciones metropolitanas. Este estudio muestra la utilidad de las imágenes de satélite de alta resolución espacial que son adecuadas para mapear y monitorear masas de agua superficiales, incluso sistemas de agua menores. La técnica sugerida distinguió el agua de otras características de la cobertura terrestre con precisión y tiempo. El uso integrado de datos de detección remota, GPS y GIS permitirá a los consultores y administradores de recursos naturales construir planes de manejo para varias aplicaciones para el manejo de recursos naturales.

Palabras clave: Teledetección, GIS, GPS, Cuerpo de agua, Alta resolución espacial.

INTRODUCTION

As a vital part of the earth's water cycle, surface water bodies, including rivers, lakes, and reservoirs, are irreplaceable to the world's environment and climate systems. Land surface water bodies must be surveyed to understand hydrological processes and manage water resources and their spatial distribution (Jakovljević et al. 2019). Remote sensing is a systematic strategy for monitoring land surface water bodies. The gathered data can give macroscopic, real-time, dynamic, and economical information that differs significantly from conventional in-situ observations (Jensen 1996). Surface water bodies are vital for human as well as ecological water resources. They are essential to support all types of life. Water helps sustain biodiversity by providing habitats for many fauna and plants or wetland ecosystems (Manavalan et al. 1993). Not only is it vital for the ecosystems as a significant component of the hydrological cycle, but it also affects all facets of our life, such as potable water, agriculture, electricity production, transport, and industrial uses. Surface water bodies in nature are dynamic as their appearance or flow time shrinks, expands, or changes due to several natural and artificial variables (Prasad et al. 2009). Variations in water systems affect other natural resources and human assets and affect the environment further. Changes in the volume of surface water frequently lead to catastrophic repercussions (Carpenter et al. 2007). In severe circumstances, rapid surface water growth might lead to flooding. Therefore, surface water must be detected appropriately, its extent extracted, its volume quantified, and its dynamics monitored (Wu et al. 2016).

Remote sensing technology offers practical means of observing the dynamics of surface water. Compared to traditional in situ measurements, remote sensing is significantly more efficient due to its capacity to monitor the earth's surface at several scales continuously (Sivanpillai and Miller 2010). Remote sensing data sets provide detailed and multi-temporal data with several physical attributes around the planet's surface that can be appropriately utilized to map the scale of aquatic bodies on a regional or even global scale and monitor their dynamics regularly and frequently (McFeeters 1996). Two sorts of sensors are commonly used to measure surface water the optical sensor and the microwave sensor (Li and Wang 2015). Because of long-wavelength radiation, microwave sensors can pierce the cloud covers and detailed vegetation coverage. They can work day and night under any weather conditions, irrespective of sun radiation (Ullah et al. 2000). Due to its high data availability and adequate spatial and temporal resolutions, optical sensors have often been used for waterbodies study. The scope of water resources information is essential to flood prediction, tracking, and relief, wetland inventory production, and water resources evaluation (Duy 2015). This information is often challenging to produce with typical survey approaches since water bodies can move swiftly or become unavailable, as in floods, tides, and storm surges. Remote sensed data are a way to delineate water borders across a wide range at a specific spot (Frazier and Page 2000). For quickly shifting hydrological characteristics to be captured, the data must be either high temporal resolution or in an extensive archive for various hydrological situations (Xu 2006). The long archival time and repetitive collection make the data helpful for mapping hydrological bodies on a regional scale.

Researchers around the globe have employed varied spatial, spectral, and temporal satellite data to create thematic land use maps and maps with a particular emphasis on aquatic bodies (Chen et al. 2018). At the same time, many strategies for extracting these elements from satellite images were employed, and each method has its qualities and virtues (Acharya et al. 2018). Using satellite images has gained considerable significance by drawing up natural resources such as forests and water bodies in recent times (Singh et al. 2015). Forestry and water resources are intensely exploited, and regularly monitored for sustainable management is necessary. Visual interpretation of satellite data gives the best definition of water bodies of different sizes, but it takes time, mainly when working with high-resolution data.

STUDY AREA

The National Capital Territory of Delhi, occupying an area of 1483 sq.km., lies between latitudes 28°24′15″ and 28°53′00″ N and longitudes 76°50′24″ and 77°20′30″ E. In the NCT Delhi, the average annual precipitation is 611,8 mm, with approximately 81% of the yearly rainfall during the monsoon months of July, August, and September is received. Delhi's physiography is characterized by the Yamuna river, the Aravalli range, and the intermingled plains formed by recent age alluvium deposits. Sandy, loamy, and sandy loam represent the lightened soils, whereas loam and silty loam indicate medium-size soils (Fig.1).

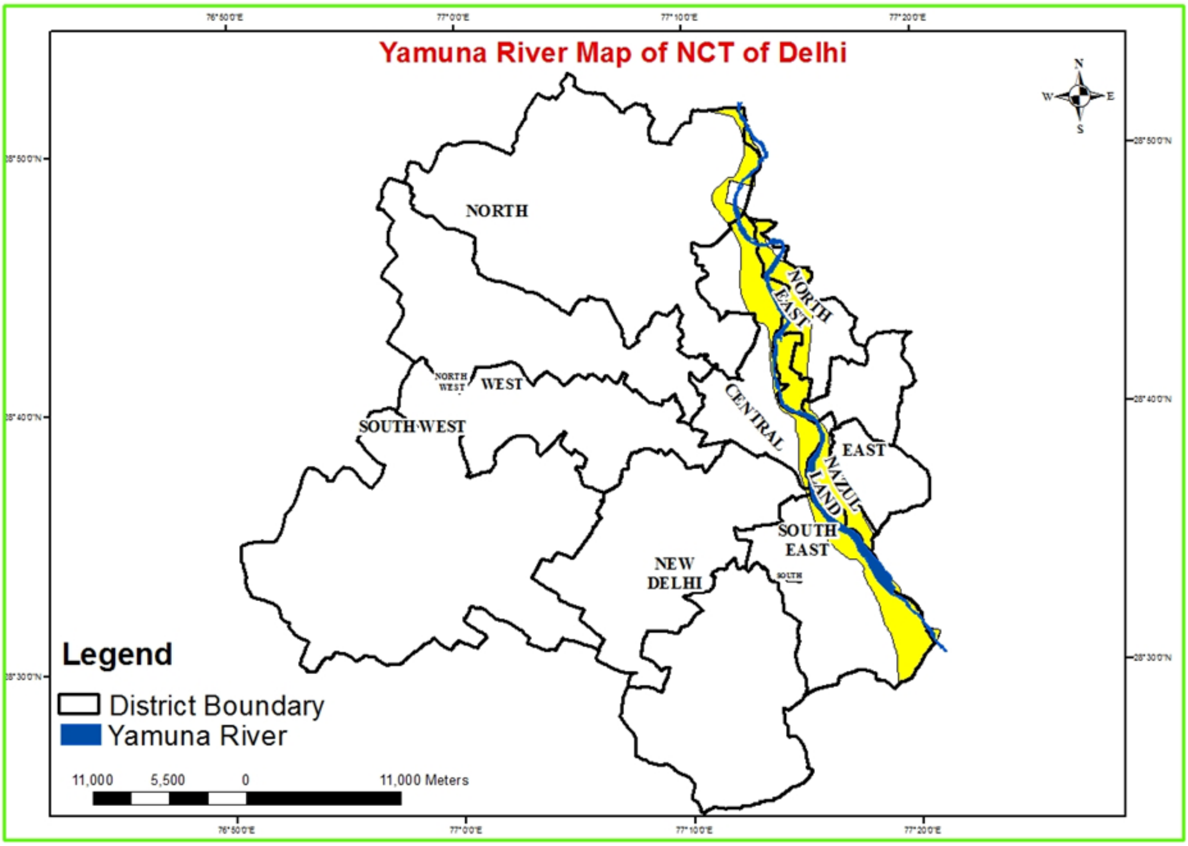

Fig. 1: Study area map.

MATERIAL AND METHODS

The water extraction indicator, which is calculated from two or more bands, is an easy and efficient technique of identifying the differences between water and non-water locations. Surface water bodies are dynamic because they are shrinking or expanding over time due to a multitude of natural and human influences. Variations in water systems substantially affect other natural resources and human resources and further affect the environment. Spatio-temporal monitoring of water body dynamics is crucial to understanding global or regional water availability, which gives descriptive insight into the natural processes that shape water resource storage. Spatio-temporal monitoring of dynamic surface water takes place typically with multi-temporal remote sensing imagery.

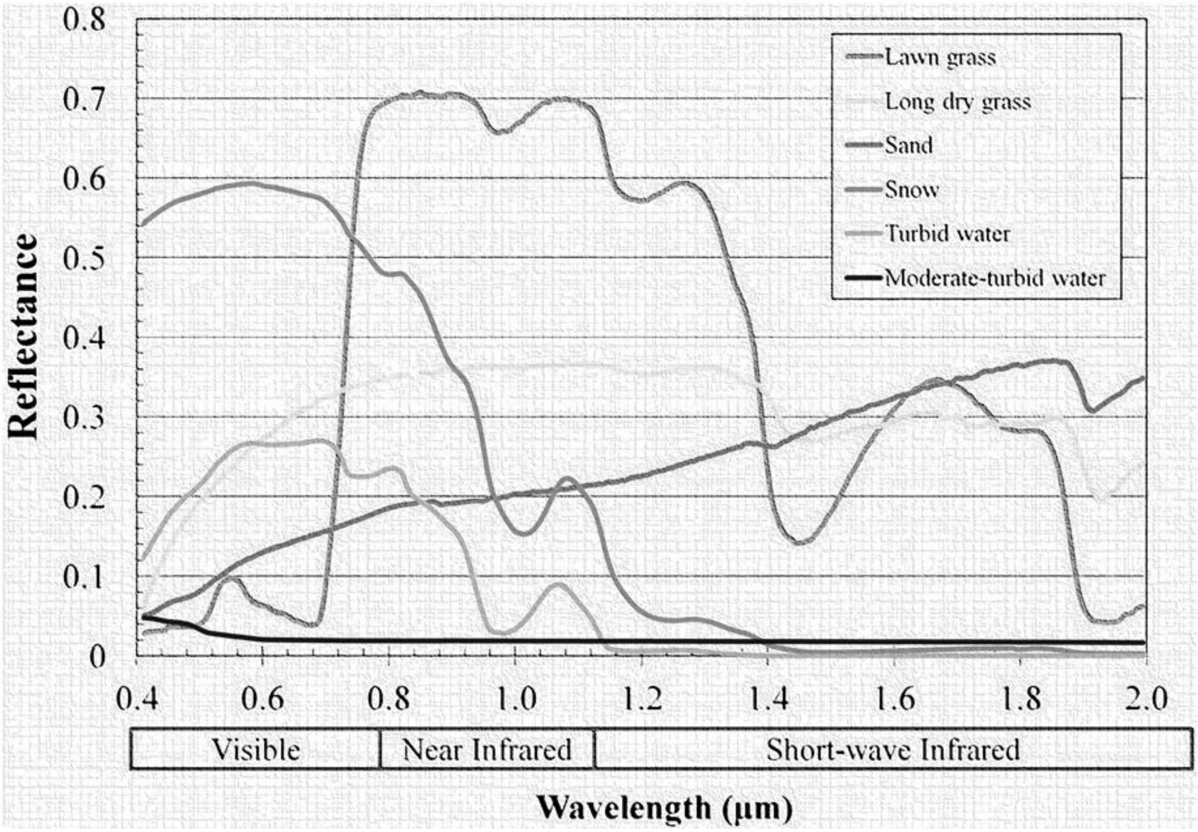

Fig. 2: The reflectance of several typical land cover objects, collected from the United States Geological Survey (USGS) digital spectral library (https://speclab.cr.usgs.gov/spectral-lib.html)

A fair amount of water extraction work has been completed recently using satellite photography. Satellite imagery with differing spatial, spectral, and temporal features has distinguished various water bodies. Using satellites to map water bodies is a beneficial application of remote sensing. An automated training tool with supervised learning and satellite data annotation is presented, enabling accurate mapping of inland water bodies on the state level. Precise monitoring of open water bodies is a basic remote sensing application. Several approaches for locating water features in multispectral imagery have been developed. The lives of humans and the well-being of ecosystems depend on natural resources such as water (Fig.2).

RESULTS AND DISCUSSION

The words land cover and land use are commonly interchanged; however, they are not equivalent phrases. Land cover describes the ground cover, such as grass, pavement, water, dirt, and trees. In worldwide monitoring studies, resource management, and planning operations, identifying, defining, and mapping land cover is vital. Establishing the baseline from which monitoring activities (change detection) can be performed by placing the various land cover patterns. It also provides the land cover information that is required for baseline thematic maps. A key factor in land use is how the land is used, for example, for enjoyment, as a habitat for wildlife, or as a crop. Baseline mapping and ongoing monitoring are both needed for land use applications. The information must be obtained to determine the present amount of land in each type of use and identify changes in land use each year. This understanding will assist in devising policies to maintain a sustainable balance in conservation, conflicting demands, and economic necessities. Urban expansion, forest depletion, and productive land disturbance are three common issues for land use research. To correctly identify these differences between land cover and land use, it is imperative to distinguish between the information that may be obtained from each. The remote sensing parameters assessed relate to land cover, from which land use can be deduced, especially using data or information derived from the past investigation. Studies involving land covers, such as those performed by wildlife and conservation organizations, governments, and forestry firms, are multidisciplinary and hence require the participation of many people, including people from across the globe and several others in government. Expansion of built-up areas is linked to population increase and economic development. This approach frequently reduces the amount of free space accessible in towns and communities. When urbanization increases, so do the conflict between land development and water. Hazard zone maps indicate that many built-up areas face a high risk of flooding. It is revealed in the group discussion that the participants are aware of the risk of flooding, but their assessments are less stringent than those of flood control specialists. Floods have been absent for such a long time those residents are not well prepared for their return. For loss of life, residents judge the risk to be minimal. Lack of expertise with low risk and the availability of warning systems contribute to underestimating dangers. Land and resource use activities that violate existing conservation easements and agreements can have a significant impact on the environmental functions and values of these protected areas, such as water quality, habitat loss (both aquatic and terrestrial), alteration of ecological balance (or a state of equilibrium), reduction of flood attenuation, and ecological disruption (Fig.3-5).

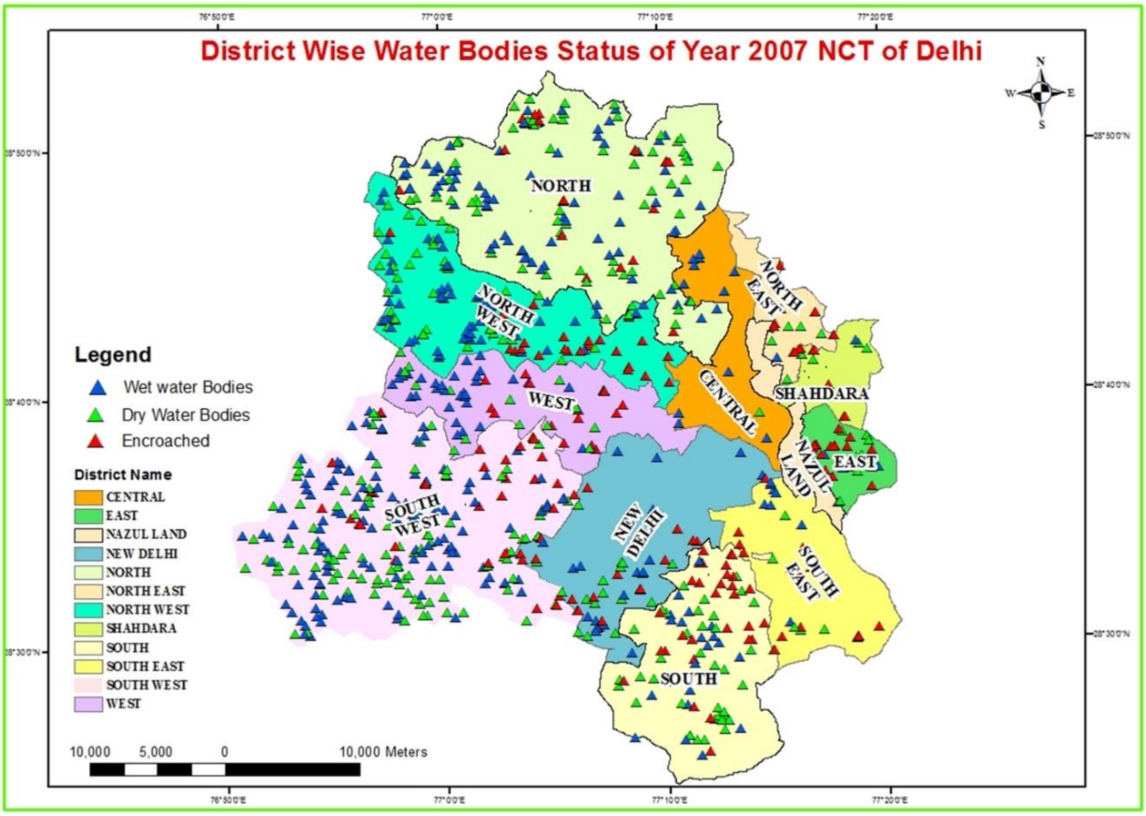

Fig. 3: Map depicting district water bodies status of the year 2007 NCT of Delhi.

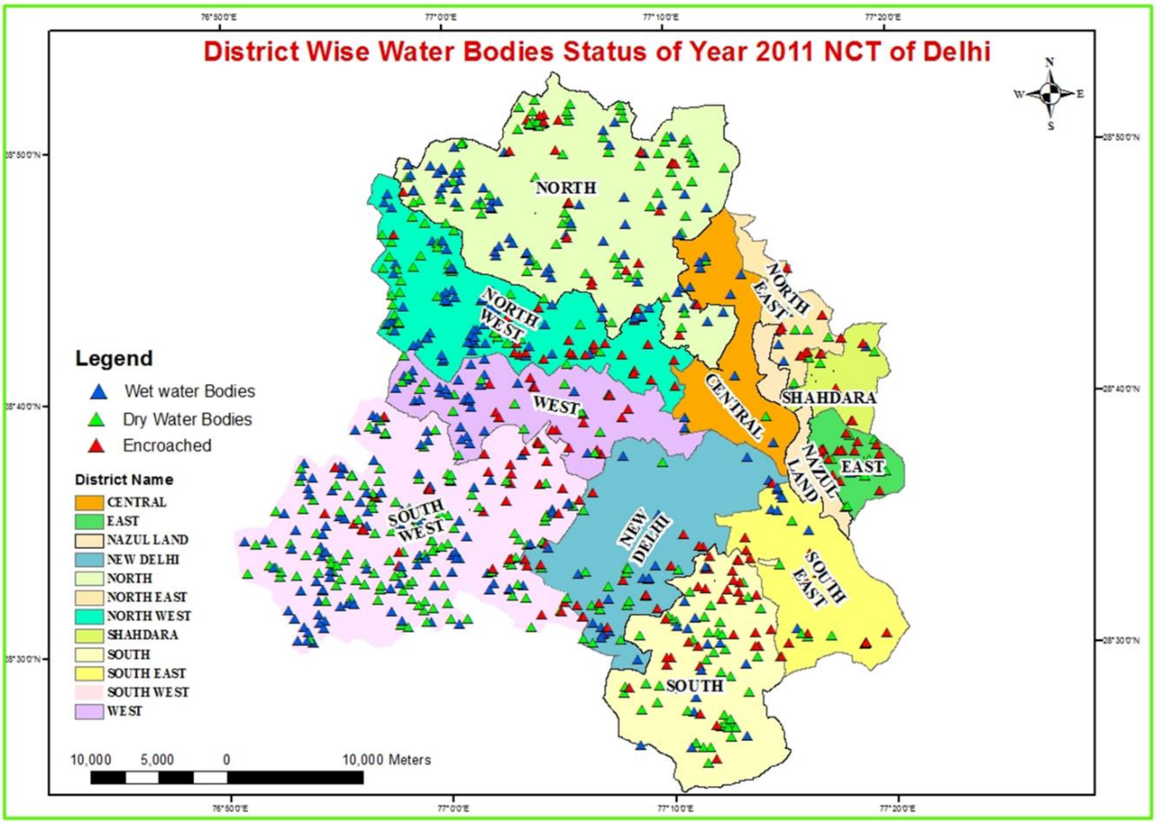

Fig.4: Map showing district water bodies status of the year 2011 NCT of Delhi.

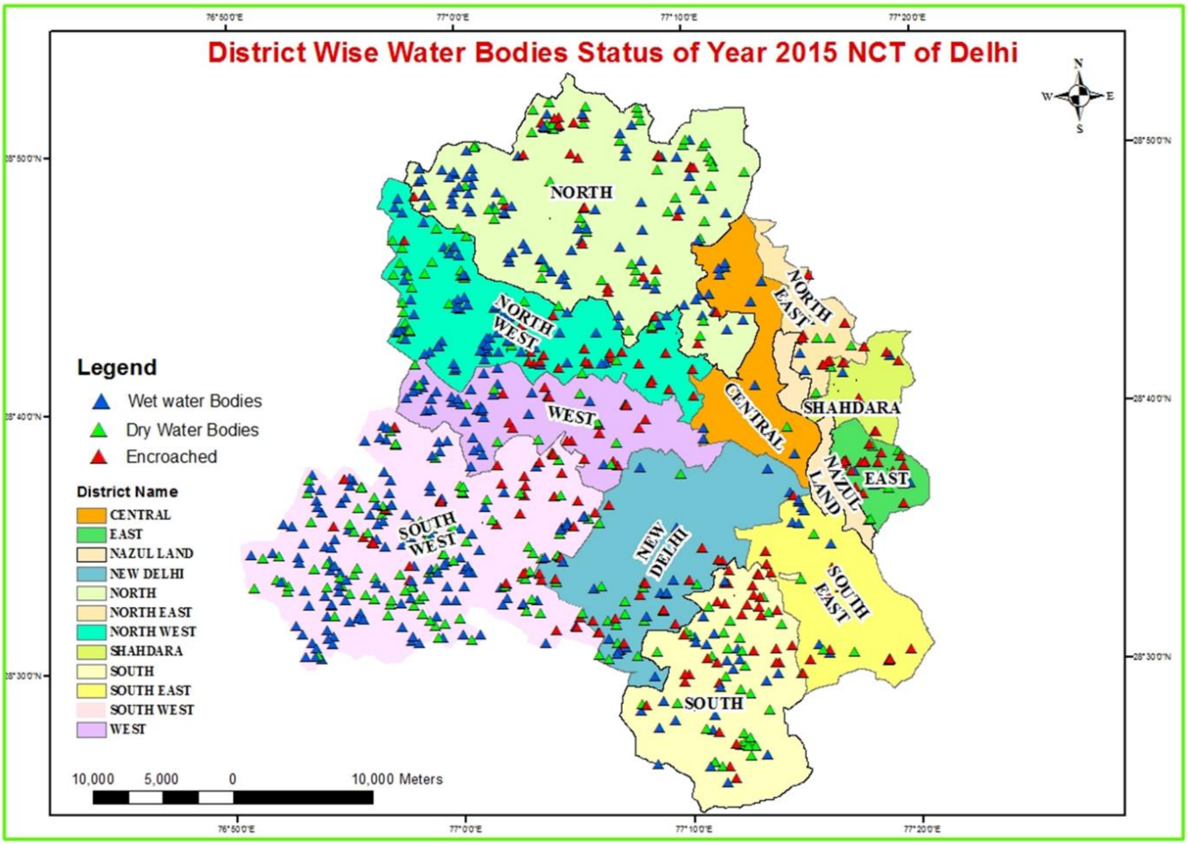

Fig.5: Map representing district water bodies status of the year 2015 NCT of Delhi.

The protection of wetland ecosystems is of fundamental importance to minimize the impacts of fertilizer and sediment pollution. A wetlands system can help remove nutrients and organic materials released into waterway runoff before reaching surface waters. This is accomplished by retaining floodwaters, allowing nutrient-rich plant matter to take root in wetlands, and settling phosphorus particles in wetland ponds (Bera et al. 2021). Floodwater storage and conveyance are possible by minimizing encroachment on a river's floodplain, river corridor, wetlands, and buffer regions. Flood peak reduction occurs when floods slow down and spread out, along with a significant reduction in pollutants settling out as well as reduced nutrient and pollutant settling at the edges of floodwaters (Kanga et al. 2021). Groundwater recharge and base flow maintenance both occur in these locations. The naturally occurring vegetation slows down in this part of the country and filters floodwaters while capturing and filtering contaminants from upstream runoff. When you have structures or roads, for example, advancing into floodplains, river corridors, marshes, lakes, and ponds, you are encroaching (Fig.6, Table.1). In addition to placing fill, removing vegetation, or changing terrain, it is referred to as encroachment if something enters the land without permission (Joy et al. 2021).

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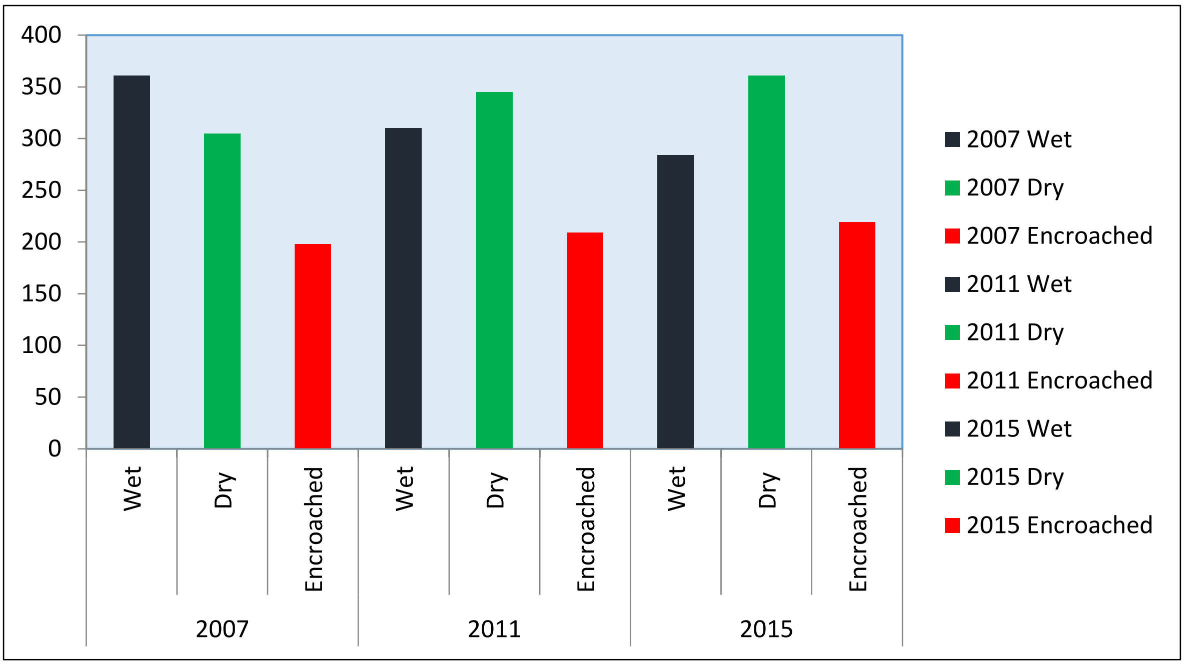

Fig.6: Map showing the distribution of water bodies change from 2007 to 2015 for NCT of Delhi

Table 1: Area statistics of waterbodies

Year Wise Water Bodies Status of NCT of Delhi				
Year	Wet	Dry	Encroached	Area Sq km
2007	361	305	198	2.220647
2011	310	345	209	2.111382
2015	284	361	219	2.04872

Fig.7: Change in waterbody area due to encroachment by anthropogenic activities

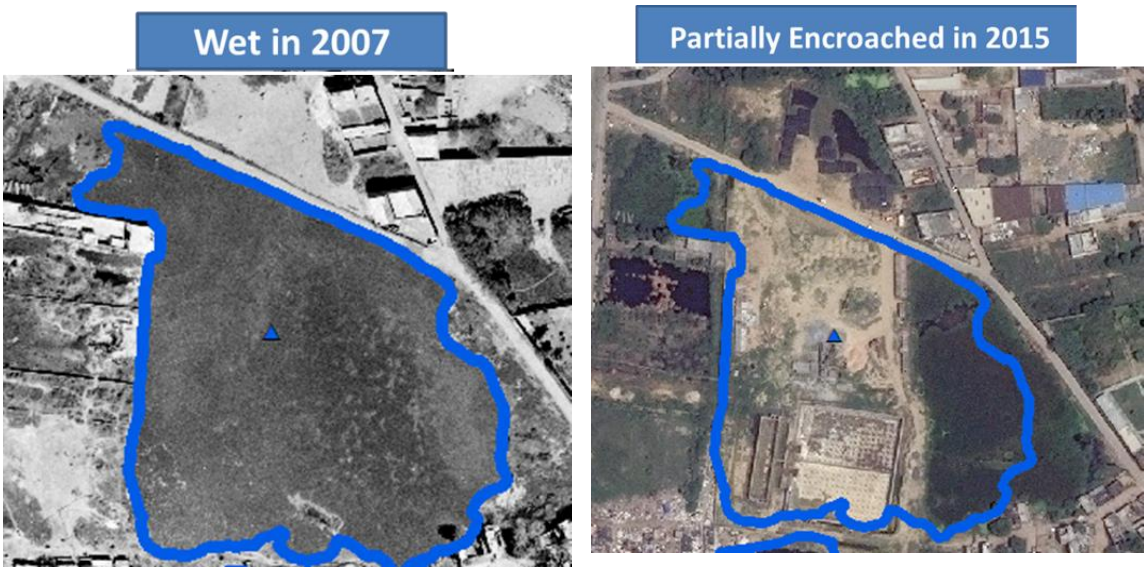

Fig.8: Change in waterbody area due to encroachment by buildings.

Aging is the word for development into natural regions such as floodplains, river corridors, wetlands, lakes, ponds, structures, roads, railway lines, improved routes, utilities, and other development. The word invasion also includes the placement in such natural regions of fill, the removal of vegetation, or an altering of topography (Fig.7-9).

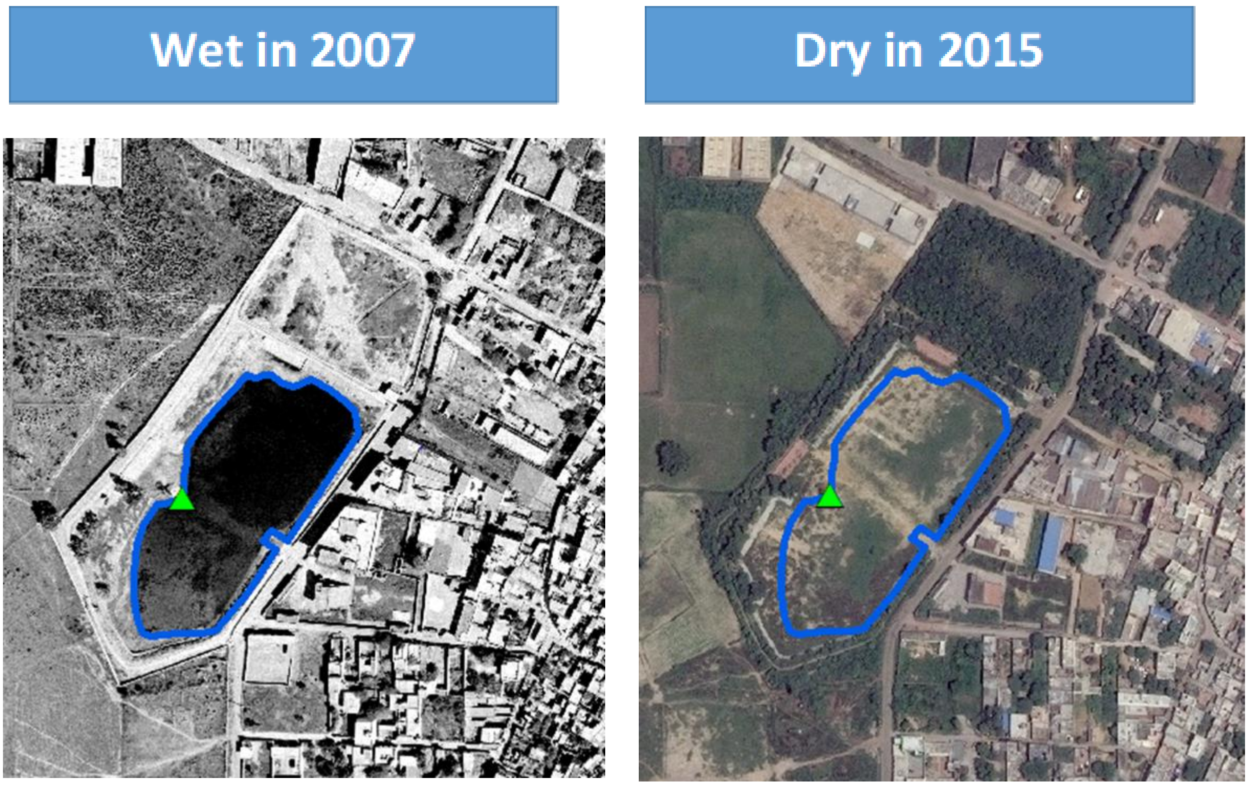

Fig.9. Change in waterbody area due to encroachment by park.

This interference influences the functions and values of these naturally occurring regions, such as water decline, habitat loss (both aquatic and terrestrial), equilibrium (or natural stable) disturbance, fluvial mitigation loss, or reduction of ecological processes. Built-in areas in river corridors and floodplains are prone to flood damage. Structures in flood-prone zones lead to flood storage losses in flood plains and wetlands and increased public safety threats. Furthermore, security from such invasions often leads to river channelling measures, including bank armouring, beaming, dredging, floodwalls, and straightening of canals to safeguard those investments. The removal of vegetation to increase visibility or access and the removal of woody waste from rivers to promote human consumption may enhance the resource degradation and vulnerability of the property to flood damage, which will create more significant public safety issues (Fig.10). This practice results in increased channel instability, excessive erosion, and the loading of nutrients, as detailed in the erosion stressor chapter, by concentrating flow and increasing stream velocity and power. The entanglement increases impermeable cover next to lakes, rivers, and wetlands, raising rates and rush volumes, sediment loading and other pollutants, and the receiving water temperature. The cumulative loss of water quality wetlands in nearby surface waters could lead to continuous water quality degradation. The magnitude of the invasion, the cumulative impacts of impervious coverage, and the extent of damage to natural infiltration may also contribute to the instability of the stream channel. Residential development and accompanying vegetation disposal frequently include entanglement in lake locations; it may also encompass highways, parks, beaches, and urban areas. Recent patterns on the banks of the lake have replaced modest "camps" with larger dwellings intended for year-round use. This new construction is usually accompanied by a significant lot clearing, lakeshore armament, an increase in lawn cover, and the impervious area overall. Wetlands can be one of the most acceptable ways to remove fertilizers and organic debris from the rivers before reaching surface waters (Kumar et al. 2021). This is achieved through flood retention, wetland plants' nitrogen uptake, and the settlement of particulate phosphorus in wetland pools. To minimize the impact of nutrient and sediment pollution, limiting invasions of wetlands is crucial. Minimizing invasion and allowing a river to reach its floodplain, river corridor, wetlands, and buffer regions gives storage and transport room. As floods decrease and expand, flood peaks will diminish, sediments, nutrients, and other pollutants will settle. These regions are also crucial for recharging groundwater and so maintaining the base flow into streams.

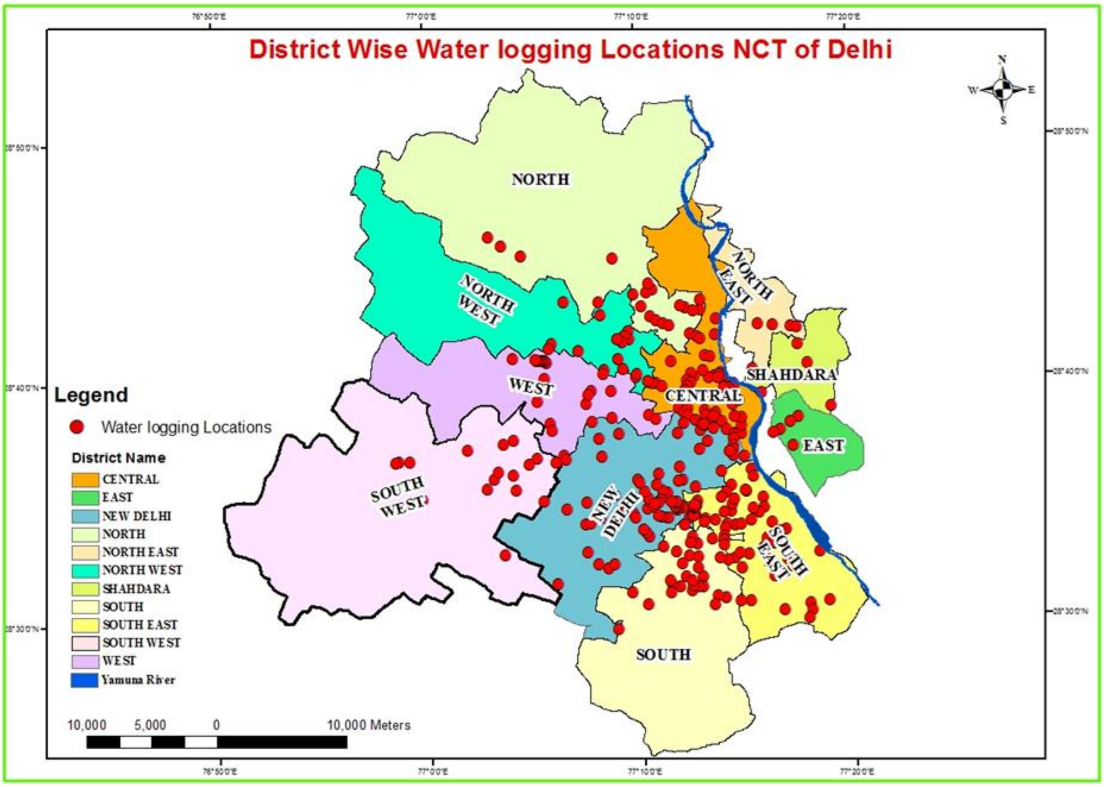

Fig. 10: Waterlogging location on storm drain of NCT of Delhi

The natural vegetation in these locations helps slow down and filter floodwaters, while contaminants from overland flow from neighbouring uplands are also captured and filtered away. The corridors, floodplains, wetlands, shorelines of the lake, and buffer regions provide a significant habitat for fish, wildlife, and some rare, endangered, or endangered species (Tomar et al. 2021). These areas are crucial for species migration, offering travel corridors for fish, birds, and other animals between habitat characteristics and dispersal routes. The reduction of intrusion minimizes the probability of habitat fragmentation and habitat loss. The lives of reptiles and amphibians need regular movements between land and water. Fish that are shallow to spawn travel in the springtime into the nearshore coastal habitats. Like ducks and loons, waterfowl prefer to nest between vegetation along the shore while retaining close closeness to waters to feed and prevent predators. For these species, it is crucial to maintain a healthy connection between different ecosystems.

Minimizing invasion also promotes indigenous plant growth and disregards non-indigenous invasive plants. Maintaining natural vegetation cover provides shade to regulate water temperatures and provides coarse woody habitats and organic inputs for inland and inland waterway habitats. Vegetation on the shoreline intercepts, filters, and removes sediment before reaching the stream or lake, which helps maintain the floor smooth and prevents sedimentation of shallow lake water (Meraj et al. 2021). This nourishes aquatic insects, which are the primary source of food for fish and birds. The growth of shore lands on lakes that result in the elimination of native vegetation is associated with measurably low water habitat degradation features such as woody habitat loss, overhanging vegetation, and increased fine silt. Slow phosphorus enrichment in lakes maintains a more biologically stable lake in its native, trophic form. Overall, limiting interference makes it possible for these regions to continue as significant sources of infiltration, encourage groundwater refuelling, and maintain proper base flow, which are essential to promoting biological integrity in streams during dry months. A wise and cost-effective strategy of public safety is to limit flood prevention. Continuing to avoid injury reduces the vulnerability to flooding, reduces property and infrastructure damage, and limits the damages. Limiting interference decreases the requirement to cancel and armour stream channels to protect this development and infrastructure subsequently.

CONCLUSION

Decisions on land use are typically made at a local level and are based on local criteria. Proposed invasions, especially in locations prone to flood damage and even if these events worsen the susceptibility of flooding in adjoining properties, are approved routinely. Hanging in river corridors and floodplains around rivers or lakeshore often lead to landowners trying to safeguard those properties by structural measures and other channelization or hardening procedures. In wetlands, structures often have persistent drainage problems, leading to landowners wanting to change the hydrology of a territory. It is difficult for species dependent upon wetlands, streams, and lakes to measure ongoing damage arising from these intrusive practices. Larger, poorly planned, or developed developments without considering the natural processes or public safety can have a cumulative and persistent effect on lakes, floodplains, wetlands, or their functions. In addition, once seasonal camps are regularly converted to houses all year long, increasing impervious surfaces and cleared spaces close to vulnerable riparian regions. This over-development of lakeshore regions impairs lake systems' physical, chemical, and biological integrity. Wetlands that are crossed several times to access single-family lots become developing-circled islands and lose their connections and functions in the broader landscape. While invasiveness is not restricted to filling, filling activities are the most permanent losses to rivers, streams, floodplains, wetlands, and lakes. After an area has been filled, it is no longer a resource for aquatic use but an upland region. Besides immediate loss, the refills can continuously affect water quality, habitat, and inundation functions, depending on the fill material's quality and activity size and position. Filling that is poorly put and not stabilized continues to be a threat to erosion.

In addition to habitat elimination, a filling can present barriers to the transit of wildlife. Develop and maintain the technical capacity to support landowners, municipalities, land developers, agencies, or organizations to conduct the river corridor and floodplain planning, including development and implementation, to encourage river corridors and floodplains to avoid effect; identify and protect wetlands, buffers, and related activities through remote sensing. To analyse alternatives for preventing, minimizing, and developing appropriate retroactivities and buffers based on a priori and project-related evaluations and planning. Planning and execution of the River Corridor; Development and implementation of the Municipal Lake Protection Plan. Capacities to support all municipalities technically by regulations to safeguard river corridors, floodplains, wetlands, shores, and related buffers. Developing and maintaining the capability to provide technical support for land use authority and public infrastructure agencies and programs in the development of plans, policies, procedures, and regulations consistent with the State Surface Water objectives and goals; and Conflict prevention strategy between human investments, dynamic stream balance and critical wetland, coastal buffer and floodplain functions. The increased education and training for municipalities and other state agencies on the implications of transport, bike and pedestrian road infrastructure intrusion. Creates an educational, multimedia program, including written material, picture libraries, films, power points presentations, field shows, and river flowers, to illustrate the impact and mitigation measures of prevention, which Division personnel may easily use in public fora when opportunities occur. Develop and maintain the State Surface Water Management Strategy as an interactive, web-based website where people can learn how the country handles stressors such as prevention and other stressors and contribute input into policies and initiatives developed to manage stressors. Develop information and technology techniques for land use in buffers, emphasizing the value of naturally vegetated buffers and the impermeable impact of grassed ponds on the water quality. Partners with regional plans commissions, municipalities, and other partners in the development of river corridor, flood land maps, and buffers to analyse floodplain buildout, to produce visualizations of the potential impacts on the resource when towns lack more robust zoning. The analysis will also assess the level of channelling required to protect investments, the influence on base flood altitudes of buildout, and the necessity for additional stream crossings. This information can be integrated into or created as a result of the Flood Resilient Communities Programme.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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