Analysis of Green Cover through canal revitalization and urban sustainability: A quantitative analysis of Urban Canal development in Lucknow, Uttar Pradesh

Sayan Munshi[1], Devesh Mani Tripathi[2], Dr. Subhrajit Banerjee[3], Dr. Indrani Chakraborty[4]

[1] Asst. Professor, ASAPK, Amity University, Kolkata, WB, India
[2] Principal Aricitect/Urban Planner, ICON Architects, Lucknow, UP, India
[3]Professor, Faculty of Architecture and Planning, AKTU Lucknow, UP, India
[4]Professor, Faculty of Architecture and Planning, AKTU Lucknow, UP, India

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Abstract - *Canals serve as critical components of sustainable development, impacting various facets of urban life. While traditional research on canal irrigation has primarily focused on rural agriculture, the urbanizing effect on canals has been underexplored. Cities along canals show tremendous climatic variation such as impact of the urban heat islands, air pollution levels, humidity control, etc. This factor of canals showing character of a river in certain cities tend to attract a significant amount of population to settle along the stretch which brings about the effect of urbanization which transforms/changes the land use and land utilization in turn results to over utilization in certain case. This paper examines the Kukrail Canal in Lucknow, India, emphasizing its ecological significance and its role in maintaining local biodiversity. Furthermore, it explores the temporal changes in land use patterns over two decades, highlighting the encroachment of urban areas into the canals catchment area. The study also investigates two best practices in canal restoration through case studies in Birmingham (UK), and Utrecht (Netherlands) showcasing successful approaches to canal revitalization. The paper concludes by proposing quantitative method of analysis of Land-use and canal development, emphasizing the importance of balancing urban development with ecological preservation to maximize the potential benefits of canals for urban communities.*

Key Words: Urban Planning, Canal Restoration, Water Body rejuvenation, Ecosystem, Environment

1. INTRODUCTION

Water canals act as an environmental regulator and a source of carbon traps in a city. There are various type of canals in a city which can be classified by nature of the supply source, functions, type of boundary surface soil, financial output, and discharge and canal alignment. (OSME, Keonjhar). Based on the types of canals the specific usage is observed in various cities. This defined the type of settlements which develops over time. The use of water to serve urban consumption through drinking and waste water canals is an important yet understudied aspect of urbanization in the cities of India. The canals establish a physical manifestation of the flows of water between the rural and the urban. The mainstream literature on canal irrigation in India has traditionally been rural-centered, and has been confined to only canals specifically built to serve agriculture. But as canals act as a transition between the rural and urban, it is observed that in some cases these canals are subjected to the effect of urbanism such as use as a medium of discharge of liquid waste. The effect of urbanism on canals includes various factors like changes to the natural habitat of local flora and fauna, biodiversity loss, degradation of ecosystem processes, Introduction of various industrial discharges, polluted surface water runoff, etc. (Soumyadeep D, IJUP 2020)

Urbanization is linked to modernization, industrialization, and the sociological process of rationalization. Urbanization is not merely a modern phenomenon, but a rapid and historic transformation of human social roots on a global scale, whereby predominantly rural culture is being rapidly replaced by predominantly urban culture. This change or transformation leads to a shift in practices of utilization of resource, which also includes the biological/Chemical composition of the surface runoff. Leading to alteration in the physical, chemical and biological properties of canals. India being a predominant society based on the agrarian based economy, a significant concentration of pesticide based surface run off can be traced. This runoff fusion acts as a major contributor of water pollution. In this conjuncture these canals flow into the urban areas and are subjected to further degradation. As cities in developing countries become over-populated and over-crowded partly as a result of the increase in population over the decades and partly as a result of migration. India shares most characteristic features of urbanization, the most significant phenomenon of 20th century which has almost affected all aspects of national life. This can be established with this fact that land-use change and canal degradation is closely linked. (Water Science School, 2019).

Now a days, it is observed that the major cities of India that are linked canals are highly polluted, and a degraded level of COD (chemical oxygen demand) and BOD (biochemical oxygen demand) is observed. Cities with canals hold a unique advantage, as these waterways offer a perfect blend of natural retreat, and cultural significance. Leveraging this resource can significantly enhance their tourism potential by promoting a destination-based approach. Tourism Destination based approach includes creation of potential tourism sites which holds the potential to attract tourism, as well as act as a image to the city which is elaborated further in the cases discusses in the paper. (Munshi, et al, 2022).

2. Indian National Stands for Canal Rejuvenation

India has had various canal restoration programs aimed at revitalizing and preserving its extensive network of canals. These canals play a crucial role in the country's agriculture, water supply, and overall socio-economic development. Some of the programs include Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), Launched in 2015, PMKSY is a flagship program of the Government of India aimed at providing a comprehensive solution to the problem of irrigation focuses on the restoration of traditional water bodies, including canals (Accounting to more than 3 lakh water bodies over 70 lakh hectares). Accelerated Irrigation Benefit Programme (AIBP), The AIBP, initiated in 1996-97, aims to accelerate the process of irrigation in the country through restoration and creation of irrigation infrastructure, which includes canals. National Mission for Clean Ganga (NMCG), NMCG, also known as Namami Gange, is a comprehensive program for cleaning and conserving the Ganga River and its tributaries, It also includes initiatives for restoring and conserving traditional water bodies like canals that feed into the Ganga. This program included creation of More than 150 sewerage treatment plant accounting 3,000 million liters per day (MLD). Integrated Watershed Management Program (IWMP), IWMP, launched in 2009, aims to restore and conserve natural resources including water bodies like rivers, lakes, and canals.

Kerala"s River and Canal Restoration Programs, being a state with an intricate network of rivers and canals, has had various programs to restore and maintain these water bodies for irrigation and transportation. Andhra Pradesh Canal Restoration Projects, has implemented several canal restoration projects to improve irrigation facilities and ensure water reaches the farmlands efficiently. Gujarat Canal Rehabilitation and Modernization Project, This project focuses on the rehabilitation and modernization of existing canal systems to improve their efficiency and effectiveness in delivering water for agricultural purposes. While non agriculture based Tourism project of canal rejuvenation include Rajasthan Canal Restoration Project, This program aimed at specific projects to restore and revitalize its extensive network of canals including the Dravyavati River Front project in Jaipur with approximately 47.5 kilometers length integrated with STPs of capacity 170 MLD (million liters per day). This project acts as a significant step towards urban renewal and environmental sustainability in Jaipur, showcasing the potential of integrated urban development initiatives in transforming degraded urban spaces into vibrant, healthy, and sustainable environments creating tourism potential for the city.

3. Canal an eccentric component of urban landscape

From the above cases of agriculture and urban canals, it is evident that canals acts as versatile urban features that serve multiple functions, contributing to the livability, sustainability, and economic vitality of cities. They have played a crucial role in the development and evolution of many urban areas throughout history. Historically, Canals are used to transport and distribute water within a city, including drinking water, industrial processes, and irrigation. They can help ensure a stable and reliable water supply, especially in areas prone to water scarcity. Canals were critical for transportation and trade. They provided navigable routes for boats and ships, facilitating the movement of goods and people within and between cities. In some cities, canals are still used for transportation, tourism, and recreational boating. (Xu R, AMR 2014). Canals are essential for managing excess rainwater and preventing flooding in urban areas. They serve as drainage channels, diverting excess water away from populated areas during heavy rainfall or storms. Canals can have a moderating effect on a city"s climate. They can help regulate temperature and humidity levels, creating more comfortable living conditions in urban areas. Canals, when properly managed, can support a diverse range of aquatic and riparian species. They contribute to local biodiversity and provide ecosystem services such as water filtration, habitat provision, and floodplain protection. Many cities have canals that hold cultural and historical significance. They may be associated with the city"s heritage, architecture, and traditions. Some cities, like Venice and Amsterdam, are renowned for their extensive canal networks. With this association Canals could be a source of inbound tourism creation, by acting as a factor additive in the tourism potentiality, drawing visitors intending to experience boat tours, explore canal-side neighborhoods, and enjoy the unique ambiance. This can boost the local economy through tourism-related activities. This versatility of canals makes it a unique feature which enhance any type of tourism i.e. Adventure tourism, Cultural tourism, Eco tourism, Medical tourism, Wildlife tourism, etc. The case of Kukrail Canal is elaborated in the further section which establishes the degradation of canal to a drainage channel over time and its potential impact over the city.

4. Kukrail Canal in Lucknow, India

Kukrail Canal or 'Kukrail Nala' (As per the Local Name, the term 'Nala' means drainage channel) is a left bank tributary of the River Gomti which forms the fourth-order (medium stream) tributary of the River. It is a groundwater-fed stream that rises in the Kukrail Reserved Forest (26°55'34.9"N 80°59'47.3"E) and Confluence at Gomti River

(26°51'35.4"N 80°58'03.4"E). It has a 200 metre wide flood plain. The Kukrail nala extends for a total distance of around 26 kilometres from its source to the site of confluence. It is a natural drain of Gomti River and a carrier of partially untreated sewage and water to the river. Kukrail Nala holds significant importance for the local ecosystem, acting as a crucial drainage system for the region. It helps prevent waterlogging and flooding in nearby areas during periods of heavy rainfall.

One of the most notable features is the Kukrail Wildlife Sanctuary, which is located along banks of the Canal. The sanctuary was established in 1978 and covers an area of around 400 acres. It serves as a protected habitat for a variety of wildlife species, including crocodiles, turtles, deer, and various bird species. The Wildlife Sanctuary offers opportunities for ecotourism and wildlife viewing. Visitors can explore the sanctuary through guided tours and observe the diverse flora and fauna of the region. Beyond its role in wildlife conservation, Kukrail Nala and its associated sanctuary play a crucial role in maintaining the environmental balance of the region. It helps in regulating water flow, preventing water pollution, and supporting local biodiversity.

4.1 Temporal Change of Land-use and Land-cover in the Urban Core of Lucknow City

Temporal land use refers to the specific ways in which land is utilized or managed over time. It involves understanding how different activities and functions on a piece of land change or evolve across various periods. This can include activities like agriculture, urban development, forestry, conservation efforts, and other forms of land management.

Fig -1: Comparative imagery of the Kukrail – Gomti Confluence 2010 (left) and 2020 (Right)

The above Fig - 1, depicts the change of landuse pattern in the Gomti-Kukrail mearging point. It can be observed that the over the time the Catchment area of the canal has reduced/occupied by the urban builtup area and the surrounding area has densified. The densified area is a mixlanduse of residential area, Small Scale Industry and Enchroached settlement. To analyse the temporal landuse a GIS based approach is used based on the Digital Elevation model of "NASA LPDAAC Collection" the yearly variations are produced through MODIS MCD12Q2 V6.1 model and Model of 2003, 2013 and 2022 (Latest Available) is produced for Analysis in ARC GIS. An Model area of 50km Buffer is considered as the study area based on the Watershed point from Kukrail Canal at 26°51"35.3"N 80°58"02.8"E.

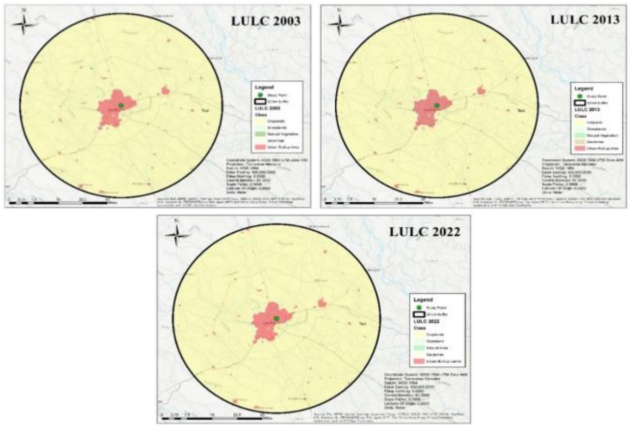

Fig -2: ARC GIS based LULC Analysis of 50Km buffer (MODIS MCD12Q2 V6.1 model)

Analysis of the Figure 4 2 ARC GIS based LULC Analysis of 50Km buffer (MODIS MCD12Q2 V6.1 model) temporal landuse change has been done using Gridcode from MCD12Q1 International Geosphere-Biosphere Programme (IGBP) Legends.

Table -1: Decadal Temporal Change of Lucknow as per MODIS MCD12Q2 V6.1 model (2003, 2013, 2022)

Class	Grid code	LULC Area 2003	Temporal Change	LULC Area 2013	Temporal Change	LULC Area 2022
Savannas	9	21	-12	9	19	28
Grasslands	10	5	10	15	4	19
Cropland	12	7563	4	7567	-32	7535
Urban and Builtup Lands	13	261	10	271	10	281
Croplands/ Natural Vegetation Mosaics	14	6	-3	3	-1	2

* International Geosphere-Biosphere Programme (IGBP) Legends.

Savannas: Tree Cover 10%-30% (Canopy >2m)

Gasslands: Dominated by herbaceous annuls (<2m)

Croplands: At least 60% of area is cultivated croplands

Urban and Builtup Lands: At least 30% impervious surface area including building material, asphalt, vehicals.

Croplands/Natural Vegetation Mosaics: Mosaics of small scale cultivation 40-60& with Natural Trees, Shurbs or Herbaceous vegetation.

The temporal change establishes the fact that along with increase in Urban Built up a significant effect on the Savannas, Grasslands and Crop land is observed throughout two decades. For savannas it is observed in Table 1, that there is an overall increase in the share when compared to the base year of 2003, Grasslands show a gradual increase in share, Croplands shows a significant decrease in share, Urban and Built-up Lands shows a Significant increase in concentration, and Croplands/Natural Vegetation shows a significant decrease in concentration.

5. Case Study of the Best Practices

The selection of the canal cities are based on the similarity in topography as of the target city of Lucknow.

5.1 The Industrial city of Birmingham

Birmingham, located in the West Midlands region of England, is known for its extensive canal network. It played a significant role in the Industrial Revolution and has left a lasting legacy on the city"s landscape and culture. Birmingham's canals were instrumental in the city's industrial development during the late 18th and early 19th centuries. They provided a means to transport raw materials and finished products to and from factories and workshops. The canals are lined with historic buildings, warehouses, and factories, many of which have been preserved and repurposed for modern use. The architecture along the canals reflects the city"s industrial heritage. Birmingham"s canal network is of national historical and cultural importance. It"s recognized for its contribution to the industrial development of the UK.

In recent decades, the canals have undergone significant regeneration efforts. The area around the canals has become a popular destination for leisure activities, including walking, cycling, and canal boat trips. It"s also home to a variety of restaurants, shops, and cultural venues.

Fig -2: Birmingham Canal Old Line

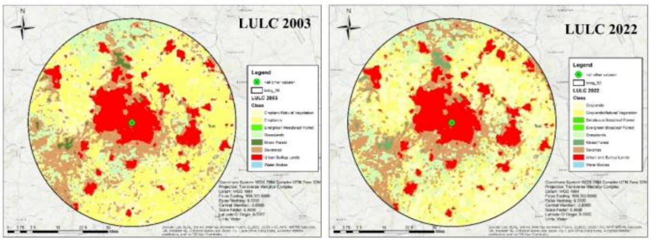

Fig -3: LULC of Birmingham 2003 (Left) and 2022

Table -2: Decadal Temporal Change of Birmingham as per MODIS MCD12Q2 V6.1 model (2003, 2013, 2022)

Class	Grid code	LULC Area 2003	Temporal Change	LULC Area 2013	Temporal Change	LULC Area 2022
Evergreen Broadleaf Forest	2		0	0	1	1
Deciduous Broadleaf Forest	4	1	1	2	-1	1
Mixed Forest	5	77	21	98	3	101
Savanas	9	1625	120	1745	-78	1667
Grasslands	10	839	-184	655	273	928
Croplands	12	2763	-287	2476	-166	2310
Urban and Builtup Lands	13	1068	5	1073	12	1085
Croplands/Natural Vegetation	14	1442	324	1766	-46	1720
Water Bodies	17	4	0	4	0	4

The land use/land cover (LULC) data from 2003 to 2022 reveals notable trends across various land classes. Evergreen Broadleaf Forest showed minimal presence, with a slight increase in 2013 that remained stable through 2022. Deciduous Broadleaf Forest experienced a modest increase from 2003 to 2013, but then decreased back to its original area by 2022. Mixed Forest areas steadily increased over the years, suggesting a gradual expansion. Savannas initially expanded between 2003 and 2013 but saw a slight decline by 2022. Grasslands experienced a significant decrease from 2003 to 2013, followed by a substantial recovery by 2022. Croplands consistently decreased over the entire period, indicating a reduction in agricultural land. Urban and Built-up Lands saw a continuous, albeit small, increase, reflecting ongoing urbanization. Croplands/Natural Vegetation areas expanded significantly by 2013 but slightly decreased by 2022. Water Bodies remained unchanged throughout the period, maintaining a constant area. These changes illustrate dynamic land use patterns influenced by natural and anthropogenic factors over the years.

5.2 The city of Utrecht, Netherlands

The canals of Utrecht, located in the Netherlands, are an integral part of the city"s history and urban landscape. Utrecht is known for its picturesque canals, which are lined with historic buildings and vibrant streets. One of the most famous canals in Utrecht is the Oudegracht. It is unique because it has a wharf-level section, where you can find many restaurants, cafes, and shops built directly into the arches of the canal"s retaining walls. Parallel to the Oudegracht is the Nieuwegracht. It was built in the 14th century and is known for its characteristic wharfs and cellar spaces, similar to the Oudegracht. Along the canals, one can find a wealth of historic buildings, including charming houses, churches, and warehouses. Many of these structures date back centuries and contribute to the city"s distinctive atmosphere.

The canals provide an opportunity for recreational activities like boating and canoeing. There are rental services that allow you to explore the city from a unique perspective. The canals serve as venues for various events and festivals throughout the year. These can range from cultural festivals to markets and even boat races.

The selection of the Energlhaven at the Vleutensespoorbrug at 52°05"55.1"N 5°04"37.1"E for the purpose of the study due to a high concentration of Transportation, commercial, Recreational and residential zone.

Fig -4: Energlhaven Canal, Ultrech, Netherlands.

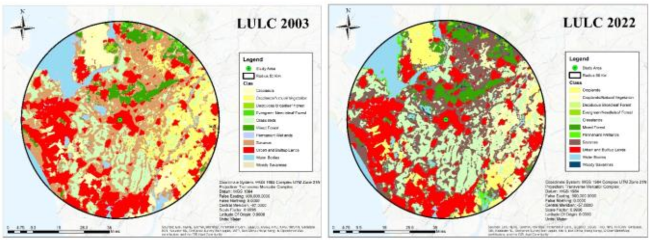

Fig -5: LULC of Utrecht 2003 (Left) and 2022 (Right)

Table -3: Decadal Temporal Change of Utrecht as per MODIS MCD12Q2 V6.1 model (2003, 2013, 2022)

Class	Grid code	LULC Area 2003	Temporal Change	LULC Area 2013	Temporal Change	LULC Area 2022
Evergreen Needle leaf Forest	1	41	-8	33	6	39
Deciduous Broadleaf Forest	4	15	-5	10	-2	8
Mixed Forest	5	390	-3	387	19	406
Woody Savannas	8	47	-7	40	8	48
Savanas	9	2181	24	2205	-119	2086
Grasslands	10	1064	227	1291	172	1463
Permanant Wetlands	11	83	-14	69	23	92
Croplands	12	702	144	846	-270	576
Urban and Builtup Lands	13	1815	23	1838	21	1859
Croplands/Natural Vegetation	14	875	-379	496	139	635
Water Bodies	17	604	-2	602	2	604

6. Relationship Analysis and Result

The methodology of analysis is based on the ranking analysis between factors which are common in all the 4 cases studied.

Table -3: Absolute value of Grid-code Areas (Data based on LULC - MODIS MCD12Q2 V6.1 2022)

Class	Grid-code	Bringimham	Utrecht	Lucknow
Savanas	9	1667	2086	28
Grasslands	10	928	1463	19
Permanent Wetlands	11		92	
Croplands	12	2310	576	7529
Urban and Builtup Lands	13	1085	1859	281
Croplands/Natural Vegetation	14	1720	635	2
Area under canals		0.00112	0.000640	0.0012000

The following Table 3, reflects the weightage between common 5 factor (Savanas, Grasslands, Croplands, Urban and Built-up Lands and Croplands/Natural Vegetation).

Table -3: Weightage analysis out of 100 (Data based on LULC - MODIS MCD12Q2 V6.1 2022)

Class	Grid code	Bringimham	Utrecht	Lucknow
Savanas	9	44.1	55.2	0.7
Grasslands	10	38.5	60.7	0.8
Croplands	12	22.2	5.5	72.3
Urban and Builtup Lands	13	33.6	57.6	8.7
Croplands/Natural Vegetation	14	73.0	26.9	0.1
Area under canals	-	37.84	21.62	40.54

The process of modelling numerous factors, or dependent variables, using a single set of predictor variables is known as multivariate multiple regression. It regresses each dependent variable on the predictors independently.

i. *Check for R and R^2*

Table -4: R & R^2 Table

Model	R	R Square	Adjusted R2	Std Error of the Estimate
1	1.000a	1.000		
a. Predictor Constant: Natural Vegetation, Grasslands				
b. Dependent Variable – Canal of Length				

The Result being 1 shows a positive indication of relation between the Variable as shown in Table 6 3 R & R2 Table

ii. *Analysis of Coefficient*

Analysing coefficient is importan in a model as it provides valuable insights into model behaviour, enhances performance, and facilitates clearer communication and understanding of predictive models.

Table -5: Coefficient Analysis Table

Model	Unstandardized Coefficients		Standardized Coefficient	Collinearity Statistics	
	B	Std. Error	Beta	Tolerance	VIF
1 (Constant)	40.795	0.000			
Grasslands	-0.389	0.000	-1.152	0.753	1.328
Natural Vegetation	0.165	0.000	0.594	0.753	1.328

The variance inflation factor (VIF) is a metric for determining how much multicollinearity there is in a collection of multivariate regression variables. If a VIF is greater than ten, substantial multicollinearity is present, according to a rule of thumb often employed in practice. The regression is in reasonable form in this case, with values around 1 as observed in Table 5.

An equation for Canal Length can be derived (Based on Standardized coefficient) as such –

Canal Length (L) = 0.594 (Grasslands) - 1.152 (Natural_Vegetaton) …………….. (i)

As per the analysis the observation form the generated Equation No. (i), The area of the canal in a region would be used to predict a ideal area under natural vegetation and grasslands in a region. Thus, to imply the equation over a study region:

Let,

Grasslands be "x" and Natural Vegetation be "y",

So that the equation can be reinterpreted as

L= 0.594x -1.152y……………………... (ii)

In this case using graphical intercepts of x and y, we have to assume the extreme cases where to find x intercept, y must be equal to zero and vice versa.

Using this information we re-interpret the condition of study region in Lucknow, where the area of canal is 0.0012000 sq km. By equating the the derived equation (ii), x-intercept is approximately =0.0020202, x=0.0020202, which gives the point (0.00202, 0). Similarly, the y-intercept is approximately =−0.0010417 y=−0.0010417, which gives the point (0,−0.0010417)(0,−0.0010417).

Therefore, the solution to the equation is the intersection point of the x-intercept and y-intercept, which is approximately (0.0020202,0)(0.0020202,0) or (0,−0.0010417)(0,−0.0010417).

Based on the finding for the case of Lucknow,

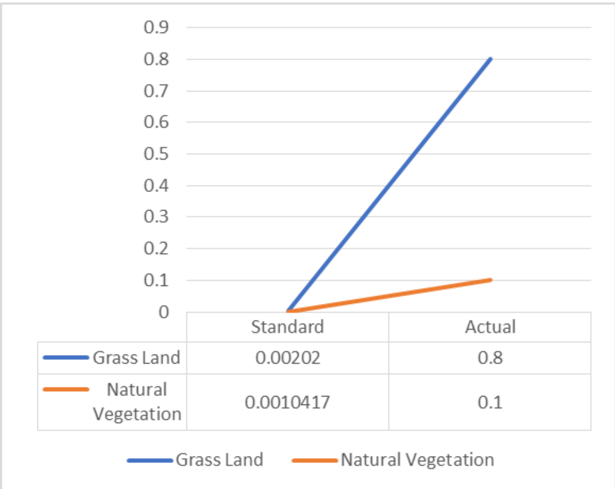

Chart -1: Observation for Deviation in for the case of Lucknow

Based on the finding for the case of Lucknow,

- Grasslands (x) : 0.00202 sq km
- Natural Vegetation (y) : = (−0.0010417) ~ = 0.0010417 sq km (Absolute value for area)

Analysing the Deviation,

It is observed form Chart 1, that the study region has a score higher than the benchmark, thus no specific intervention is recommended for the case.

7. Recommendation

Based on the analysis, the relation between the variables is important to maintain a minimum green cover the following recommendation is framed in

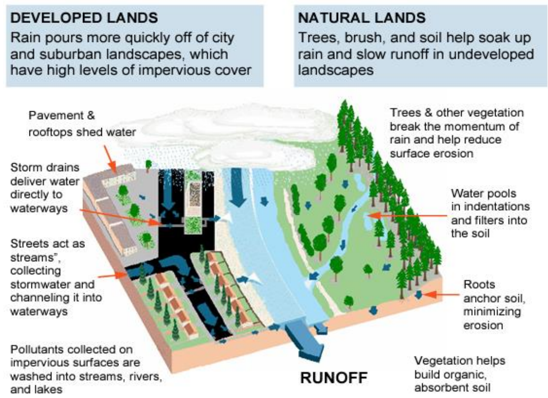

Fig -5: Illustration of the impact of Developed Lands (Urban areas) and Natural Lands. (Source: Emily Ruby, OEHHA)

8. Conclusion

The revitalization and preservation of water canals hold immense significance for the sustainable development of urban areas in India. Traditionally viewed as rural-centric, canals have emerged as pivotal conduits linking rural and urban environments. However, the influence of urbanism on canals has been profound, leading to environmental repercussions such as habitat alteration, biodiversity loss, and water pollution. Two exemplary case studies, Birmingham in the UK and Utrecht in the Netherlands, shed light on successful canal revitalization efforts. Birmingham"s extensive canal network, deeply intertwined with its industrial heritage, has undergone substantial regeneration, evolving into a vibrant hub for leisure and cultural activities. While, Utrecht"s picturesque canals, lined with historic structures, serve as a key attraction for both residents and tourists, contributing significantly to the city"s unique ambiance. Through the study it has been found that temporal land-use and land-cover analyses plays a major role in determining the ambient share of landuse under canals, particularly the catchment areas of canals. Hence, through the structural equation and Integration of GIS this equitable share can be determined which can be used to increase the probability in tourism development.

Ultimately, the rejuvenation of water canals is not merely a matter of infrastructure development, but a holistic endeavor that embraces environmental conservation, cultural preservation, and community engagement. Through strategic interventions and collective efforts, India"s cities can harness the transformative power of canals to achieve enduring prosperity and sustainable urban development.

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