

Spatial & Temporal Impacts of Climate and LULC on Water Quality in the Kelani River Basin

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Abstract

The Kelani River, a major freshwater resource in Sri Lanka, has experienced significant water quality degradation over the past two decades due to land use and land cover (LULC) changes and climate variability. This study investigates the spatial and temporal impacts of these factors on key water quality parameters from 2003 to 2023 across the upstream, midstream, and downstream segments of the river. Using remote sensing, GIS (ArcGIS Pro), and statistical analysis in Python, the study evaluates relationships between LULC categories and water quality parameters, as well as between climate factors and water quality parameters such as pH, dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD), nitrate, phosphate, turbidity, electrical conductivity (EC), and temperature. Findings reveal a substantial increase in developed land, particularly downstream, alongside a decline in vegetation, which contributes to elevated organic pollution and reduced oxygen levels. Strong positive correlations ($r=0.86$) were observed between rainfall and turbidity, as well as temperature and BOD ($r=0.61$), highlighting the influence of seasonal climate variability on water quality of midstream and downstream. These results underscore the need for integrated watershed management that accounts for both spatial and temporal variations in land use and climate, to safeguard the Kelani River's water quality and support sustainable resource planning.

Keywords: Climate Variability, Correlation Analysis, GIS, Land Use Change, Water Quality

1 Introduction

Access to clean and safe water is critical for human life and ecosystem [1], [2]. It contributes significantly to socioeconomic growth [2]. As worldwide populations grow and human activities increase, the demand for freshwater rises dramatically [3]. One of the most important environmental concerns today is the degradation of water quality, which is frequently caused by land use changes such as intensive farming activities and climatic changes [4], [5], [6].

Land use changes significantly impact river basin water quality through increased

contaminants, including sediments, fertilisers, heavy metals, and organic waste from human activities [6], [7]. These pollutants creating environmental and public health risks [8].

Global studies demonstrate this relationship. Indonesia's Citarum River Basin receives over 2,800 tonnes of daily waste from domestic, agricultural, and industrial sources [9], while Tanzania's Ruvu River system shows lower pollutant levels in forested areas compared to agricultural regions [10]. Climate change further exacerbates these risks through rising temperatures, altered rainfall patterns, and ecological disruptions [11].

Sri Lanka faces similar water quality challenges, particularly with the Kelani River, the country's fourth-longest river, extending 144 km from central highlands to the western coast [2], [12]. This economically and ecologically vital river supplies drinking water to over 80% of population in the capital and supports hydropower generation, transportation, fishing, and irrigation [12].

The Kelani River Basin encompasses diverse land uses, forest reserves and tea plantations upstream, with rubber plantations, paddy fields, and expanding urban-industrial areas in the middle and lower basins [12]. This land use diversity makes the river highly vulnerable to contamination [13]. The Kelani River, identified as Sri Lanka's most polluted river by the Environmental Foundation Limited, faces degradation from natural processes and extensive human activities [14], [15]. Multiple industries including rubber, textile, fertilizer, and oil refineries discharge waste directly into the river [12], [16]. Export processing zones add substantial industrial waste, with many facilities exceeding acceptable water quality standards [17].

This research aims to comprehensively assess how LULC changes and climate variability within the Kelani River basin have influenced water quality over time and space. The study seeks to establish relationships between land use types (developed, agricultural, vegetated areas), climate factors, and key water quality parameters.

2 Methodology

2.1 Study Area

The Kelani River originates from the Sri Pada Mountain Range and flows through several districts before reaching the sea [6]. Covering a basin area of 2,230 km², it receives about 2,400 mm of annual rainfall and has a highly variable discharge, peaking during the monsoon [14], [18].

An overview map of the basin was produced using ArcGIS Pro (version 3.0), and a 30-meter resolution Digital Elevation Model (DEM) was downloaded from the United States Geological Survey (USGS), and a river network was derived from flow accumulation using ArcGIS Pro. To facilitate spatial analysis of land use and water quality, the main river has been divided into upstream, midstream, and downstream sections.

2.2 Water Quality Data

Water quality parameter data for the Kelani River from 2003 to 2023 were obtained from Sri Lanka's Central Environmental Authority (CEA). The sampling was conducted monthly at 17 monitoring stations in total. pH, Temperature, Turbidity, EC, DO, BOD, COD, Nitrate, Phosphate, and Chloride were the ten water quality parameters selected for the study. Because they were consistently monitored during the years mentioned.

2.3 Sampling Location

The selection of sampling stations was limited to the main channel of the Kelani River to focus on the core hydrological system. The selected locations include:

- Upstream: Nakkawita Bridge, Aguruwella Bridge, Karawanella Bridge, and Thaldawa Bridge.
- Midstream: Pugoda Ferry, Hanwella Bridge.
- Downstream: Kaduwela Bridge, Weliwita Bridge, and Japanese Friendship Bridge.

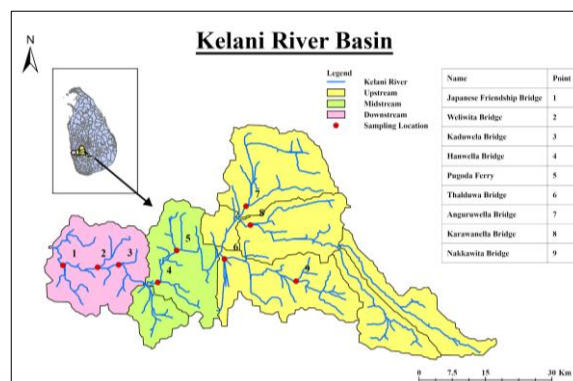


Figure 1: Study area with sampling locations

2.4 Data Selection

The years 2003, 2007, 2011, 2015, 2019, and 2023 were chosen based on the completeness of datasets and the availability of satellite imagery with less than 10% cloud cover.

2.5 Water Quality Analysis

Temporal and spatial trend studies were performed to evaluate the changes in water quality. Microsoft Excel was used to create bar charts of water quality trends, showing both temporal and spatial trends. Reference lines for standard threshold values (drawn from national water quality standards that require simple treatment, for drinking) have been included.

2.6 LULC Analysis

The USGS Earth Explorer website provided the Landsat images. This study used Level 1 data from the Landsat Collection 2. For 2003, 2007, and 2011, Landsat 5 Thematic Mapper (TM) and for 2015, 2019, and 2023, Landsat 8 Operational Land Imager and Thermal Infrared Sensor (OLI/TIRS) were used. False colour composites (FCC) were created for categorisation and visual interpretation. Landsat 5 TM's 4-3-2 (RGB) band combination and Landsat 8 OLI/TIRS's 5-4-3 (RGB) band combination was employed.

2.6.1 Supervised Classification

To accurately define land cover features in different periods, training samples were produced using high-resolution temporal imagery from Google Earth Pro and ESRI Wayback images. The following five general LULC classes were identified: agricultural, vegetation, developed, water bodies and others. The Maximum Likelihood Classifier was used to classify the generated composite images for selected years independently.

2.6.2 Accuracy Assessment of LULC Maps

LULC classification accuracy was evaluated using 100 stratified random validation points per year. Validation points were generated based on a stratified random sampling method to achieve equal representation of all land cover classes. All points were cross-checked with high-resolution reference imagery from Google Earth Pro and ESRI Wayback images. A confusion matrix was created for each classified map.

2.6.3 Climate Data Collection

Historical monthly climate data (2003-2020) were obtained from Sri Lanka's Department of Meteorology. Data was categorized by Sri Lanka's monsoon seasons for seasonal trend analysis.

- First Inter-Monsoon (FIM): March-April
- Southwest Monsoon (SWM): May-September
- Second Inter-Monsoon (SIM): October-November
- Northeast Monsoon (NEM): December-February

2.6.4 Spatial Interpolation

Rainfall and temperature data were converted into continuous spatial maps using ArcGIS Pro's Ordinary Kriging interpolation. Zonal Statistics

tools calculated mean rainfall and temperature values for each river segment.

2.6.5 Statistical Analysis:

Correlation analyses were performed using Pearson correlation:

- LULC-Water Quality Correlation: Examined relationships between land use percentages and water quality parameters.
- Climate-Water Quality Correlation: Analyzed how seasonal rainfall and temperature patterns affect water quality separately

Statistical significance was set at $p < 0.05$ and $p < 0.01$. Python libraries were used for data processing, statistical calculations, and visualization of correlation results.

3 Results

3.1 Water Quality

The spatial and temporal analysis of water quality in the Kelani River Basin from 2003 to 2023 revealed significant variations across upstream, midstream, and downstream segments. Most water quality parameters remained within the permissible limits; however, clear trends emerged along the river's flow path.

Temperature showed a gradual rise over the years, with the highest values observed in particularly in downstream areas such as the Japanese Friendship Bridge. pH levels remained stable throughout the basin, consistently within the acceptable range. BOD values vary from upstream to downstream, with peaks in 2003, 2015, and 2019. COD levels increased progressively toward the downstream sections, and in certain years, they exceeded the permissible limit. DO levels were higher in the upstream region but declined downstream, occasionally nearing or falling slightly below the permissible minimum, which aligns with increased oxygen demand from organic matter.

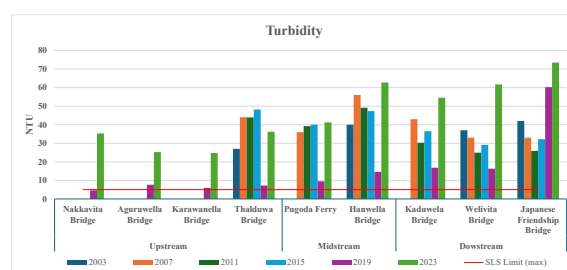


Figure 2: Spatial and Temporal Variation of Turbidity Levels

Among all parameters, turbidity was the only one that consistently exceeded the permissible

limit, likely due to flood events, surface runoff, or sediment transportation. Chloride and EC showed similar spatial patterns, low in the upstream and midstream segments but significantly elevated downstream, especially at the Japanese Friendship Bridge. Phosphate concentrations also increased slightly downstream, though they remained within permissible limits. In contrast, nitrate levels were consistently low across all segments and years.

3.2 LULC

For the Upstream, Midstream, and Downstream segments of the Kelani River Basin, the percentage of the LULC categories was calculated for selected years. The data reflect relative changes in land use per area: upstream (~1486.63 km²), midstream (~431.94 km²), and downstream (~393.46 km²).

In the Upstream region, the proportion of agricultural land rose from 27.40% to 36.03%, the percentage of developed land rose from 2.43% in 2003 to 5.26% in 2023, and the percentage of vegetation fell from 69.18% to 57.77%. Water and Other showed negligible variations, ranging from 0.60% to 0.69% and 0.39% to 0.24%, respectively.

The midstream region had a significant increase in agricultural land from 31.31% to 55.63%, a decrease in vegetation from 62.06% to 30.37%, and a rise in developed land from 4.94% in 2003 to 12.13% in 2023. Others and water showed minimal variation over time.

In the downstream area, agricultural land fluctuated between 32.81% and 31.51%, reaching its highest in 2015; developed land increased from 31.29% in 2003 to 56.74% in 2023; and vegetation dropped sharply from 31.39% to 8.5%.

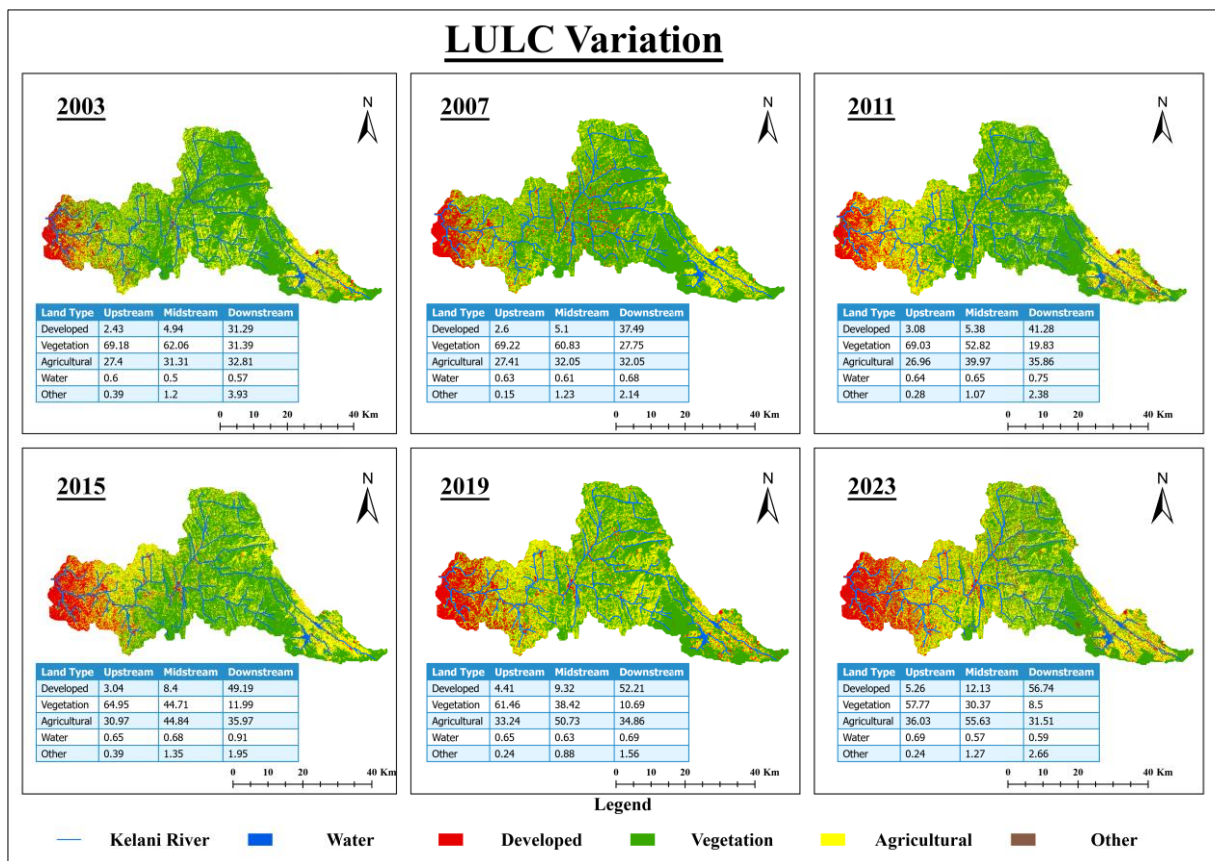


Figure 3: Spatial and temporal land use variations in the Kelani River Basin (2003–2023)

3.3 Rainfall

Precipitation within the Kelani River Basin varies extremely spatially and temporally. The SWM is always the highest rainfall in the Upstream region, with the highest being 1035.67 mm in 2019, and the lowest being the FIM at 206.82 mm in 2019.

The Midstream region follows the same trend, where the SWM was 858.57 mm in 2019, compared to the FIM at 206.82 mm. In the Downstream region, SIM received the highest rainfall at 773.61 mm in 2019, and that of the FIM was the minimum at 206.82 mm.

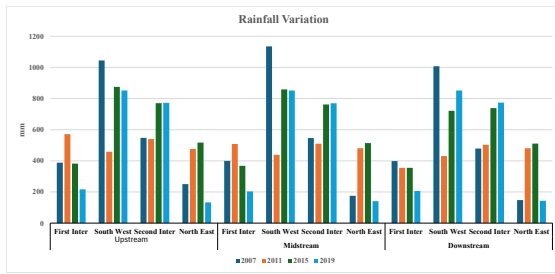


Figure 4: Spatial and Temporal Variation of Rainfall

3.4 Temperature

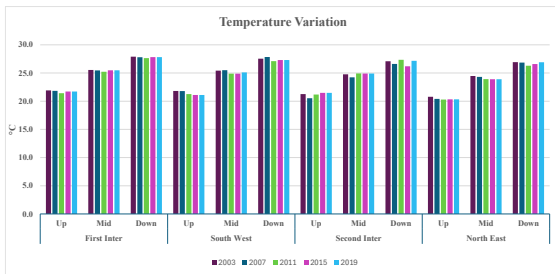


Figure 54: Spatial and Temporal Variation of Temperature

The spatial variation in temperature along the Kelani River from 2003-2019 reveals a distinct gradient influenced by land cover and anthropogenic activity. The upstream region consistently exhibited the lowest temperatures, which can be attributed to the presence of dense

vegetation and minimal human interference. The midstream section displayed moderate temperature levels & the downstream region recorded the highest and most stable temperatures, likely resulting from extensive urbanization and reduced vegetation cover.

3.5 Correlation Analysis

3.5.1 LULC & Water Quality

Overall Analysis of water quality parameters revealed several significant correlations with land use types.

Developed areas were positively correlated with DO, chloride and EC at a 0.01 significance level, and BOD was positively correlated at a 0.05 significance level, indicating that developed areas are accountable for increased organic pollution and ionic content.

Vegetation was negatively correlated with chloride, EC, and BOD but positively correlated with DO at a 0.01 significance level, suggesting that vegetated areas promote oxygenation and reduce pollution.

The agricultural land use was inversely correlated with DO and positively correlated with phosphate at a 0.05 significance level, implying its contribution to nutrient enrichment and oxygen consumption.

Table 1: Correlation between LULC types and WQ parameters (Overall)

	pH	DO	BOD	NO ₃ ⁻	PO ₄ ³⁻	Cl ⁻	EC	Turb.	COD	Temp,
Developed	0.031	-0.607**	0.588*	0.210	0.286	0.894**	0.947**	-0.082	0.447	0.320
Vegetation	0.032	0.755**	-0.669**	-0.344	-0.468	-0.780**	-0.838**	0.121	-0.440	-0.227
Agriculture	-0.145	-0.514*	0.283	0.429	0.565*	-0.185	-0.150	-0.131	0.041	-0.208

p < 0.01 (2-tailed): significant correlation (**), p < 0.05 (2-tailed): significant correlation (*)

3.5.2 Rainfall & Water Quality

The rainfall variation among various sections of the streams was considered, and this revealed various trends in indicators of water quality.

Turbidity was found to have a very strong positive correlation with rainfall across all the sections at a 0.01 significance level, indicating that high rainfall corresponds to high turbidity. BOD also indicated significant positive relationships, particularly in the midstream and downstream sections at the 0.01 level, and in the upstream at the 0.05 level, which show that rain

increases organic matter in the water. COD had a robust positive correlation for the downstream area at the level of 0.01 but was lower for the midstream and was even negative for the upstream area. EC and Chloride were greatly negatively correlated in the downstream and upstream sections, which confirms that the parameters are being diluted by rainfall. The other parameters, like DO, nitrate, phosphate, temperature, and pH, showed weaker or non-significant correlations during the sections, with pH having a strong negative correlation in the upstream section.

Table 2: Impact of Rainfall on WQ parameters across stream sections

Parameter	Downstream m Corr	Midstream m Corr	Upstream m Corr
BOD	0.65**	0.67**	0.58*
COD	0.62**	0.11	-0.30
Cl ⁻	-0.56*	-0.27	-0.53*
DO	-0.18	-0.33	-0.45
EC	-0.63**	-0.43	-0.64**
NO ₃ ⁻	-0.02	-0.16	-0.20
PO ₄ ³⁻	0.01	0.05	0.11
Temp	-0.48	-0.12	-0.35
Turbidity	0.80**	0.92**	0.86**
pH	0.06	-0.44	-0.65**

p < 0.01(2-tailed): significant correlation (**),
p < 0.05 (2-tailed): significant correlation (*)

3.5.3 Temperature & Water Quality

The temperature variation across different sections of the stream exhibited significant trends with several water quality parameters.

Table 3: Impact of Temperature on WQ parameters across stream sections

Parameter	Downstream m Corr	Midstream m Corr	Upstream m Corr
BOD	0.39	0.73**	0.72**
COD	-0.11	-0.14	0.03
Cl ⁻	-0.11	-0.48	0.07
DO	-0.36	-0.13	-0.32
EC	-0.23	0.14	0.07
NO ₃ ⁻	-0.15	-0.06	-0.06
PO ₄ ³⁻	0.03	0.22	0.32
Temp	0.60*	0.56*	0.53*
Turbidity	-0.04	0.40	0.37
pH	0.20	0.04	-0.21

p < 0.01(2-tailed): significant correlation (**),
p < 0.05 (2-tailed): significant correlation (*)

BOD showed a strong positive correlation with temperature in all three sections of the stream. The correlation was statistically significant at the 0.01 level for both the midstream and upstream sections, and moderately strong at the downstream section, though not significant at the 0.05 level. Temperature itself showed a statistically significant positive correlation in all three sections, downstream, midstream, and upstream, emphasising its consistent influence across the catchment.

Other parameters displayed weaker and non-significant correlations with temperature. DO and COD showed weak negative correlations, respectively, in all sections. Similarly, EC, Chloride, Nitrate, and Phosphate exhibited either weak positive or weak negative correlations, indicating limited or no direct influence of temperature on their concentrations.

Turbidity showed moderate but non-significant positive correlations in the midstream and upstream regions. pH had a weak positive correlation in the downstream and midstream.

4 Discussion

The comprehensive analysis of the Kelani River Basin from 2003 to 2023 reveals that water quality is shaped by a complex interplay of LULC changes and climatic variability. The most pronounced changes were observed in the downstream segments, where urban and industrial expansion have led to significant environmental pressures. The increase in built-up areas from 31.29% in 2003 to 56.74% in 2023 downstream correlates with rising levels of organic pollution BOD, COD, and ionic content (chloride, EC), often exceeding or closely approaching national water quality standards. This pattern is consistent with global experiences in river basins undergoing rapid urbanization, where industrial discharge, untreated wastewater, and increased impervious surfaces contribute to deteriorating water quality.

Vegetation cover plays a protective role, as evidenced by its strong positive correlation with DO and negative correlation with pollutants such as BOD, chloride, and electrical conductivity. The decline in vegetation, especially in downstream and midstream areas, has compromised the river's natural ability to filter pollutants and sustain water quality. In contrast, agricultural land expansion was associated with elevated phosphate levels, likely due to fertiliser runoff, and reduced DO, reflecting increased nutrient loading and organic matter input.

Rainfall and temperature were also significant drivers of water quality dynamics. Turbidity consistently exceeded thresholds during high rainfall periods, particularly in midstream and downstream sections, due to sediment-laden runoff from developed and agricultural lands. The positive correlation between rainfall and BOD underscores the role of surface runoff in

transporting organic pollutants into the river. Temperature increases, especially in downstream urbanized areas, were linked to higher BOD and water temperature, reflecting urban heat island effects and reduced vegetative shading.

These findings align with global trends where river basins with intensive urban and agricultural land use experience degraded water quality due to increased pollutant loads and reduced riparian buffering. The Kelani River's status as a critical source of drinking water for Colombo emphasizes the urgency of integrated watershed management. The downstream segment's vulnerability to industrial and urban pollution highlights the need for stricter regulation of wastewater discharge and enhanced monitoring of water quality parameters.

Despite the comprehensive nature of this study, several limitations should be acknowledged. The temporal analysis was constrained by the availability of cloud-free satellite imagery, limiting the land use classification to six discrete years rather than enabling a continuous annual assessment. Spatial resolution was also a limiting factor, as the 30-meter Landsat imagery may not sufficiently capture fine-scale land use variations, particularly in heterogeneous or rapidly changing areas. Additionally, the analysis focused exclusively on the main channel of the Kelani River, thereby excluding potential influences from tributaries and localised point-source discharges, which may contribute significantly to overall water quality dynamics.

To address these limitations, future research should consider incorporating higher-resolution remote sensing data, such as Sentinel imagery, which offers improved spatial and temporal granularity. Integrating continuous in-situ water quality monitoring would enhance temporal resolution and allow for real-time assessment of pollutant fluctuations. Furthermore, the application of predictive modelling techniques, such as Random Forest regression or Long Short-Term Memory (LSTM) neural networks could enable more accurate forecasting of water quality trends. Employing multi-criteria decision analysis (MCDA) frameworks may also support policymakers in prioritising land use interventions and guiding resource allocation for watershed management and rehabilitation.

Conclusion

This study underscores the profound impacts of land use land cover changes and climate variability on the water quality of the Kelani River Basin. Over the past two decades, the expansion of built-up and agricultural land, coupled with declining vegetation, has led to increased pollution loads, particularly in downstream areas. The results demonstrate strong correlations between developed land and organic/inorganic pollutants, as well as between vegetation cover and improved water quality. Climatic factors, especially rainfall and temperature, further modulate these impacts by influencing runoff, sediment transport, and thermal regimes.

To safeguard the Kelani River's water quality and ensure its continued role as a vital resource for drinking water, industry, and agriculture, integrated watershed management strategies are essential. Recommendations include:

- Strengthening regulatory frameworks for industrial and urban wastewater discharge.
- Promoting riparian vegetation restoration to enhance natural pollutant filtration and temperature regulation.
- Implementing sustainable agricultural practices to reduce runoff fertilizer and nutrient loading.
- Enhancing monitoring networks to provide early warnings of water quality deterioration and support adaptive management.

By addressing the land use change and climate variability, stakeholders can ensure the long-term sustainability of the Kelani River Basin and protect the health and well-being of the communities that depend on it.

References

- [1] N. Khatoon, "Correlation Study For the Assessment of Water Quality and Its Parameters of Ganga River, Kanpur, Uttar Pradesh, India," *IOSR Journal of Applied Chemistr*, vol. 5, no. 3, pp. 80–90, 2013, doi: 10.9790/5736-0538090.
- [2] M. G. Y. L. Mahagamage and P. M. Manage, "Water Quality Index (CCME-WQI) Based Assessment Study of Water Quality in Kelani River Basin, Sri Lanka," *International Journal of Environment and Natural Resources*, vol. 1, no. November 2014, pp. 199–204, 2014.
- [3] V. N. Chigor, V. J. Umoh, C. A. Okuofu, J. B. Ameh, E. O. Igbiosa, and A. I.

- Okoh, "Water quality assessment: Surface water sources used for drinking and irrigation in Zaria, Nigeria are a public health hazard," *Environ Monit Assess*, vol. 184, no. 5, pp. 3389–3400, May 2012, doi: 10.1007/s10661-011-2396-9.
- [4] M. Camara, N. R. Jamil, and A. F. Bin Abdullah, "Impact of land uses on water quality in Malaysia: a review," *Ecol Process*, vol. 8, no. 10, 2019, doi: 10.1186/s13717-019-0164-x.
- [5] J. T. Samarasinghe *et al.*, "The Assessment of Climate Change Impacts and Land-use Changes on Flood Characteristics: The Case Study of the Kelani River Basin, Sri Lanka," *Hydrology*, vol. 9, no. 10, Oct. 2022, Doi: 10.3390/hydrology9100177.
- [6] S. P. H. P. Perera and A. K. R. N. Ranasinghe, "Mapping and Analysis of Land Use/Land Cover Change in Kelani Watershed, Sri Lanka," *The Asian Review of Civil Engineering*, vol. 9, no. 2, pp. 21–26, Nov. 2020, doi: 10.51983/tarce-2020.9.2.2560.
- [7] K. E. Clark *et al.*, "Land Use and Land Cover Shape River Water Quality at a Continental Caribbean Land-Ocean Interface," *Frontiers in Water*, vol. 4, Mar. 2022, doi: 10.3389/frwa.2022.737920.
- [8] D. Sudeshika, Y. Imamura, D. Harada, and S. Egashira, "Impacts of land cover changes on the rainfall-runoff and sediment transport processes in the Kelani River," in *Proc. Asian Conf. Remote Sens. (ACRS)*, 2024.
- [9] M. Sholeh, P. Pranoto, S. Budiastuti, and S. Sutarno, "Analysis of Citarum River pollution indicator using chemical, physical, and bacteriological methods," in *AIP Conference Proceedings*, American Institute of Physics Inc., Dec. 2018. doi: 10.1063/1.5082473.
- [10] Elizabeth Ngoye and J. F. Machiwa, "The influence of land-use patterns in the Ruvu river watershed on water quality in the river system," *Physics and Chemistry of the Earth*, vol. 29, pp. 1161–1166, 2004, doi: 10.1016/j.pce.2004.09.002.
- [11] D. K. Chauhan, A. Tripathi, and N. Kumar, "Impacts of Climate Change and Pollution on Ganges River System: A Mini Review on Biological Effects, Knowledge Gaps and Research Needs," *SM Journal of Biology*, vol. 3, p. 1017, Sep. 2017.
- [12] H. Sawmika, G. Thusitha, and M. Samarakoon, "Impact of Land Use on Water Quality of Kelani River," Ratmalana, 2019. Accessed: Mar. 24, 2025. [Online]. Available: <http://ir.kdu.ac.lk/handle/345/2234>
- [13] C. Narangoda, D. Amarathunga, and C. D. Dangalle, "Evaluation of water quality in the upper and lower catchments of the Kelani River Basin, Sri Lanka," *Water Pract Technol*, vol. 18, no. 3, pp. 716–737, Mar. 2023, doi: 10.2166/wpt.2023.034.
- [14] M. M. G. T. De Silva, S. B. Weerakoon, S. Herath, U. R. Ratnayake, and S. Mahanama, "Flood Inundation Mapping along the Lower Reach of Kelani River Basin under the Impact of Climatic Change," *Journal of the Institution of Engineers, Sri Lanka*, vol. 45, no. 02, pp.23-30, 2012, doi: 10.4038/engineer.v45i2.6938.
- [15] C. M. Fayas, N. S. Abeysingha, K. G. S. Nirmanee, D. Samarathunga, and A. Mallawatantri, "Soil loss estimation using rusle model to prioritize erosion control in KELANI river basin in Sri Lanka," *International Soil and Water Conservation Research*, vol. 7, no. 2, pp. 130–137, Jun. 2019, doi: 10.1016/j.iswcr.2019.01.003.
- [16] A. G. Ileperuma, "Environmental pollution in sri lanka : A review," *J Natl Sci Found*, vol. 28, no. 4, pp. 301–325, Dec. 2010, doi: 10.4038/jnsfsr.v28i4.2644.
- [17] R. Makubura, D. P. P. Meddage, H. M. Azamathulla, M. Pandey, and U. Rathnayake, "A Simplified Mathematical Formulation for Water Quality Index (WQI): A Case Study in the Kelani River Basin, Sri Lanka," *Fluids*, vol. 7, no. 5, May 2022, doi: 10.3390/fluids7050147.
- [18] M. G. Y. L. Mahagamage, S. D. M. Chinthaka, and P. M. Manage, "Assessment of water quality index for groundwater in the Kelani River basin, Sri Lanka," *International Journal of Agriculture and Environmental Research*, vol. 2, no. 5, pp. 1158–1171, Sep. 2016.