

The Role Of Wetlands In Flood Regulation: A Case Study Of Nakivubo Wetland, Kampala City

Ssegirinya Ronald¹, Ngumenawe Moses²

1, 2 Metropolitan International University

Abstract

Wetlands provide critical regulating ecosystem services, including the attenuation of storm water runoff and mitigation of urban flooding, yet rapid urbanization in many African cities has led to significant wetland degradation with poorly understood consequences for flood risk. This study examined the role of wetlands in flood regulation, using Nakivubo Wetland in Kampala City as a case study, guided by objectives assessing the wetland's ecological condition and spatial extent, its hydrological functions, the relationship between its degradation and flooding, and the drivers of its degradation. A descriptive case study design integrating remote sensing/GIS land cover change analysis with household surveys (n = 103), key informant interviews, and field observation was employed. Land cover analysis showed a 42.0 percent loss of papyrus-dominated wetland vegetation between 1993 and 2023, accompanied by a 276.0 percent increase in built-up area. Households nearest the most degraded sections of the wetland reported significantly more frequent flooding (mean = 4.10 episodes/year) than those near better-preserved sections (mean = 0.95 episodes/year). Wetland vegetation loss was strongly correlated with flood frequency ($r = 0.710$, $p < 0.01$), and regression analysis showed vegetation loss and distance from the wetland edge jointly explained 59.9 percent of the variance in flood frequency ($R^2 = 0.599$). Path analysis confirmed that the erosion of the wetland's water storage and attenuation capacity partially mediates the relationship between vegetation loss and flooding, with a significant indirect effect ($\beta = 0.340$, $p < 0.01$) in addition to a significant direct effect ($\beta = 0.481$, $p < 0.01$), producing a total effect of 0.821. The study concludes that continued encroachment, weak enforcement, and solid waste dumping have substantially compromised the wetland's natural flood regulation function, and recommends strengthened enforcement, wetland restoration, improved solid waste management, and the integration of wetland conservation into citywide drainage planning.

Keywords: Wetlands, flood regulation, ecosystem services, urban flooding, land cover change, path analysis, Nakivubo Wetland, Kampala

Introduction

Wetlands are widely recognized in ecological and environmental management literature as among the most productive and functionally important ecosystems on earth, providing a range of goods and services that include water purification, biodiversity conservation, carbon sequestration, and, critically for rapidly urbanizing cities, the regulation of stormwater runoff and the mitigation of flooding(Nicholas et al., 2023). In Uganda, wetlands cover a significant proportion of the national land area and have historically played an important buffering role in urban and peri-urban drainage systems, absorbing excess rainwater, slowing the velocity of surface runoff, and gradually releasing stored water into rivers and lakes, thereby reducing the frequency and severity of downstream flooding(Christopher, 2022). Kampala City, built on a series of hills interspersed with valleys and wetlands, has for decades relied on its network

Received: 10.09.2026

Accepted: 15.09.2026

Published on: 30.09.2026

of natural wetlands, including the Nakivubo Wetland, to manage the substantial volumes of stormwater generated during the city's frequent and often intense rainfall events(Jackline et al., 2023). The Nakivubo Wetland, located in the eastern part of the city and draining into Lake Victoria through the Nakivubo Channel, has historically served as the primary natural drainage corridor for a large catchment area encompassing both densely populated residential neighborhoods and industrial zones, making it one of the most ecologically and functionally significant wetlands within the city's boundaries. However, over the past few decades, Nakivubo Wetland has experienced substantial degradation as a result of encroachment for settlement and industrial development, drainage and reclamation for agriculture, solid waste dumping, and pollution from untreated industrial and domestic effluent, all of which have progressively diminished its capacity to perform its natural flood regulation function(Christopher, 2022).

This study is situated within the growing concern among urban planners, environmental scientists, and city authorities regarding the increasing frequency and severity of flooding in Kampala, particularly in low-lying areas surrounding degraded wetlands, and the recognition that the loss of natural wetland buffering capacity may be a significant contributing factor to this trend(Julius et al., 2026). As Kampala continues to urbanize rapidly, with informal settlements and industrial facilities expanding into wetland areas that were previously left undeveloped, there is a pressing need to understand empirically how the remaining functional portions of Nakivubo Wetland continue to contribute to flood regulation, and how the degradation that has already occurred has altered the hydrological dynamics of the surrounding catchment(Willies et al., 2022). This study therefore seeks to examine the role that Nakivubo Wetland plays in regulating flood events within its catchment, with a view to generating evidence that can inform wetland conservation policy, urban drainage planning, and broader efforts to enhance the resilience of Kampala City to the impacts of both rapid urbanization and climate variability.

PROBLEM STATEMENT

Kampala City has in recent years experienced a marked increase in the frequency and severity of urban flooding, with numerous neighborhoods within and around the Nakivubo catchment, including Bwaise, Kinawataka, and parts of the central business district, regularly experiencing flash floods that damage property, disrupt economic activity, displace residents, and pose serious public health risks associated with contamination of floodwaters by sewage and solid waste(Christopher & Felex, 2022a). While these flooding events are frequently attributed in public discourse to inadequate engineered drainage infrastructure and heavy rainfall, there is growing scientific and policy interest in the extent to which the progressive degradation of natural wetlands, particularly Nakivubo Wetland, has diminished the city's natural capacity to absorb and regulate stormwater, thereby exacerbating flood risk independent of, or in combination with, infrastructural deficiencies(Julius & Audrey, 2026).

Despite the existence of national wetland conservation policies and the designation of Nakivubo as a protected wetland area, encroachment for industrial and residential development, papyrus harvesting, and solid waste disposal have continued largely unabated, raising concern that the wetland's hydrological functions are being progressively compromised at a time when the city can least afford to lose this natural infrastructure(Regan et al., 2024). However, there remains a notable gap in localized empirical evidence that directly links the specific condition and extent of Nakivubo Wetland to measurable flood regulation outcomes within its catchment, meaning that policy debates and enforcement decisions regarding wetland protection in this area often proceed without a firm evidentiary basis regarding the actual magnitude of the flood mitigation services that the wetland provides or the flood risk consequences of its continued degradation(Christopher & Felex, 2022b). This study seeks to fill this gap by systematically investigating the role of Nakivubo Wetland in flood regulation, generating evidence that can support more informed decision-making by the Kampala Capital City Authority, the National Environment Management Authority, and other relevant stakeholders responsible for wetland management and urban flood risk reduction.

Main Objective

The main objective of this study is to examine the role of wetlands in flood regulation, with specific reference to Nakivubo Wetland in Kampala City.

Specific Objectives

The specific objectives guiding this study are, to assess the current ecological condition and spatial extent of Nakivubo Wetland in comparison to its historical coverage; to establish the hydrological functions performed by Nakivubo Wetland in regulating stormwater runoff and mitigating flooding within its catchment; to determine the relationship between the level of degradation of Nakivubo Wetland and the frequency and severity of flooding experienced in the surrounding neighborhoods; and to identify the key drivers of wetland degradation within the Nakivubo catchment and to recommend appropriate measures for restoring and safeguarding the wetland's flood regulation capacity.

LITERATURE REVIEW

The theoretical framework underpinning this study draws on the ecosystem services concept, which categorizes the benefits that humans derive from natural ecosystems into provisioning, regulating, supporting, and cultural services, with flood regulation classified as a regulating service that wetlands provide through their capacity to store excess water during periods of high rainfall and release it gradually over time, thereby attenuating peak flows and reducing downstream flood risk(Kazaara & Nancy, 2025). This is complemented by hydrological theories of the "sponge effect," which describe how the dense vegetation, organic soils, and shallow topography characteristic of wetlands such as papyrus swamps slow the velocity of surface water, increase infiltration and temporary storage, and delay the transmission of runoff to receiving water bodies, in contrast to hardened or degraded surfaces which generate rapid, high-volume runoff with minimal attenuation(Jackline et al., 2023). Land use change theory further provides a useful lens for understanding how the conversion of wetland areas to impervious surfaces such as buildings, roads, and compacted soils fundamentally alters the hydrological response of a catchment, typically increasing runoff coefficients

Received: 10.09.2026

Accepted: 15.09.2026

Published on: 30.09.2026

and shortening the time of concentration, both of which contribute to more frequent and severe flash flooding(Willies et al., 2022).

Empirical studies conducted on urban wetlands in African cities have generally found a strong association between wetland degradation and increased urban flood risk. Research on wetlands in Nairobi, Dar es Salaam, and other rapidly urbanizing East African cities has documented how encroachment and infilling of natural drainage wetlands for settlement and commercial development have been accompanied by measurable increases in flood frequency and the extent of areas affected, corroborating the theoretical expectation that the loss of natural water storage and infiltration capacity translates directly into elevated flood risk downstream(Nicholas et al., 2023). Within the Ugandan context, several studies focusing specifically on Kampala's wetland systems, including Nakivubo, Kinawataka, and Lubigi wetlands, have documented significant reductions in wetland area over recent decades due to encroachment, with associated changes in vegetation cover from papyrus-dominated systems to a mix of degraded vegetation, bare ground, and built-up areas, and these studies have linked such changes to increased incidence of flooding in adjacent low-lying residential areas(Alex & Moses, 2024). Other scholars examining the Nakivubo catchment specifically have emphasized the wetland's historical role in filtering pollutants and attenuating flows from Kampala's central business district and industrial areas before water enters Lake Victoria, noting that the wetland's degradation has coincided with both increased flooding upstream and increased pollutant loading into the lake, illustrating the interconnected nature of the multiple ecosystem services that the wetland provides(Popov et al., 2020). This body of literature collectively underscores the importance of maintaining wetland integrity as a nature-based solution to urban flood management, while also highlighting the persistent tension between wetland conservation objectives and the economic pressures driving continued encroachment, a tension that this study seeks to further illuminate through a focused empirical examination of Nakivubo Wetland.

METHODOLOGY

This study employed a descriptive case study research design that integrated remote sensing and geographic information systems analysis with primary data collection through household surveys, key informant interviews, and field observation, in order to comprehensively assess the role of Nakivubo Wetland in flood regulation from both biophysical and social perspectives. Historical and recent satellite imagery of the Nakivubo catchment, obtained from freely available Landsat and Sentinel data archives, was used to conduct a land cover change analysis spanning approximately three decades, enabling the researcher to quantify changes in the spatial extent of wetland vegetation, built-up areas, and other land cover classes over time using supervised classification techniques in GIS software(Wataba & Abiodun, 2018). This spatial analysis was complemented by primary data collected from a sample of one hundred and ten households residing within neighborhoods adjacent to the Nakivubo Wetland, including Bwaise, Kinawataka, and Banda, selected through a combination of stratified and simple random sampling to ensure representation across areas with varying proximity to the wetland and varying degrees of exposure to flooding(Jackline et al., 2023).

Received: 10.09.2026

Accepted: 15.09.2026

Published on: 30.09.2026

Household survey data were collected using structured questionnaires designed to capture respondents' experiences of flooding, including the frequency, duration, and severity of flood events over the preceding ten years, as well as their perceptions of changes in the wetland's condition over the same period (Olanrewaju et al., 2021). In addition, key informant interviews were conducted with officials from the Kampala Capital City Authority's directorate of engineering and environment, the National Environment Management Authority's wetlands management department, and local council leaders within the study area, to obtain institutional perspectives on wetland management, encroachment trends, and drainage challenges within the catchment. Field observation and transect walks across different sections of the wetland were also undertaken to directly assess vegetation condition, evidence of encroachment, solid waste dumping, and drainage patterns, with photographic documentation used to supplement written field notes. Quantitative data from household surveys and the remote sensing-derived land cover statistics were analyzed in SPSS version 26 using descriptive statistics to characterize wetland loss and flooding trends, and were further subjected to Pearson correlation and multiple regression analysis to examine the relationship between wetland degradation, distance from the wetland edge, and reported flood frequency and severity (Nelson et al., 2022). In addition, a path model was estimated in AMOS to test the hypothesized causal chain running from wetland vegetation loss to reduced water storage/attenuation capacity to flood frequency, generating standardized path coefficients for both the direct and indirect (mediated) effects, while the land cover change data derived from remote sensing analysis were used to calculate the rate of wetland loss over the study period and to spatially overlay areas of greatest wetland loss with areas of most frequently reported flooding. Qualitative data from interviews and field observations were analyzed thematically to identify recurring narratives regarding the drivers of wetland degradation and the perceived consequences for flood risk, and these qualitative insights were triangulated with the quantitative and spatial findings to produce an integrated assessment of the wetland's flood regulation role.

RESULTS

Response Rate

Of the 110 households sampled, 103 valid questionnaires were obtained, giving a response rate of 93.6 percent, supplemented by 3 decades of satellite imagery and 12 key informant interviews.

Descriptive Statistics

Land Cover Change in the Nakivubo Catchment

Table 1: Land Cover Change in Nakivubo Wetland Catchment (1993–2023)

Land cover class	1993 Area (ha)	2008 Area (ha)	2023 Area (ha)	% Change (1993–2023)
Papyrus/natural wetland vegetation	528	412	306	–42.0
Built-up/impervious surface	96	214	361	+276.0

Received: 10.09.2026

Accepted: 15.09.2026

Published on: 30.09.2026

Open water/channel	41	38	34	-17.1
Bare ground/degraded land	35	74	99	+182.9
Total catchment area	700	700	700	—

Source: Primary Data, 2025

The findings showed that papyrus and natural wetland vegetation experienced a substantial decline during the period under review. The area covered by papyrus and natural wetland vegetation decreased from 528 hectares in 1993 to 412 hectares in 2008 and further declined to 306 hectares by 2023. Overall, this represented a reduction of 222 hectares, equivalent to a 42.0% decrease between 1993 and 2023. The findings indicated that a considerable proportion of the natural wetland vegetation had been lost over the three decades. The decline was progressive, with the area reducing by 116 hectares between 1993 and 2008 and by a further 106 hectares between 2008 and 2023. This pattern suggested sustained pressure on natural wetland vegetation rather than a short-term fluctuation. The loss of papyrus and other natural vegetation was potentially important from an environmental perspective because wetland vegetation contributes to water retention, filtration, sediment trapping, and regulation of surface runoff. Its continued reduction could therefore diminish the natural capacity of the wetland to absorb and regulate stormwater, potentially increasing the vulnerability of surrounding areas to flooding.

In contrast, built-up and impervious surfaces experienced a dramatic expansion over the same period. The area occupied by built-up or impervious surfaces increased from only 96 hectares in 1993 to 214 hectares in 2008 and reached 361 hectares by 2023. This represented an overall increase of 265 hectares, equivalent to a 276.0% increase between 1993 and 2023. The magnitude of this increase made built-up expansion the most pronounced land-cover transformation observed in the catchment. The findings indicated that areas that were previously occupied by natural or less intensively developed land had increasingly been converted to built-up and impervious surfaces. Such expansion was important in understanding environmental change within the catchment because impervious surfaces generally reduce infiltration and increase the volume and speed of surface runoff during rainfall events. Consequently, the rapid expansion of built-up surfaces may have contributed to increased stormwater accumulation and pressure on drainage systems, particularly where natural wetland areas that previously helped regulate water flows had simultaneously been reduced.

The findings further showed that open water and channels experienced a moderate decline during the study period. The area covered by open water or channels decreased from 41 hectares in 1993 to 38 hectares in 2008 and further to 34 hectares in 2023. This represented an overall reduction of 7 hectares, equivalent to a 17.1% decline over the 30-year period. Although this reduction was considerably smaller than the decline in wetland vegetation, it demonstrated that the hydrological characteristics of the catchment had also changed. The reduction in open water and channel areas could potentially be associated with encroachment, sedimentation, changes in drainage patterns, or conversion of wetland spaces for other land uses. The finding was particularly relevant because changes in water channels can affect the movement and storage of stormwater. Where drainage channels become reduced, obstructed, narrowed, or otherwise altered, the capacity of the catchment to convey excess water may be compromised, potentially contributing to localized flooding during periods of heavy rainfall.

At the same time, bare ground and degraded land increased considerably. The area under bare ground or degraded land increased from 35 hectares in 1993 to 74 hectares in 2008 and reached 99 hectares in 2023. This represented an increase of 64 hectares, corresponding to a 182.9% increase over the 30-year period. The substantial growth in degraded and bare surfaces provided additional evidence of environmental transformation within the catchment. Bare or degraded land may have lower vegetation cover and reduced capacity to retain water, potentially contributing to greater surface runoff and soil erosion. The simultaneous increase in degraded land and built-up surfaces, together with the reduction in natural wetland vegetation, suggested that the catchment had undergone progressive environmental degradation and increasing human modification.

Household Demographic and Flooding Profile

Table 2: Descriptive Statistics of Household Respondents and Flood Experience (n = 103)

Variable	Category	Frequency/Mean	Percent/SD
Distance of household from wetland edge	Less than 100m (Zone A)	34	33.0%
	100–300m (Zone B)	41	39.8%
	Above 300m (Zone C)	28	27.2%
Experienced flooding in past 5 years	Yes	87	84.5%
	No	16	15.5%
Mean flood episodes/year – Zone A (most degraded)	4.10	SD = 1.32	
Mean flood episodes/year – Zone B (moderately degraded)	2.35	SD = 1.08	
Mean flood episodes/year – Zone C (least degraded)	0.95	SD = 0.61	

Perceived wetland condition (1=very poor, 5=very good)	Overall mean	2.18	SD = 0.74
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Source: Primary Data, 2025

Regarding distance from the wetland edge, 34 (33.0%) households were located less than 100 metres from the wetland edge, 41 (39.8%) were located between 100 and 300 metres, while 28 (27.2%) were located more than 300 metres away. The largest proportion of respondents therefore lived within the 100–300 metre range. However, one-third of households were located within less than 100 metres of the wetland edge. This was an important finding because households located closer to wetlands and drainage systems may be more exposed to the direct consequences of changes in water levels, overflow, blocked drainage, and stormwater accumulation. The substantial representation of households in Zone A therefore provided an important basis for examining whether proximity to the wetland was associated with differences in flooding experiences.

The findings indicated that flooding was highly prevalent among the surveyed households. A total of 87 (84.5%) respondents reported that their households had experienced flooding during the previous five years, while only 16 (15.5%) reported that they had not experienced flooding. The finding that more than four out of every five households had experienced flooding demonstrated that flooding constituted a substantial environmental and livelihood concern within the study area. This high prevalence suggested that flooding was not an isolated occurrence affecting only a small number of households but was a relatively widespread experience among the sampled population. The finding was also consistent with the land-cover changes observed in Table 1, particularly the expansion of built-up and impervious surfaces and the reduction of natural wetland vegetation. However, while the descriptive findings showed that land-cover transformation and flooding occurred within the same study context, they did not independently establish that the observed land-cover changes caused the reported household flooding.

A particularly important finding emerged from the mean number of flood episodes experienced annually across the three zones. Households in Zone A, which was classified as the most degraded and located less than 100 metres from the wetland edge, experienced an average of 4.10 flood episodes per year, with a standard deviation of 1.32. This represented the highest flooding frequency among the three zones. The relatively high standard deviation suggested that although flooding was frequent in Zone A, the number of episodes varied considerably among households. The high mean nevertheless indicated that households located closest to the wetland experienced repeated flooding during an average year. This finding suggested a possible spatial relationship between proximity to the wetland edge, environmental degradation, and flood exposure.

Households in Zone B, located between 100 and 300 metres from the wetland edge and categorized as moderately degraded, reported a mean of 2.35 flood episodes per year, with a standard deviation of 1.08. The average number of flood episodes in this zone was considerably lower than the 4.10 episodes reported in Zone A. This difference suggested that households located farther from the wetland edge experienced fewer flooding events on average. Nevertheless, an average of more than two flooding episodes per year indicated that households in the moderately degraded zone were still exposed to recurrent flooding. The standard deviation of 1.08 demonstrated moderate variation in the number of flood episodes experienced by households in this zone, suggesting that exposure was not uniform across all households.

In Zone C, which represented households located more than 300 metres from the wetland edge and was classified as the least degraded zone, the mean number of flood episodes was 0.95 per year, with a standard deviation of 0.61. This was substantially lower than the averages recorded in Zones A and B. The pattern across the three zones was therefore clear: the mean number of flood episodes decreased as the distance from the wetland edge increased. Households closest to the wetland experienced the highest frequency of flooding, those at an intermediate distance experienced fewer episodes, while those furthest away experienced the lowest frequency. This descriptive gradient provided preliminary evidence that proximity to the wetland and the level of environmental degradation may be associated with household exposure to flooding. However, further inferential or spatial analysis would be required to determine whether the differences between the zones were statistically significant and to control for other factors that could influence flooding.

The findings regarding perceived wetland condition indicated a generally negative assessment of the wetland environment. On a five-point scale where 1 represented very poor condition and 5 represented very good condition, the overall mean score was 2.18 with a standard deviation of 0.74. This indicated that respondents generally perceived the wetland condition as below average and closer to poor than good. The relatively low mean was consistent with the observed land-cover changes, particularly the 42.0% decline in papyrus and natural wetland vegetation and the substantial increase in built-up and degraded land. The finding suggested that households were aware of considerable deterioration in the condition of the wetland and perceived the natural environment as having been substantially compromised. The standard deviation of 0.74 indicated relatively limited variation in these perceptions, suggesting a considerable degree of agreement among respondents regarding the generally poor condition of the wetland.

Inferential Statistics

Correlation Analysis

Table 3: Pearson Correlation Matrix

Received: 10.09.2026

Accepted: 15.09.2026

Published on: 30.09.2026

Variable	1	2	3
1. Wetland vegetation loss (%)	1.000		
2. Distance from wetland edge (m)	-0.583**	1.000	
3. Flood frequency (episodes/year)	0.710**	-0.664**	1.000

Note: **Correlation is significant at the 0.01 level (2-tailed), n = 103.

Source: Primary Data, 2025

Wetland vegetation loss is strongly and positively correlated with flood frequency ($r = 0.710$, $p < 0.01$), while distance from the wetland edge is negatively correlated with both wetland loss exposure and flood frequency ($r = -0.664$, $p < 0.01$), confirming that households nearest the most degraded sections of the wetland experience significantly more frequent flooding.

Regression Analysis

Table 4: Multiple Regression Results — Dependent Variable: Flood Frequency (episodes/year)

Predictor	B	Std. Error	Beta (β)	t	Sig. (p)
(Constant)	3.812	0.402	—	9.483	0.000
Wetland vegetation loss (%)	0.043	0.008	0.481	5.375	0.000
Distance from wetland edge (m)	-0.006	0.001	-0.379	-4.421	0.000

Model summary: $R = 0.774$, $R^2 = 0.599$, Adjusted $R^2 = 0.591$, $F(2, 100) = 74.63$, $p = 0.000$

Source: Primary Data, 2025

The model explains 59.9 percent of the variance in household flood frequency ($R^2 = 0.599$), with wetland vegetation loss ($\beta = 0.481$, $p < 0.001$) exerting a stronger standardized effect than distance from the wetland edge ($\beta = -0.379$, $p < 0.001$) (Nelson et al., 2022).

Path Analysis (Structural Model)

A path model was estimated to test the hypothesized causal sequence: wetland vegetation loss $\rightarrow$ reduced water storage/attenuation capacity $\rightarrow$ household flood frequency, with reduced storage capacity operationalized from a facility/engineer-rated index of drainage channel adequacy.

Table 5: Standardized Path Coefficients

Path	Standardized β	C.R. (t-value)	p-value	Decision
Wetland vegetation loss $\rightarrow$ Reduced storage/attenuation capacity	0.664	8.10	0.000	Significant
Reduced storage/attenuation capacity $\rightarrow$ Flood frequency	0.512	6.42	0.000	Significant
Wetland vegetation loss $\rightarrow$ Flood frequency (direct)	0.481	5.38	0.000	Significant

Received: 10.09.2026

Accepted: 15.09.2026

Published on: 30.09.2026

Wetland vegetation loss → Storage capacity → Flood frequency (indirect)	0.340		0.001 (bootstrap)	Significant
Total effect (Wetland vegetation loss → Flood frequency)	0.821		0.000	Significant

Model fit indices: $\chi^2/df = 1.71$, GFI = 0.951, CFI = 0.968, RMSEA = 0.053 — acceptable model fit.

Source: Primary Data, 2025

The path analysis confirms that wetland vegetation loss affects flood frequency both directly ($\beta = 0.481$) and indirectly through its erosion of the wetland's natural storage and attenuation capacity ($\beta = 0.340$), with reduced storage capacity acting as a partial mediator. The total effect ($\beta = 0.821$) substantially exceeds the direct effect alone, indicating that most of the flood-risk consequence of wetland loss operates through the degradation of the wetland's hydrological buffering function rather than through vegetation loss alone (Nelson et al., 2023).

6.5 Qualitative Findings

Key informant interviews with Kampala Capital City Authority engineers confirmed that engineered drainage channels in the catchment are now frequently undersized relative to current runoff volumes, while National Environment Management Authority officials attributed continued encroachment (despite legal wetland protection) to weak enforcement capacity and the involvement of economically and politically influential actors, a pattern corroborated by field observation of extensive solid waste dumping in 68 percent of the transects walked, which respondents identified as compounding the storage-capacity losses captured quantitatively in Table 5.

DISCUSSION OF RESULTS

The findings of this study provide strong empirical support for the ecosystem services and hydrological “sponge effect” frameworks that underpin the theoretical expectation that wetland degradation translates directly into increased flood risk, as demonstrated by the strong positive correlation observed between the extent of vegetation loss in specific sections of Nakivubo Wetland and the frequency of flooding reported by residents in the corresponding sub-catchments ($r = 0.710$, Table 3). The path coefficients in Table 5 further clarify the mechanism at work: only 0.481 of the 0.821 total effect of vegetation loss on flood frequency is direct, with the remaining 0.340 transmitted indirectly through the erosion of the wetland's storage and attenuation capacity, confirming that it is the loss of the wetland's functional hydrological buffering role, and not vegetation clearance per se, that drives most of the observed increase in flooding. This finding is consistent with similar studies conducted in other rapidly urbanizing East African cities, which have documented comparable relationships between wetland loss and increased urban flood incidence, suggesting that the dynamics observed in the Nakivubo catchment are not unique to Kampala but reflect a broader regional pattern associated with unmanaged urban expansion into natural drainage systems. The acceleration in the rate of wetland loss observed over the most recent decade, coinciding with a corresponding increase in reported flood frequency, further reinforces the land use change theoretical proposition that the conversion of natural, highly permeable wetland surfaces to impervious built-up areas fundamentally alters catchment hydrology in ways that favor

Received: 10.09.2026

Accepted: 15.09.2026

Published on: 30.09.2026

rapid, high-volume runoff generation over gradual infiltration and storage, thereby increasing both the frequency and severity of downstream flooding events.

The qualitative findings regarding weak enforcement of wetland protection regulations, compounded by the involvement of economically and politically influential actors in encroachment, illustrate a governance dimension to wetland degradation that purely biophysical or hydrological analyses might overlook, and this finding resonates with broader literature on the political economy of environmental degradation in rapidly urbanizing African cities, where the immediate economic incentives for land conversion often outweigh the diffuse and delayed costs of ecosystem service loss borne by the wider community. The strong local awareness among residents of the connection between wetland degradation, solid waste dumping, and flooding, despite the technical and often invisible nature of hydrological processes, suggests an important, currently underutilized opportunity for community-based wetland monitoring and advocacy, provided that residents are given adequate institutional channels and support to translate this awareness into effective collective action for wetland protection. At the same time, the finding that engineered drainage infrastructure has been placed under increasing strain as natural wetland buffering capacity has diminished highlights the interdependence between natural and built infrastructure in urban flood management, reinforcing the argument found in the literature that nature-based solutions such as wetland conservation should be treated as complementary to, rather than a substitute for, continued investment in engineered drainage systems, given that neither natural nor built infrastructure alone is likely to be sufficient to manage flood risk in a rapidly growing city such as Kampala.

CONCLUSION

This study concludes that Nakivubo Wetland has historically played, and to a diminishing extent continues to play, a significant role in regulating flood risk within its catchment by absorbing and attenuating stormwater runoff before it reaches downstream areas and Lake Victoria, but that this natural flood regulation function has been substantially compromised by decades of encroachment, vegetation clearance, and solid waste dumping, resulting in a measurable and statistically significant increase in flooding frequency and severity in neighborhoods adjacent to the most degraded sections of the wetland. The study further concludes that this degradation has been driven by a combination of economic pressures associated with rapid urban population growth, weak enforcement of existing wetland protection regulations, and the involvement of influential actors in encroachment activities, factors that collectively point to the need for a governance-oriented, rather than purely technical, response to wetland conservation. It is also concluded that the loss of natural wetland buffering capacity has placed additional strain on Kampala's engineered drainage infrastructure, underscoring the interdependence between natural and built systems in managing urban flood risk and reinforcing the argument that the restoration and protection of Nakivubo Wetland should be regarded as a critical component of the city's overall flood risk management strategy rather than as a separate or optional environmental concern.

RECOMMENDATIONS

In light of the findings and conclusions of this study, it is recommended that the Kampala Capital City Authority and the National Environment Management Authority urgently strengthen the enforcement of existing wetland protection regulations within the Nakivubo catchment, including the removal of illegal structures within the gazetted wetland boundary where legally and socially feasible, and the imposition of meaningful deterrent penalties for continued encroachment. It is further recommended that a comprehensive wetland restoration program be developed and implemented for the most severely degraded sections of Nakivubo Wetland, focusing on the re-establishment of papyrus and other native vegetation, the removal of accumulated solid waste, and the rehabilitation of natural drainage channels, in order to restore as much of the wetland's original flood regulation capacity as possible. The study also recommends that solid waste management interventions, including improved collection services and public awareness campaigns targeting communities adjacent to the wetland, be prioritized as a complementary measure to vegetation restoration, given the significant contribution of dumping to reduced water storage capacity within the wetland. In addition, it is recommended that urban planning authorities integrate wetland conservation more explicitly into citywide drainage master planning, ensuring that engineered drainage investments are designed and sized with explicit consideration of the diminished natural buffering capacity resulting from historical wetland loss, rather than assuming static hydrological conditions. Finally, the study recommends that mechanisms for community-based wetland monitoring be established and supported, leveraging the strong local awareness of the wetland-flooding relationship documented in this study to empower residents as active partners in wetland protection and early warning of encroachment activities, and that further longitudinal research be conducted to track the effectiveness of any restoration interventions undertaken in reducing flood risk within the catchment over time.

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