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The Role of Nature-Based Solutions in Building Urban Climate Resilience in Rwanda: A Case Study of Gasabo District

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Abstract

This study examined the role of Nature-Based Solutions (NbS) in enhancing urban climate resilience in Gasabo District, Kigali City, Rwanda, focusing on biodiversity conservation, flood risk reduction, and climate regulation. A mixed-methods design was used, combining quantitative data from 400 household respondents across 15 sectors, qualitative insights from 15 key informants, and GIS/Remote Sensing analysis of Land Use Land Cover (LULC) and NDVI changes between 2005 and 2025. Findings show that NbS interventions such as urban tree planting, agroforestry, and wetland restoration are widely implemented. Vegetation cover increased from 27% in 2005 to 39% in 2025, while mean NDVI rose from 0.680 to 0.726, indicating improved ecosystem health. Results further confirm strong contributions of NbS to biodiversity, flood reduction, and climate regulation. Correlation analysis revealed strong positive relationships between NbS and urban resilience indicators. The study concludes that NbS significantly enhance urban climate resilience and recommends scaling up interventions, improving institutional coordination, and integrating NbS into urban planning and climate adaptation strategies.

Keywords: *Agroforestry; Biodiversity Conservation; Climate Change Adaptation; Flood Risk Reduction; GIS; Nature-Based Solutions; Urban Resilience*.

1. Introduction

At the global level, climate change is increasingly threatening sustainable urban development by intensifying floods, droughts, heatwaves, and other extreme events that disproportionately affect urban populations (IPCC, 2021). Rapid urbanization and environmental degradation have further increased city vulnerability, driving the adoption of Nature-Based Solutions (NbS) as ecosystem-based strategies that enhance resilience while delivering social, economic, and ecological co-benefits (Cohen-Shacham et al., 2016). Globally, cities are integrating interventions such as urban forests, wetlands, green infrastructure, and reforestation into planning systems to reduce flooding, mitigate urban

heat, and improve air quality (Kabisch et al., 2017).

In Africa, especially Sub-Saharan regions, climate risks are amplified by unplanned urban growth, weak infrastructure, and socio-economic vulnerability. Cities like Lagos, Nairobi, and Accra face recurrent flooding and environmental degradation linked to ecosystem loss and poor drainage systems (Adelekan, 2016). Although African countries are adopting NbS such as wetland conservation and urban greening, implementation is constrained by limited funding, weak coordination, and insufficient monitoring, with limited evidence on long-term effectiveness (Adelekan, 2016).

In Rwanda, NbS are central to national climate strategies, including wetland restoration, urban greening, and agroforestry supported by the Green Growth and Climate Resilience Strategy and the Rwanda Green Fund (Ministry of Environment, 2019; 2023). In Gasabo District, initiatives like Nyandungu Wetland restoration aim to address flooding, biodiversity loss, and rising emissions. However, challenges such as rapid urbanization, wetland encroachment, and recurring floods persist. Despite strong policy commitment, there is limited empirical evidence on NbS effectiveness. This study addresses this gap by assessing their contribution to biodiversity, flood reduction, and climate regulation.

1.2 Objectives of the Research

1.2.1 General objective

The general objective of the study is to examine the contribution of selected Nature-Based Solutions in building urban climate resilience in Gasabo District, Kigali, Rwanda.

1.2.2. Specific objectives

(i) To assess the implementation level and spatial distribution of selected Nature-Based Solutions in Gasabo District using community perceptions and GIS/Remote Sensing analysis.
(ii) To evaluate the contribution of selected Nature-Based Solutions to urban climate resilience in Gasabo District through biodiversity conservation, flood risk reduction, and climate regulation indicators.
(iii) To determine the relationship between Nature-Based Solutions interventions and urban climate resilience in Gasabo District.

2. Research methods

2.1 Description of the study area

This study was conducted in Gasabo District, one of the three administrative districts constituting Kigali City, Rwanda. According to the Fifth Population and Housing Census (NISR, 2023), Gasabo District has a population of approximately 879,505 inhabitants, representing about 50.4% of Kigali City's total population, making it the most populated district in the city. The district covers both urban and rural settings and comprises fifteen sectors namely: Bumbogo, Gatsata, Gikomero, Gisozi, Jabana, Jali, Kacyiru, Kimihurura, Kimironko, Kinyinya, Ndera, Nduba, Remera, Rusororo, and Rutunga.

Gasabo District was selected because of its rapid urbanization and the implementation of multiple NbS initiatives aimed at enhancing environmental sustainability and climate

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resilience. The district hosts several ecological restoration and environmental management interventions including wetland restoration projects such as Nyandungu Eco-Park, urban tree planting initiatives, and agroforestry systems. Furthermore, the district exhibits diverse land use characteristics, ranging from highly urbanized sectors to peri-urban and rural areas, making it suitable for assessing the implementation and spatial distribution of Nature-Based Solutions and their contribution to urban climate resilience.

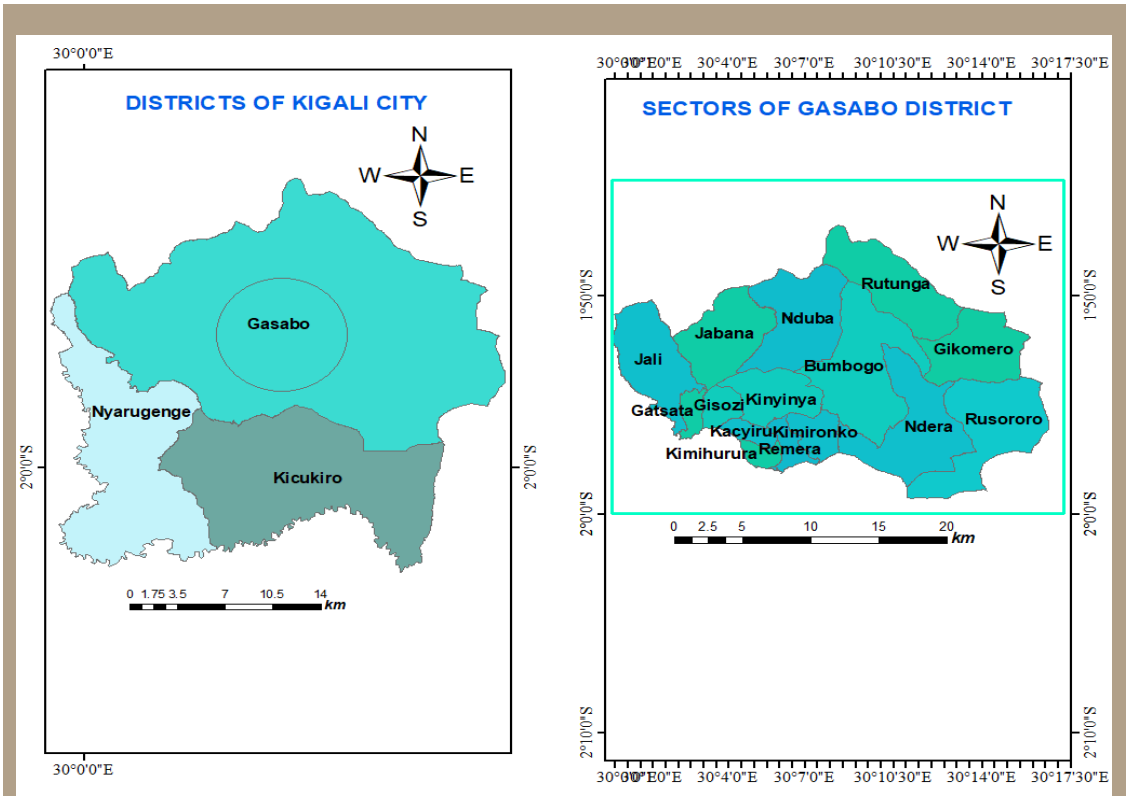

Figure 3.1.Geographical location map of the study area

Source: Researcher mapping in Arc GIS 10.8, 2025

2.2. Research design and data collection methods

This study adopted mixed-methods research design integrating quantitative, qualitative, and geospatial approaches to assess the contribution of Nature-Based Solutions (NbS) to urban climate resilience in Gasabo District. The quantitative component employed a cross-sectional survey design, while the qualitative component utilized Key Informant Interviews (KIIs). The target population comprised community members residing in the fifteen sectors of Gasabo District, estimated at 879,505 residents according to the Fifth Rwanda Population and Housing Census (NISR, 2022), and institutional stakeholders involved in environmental governance and NbS implementation. Using Yamane's formula with a 5% margin of error, a sample size of 400 household respondents was determined for the survey, complemented by 15 purposively selected key informants, resulting in a total sample of 415 participants.

A mixed sampling strategy was employed, combining stratified random sampling for household respondents and purposive sampling for key informants. Stratified random sampling ensured proportional representation across the fifteen sectors, while purposive

sampling enabled the selection of knowledgeable stakeholders from relevant institutions. Data was collected using structured questionnaires, semi-structured interview guides, document reviews, and GIS/Remote Sensing tools. Spatial data from Landsat and Sentinel satellite imagery were analyzed using Land Use and Land Cover (LULC) classification and the Normalized Difference Vegetation Index (NDVI) to assess environmental changes between 2005 and 2025. Validity was ensured through expert review, pre-testing of instruments with 20 respondents, and methodological triangulation. Reliability was assessed using Cronbach's Alpha, with a coefficient of 0.70 or above considered acceptable, alongside standardized data collection procedures to ensure consistency.

3.6. Data analysis and processing

After data collection, all questionnaires, interview transcripts, observation notes, and documentary materials were reviewed to ensure completeness, consistency, and accuracy. Quantitative data obtained from household surveys were coded and entered SPSS version 29 for analysis. Likert-scale responses were assigned numerical values ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), and the dataset was verified through data-cleaning procedures to minimize errors. Qualitative data from Key Informant Interviews (KIIs) were transcribed verbatim and organized into thematic categories related to Nature-Based Solutions (NbS), governance structures, institutional coordination, and community participation. The study employed a mixed-methods analytical approach that integrated quantitative, qualitative, and geospatial techniques. Descriptive statistics, including frequencies, percentages, mean scores, and standard deviations, were used to assess the implementation of NbS and their contribution to biodiversity conservation, flood risk reduction, and climate regulation. Qualitative data were analyzed using thematic content analysis to provide deeper insights into policy implementation, governance systems, institutional support, and implementation challenges.

To determine the relationship between Nature-Based Solutions and urban climate resilience, inferential statistical analyses were conducted using Pearson Product-Moment Correlation and Multiple Linear Regression in SPSS version 29. These analyses examined the strength, direction, and predictive influence of exposure to NbS, implementation levels, and institutional support on urban climate resilience indicators. Additionally, GIS and Remote Sensing techniques were utilized to analyze Land Use and Land Cover (LULC) changes and vegetation dynamics between 2005 and 2025 using Landsat and Sentinel satellite imagery. The Normalized Difference Vegetation Index (NDVI) was calculated to assess vegetation density, ecosystem health, and ecological restoration trends. Findings were presented through tables, charts, thematic maps, and descriptive interpretations. The integration of statistical, qualitative, and geospatial analyses strengthened methodological triangulation and generated comprehensive evidence on the contribution of Nature-Based Solutions to urban climate resilience in Gasabo District.

3. Results

3.1 Socio-Demographic Characteristics of Respondents

The socio-demographic characteristics of respondents were analyzed to establish the background profile of participants and assess their suitability for providing information on Nature-Based Solutions (NbS) and urban climate resilience in Gasabo District. A total of 400 valid responses were obtained, with no missing values recorded, indicating a complete dataset for statistical analysis. Table 4.1 presents the descriptive statistics for the key socio-

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demographic variables considered in the study.

Table *3*:1. Descriptive Statistics of Socio-Demographic of Respondents

		Gender	Age Group	Education Level	Occupation	Sector of Residence	Length of residence
N	Valid	400	400	400	400	400	400
	Missing	0	0	0	0	0	0
Mean		1.54	2.53	2.39	2.20	7.80	3.15
Median		2.00	3.00	2.00	1.00	9.00	3.00
Mode		2	3	2	1	10	4
Std. Deviation		.499	.981	.764	1.675	4.320	.956
Variance		.249	.962	.583	2.804	18.662	.915

Source: Researcher, 2026

The socio-demographic characteristics of respondents indicate a generally suitable and representative sample for assessing Nature-Based Solutions (NbS) in Gasabo District. The gender composition was relatively balanced, with females accounting for 53.8% and males 46.3%, reflecting a slight female predominance. This balance strengthens the study because men and women interact differently with environmental resources and may experience climate change impacts differently. The age structure shows that most respondents were within the economically active group, particularly the 26–45 years category, suggesting that participants were actively engaged in livelihood activities and capable of observing long-term environmental changes such as flooding, vegetation cover, and ecosystem restoration. Educational levels were mainly primary and secondary, which was adequate since the study focused on observable environmental perceptions rather than technical ecological measurements. Occupationally, farming dominated, highlighting respondents' direct dependence on natural resources and their exposure to NbS interventions such as agroforestry, soil conservation, and wetland restoration.

Spatially, respondents were drawn from all fifteen sectors of Gasabo District, ensuring broad geographical coverage across urban, peri-urban, and rural settings. This enhances the representativeness of the findings because NbS implementation varies across different ecological and socio-economic contexts. In addition, many respondents had lived in the area for more than twenty years, indicating strong local environmental knowledge and the ability to reliably assess changes in biodiversity, flooding patterns, and land use over time. Overall, the socio-demographic profile demonstrates that the sample was well suited for the study, as it combined gender balance, economic activity, agricultural engagement, long-term residence, and spatial diversity, thereby strengthening the validity and reliability of findings on NbS implementation and urban climate resilience in Gasabo District.

3.1 Implementation Level of Nature-Based Solutions in Gasabo District

Table *3*:2. Descriptive Statistics of Implementation Nature Based Solution Statistics

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		Wetland restoration projects are well implemented in my area	Urban tree planting programs are adequately implemented	Agroforestry practices are effectively promoted	Government institutions support NbS implementation	Community members actively participate in NbS programs
N	Valid	400	400	400	400	400
	Missing	0	0	0	0	0
Mean		3.34	4.02	4.17	4.56	4.39
Median		4.00	4.00	4.00	5.00	4.00
Mode		5	5	4	5	4
Std. Deviation		1.544	1.135	.879	.590	.658
Variance		2.384	1.288	.773	.348	.433
Range		4	4	4	4	4

Source: Researcher, 2026

The findings revealed that Nature-Based Solutions (NbS) are implemented at a generally high level across Gasabo District. Four of the five assessed indicators recorded mean scores above 3.50, indicating high implementation levels. Government institutional support achieved the highest mean score (M = 4.56), followed by community participation (M = 4.39), agroforestry promotion (M = 4.17), and urban tree planting programs (M = 4.02). In contrast, wetland restoration recorded a moderate implementation level (M = 3.34) and the highest variability among respondents, suggesting uneven implementation experiences across different sectors. The relatively low standard deviations for institutional support, community participation, and agroforestry indicate strong agreement among respondents regarding the effectiveness of these interventions.

The results demonstrate that the successful implementation of NbS in Gasabo District is largely driven by strong government support and active community engagement, consistent with Socio-Ecological Systems Theory which emphasizes the interaction between institutions and communities in environmental governance (Folke et al., 2016). Institutional commitment has facilitated the planning and coordination of environmental restoration initiatives, while community participation has strengthened local ownership and sustainability of interventions. Vegetation-based interventions such as agroforestry and urban tree planting were widely adopted and contribute to soil conservation, biodiversity enhancement, carbon sequestration, and climate regulation, aligning with Ecosystem Services Theory (MEA, 2005; Cohen-Shacham et al., 2016). However, wetland restoration initiatives were less consistently implemented across the district, indicating spatial disparities in ecosystem-based interventions. This uneven distribution may limit the effectiveness of wetlands in providing critical services such as flood regulation and biodiversity conservation, as emphasized in Urban Resilience Theory (Meerow et al., 2016). Overall, while Gasabo District demonstrates strong NbS implementation, expanding wetland restoration would enhance equitable distribution of resilience benefits across all sectors.

3.2 Contribution of Nature-Based Solutions to Biodiversity Conservation

Table 3:3 presents respondents' perceptions regarding the contribution of Nature-Based Solutions (NbS) to biodiversity conservation in Gasabo District. Biodiversity conservation

was assessed through five indicators, namely the increase in plant species, increase in animal and bird species, improvement of green spaces, protection of natural habitats, and overall improvement in biodiversity resulting from NbS interventions. The results reveal consistently high mean scores across all indicators, ranging from 4.07 to 4.37, indicating that respondents strongly perceive Nature-Based Solutions as making a substantial contribution to biodiversity conservation within the district.

Table *3*:3. Descriptive Statistics of Contribution of Nature-Based Solutions to Biodiversity Conservation

		There is an increase in plant species in my area	There is an increase in animal/bird species	Green spaces have improved in my community	NbS help protect natural habitats	Biodiversity has improved due to NbS
N	Valid	400	400	400	400	400
	Missing	0	0	0	0	0
Mean		4.23	4.07	4.33	4.37	4.30
Median		4.00	4.00	4.00	4.00	4.00
Mode		4	4	4	4	4
Std. Deviation		.765	.962	.654	.652	.704
Variance		.585	.925	.428	.425	.496
Range		4	4	4	4	4

Source: Researcher, 2026

The findings indicate that respondents strongly perceived positive biodiversity outcomes from Nature-Based Solutions (NbS) in Gasabo District. The increase in plant species recorded a high mean score (M = 4.23, SD = 0.765), suggesting that interventions such as urban tree planting, agroforestry, wetland restoration, and ecosystem rehabilitation have contributed to vegetation recovery and floral diversity. Similarly, improvements in green spaces were highly rated (M = 4.33, SD = 0.654), reflecting visible enhancements in urban green infrastructure that support both ecological and social functions. Respondents also strongly agreed that NbS help protect natural habitats (M = 4.37, SD = 0.652), indicating widespread recognition of their role in conserving wetlands, forests, and other ecosystems. Overall biodiversity improvement was also rated highly (M = 4.30, SD = 0.704), demonstrating a strong consensus that NbS contribute positively to ecological restoration across the district. These findings are consistent with Ecosystem Services Theory, which emphasizes the role of vegetation in supporting habitat provision, soil improvement, and climate regulation (MEA, 2005), as well as studies by Kabisch et al. (2017) and Cohen-Shacham et al. (2016) highlighting NbS contributions to urban ecological restoration.

In contrast, perceived increases in animal and bird species recorded a slightly lower but still high mean score (M = 4.07, SD = 0.962), with greater variability across respondents. This suggests that fauna recovery is less uniform and may lag behind vegetation restoration due to habitat requirements and ecological stability needs. Nevertheless, the positive trend indicates improving ecological balance and habitat connectivity, consistent with Urban Resilience Theory (Meerow et al., 2016). Overall, all indicators exceeded mean scores of 4.0, confirming a high perceived contribution of NbS to biodiversity conservation. The results demonstrate that ecosystem restoration initiatives in Gasabo District are enhancing natural habitats, improving green infrastructure, and strengthening ecological resilience.

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These findings strongly support Specific Objective II and align with Ecosystem Services, Socio-Ecological Systems, and Urban Resilience theories, which emphasize that biodiversity conservation and habitat protection are central pathways through which NbS enhance environmental sustainability and urban climate resilience (Folke et al., 2016; Kabisch et al., 2017).

3.3 Contribution of Nature-Based Solutions to Flood Risk Reduction

Table *3*:4. Descriptive Statistics of Contribution of Nature-Based Solutions to Flood Risk Reduction

		Flooding has reduced in my area	Wetlands help control water flow	Trees reduce water runoff	Soil erosion has decreased	NbS reduce damage caused by heavy rains
N	Valid	400	400	400	400	400
	Missing	0	0	0	0	0
Mean		4.35	4.33	4.44	4.41	4.42
Median		4.00	4.00	4.00	4.00	4.00
Mode		4	4	4	4	4
Std. Deviation		.658	.743	.602	.589	.608
Variance		.433	.552	.362	.347	.369
Range		4	4	4	4	4

Source: Researcher, 2026.

The findings indicate that Nature-Based Solutions (NbS) have made a substantial contribution to flood risk reduction in Gasabo District, with all indicators recording very high mean scores above 4.30. Respondents strongly agreed that NbS reduce flooding (M = 4.35), enhance wetland water regulation (M = 4.33), reduce surface runoff through urban trees (M = 4.44), minimize soil erosion (M = 4.41), and reduce damage from heavy rainfall (M = 4.42). These consistently high scores, supported by low variability in responses, reflect a strong consensus that NbS are effective in mitigating hydrological risks. The findings align with Ecosystem-based Adaptation (EbA) principles, which emphasize the use of natural ecosystems to reduce climate-related hazards such as floods (Seddon et al., 2020). They also correspond with Ecosystem Services Theory, which highlights regulating services such as water flow control, runoff reduction, and erosion prevention as key benefits of NbS (MEA, 2005; Kabisch et al., 2017).

The results further demonstrate that urban trees are perceived as the most effective NbS intervention for flood control (M = 4.44), highlighting their role in intercepting rainfall and enhancing infiltration. Wetlands were also recognized as important water regulators (M = 4.33), acting as natural storage systems that reduce peak flows and flood intensity. Similarly, high agreement on reduced soil erosion (M = 4.41) and reduced rainfall damage (M = 4.42) indicates that vegetation-based interventions are strengthening landscape stability and disaster risk reduction. Overall, the findings confirm that NbS significantly enhance urban climate resilience by improving hydrological regulation and reducing exposure to extreme weather events, consistent with Urban Resilience Theory and Socio-Ecological Systems Theory (Meerow et al., 2016; Folke et al., 2016). These results strongly support Objective II of the study, demonstrating that NbS are effective, scalable, and sustainable strategies for flood risk reduction in Gasabo District.

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3.4 Contribution of Nature-Based Solutions to Climate Regulation

Table 4:5 presents respondents' perceptions regarding the contribution of Nature-Based Solutions (NbS) to climate regulation in Gasabo District. The findings indicate that all climate regulation indicators recorded high mean scores above 4.0, demonstrating a strong perception that NbS interventions have contributed significantly to improving environmental conditions within the district. Specifically, respondents reported increased tree cover (M = 4.34, SD = 0.679), improved environmental greenness (M = 4.39, SD = 0.639), reduced temperatures due to vegetation (M = 4.30, SD = 0.696), improved air quality (M = 4.37, SD = 0.671), and increased vegetation on farms through agroforestry practices (M = 4.18, SD = 0.829). The consistently high mean scores suggest that communities are observing visible environmental improvements associated with the implementation of wetland restoration, urban tree planting, and agroforestry initiatives across Gasabo District.

Table *3*:5. Descriptive Statistics of Contribution of Nature-Based Solutions to Climate Regulation

		Tree cover has increased in my area	The environment is greener than before	Temperatures have reduced due to trees/vegetation	Air quality has improved in my area	Agroforestry has increased vegetation on farms
N	Valid	400	400	400	400	400
	Missing	0	0	0	0	0
Mean		4.34	4.39	4.30	4.37	4.18
Median		4.00	4.00	4.00	4.00	4.00
Mode		4	4	4	4	4
Std. Deviation		.679	.639	.696	.671	.829
Variance		.461	.409	.484	.450	.688
Range		4	4	4	4	4

Source: Researcher, 2026

The findings show that environmental greenness (M = 4.39) and improved air quality (M = 4.37) were among the highest-rated indicators, suggesting that respondents observed substantial increases in vegetation cover and overall environmental quality in their communities. These improvements are significant in urban contexts because vegetation enhances carbon storage, microclimate regulation, and ecological stability. The strong perception of improved air quality further reflects the benefits of increased tree cover and green spaces. Respondents also strongly agreed that tree cover had increased (M = 4.34) and that local temperatures had decreased due to vegetation growth (M = 4.30), indicating that Nature-Based Solutions (NbS) are contributing to urban cooling through shading and evapotranspiration processes. Agroforestry also recorded a high mean score (M = 4.18), although slightly lower than other indicators, suggesting variation in implementation across sectors due to differences in land availability and adoption levels.

These survey findings are strongly supported by GIS and Remote Sensing results, which show that forest and vegetation cover increased from 27% in 2005 to 39% in 2025, while degraded forest declined from 59% to 36%. Additionally, NDVI analysis revealed an improvement in vegetation health from 0.680 to 0.726 over the same period, confirming measurable ecological restoration. The alignment between perception data and spatial

analysis strengthens the validity of the findings. These results are consistent with Ecosystem Services Theory, which emphasizes regulating services such as climate regulation and air purification (MEA, 2005), and with studies by Kabisch et al. (2017) and Cohen-Shacham et al. (2016), which highlight the role of NbS in improving urban environmental quality. Overall, the findings demonstrate that NbS significantly enhance climate regulation and urban resilience in Gasabo District, supporting Sustainable Development and Urban Resilience Theory (Meerow et al., 2016).

4 Relationship Between Nature-Based Solutions and Urban Resilience Indicators

		Biodiversity_Index	Flood_Reduction_Index	Climate_Reguration_Index
Exposure_NBS_Index	Pearson Correlation	.684**	.589**	.655**
	Sig. (2-tailed)	.000	.000	.000
	N	400	400	400
Implementation_NBS_Index	Pearson Correlation	.761**	.707**	.697**
	Sig. (2-tailed)	.000	.000	.000
	N	400	400	400
Institution_Support_Index	Pearson Correlation	.747**	.692**	.709**
	Sig. (2-tailed)	.000	.000	.000
	N	400	400	400
	N	400	400	400

Correlation is significant at the 0.01 level (2-tailed).

This section presents the results of the Pearson correlation analysis examining the relationships between Nature-Based Solutions (NbS) and urban resilience indicators in Gasabo District. The analysis considered three independent variables (exposure to NbS, implementation of NbS, and institutional support) and their association with Biodiversity Conservation, Flood Risk Reduction, and Climate Regulation. The results show that all relationships are positive and statistically significant at the 0.01 level ($p < 0.01$), indicating strong and reliable associations between NbS interventions and urban resilience outcomes. This confirms that higher levels of NbS exposure, implementation, and institutional support are consistently linked with improved ecological and climate-related outcomes across the study area.

The analysis further shows strong interrelationships among the independent variables, with Exposure to NbS strongly correlated with Implementation ($r = 0.797$) and Institutional Support ($r = 0.694$), while Implementation is also strongly associated with Institutional Support ($r = 0.769$). This reflects a mutually reinforcing system where awareness, governance, and implementation capacity interact to strengthen NbS effectiveness, consistent with the Socio-Ecological Systems (SES) framework (Folke et al., 2016). Regarding biodiversity conservation, strong positive correlations were observed, particularly with Implementation ($r = 0.761$), Institutional Support ($r = 0.747$), and Exposure ($r = 0.684$), highlighting the importance of effective execution and governance in achieving ecological outcomes (MEA, 2005; Kabisch et al., 2017). Similarly, flood risk

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reduction shows strong relationships with Implementation (r = 0.707), Institutional Support (r = 0.692), and Exposure (r = 0.589), supporting Ecosystem-based Adaptation principles (Seddon et al., 2020). Climate regulation also exhibits strong correlations, especially with Institutional Support (r = 0.709), followed by Implementation (r = 0.697) and Exposure (r = 0.655), reinforcing the role of governance in climate resilience (Meerow et al., 2016). Overall, the findings confirm that NbS are strongly associated with urban resilience, with implementation quality and institutional support emerging as the most influential drivers.

4.1 Regression Analysis: Influence of Nature-Based Solutions on Urban Resilience

This section presents the results of the multiple linear regression analysis conducted to examine the influence of Nature-Based Solutions (NbS) on urban resilience to climate change in Gasabo District. The analysis considers three key explanatory variables: Exposure to NbS, Implementation of NbS, and Institutional Support as predictors of the Urban Resilience to Climate Change Index. The objective of this analysis is to determine the extent to which these factors contribute to variations in urban resilience and to identify the most influential drivers among them.

Table 0:6. Regression Analysis Model Summary

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.852[a]	.726	.724	.27180

a. Predictors: (Constant), Institution_Support_Index, Exposure_NBS_Index, Implementation_NBS_Index

The model summary results indicate a strong and statistically significant relationship between the independent variables and urban resilience. The correlation coefficient (R = 0.852) suggests a very strong positive association between NbS-related factors and urban resilience outcomes. The coefficient of determination (R^2 = 0.726) indicates that approximately 72.6% of the variation in urban resilience is explained by the combined effect of exposure, implementation, and institutional support. The adjusted R^2 (0.724) further confirms the robustness of the model, showing minimal shrinkage and suggesting that the model is well-fitted and generalizable. The standard error of the estimate (0.27180) is relatively low, indicating that the predicted values closely approximate the observed data. These findings demonstrate that NbS interventions and governance factors play a substantial role in shaping urban resilience in the study area.

Table 0:7. Regression Analysis ANOVA

ANOVA[a]

Model	Sum of Squares	df	Mean Square	F	Sig.

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1	Regression	77.426	3	25.809	349.367	.000[b]
	Residual	29.254	396	.074		
	Total	106.680	399			

a. Dependent Variable: Urban_Resilience_Climate_Change_Index
b. Predictors: (Constant), Institution_Support_Index, Exposure_NBS_Index, Implementation_NBS_Index

The ANOVA results further confirm the overall significance of the regression model. The model is statistically significant ($F = 349.367$, $p < 0.001$), indicating that the set of independent variables collectively provides a strong prediction of urban resilience. This suggests that the model has high explanatory power and that at least one of the predictor variables significantly contributes to the dependent variable. The large F-statistic reflects the strength of the relationship and supports the validity of the regression model in explaining variations in urban resilience outcomes.

Table 0:8. Regression Analysis Coeffients

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.212	.101		11.946	.000
	Exposure_NBS_Index	.081	.031	.116	2.606	.010
	Implementation_NBS_Index	.292	.038	.390	7.773	.000
	Institution_Support_Index	.364	.037	.414	9.833	.000

a. Dependent Variable: Urban_Resilience_Climate_Change_Index

The regression coefficients provide important insights into the relative contribution of each independent variable. Institutional support emerges as the most influential predictor of urban resilience ($\beta = 0.414$, $p < 0.001$), followed by implementation of NbS ($\beta = 0.390$, $p < 0.001$), and exposure to NbS ($\beta = 0.116$, $p = 0.010$). The positive coefficients indicate that increases in each of these variables are associated with improvements in urban resilience. Specifically, a one-unit increase in institutional support is associated with a 0.364 increase in the urban resilience index, holding other factors constant. Similarly, a one-unit increase in NbS implementation leads to a 0.292 increase in resilience, while exposure contributes a smaller but still statistically significant effect (B = 0.081).

These findings highlight that while awareness and exposure to NbS are important, the effectiveness of NbS in enhancing urban resilience is largely driven by the quality of implementation and the strength of institutional frameworks. The dominant role of institutional support underscores the importance of governance, policy coordination, and resource allocation in ensuring the success of NbS interventions. This aligns with Urban Resilience Theory, which emphasizes the role of institutions in enabling adaptive capacity and managing climate risks (Meerow et al., 2016). Similarly, the strong influence of

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implementation reflects the importance of technical execution and sustained investment in NbS projects, consistent with the principles of Ecosystem-based Adaptation (Seddon et al., 2020).

The relatively smaller coefficient for exposure suggests that simply being aware of or living near NbS interventions is not sufficient to significantly enhance resilience unless these interventions are effectively implemented and supported by strong institutions. This finding reinforces earlier correlation results and highlights the need for a comprehensive approach that integrates community engagement with institutional capacity and technical effectiveness.

The regression results provide strong empirical evidence supporting the study's conceptual framework and Objective III, which seeks to analyze the influence of Nature-Based Solutions on urban resilience. The findings confirm that NbS contribute significantly to resilience outcomes, but their effectiveness depends largely on governance quality and implementation strength. This underscores the need for policy-makers to prioritize institutional strengthening, improve coordination among stakeholders, and ensure the effective execution of NbS interventions. The results also validate the theoretical foundations of the study, particularly the Socio-Ecological Systems framework, which emphasizes the interaction between ecological interventions and institutional structures in achieving sustainable outcomes (Folke et al., 2016).

4.2 Spatial Analysis of Land Use Land Cover Change and Vegetation Dynamics in Gasabo District

This section presents and analyzes the spatial findings derived from Geographic Information System (GIS) and remote sensing techniques, focusing on Land Use Land Cover (LULC) changes and vegetation dynamics in Gasabo District between 2005 and 2025. The analysis provides objective, spatial evidence of environmental transformations and complements the quantitative and qualitative findings of this study. Specifically, the section examines changes in land cover categories, vegetation health using NDVI, and their implications for Nature-Based Solutions (NbS) and urban resilience.

4.2.1 Interpretation of Spatial Analysis of Land Use Land Cover (LULC) Change of 2005 and 2025.

The LULC analysis reveals significant transformations in land use patterns in Gasabo District over the 20-year period from 2005 to 2025. These changes reflect the combined effects of urbanization, environmental policies, and the implementation of Nature-Based Solutions.

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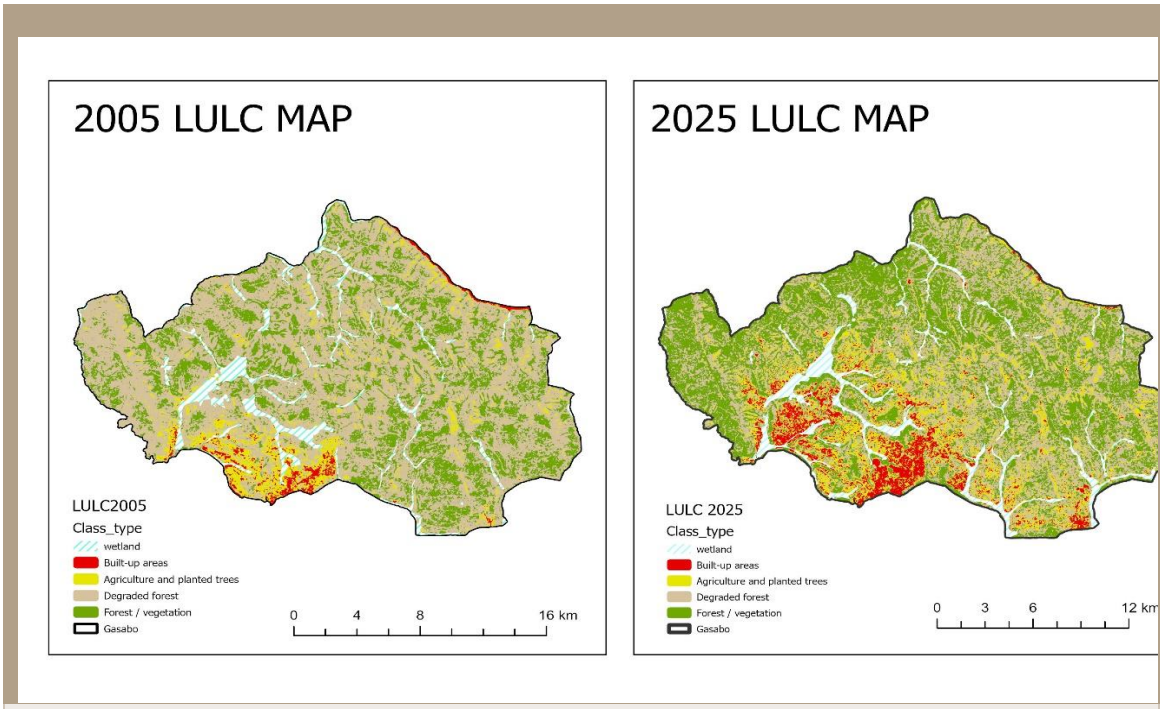
Figure 0:2. Spatial Analysis of Land Use Land Cover (LULC) Change of 2005 and 2025.



Source: Researcher, 2026

Table 0:9. Summary LULC Map 2005

N0	Class type	AREA_HA 2005	Percentage
1	Agriculture	3,038.82	7%
2	Built-up areas	700.81	2%
3	Degraded forest	25,413.01	59%
4	Forest / vegetation	11,394.84	27%
5	wetland	2,365.93	6%
	Grand total	**42,913.40**	**100%**

Source: Researcher, 2026

In 2005, the dominant land cover type was degraded forest, accounting for 59% (25,413.01 ha) of the total area, indicating substantial environmental degradation and reduced ecosystem functionality. Forest and vegetation cover constituted 27% (11,394.84 ha), while wetlands accounted for 6% (2,365.93 ha). Agricultural land represented 7% (3,038.82 ha), and built-up areas were minimal at only 2% (700.81 ha), reflecting relatively low levels of urban development at that time.

Table 0:10. Summary LULC Map 2025

No	Class type	AREA_HA 2025	Percentage
1	Agriculture	5,689.16	13%
2	Built-up areas	2,640.15	6%
3	Degraded forest	15,347.22	36%
4	Forest / vegetation	16,646.87	39%
5	wetland	2,586.82	6%
	Grand total	**42,910.21**	**100%**

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The spatial analysis of Land Use and Land Cover (LULC) changes indicates significant ecological transformation in Gasabo District between 2005 and 2025. Forest and vegetation cover increased markedly to 39% (16,646.87 ha), reflecting an approximate 12 percentage-point rise. In contrast, degraded forest areas declined substantially from 59% to 36% (15,347.22 ha), indicating a major shift from degraded landscapes toward more ecologically functional and restored environments. Wetland areas remained relatively stable in proportional terms at 6%, but increased in absolute area from 2,365.93 ha to 2,586.82 ha, suggesting targeted restoration efforts, particularly in ecosystems such as Nyandungu Eco-Park. These changes provide strong spatial evidence of ecosystem rehabilitation, consistent with Nature-Based Solutions (NbS) interventions including reforestation, agroforestry, and wetland restoration, and align with survey findings reporting improved biodiversity and green spaces.

In contrast, built-up areas expanded significantly from 2% (700.81 ha) to 6% (2,640.15 ha), reflecting rapid urbanization and population growth in Kigali's expanding urban system. Agricultural land also increased from 7% to 13%, indicating intensified peri-urban and rural farming activities. Despite this expansion of human land uses, the simultaneous increase in vegetation cover and reduction in degraded land suggests that NbS interventions have helped mitigate the environmental pressures associated with urban growth. These findings demonstrate that sustainable land management strategies can balance urban development with ecological restoration. The results support Ecosystem Services Theory, which emphasizes the role of restored ecosystems in enhancing biodiversity, soil stability, and climate regulation (Kabisch et al., 2017), and are also consistent with the Environmental Kuznets Curve (EKC) hypothesis, which suggests that environmental quality can improve alongside development through effective policy and sustainable practices.

4.2.2 NDVI Analysis and Vegetation Dynamics

The Normalized Difference Vegetation Index (NDVI) analysis was conducted to assess changes in vegetation health, density, and productivity in Gasabo District between 2005 and 2025. NDVI values range from -1 to +1, with higher values indicating denser and healthier vegetation.

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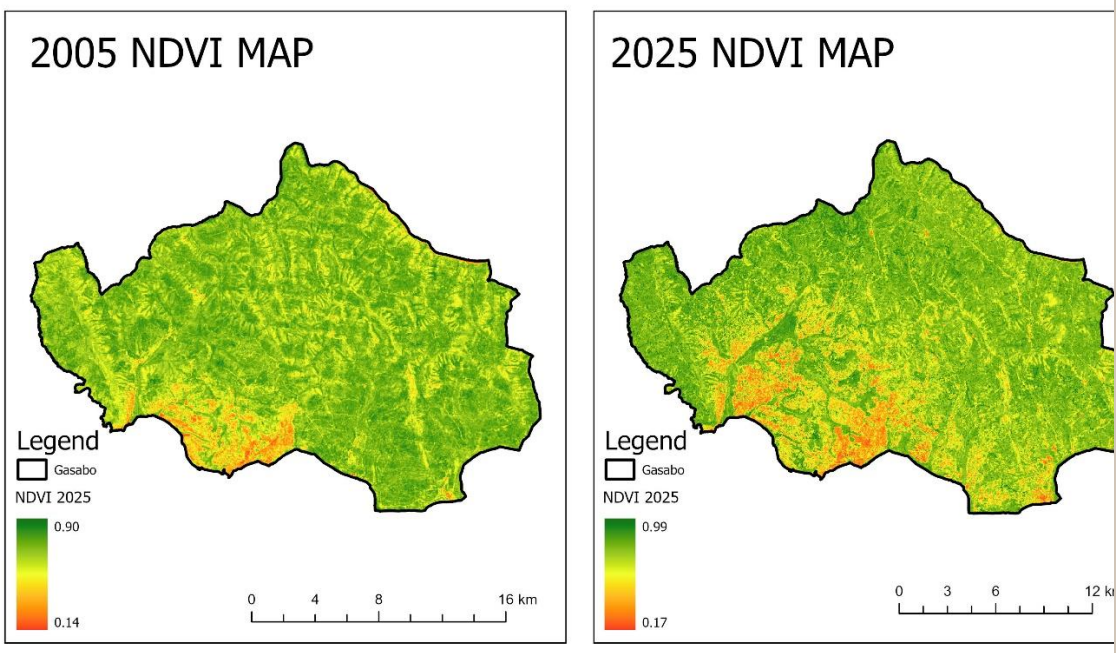
Figure 0:3. Map of NDVI Analysis of 2005 and 2025



Source: Researcher, 2026

Table 0:11. NDVI Summary of 2025 and 2005

NDVI Summary		
2025		**2005**
Statistic	**Value**	**Value**
Minimum (min)	0.17737158	0.14386204
Maximum (max)	0.99996674	0.92017192
Mean	0.72554914	0.68015659
Standard Deviation (stddev)	0.13461039	0.09990729
Total Pixels (npixels)	480,360	480,360

Source: Researcher, 2026

The results show a clear improvement in vegetation conditions over time in Gasabo District. The mean NDVI value increased from 0.680 in 2005 to 0.726 in 2025, indicating improved vegetation health and higher biomass density. This suggests that previously degraded or sparsely vegetated areas have undergone ecological recovery. The minimum NDVI value also increased from 0.144 to 0.177, reflecting a reduction in severely degraded or barren land, consistent with LULC findings. In addition, the maximum NDVI value rose from 0.920 to 0.999, indicating the presence of very dense and healthy vegetation in restored forest and wetland areas.

The increase in standard deviation from 0.099 to 0.135 shows greater spatial variability in vegetation, reflecting a more diverse landscape of forests, agriculture, and urban green spaces. These NDVI trends provide strong empirical evidence of ecosystem improvement

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linked to Nature-Based Solutions (NbS) such as urban tree planting, agroforestry, and wetland restoration. As vegetation increases, so does carbon absorption, confirming the role of NbS in climate regulation and supporting Ecosystem Services Theory (Cohen-Shacham et al., 2016) and Urban Resilience Theory (Meerow et al., 2016).

4.3 Analysis and Interpretation of Qualitative Findings from Key Informant Interviews (KII)

The qualitative findings from key informant interviews provide in-depth insights into the implementation, governance, effectiveness, and sustainability of Nature-Based Solutions (NbS) in Gasabo District, complementing quantitative and spatial results through thematic analysis. NbS interventions such as wetland restoration, urban tree planting, and agroforestry are implemented in targeted high-risk and ecologically sensitive areas, guided by national frameworks like the Green Growth and Climate Resilience Strategy (GGCRS) and coordinated by institutions including REMA, RWB, and the City of Kigali. This reflects an evidence-based approach supported by GIS and environmental assessments.

Key informants rated NbS effectiveness as high, particularly for wetland restoration in flood regulation, tree planting in climate regulation, and agroforestry in soil and biodiversity enhancement, although variability exists in agroforestry adoption. Strong institutional frameworks support implementation, but challenges such as coordination gaps, limited resources, and urban expansion persist. Community participation was reported as important but uneven across urban and rural areas. Monitoring relies on GIS, NDVI, and field systems, though standardization is limited.

Therefore, findings confirm that NbS significantly enhance biodiversity, flood risk reduction, and climate regulation. The convergence of qualitative, quantitative, and GIS evidence strengthens methodological triangulation and validates NbS as a key strategy for urban resilience in Gasabo District (Folke et al., 2016; Kabisch et al., 2017).

4. Conclusion

The study concludes that Nature-Based Solutions (NbS) significantly enhance urban climate resilience in Gasabo District through interventions such as urban tree planting, agroforestry, and wetland restoration, which improve biodiversity, reduce flood risks, and support climate regulation. Their effectiveness depends on strong institutional support, governance structures, and active community participation, with better outcomes observed where implementation is more coordinated. The integration of survey, key informant, and GIS/Remote Sensing data provides strong evidence of NbS effectiveness. The study recommends scaling up NbS as a key strategy for sustainable urban development and climate adaptation in Rwanda.

5. References

Adam, A. M. (2020). Sample Size Determination in Survey Research. Journal of Scientific Research and Reports, 90–97. https://doi.org/10.9734/jsrr/2020/v26i530263

Adelekan, I. O. (2016). Flood risk management in the coastal city of Lagos, Nigeria. Journal of Flood Risk Management, 9(3), 255–264. https://doi.org/10.1111/jfr3.12179

Bagenzi, E., & Maake, A. O. (2025). Effects of Forest Landscape Restoration Initiatives on the Socio-Economic Development of Smallholder Farmers in Rwanda: A Case of Bweyeye Sector, Rwanda. Journal of Agriculture, 9(1). https://doi.org/10.53819/81018102t2472

Bush, J., & Doyon, A. (2019). Building urban resilience with nature-based solutions: How can urban planning contribute? Cities, 95, 102483. https://doi.org/10.1016/j.cities.2019.102483

Cohen-Shacham, E., Walters, G., Janzen, C., & Maginnis, S. (Eds.). (2016). Nature-based solutions to address global societal challenges. IUCN International Union for Conservation of Nature. https://doi.org/10.2305/IUCN.CH.2016.13.en

Daily, G. C. (1997). Introduction: What are ecosystem services. Nature's services. 1(1).

Davies, C., Chen, W. Y., Sanesi, G., & Lafortezza, R. (2021). The European Union roadmap for implementing nature-based solutions: A review. Environmental Science & Policy, 121, 49–67. https://doi.org/10.1016/j.envsci.2021.03.018

Egerer, M., & Anderson, E. (2020). Social-Ecological Connectivity to Understand Ecosystem Service Provision across Networks in Urban Landscapes. Land, 9(12), 530. https://doi.org/10.3390/land9120530

Elmqvist, T., Andersson, E., Frantzeskaki, N., McPhearson, T., Olsson, P., Gaffney, O., Takeuchi, K., & Folke, C. (2019). Sustainability and resilience for transformation in the urban century. Nature Sustainability, 2(4), 267–273. https://doi.org/10.1038/s41893-019-0250-1

Folke, C., Biggs, R., Norström, A. V., Reyers, B., & Rockström, J. (2016). Social-ecological resilience and biosphere-based sustainability science. Ecology and Society, 21(3), art41. https://doi.org/10.5751/ES-08748-210341

Frantzeskaki, N. (2019). Seven lessons for planning nature-based solutions in cities. Environmental Science & Policy, 93, 101–111. https://doi.org/10.1016/j.envsci.2018.12.033

Gantner, G. (2025). Exploring the potential of nature-based solutions in informal settlements upgrading: A transformative approach for Sub-Saharan Africa. Npj Urban Sustainability, 5(1), 74. https://doi.org/10.1038/s42949-025-00258-0

Holling, C. S. (1973). Resilience and stability of ecological systems.

Kabisch, N., Korn, H., Stadler, J., & Bonn, A. (Eds.). (2017). Nature-Based Solutions to Climate Change Adaptation in Urban Areas: Linkages between Science, Policy and Practice. Springer International Publishing. https://doi.org/10.1007/978-3-319-56091-5

Kibii, C., Guerra, F., Bananayo, P. B., & Sandholz, S. (2025). Nature-based solutions for climate change adaptation and resilience in urban informal settlements: Insights from kibera, kenya and Villa 20, Argentina. Nature-Based Solutions, 7, 100216. https://doi.org/10.1016/j.NbSj.2025.100216

Kiribou, R., Djene, S., Bedadi, B., Ntirenganya, E., Ndemere, J., & Dimobe, K. (2024). Urban climate resilience in Africa: A review of nature-based solution in African cities' adaptation plans. Discover Sustainability, 5(1), 94. https://doi.org/10.1007/s43621-024-00275-6

Kjell, A., & Lundberg, M. (2025). Nature-based solutions for urban flood risk management: A case study of informal settlements in Kigali [Master Thesis]. Lund University.

Long'or Lokidor, P., Taka, M., Lashford, C., & Charlesworth, S. (2024). Nature-based Solutions for sustainable flood management in East Africa. Journal of Flood Risk Management, 17(1), e12954. https://doi.org/10.1111/jfr3.12954

MEA. (2005). Ecosystems and Human Well-Being: Wetlands and water synthesis. https://vtechworks.lib.vt.edu/items/05f6e5e0-3cac-4418-bc7d-9a4edc5fbab0

Meerow, S., Newell, J. P., & Stults, M. (2016). Defining urban resilience: A review. Landscape and Urban Planning, 147, 38–49. https://doi.org/10.1016/j.landurbplan.2015.11.011

Ministry of Environment. (2019, June). National Environment and Climate Change Policy.

Ministry of Environment. (2023). Green Growth and Climate Resilience Strategy.

Mosisa, G. B., Bedadi, B., Dalle, G., & Tassie, N. (2025). Nature-based solutions for urban climate resilience: Implementation, contribution, and effectiveness. Nature-Based Solutions, 8, 100245. https://doi.org/10.1016/j.NbSj.2025.100245

Muhayimana, V., Mupenzi, C., & Kamuhanda, J. K. (2025). Assessing the Contribution of Nature-Based Solutions on Climate Resilience in the City of Kigali: A Case Study of Nyandungu Urban Wetland, Rwanda. 9(2), 69–101.

National Institute of Statistics of Rwanda (NISR). (2023). The Fifth Rwanda Population and Housing Census, District Profile: Gasabo [Census].

Özokcu, S., & Özdemir, Ö. (2017). Economic growth, energy, and environmental Kuznets curve. Renewable and Sustainable Energy Reviews, 72, 639–647. https://doi.org/10.1016/j.rser.2017.01.059

Rao, G. R., ed, Prabhakar, M., ed, Venkatesh, G., ed, Srinivas, I., ed, & Reddy, K. S., ed. (2018). Agroforestry opportunities for enhancing resilience to climate change in rainfed areas. ICAR - Central Research Institute for Dryland Agriculture.

Seddon, N., Chausson, A., Berry, P., Girardin, C. A. J., Smith, A., & Turner, B. (2020). Understanding the value and limits of nature-based solutions to climate change and other global challenges. Philosophical Transactions of the Royal Society B: Biological Sciences, 375(1794), 20190120. https://doi.org/10.1098/rstb.2019.0120

Twizerimana, S., Tuyishime, E., & Uwizeyimana, J. (2025). Managing urban growth and protecting the environment in Gasabo District, Rwanda. Discover Sustainability, 6(1), 1277. https://doi.org/10.1007/s43621-025-02117-5