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Nature-Based Solutions in Brazilian Cities: A Multilevel Analysis

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Abstract

Nature-Based Solutions (NBS) are increasingly incorporated into climate adaptation agendas, yet their documentary presence reveals only part of how they are territorially and institutionally embedded. This study examines how NBS are incorporated into selected Brazilian climate adaptation instruments across national, federal-sectoral, and municipal planning levels. A qualitative comparative documentary analysis was conducted on seven primary instruments, complemented by official governance, implementation, monitoring, or legal documents when directly linked to a primary unit. A seven-dimensional coding matrix examined risk framing; the role of NBS and ecological processes; territorial scale and articulation; policy integration and multilevel governance; institutionalization and implementation capacity; knowledge, participation, and inclusion; and temporality, monitoring, and learning. Evidence was classified as declarative, specified, or operationalized, and a second-order synthesis identified four non-exclusive configurations: strategic-normative, sectoral-operational, territorial-ecological, and institutional-monitored. The results show that formal NBS inclusion, ecological-process integration, and institutionalization vary independently across instruments. Sectoral instruments can display strong programmatic specification while remaining territorially bounded, whereas municipal plans may articulate ecological and social processes with different degrees of operational formalization. The study contributes a non-hierarchical, non-scoring documentary framework for comparing the position of NBS within a multilevel adaptation architecture and for keeping documented incorporation analytically distinct from material implementation. Because the corpus is purposive and document-based, the configurations represent analytical patterns in the selected cases; questions of prevalence and effectiveness across Brazilian municipalities remain outside the study's inferential scope.

1 INTRODUCTION

Climate change has made the importance of adaptation in public planning increasingly clear and urgent. In cities, its effects extend across mobility, sanitation, housing, health, land use, infrastructure, ecosystems, and socio-spatial inequalities. Climate therefore becomes a cross-cutting dimension of planning, while urban risks arise from the combination of hazards, exposure, vulnerabilities, patterns of territorial occupation, and interdependencies among social, ecological, and technological systems (Uittenbroek et al., 2013; Markolf et al., 2018; Sainz de Murieta et al., 2021).

In this context, Nature-Based Solutions (NBS) have gained greater prominence in adaptation agendas by mobilizing ecosystems and natural processes to address societal challenges while combining risk reduction, human well-being, and biodiversity benefits (Cohen-Shacham et al., 2019; Seddon et al., 2020). In urban areas, this repertoire includes rain gardens, urban tree cover, restoration of watercourses and wetlands, and green and blue infrastructure. The diffusion of the concept leaves open an important analytical question about the position occupied by NBS in planning: the same solution may appear as a localized technical intervention, an infrastructure component, or part of a strategy that articulates territory, policies, institutions, and ecological processes.

The adaptation mainstreaming literature provides a useful lens for distinguishing these situations. Mainstreaming adaptation into existing policies may involve programmatic, regulatory, managerial, budgetary, and organizational changes alongside terminological inclusion in sectoral plans (Wamsler, 2015; Wamsler & Pauleit, 2016). Dedicated climate policies and sectoral integration can coexist: Reckien et al. (2019) document their combined presence, while Uittenbroek (2016) shows that policy texts and implementation routines may change at different speeds.

Recent NBS literature shifts the focus from the isolated effectiveness of interventions toward their incorporation into ordinary planning and governance practices. Reviews and comparative studies identify institutional change, multilevel governance, cross-sectoral coordination, policy mixes, implementation capacity, and reflexive learning as central components of this process (Adams et al., 2023; Hölscher et al., 2023; van der Jagt, Tozer, et al., 2023). Wolff et al. (2026) reinforce this perspective by identifying distinct mainstreaming pathways shaped by context and institutional starting points.

Analytical caution is required when frameworks developed predominantly in the Global North are used to interpret cities in the Global South. Different levels of informality, inequality, administrative capacity, access to resources, community participation, and recognition of local knowledge shape both intervention design and pathways of institutionalization (Wolff et al., 2022; Kuller et al., 2022). In Brazil, Torres et al. (2023) warn against treating NBS as decontextualized panaceas. In parallel, the social-ecological-technological systems (SETS) approach moves infrastructure away from a position external to nature and understands it as part of interdependent systems, making it useful for jointly examining drainage, mobility, land use, rivers, green areas, and social vulnerabilities (Markolf et al., 2018; McPhearson et al., 2022).

Brazil's current adaptation architecture provides a timely empirical field for examining these issues. The Climate Plan Adaptation combines a National Adaptation Strategy with sectoral and thematic plans, while municipalities consolidate or revise their own climate action instruments (Brazil, 2025a, 2025b, 2025c). Brazilian scholarship has already begun to characterize how NBS enter urban governance. Seleguim et al. (2024), through in-depth analysis of Campinas and Santos, examined political strategies, co-benefits, facilitators, and limitations associated with incorporating NBS into local urban agendas. At a broader scale, Wütrich et al. (2026) mapped 903 legal norms across 389 municipalities and showed that municipal institutionalization of NBS is recent, uneven, and often occurs through specific strategies with limited reliance on the umbrella term itself.

These studies establish that NBS are already being incorporated into Brazilian urban policy through distinct political and legal pathways. The present study addresses a complementary question: how NBS occupy different territorial and institutional positions across functionally distinct levels of a climate-adaptation architecture. International governance frameworks also identify multiple dimensions relevant to NBS uptake, including integrated working, legislation, participation, monitoring, knowledge, financing, and environmental justice (van der Jagt, Buijs, et al., 2023). Within this literature, the

analytical gap pursued here concerns multilevel documentary comparison across national, federal-sectoral, and municipal adaptation instruments, with joint attention to territorial and ecological integration, policy integration, institutionalization, participation, and monitoring.

This framing locates the study's novelty in the combination and application of established insights. The protocol brings together adaptation mainstreaming, NBS governance, policy integration, and social-ecological-technological systems to compare the documentary position of NBS across planning levels through a non-scoring approach.

Accordingly, this research is guided by the following question: how are Nature-Based Solutions incorporated into Brazilian climate adaptation instruments, and what configurations of territorial, cross-sectoral, and institutional integration can be identified across national, federal-sectoral, and municipal levels? The general objective is to analyze this incorporation by identifying and comparing forms of integration and their relationships with risk framing, implementation capacity, monitoring, and participation. The contribution proceeds along three paths: conceptually, it integrates the literatures on adaptation mainstreaming, NBS governance, policy integration, institutionalization, and social-ecological-technological systems; empirically, it compares different functional positions within Brazil's adaptation architecture; and methodologically, it applies a matrix capable of distinguishing terminological presence, programmatic incorporation, territorial and ecological integration, institutional articulation, and documented operationalization while keeping mainstreaming, systemic orientation, transformation, and performance ranking analytically separate.

2 THEORETICAL FRAMEWORK

2.1 ADAPTATION MAINSTREAMING AND POLICY INTEGRATION

Adaptation mainstreaming can be understood as the incorporation of adaptation concerns, objectives, and practices into policy and decision-making domains that have their own primary purposes. The literature offers several definitions that converge on an understanding of integration extending beyond the existence of a dedicated climate plan. Uittenbroek et al. (2013) show that adaptation must be accommodated within established urban planning routines, instruments, and arenas; in reviewing empirical evidence, Runhaar et al. (2018) reinforce that outcomes depend both on the strategies employed and on the institutional conditions that enable their incorporation.

Wamsler (2015) offers a particularly useful translation for documentary analysis by identifying mainstreaming-related changes in territorial measures, organizational structures, formal and informal policies and instruments, cooperation and external networks, and working practices. Wamsler and Pauleit (2016) distinguish programmatic, managerial, regulatory, and directed strategies. An action foreseen in a plan, a regulatory change, an interdepartmental responsibility, and a financing mechanism therefore represent distinct forms of incorporation and require separate evidentiary treatment.

The notion of policy integration adds another layer to the problem. Beyond inserting a climate objective into existing sectors, the relevant question is whether the objectives, instruments, and responsibilities of different policies become articulated. In this research, horizontal integration refers to connections among sectors or agencies located at approximately the same level of government; vertical integration refers to relationships among levels of government, decision scales, and instruments that are functionally or normatively connected. The co-presence of mobility, sanitation, housing, and environmental issues in the same plan provides contextual breadth. Classification as horizontal integration requires substantive cross-references, shared objectives, coordinated instruments, co-responsibilities, or joint implementation mechanisms.

Institutionalization adds a separate analytical dimension to mainstreaming. It refers to the stabilization of objectives and practices in rules, competencies, routines, resources, organizational structures, and procedures that can persist beyond specific projects. Uittenbroek (2016) shows that policy texts may incorporate adaptation while implementation routines remain stable. This study therefore examines documented institutionalization as the set of formalized conditions present in the instruments analyzed and reserves claims about material implementation for cases supported by specific official evidence.

2.2 MAINSTREAMING AND INSTITUTIONALIZATION OF NATURE-BASED SOLUTIONS

In the NBS literature, mainstreaming has come to describe the process through which interventions that are initially isolated, experimental, or demonstrative achieve more stable forms of insertion into urban planning and governance. In a systematic review, Adams et al. (2023) show that this process involves institutional change, knowledge, multilevel governance, and urban transitions. In their analysis of ten European cities, Hölscher et al. (2023) highlight capacities associated with systems approaches, inclusive collaboration, and reflexivity, suggesting that scaling up NBS requires connecting policies and departments, creating conditions for learning, and changing decision-making practices beyond the simple replication of green projects.

Van der Jagt, Tozer, et al. (2023) add the importance of policy mixes: planning, regulation, incentives, financing, and administrative procedures express integration when substantive relationships connect them. The notion of institutional readiness reinforces this point by emphasizing competencies, rules, coordination, resources, and administrative capacity alongside technical maturity (Van Cauwenbergh et al., 2022).

A complementary strand of the literature has developed broader governance-assessment frameworks. Based on a systematic review, van der Jagt, Buijs, et al. (2023) identify nine dimensions of urban NBS governance, including integrated working, legislation and policy, collaborative arrangements, community engagement, monitoring, knowledge, financing, and environmental justice. Their framework is designed primarily for city-level governance assessment through indicators and survey-based evaluation. The present study overlaps with several of these concerns and extends them through three design choices: documentary evidence as the empirical basis, comparison across functionally distinct planning levels, and explicit treatment of territorial

and ecological relations as analytical dimensions within a non-scoring framework. Its methodological contribution lies in this specific combination and documentary operationalization for multilevel comparison.

Recent literature also challenges linear interpretations of scaling. Replicating interventions may expand territorial reach while rules, budgets, maintenance, or routines remain unchanged; conversely, a guideline incorporated into a permanent instrument may represent institutionalization before extensive physical replication occurs. Wolff et al. (2026) describe pathways of grounding, capitalising, embedding, and anticipating, showing that mainstreaming depends on context, opportunities, and pre-existing institutions. These insights support the use of multidimensional configurations in the present study in place of an aggregate maturity or systemic-orientation index.

2.3 TERRITORIALITY, ECOLOGICAL PROCESSES, AND ORIENTATION OF CHANGE

The incorporation of NBS into planning also requires distinguishing the presence of natural components from the integration of ecological processes. A tree, a rain garden, or a wetland may fulfill a delimited technical function while connectivity, hydrological dynamics, ecological persistence, and territorial relationships remain outside strategy formulation. The SETS approach broadens the unit of analysis by conceiving social, ecological, and technological components as interdependent systems (Markolf et al., 2018; McPhearson et al., 2022). In cities, this lens is especially relevant because drainage, mobility, land use, rivers, green areas, infrastructure, and socio-spatial inequalities may jointly contribute to the production of climate risk.

These distinctions can be translated into observable documentary evidence. Risk framing may range from damage to assets to vulnerabilities and territorial dynamics; nature may appear as a technical device, infrastructure, or ecological process; monitoring may extend from physical outputs to ecological conditions; and participation may range from information provision to influence over diagnosis and priorities. This operationalization brings relational questions into the corpus while preserving them as analytical categories rather than prior normative judgments.

The literature on transformational adaptation provides an additional interpretive lens. Pelling et al. (2015) associate transformation with profound changes in structures, relationships, and trajectories; Palomo et al. (2021) examine NBS in light of practical, political, and personal changes. Incremental adaptation can be appropriate in many contexts, and the analysis assigns no normative hierarchy to incremental, systemic, or transformational orientations. Climate-resilient development, in turn, provides a broader framing that articulates adaptation, mitigation, and sustainable development (Intergovernmental Panel on Climate Change [IPCC], 2022). In this research, the orientation of change serves as a second-order interpretation constructed after the empirical dimensions have been combined.

2.4 GLOBAL SOUTH, KNOWLEDGE, AND JUSTICE IN URBAN ADAPTATION

The transferability of international frameworks is both a theoretical and methodological issue. Examining participatory NBS in the Global South, Wolff et al. (2022) show that forms of community engagement vary according to objectives, institutional arrangements, and territorial conditions. In discussing planning support in Indonesia, Kuller et al. (2022) likewise demonstrate the importance of adapting instruments to settings with different levels of formalization. The Brazilian application therefore requires contextualized interpretation so that an idealized European city does not operate as a tacit benchmark for capacities, participation, and institutionalization.

Olazabal et al. (2021) add an epistemic dimension by showing that dominant forms of knowledge can narrow the adaptation solution space. Participation and knowledge are therefore distinguished analytically within the protocol, even when coded within the same broader dimension. Information, consultation, co-production, and the incorporation of local or traditional knowledge represent distinct relationships with decision-making; evidence of co-production requires influence over problem framing, priorities, criteria, or alternatives. Climate justice is recorded when it functions as a criterion for diagnosis, prioritization, benefit distribution, or action.

In Latin America, van Lierop et al. (2024) show that monitoring and assessment are integral to NBS governance itself and must be understood in relation to institutional capacities. In Brazil, Torres et al. (2023) place territory, inequalities, and institutional arrangements at the center of the analysis of justice in NBS. Together, these contributions support the inclusion of knowledge, participation, justice, monitoring, and learning in the protocol and direct attention to both the solutions named in plans and the territorial and institutional relationships that give them meaning.

3 METHODOLOGY

3.1 RESEARCH DESIGN AND DOCUMENTARY CORPUS

The research adopts a qualitative, exploratory-analytical approach based on comparative documentary analysis of Brazilian climate adaptation instruments. Documentary analysis is used as a systematic procedure for examining, interpreting, and triangulating documents while simultaneously recognizing their value as institutional sources and their limitations as representations of practice (Bowen, 2009). The design is multilevel: national and federal-sectoral documents are examined according to their roles in guidance, coordination, and thematic translation, while municipal plans are analyzed as instruments of territorialization, integration, and local operationalization. Comparison follows these distinct institutional positions through within-level reading and vertical analysis across planning scales.

The main corpus was purposively defined according to four criteria: official status; substantive treatment of climate adaptation; relevance to urban planning, infrastructure, territory, or ecological processes; and availability of sufficient content on actions, governance, implementation, or monitoring. The sampling frame was analytical and focused on purposive comparison of functionally distinct instruments. At the federal level, the National Adaptation Strategy was included as the overarching coordination instrument; the Cities Plan as an explicitly urban and cross-sectoral translation of

adaptation; and the Transport Sector Plan as an infrastructure-oriented sectoral contrast in which NBS coexist with engineering measures. The Transport Plan therefore provides a test of how mainstreaming within a technically bounded sector relates to the territorial and institutional patterns observed in explicitly urban instruments.

Municipal instruments were selected as information-rich cases intended to maximize analytical variation. The final set combines different territorial and institutional contexts - Belo Horizonte, Recife, Manaus, and São Paulo - while retaining the availability of auditable official sources and sufficient material for coding as requirements. The explicit or substantive presence of NBS served as an eligibility condition that ensured enough empirical material to differentiate forms of incorporation. The resulting sample supports analytical comparison, while statistical generalization to Brazilian municipalities lies outside the study design.

Document retrieval was closed on September 26, 2026. Retrieval within the selected instruments used a broad vocabulary that included "Nature-Based Solutions," ecosystem-based adaptation, green and blue infrastructure, restoration, renaturalization, urban tree cover, wetlands, connectivity, sustainable drainage, and other ecosystem processes. Term searches served as a navigation aid, with inclusion and coding determined by contextual reading.

Supplementary official documents were used when directly linked to governance, implementation, monitoring, or legal anchoring of one of the seven primary instruments. They formed a second documentary layer, kept separate from the primary comparison units. Because availability varies among jurisdictions, supplementary-document coverage was treated as a limitation and excluded from comparative judgments of implementation or institutional capacity.

Table 1

Main documentary corpus of the research

Scale	Instrument	Year	Rationale / functional position
National	National Adaptation Strategy, Climate Plan	2025	Overarching national strategy for coordination, objectives, and multilevel adaptation governance.
Federal/sectoral	Climate Plan Adaptation - Cities	2025	Explicitly urban and cross-sectoral federal adaptation instrument.
Federal/sectoral	Transport Sector Plan	2025	Infrastructure-oriented sectoral contrast in which NBS coexist with engineering adaptation measures.
Municipal	Belo Horizonte Local Climate Action Plan	2022	Large inland metropolis; municipal instrument linking climate adaptation to urban planning and infrastructure.
Municipal	Recife Local Climate Action Plan	2020	Coastal metropolitan context; municipal climate plan complemented by a later official monitoring instrument.
Municipal	Manaus City Climate Action Plan	2025	Amazonian capital with a recent climate-action instrument and strong riverine and urban-stream interfaces.
Municipal	PlanClima SP, first revision	2026 (2025 revision)	Megacity case with a revised climate plan and separate formal documentation of interdepartmental governance.

Note. Prepared by the authors based on official documents. For each instrument, the title, year or version, institutional URL, and access date were recorded. Later documents directly linked to implementation, governance, or monitoring were retained as a separate supplementary layer and cited independently.

3.2 UNITS OF ANALYSIS AND CODING PROTOCOL

The context unit corresponds to the complete document. The recording unit is a semantically complete documentary segment, such as a paragraph, item, action line, table cell, target, indicator, or normative provision; the unit actually coded is the proposition or action expressed in that segment. The same unit may receive codes from several dimensions because territoriality, institutional integration, ecological processes, and temporality may coexist in the same passage. Headings, table titles, higher-level objectives, and table columns form part of the context when necessary for interpretation. This choice follows the principle of documentary analysis that meaning is established in relation to the document's purpose, institutional position, and context of production (Bowen, 2009).

The protocol combines predominantly deductive categories derived from the literature on adaptation mainstreaming, NBS governance, policy integration, institutionalization, multilevel governance, SETS, and territorial planning, while preserving controlled space for emergent observations when the Brazilian corpus reveals phenomena unanticipated by the initial framework. The main matrix contains seven dimensions. The orientation of change - incremental, systemic, or transformational - serves solely as a sensitizing lens for interpretation; the seven coded dimensions constitute the primary protocol. The resulting configurations remain unranked along these orientations.

Table 2

Analytical matrix for documentary coding

Dimension	Central question	Evidence families
D1. Risk framing	What conception of the climate problem justifies the action?	Hazard; asset/service; vulnerability; inequality; territorial dynamics; interdependencies.
D2. Role of NBS and ecological processes	What is nature expected to do in planning?	Explicit NBS; technical measure; multifunctionality; green/blue infrastructure; ecological process; biodiversity.
D3. Scale and territorial articulation	At what scale does the action operate, and how are scales and systems connected?	Asset/plot; neighborhood/corridor; municipality; watershed/ecosystem; region; connectivity; multiscalar articulation.
D4. Policy integration and multilevel governance	Does the action substantively connect to other sectors, instruments, and levels?	Horizontal integration; vertical integration; shared objectives; articulated instruments; co-responsibility; policy mix.
D5. Institutionalization and implementation capacity	Are there documented conditions for the action to enter routines and instruments?	Responsible actor; rule; financing; implementation mechanism; deadline; maintenance; capacity; continuity.
D6. Knowledge, participation, and inclusion	Who participates in constructing the problem and the solution, and with what influence?	Information; consultation; co-production; local/traditional knowledge; vulnerability; justice; traceability.
D7. Temporality, monitoring, and learning	Does the plan track change and provide for adaptive revision?	Scenarios; time horizon; indicators; baseline; targets; frequency; responsible actors; ecological indicators; feedback.

Note. Prepared by the authors.

Where evidence could plausibly map to more than one dimension, coding followed the function performed by the passage in context. Vulnerability or inequality was coded under D1 when it explained how climate risk was produced, and under D6 when it operated as a criterion of inclusion, justice, participation, or prioritization. A responsible actor was coded under D5 when responsibility concerned implementation and under D7 when it concerned monitoring, reporting, or revision. Spatial scale, connectivity, and ecological-territorial relations were coded under D3, whereas inter-organizational or intergovernmental relations were coded under D4. Multiple assignment was retained when a passage simultaneously performed more than one of these functions.

Five cross-cutting rules guide coding. First, the explicitness rule applies: coding requires content explicitly stated or directly supported by the passage and its immediate context. Second, titles, headings, higher-level objectives, and table columns may form part of the context. Third, terms such as "green," "sustainable," "ecological," and "resilient" require contextual evidence before classification as NBS. Fourth, codes allow multiple assignment. Fifth, a dimension is recorded as absent only after the relevant sections have been read and contextual evidence has been assessed.

Each piece of evidence also receives an independent documentary status. E1, declarative, corresponds to a principle, intention, or generic recommendation; E2, specified, identifies a clearly defined action, instrument, location, objective, or relationship; E3, operationalized in the document, requires concrete implementation elements such as a responsible actor, mechanism, deadline, financing, target, or indicator; U records passages with insufficient context for a consistent decision. These statuses are categorical and unsummed. At the document level, NI means "not identified in the corpus consulted," preserving documentary silence as an evidentiary condition rather than as proof of absence in practice. In Table 3, E-statuses indicate the strongest status among the illustrative documentary anchors used to support the comparative interpretation; they summarize those anchors rather than every coded segment in each instrument.

The analysis consistently separates documentary presence from effective implementation. Formulations such as "the plan provides for," "the document assigns responsibility," and "the instrument establishes an indicator" are used for documentary evidence; claims of execution require specific official evidence from the supplementary corpus. Documents directly linked to governance, monitoring, or implementation remain a supplementary documentary layer and clarify the primary cases. All analyzed materials are publicly available institutional documents, and the study involved exclusively documentary sources with no human-participant or personal data.

3.3 PILOT, CONSISTENCY, AND COMPARATIVE STRATEGY

An exploratory pilot was conducted to calibrate the coding protocol across three distinct functional positions within the adaptation architecture: the National Adaptation Strategy (NAS), Climate Plan Adaptation - Cities, and the Recife Local Climate Action Plan. The sample targeted segments on diagnosis, guidelines, actions, implementation, participation, and monitoring. The pilot assessed whether the seven dimensions distinguished analytically different phenomena and whether the evidence rules were applicable to documents with different institutional functions.

The pilot led to four adjustments to the protocol. First, horizontal integration came to require a shared objective, articulated instrument, co-responsibility, or another substantive mechanism across sectors. Second, co-production came to require evidence of influence over diagnosis, priorities, criteria, or alternatives, which separated it from generic community involvement or workshop participation. Third, explicit mention of NBS or ecosystem-based adaptation (EbA) was coded separately from the incorporation of ecological processes, with hydrology, connectivity, biodiversity, or other ecological dynamics providing the relevant evidence for the latter. Fourth, official documents directly linked to implementation or monitoring were retained as supplementary material capable of clarifying the primary instrument.

Because this calibration stage was carried out by a single coder, no inter-coder agreement measure is reported. Ambiguous decisions were recorded in memos and used to make inclusion and exclusion rules explicit and to re-examine borderline passages. The comparison was conducted in two directions: within-level, among instruments with similar functions, and vertical, among national strategy, sectoral translation, and municipal territorialization. The configurations presented in the results were constructed through second-order synthesis after coding. Three criteria guided retention of a configuration label: (1) the combination linked at least two dimensions in a coherent planning position; (2) it captured a substantively distinct relationship among policy function, territorial or ecological integration, and institutionalization; and (3) it remained distinguishable from adjacent configurations while preserving a non-hierarchical comparison. Recurrence could occur across documents or through a distinct functional position within the multilevel architecture; this criterion allows the strategic-normative configuration to capture the specific role most clearly anchored in the National Adaptation Strategy. The synthesis relied on qualitative criteria rather than an aggregate score, minimum frequency threshold, or cluster algorithm. Table 3 provides a condensed audit trail linking the illustrative coded anchors and their strongest evidence status to the configurations, while contradictory or limiting evidence is retained in the accompanying discussion. Supplementary Appendix A expands this audit trail into a dimension-by-document matrix covering all seven analytical dimensions for all seven primary instruments. NR marks dimensions unused as evidentiary anchors in the reported comparative synthesis, whereas NI remains reserved for phenomena not identified after review of the relevant documentary sections.

4 RESULTS AND DISCUSSION

The comparative documentary analysis showed that the matrix distinguishes different forms of incorporation of NBS and adaptation while preserving a non-hierarchical comparison. The NAS concentrates normative framing, multilevel integration, participation, and long-term orientation; the federal Cities and Transport plans translate these guidelines into sectoral objects, associating them with targets, programs, financing, and risk management; and municipal instruments reveal diverse combinations of territoriality, ecological processes, governance, implementation, and monitoring. The comparison therefore shifts the analytical focus from the presence of NBS to the position they occupy within the architecture of each instrument.

4.1 POSITION ASSIGNED TO NBS AND ECOLOGICAL PROCESSES

In the Cities Plan, the incorporation of NBS has explicit programmatic specification. Target M7 establishes that 100% of the contracted urban infrastructure portfolio should incorporate adaptation measures appropriate to local climate hazards by 2035; among the associated actions, A6.M7 promotes NBS and Ecosystem-based Adaptation in urban infrastructure projects, with community involvement, prioritization of vulnerable territories, and identification of budgetary and non-budgetary funding sources. A8.M7 connects green areas, permeability, and urban tree cover to urban biodiversity, while A9.M7 links NBS and local practices to disaster prevention in vulnerable territories (Brazil, 2025b). In the Transport Sector Plan, PRO-Adaptavias is presented as a permanent instrument for adapting federal land transport infrastructure, articulating engineering and nature-based solutions, institutional strengthening, resource mobilization, and risk management (Brazil, 2025c). Here the evidence is predominantly technical-institutional: ecological integration requires additional evidence that ecological processes structure diagnosis or territorial design. Among the municipalities, Belo Horizonte explicitly prioritizes NBS, the maintenance of watercourses in natural channels, urban tree cover as a parameter for road interventions, and climate justice criteria for infrastructure projects (Belo Horizonte, 2022). Recife links NBS to drainage upgrading and provides for the revitalization or renaturalization of water bodies, bringing hydraulic functions and environmental restoration closer together (Recife, 2020). São Paulo associates NBS with urban drainage and organizes targets, indicators, deadlines, and responsible agencies within an interdepartmental monitoring structure (São Paulo, 2026a). Manaus combines technical and ecological-territorial functions: the plan incorporates reforestation and riparian forest restoration, green infrastructure along urban streams, ecological corridors, preventive maintenance, and indicators of vegetation cover and connectivity. In this case, nature appears simultaneously as infrastructure, a risk-reduction mechanism, and a component of ecological processes whose continuity is integrated into action design (Manaus, 2025).

This contrast supports the analytical distinction between the presence of NBS as a named technical option and the integration of ecological processes into planning. In SETS terms, more explicit ecological-process integration appears where ecological dynamics are connected to infrastructure, vulnerability, and territorial relations (Markolf et al., 2018; McPhearson et al., 2022). The finding therefore qualifies a purely programmatic reading of mainstreaming: formal inclusion and ecological integration represent related but analytically distinct forms of incorporation. It also complements the Brazilian city-level analysis of Seleguim et al. (2024), which emphasizes political strategies and local governance arrangements, by showing that documentary incorporation and ecological-territorial integration can occupy different positions even within formal adaptation instruments.

4.2 TERRITORIALITY, CROSS-SECTORAL INTEGRATION, AND MULTILEVEL GOVERNANCE

Territoriality proved independent of mere administrative scale and of the number of sectors mentioned. The NAS explicitly adopts multilevel and cross-cutting governance and promotes policy coherence while considering territorial specificities (Brazil, 2025a). In the Cities Plan, the analysis extends from intra-urban to supra-municipal scales, articulating infrastructure, disaster prevention, vulnerability, and participation (Brazil, 2025b). The Transport Plan internalizes adaptation within sectoral planning and risk management and creates a permanent program for land transport infrastructure; its sectoral organizing object gives this mainstreaming a comparatively narrow territorial reach (Brazil, 2025c). In Belo Horizonte, watercourses, water security, urban tree cover, the road system, and climate justice are related to common urban problems, providing evidence of territorial articulation, while formal co-responsibility among agencies remains undocumented for individual actions (Belo Horizonte, 2022). São Paulo provides explicit evidence of horizontal integration: the revision involved interdepartmental coordination and dialogue with agencies responsible for implementation, while follow-up was formalized through an interdepartmental working group (São Paulo, 2026a, 2026b). In Manaus, the Climate Action Plan applies a climate perspective to

urban and sectoral instruments and organizes interventions in risk areas and along urban streams. Its sub-actions include community validation of priority areas, safe resettlement where risk cannot be mitigated, and upgrading of stream margins through the integration of green infrastructure, basic sanitation, and resilient community spaces, showing that territorial articulation and policy integration can coexist within the same unit of action (Manaus, 2025). These contrasts reinforce a central insight from the policy-integration literature: substantive integration emerges from connections among sectors, instruments, responsibilities, and spatial scales (Wamsler, 2015; Wamsler & Pauleit, 2016). The Brazilian cases further show that territorial integration depends on these substantive spatial relationships rather than on administrative scale alone.

4.3 INSTITUTIONALIZATION, IMPLEMENTATION, MONITORING, AND LEARNING

The comparison also revealed that institutionalization and operationalization take different forms. In the transport sector, PRO-Adaptavias was established by Ordinance No. 64/2025 and combines strategic planning, implementation of adaptation measures, engineering and nature-based solutions, partnerships, information production, and risk management, configuring documented institutionalization beyond an isolated project provision (Brazil, 2025c). In the Cities Plan, targets and actions are connected to budget programs, non-budgetary sources, potential projects, and indicators, allowing programmatic commitment to be distinguished from documented implementation mechanisms (Brazil, 2025b). In São Paulo, the revision records targets, indicators, deadlines, and responsible agencies, and SGM Ordinance No. 153/2026 established an Interdepartmental Working Group responsible for monitoring implementation and preparing an annual PlanClima SP report (São Paulo, 2026a, 2026b). In Recife, MOCLIMA monitors targets for 2030, 2037, and 2050 and allows strategies to be revised based on monitoring, providing evidence of institutional feedback (Recife, 2022). Belo Horizonte states that climate actions will be planned, followed up, and monitored; later implementation records remain supplementary to the content formalized in 2022 (Belo Horizonte, 2022). Manaus identifies lead and partner institutions, deadlines, targets, and indicators for each action, along with continued maintenance and mechanisms for monitoring, evaluation, reporting, and revision. The institutionalization recommendation formulated in the Climate Action Plan was subsequently converted into a normative anchor by Ordinary Law No. 3,667 of June 12, 2026, which established the Manaus Mitigation and Adaptation Plan and created the Technical Commission for Environmental and Climate Data Management (Manaus, 2025, 2026). This sequence provides evidence of institutionalization; material execution requires a separate empirical assessment.

This pattern is consistent with the distinction between policy incorporation and organizational implementation emphasized by Uittenbroek (2016) and with the institutional-readiness argument that rules, responsibilities, resources, and administrative capacity are integral to technical maturity (Van Cauwenbergh et al., 2022).

This distinction is especially relevant in light of the nationwide legal mapping by Wütrich et al. (2026), which shows that municipal institutionalization of NBS in Brazil is recent and uneven and often occurs through specific legal strategies with limited reliance on the umbrella term. The present corpus addresses a different level of inference by examining how legal or programmatic anchoring relates to other dimensions of incorporation. A formally institutionalized measure may remain territorially or ecologically narrow, while a territorially integrated measure may have weaker formal specification. Across the selected instruments, monitoring carries the greatest analytical weight when it creates a documented possibility of feedback, revision, or institutional continuity.

4.4 RISK FRAMING, PARTICIPATION, AND ADAPTIVE LEARNING

Risk framing, participation, and learning operate as cross-cutting qualifiers of the patterns described above. The Cities Plan links adaptation measures to local climate hazards, prioritizes vulnerable territories, and includes community involvement in actions associated with NBS and ecosystem-based adaptation (Brazil, 2025b). Belo Horizonte connects infrastructure interventions to climate-justice criteria (Belo Horizonte, 2022), while Manaus combines interventions in risk areas with community validation of priorities, safe resettlement where risk cannot be mitigated, and ecological-territorial measures along urban streams (Manaus, 2025). These cases show that similar physical or institutional measures can occupy different analytical positions depending on how vulnerability is framed and whose knowledge or participation enters the decision process.

Temporality and learning likewise differentiate otherwise similar forms of mainstreaming. The National Adaptation Strategy provides a long-term and multilevel orientation (Brazil, 2025a), while Recife links target monitoring to the possibility of strategy revision (Recife, 2022); São Paulo formalizes annual interdepartmental follow-up (São Paulo, 2026a, 2026b); and Manaus combines indicators, reporting, maintenance, and revision mechanisms (Manaus, 2025, 2026). In this sense, D1, D6, and D7 operate as cross-cutting qualifiers of territorial, sectoral, and institutional integration. The result extends the mainstreaming discussion beyond the insertion of NBS into policy instruments by showing that the framing of vulnerability, the influence of participation, and the capacity for feedback affect the meaning of that incorporation (Olazabal et al., 2021; van Lierop et al., 2024).

Table 3
Condensed audit trail linking coded evidence to analytical configurations

Instrument	Illustrative coded anchors and strongest evidence status	Configuration(s) supported
National Adaptation Strategy (NAS)	D3-E2: territorial specificity; D4-E2: multilevel and cross-cutting governance; D6-E2: participation; D7-E2: long-term orientation.	Strategic-normative.
Climate Plan Adaptation - Cities	D1-E2: local hazards and vulnerable territories; D2-E3: NBS/EbA linked to targets and actions; D3-E2: multiscalar articulation; D5-E3: funding and implementation mechanisms; D6-E2: community involvement; D7-E3: indicators and time horizon.	Sectoral-operational; territorial-ecological.
Transport Sector Plan	D2-E2: engineering and NBS identified within the sectoral program; D5-E3: permanent program, formal institutional basis, institutional strengthening, and resource mobilization.	Sectoral-operational.
Belo Horizonte	D2-E2: NBS, natural watercourses, and urban tree cover; D3-E2: links among watercourses, road interventions, and urban systems; D6-E2: climate-justice criteria.	Territorial-ecological.
Recife	D2-E2: NBS, drainage, and renaturalization; D3-E2: water bodies and urban drainage; D7-E3: long-term targets and monitoring with provision for strategy revision.	Territorial-ecological; institutional-monitored.
São Paulo	D2-E2: NBS in urban drainage; D4-E3: formal interdepartmental governance; D5-E3: responsible agencies and implementation structure; D7-E3: measurable targets and annual monitoring.	Territorial-ecological; institutional-monitored.
Manaus	D1-E2: risk areas and vulnerability; D2-E3: riparian restoration, green infrastructure, ecological corridors, and indicators; D3-E2: urban streams and territorial articulation; D5-E3: responsible institutions, maintenance, and legal anchoring; D6-E2: community validation; D7-E3: indicators, reporting, and revision.	Territorial-ecological; institutional-monitored.

Note. Codes identify the analytical dimension (D1-D7) and the strongest evidence status among the illustrative anchors reported in Sections 4.1–4.4: E1 = declarative; E2 = specified; E3 = operationalized in the document. The table provides a condensed audit trail, while Supplementary Appendix A contains the expanded dimension-by-document matrix and source/locator information where identifiable from the documentary record. Configurations are non-exclusive analytical patterns with no scoring or maturity ordering.

4.5 CONFIGURATIONS OF INTEGRATION IN BRAZILIAN ADAPTATION PLANNING

Table 3 makes explicit the documentary path from coded dimensions to the interpretive synthesis. On that basis, the second-order analysis identified four non-exclusive configurations defined by coherent combinations of dimensions and contrasts among documents. The strategic-normative configuration, most visible in the NAS, organizes guidelines, multilevel integration, and long-term orientation; the sectoral-operational configuration, observed most clearly in the Cities and Transport plans, translates adaptation and NBS into targets, programs, risk management, financing, and instruments within established sectors; the territorial-ecological configuration emerges when ecological processes and vulnerabilities are related to watersheds, watercourses, urban streams, urban tree cover, drainage, green infrastructure, and concrete spatial relations; and the institutional-monitored configuration brings together formal responsibilities, maintenance, indicators, reporting, revision, and feedback. The institutional-monitored label therefore requires evidence extending beyond formal institutionalization to monitoring and feedback. The same instrument may support more than one configuration, and the labels capture predominant combinations that can overlap.

The main implication is that these configurations are non-hierarchical and potentially overlapping. Their distribution also shows variation within the same institutional level: the Cities Plan, for example, combines sectoral-operational specification with territorial-ecological evidence, while municipal instruments differ in the degree to which territorial articulation is accompanied by formal responsibilities, monitoring, and feedback. One instrument may display strong institutional specification with a predominantly technical framing, while another may articulate territory and ecological processes with fewer implementation mechanisms. Manaus illustrates overlap among dimensions by combining NBS, territorial scale, responsible institutions, deadlines, maintenance, and indicators in drainage and urban-stream actions. This pattern converges with the mainstreaming literature, which describes programmatic, regulatory, managerial, and institutional pathways that depend on context (Wamsler & Pauleit, 2016; Adams et al., 2023; Wolff et al., 2026). Analytically, the matrix compares the territorial and institutional position of NBS while keeping mainstreaming distinct from transformation. For public sustainability management, scaling up NBS requires alignment among instruments, responsibilities, resources, territorial scales, participation, and learning mechanisms. The analysis also indicates that term frequency is a weak proxy for integration because substantive relationships may be expressed through hydrological processes, infrastructure, territory, and governance even when the label NBS is used sparingly.

Existing NBS governance frameworks already establish the multidimensional character of governance. Van der Jagt, Buijs, et al. (2023) demonstrate this through nine city-level governance dimensions, while Brazilian studies document local political strategies (Seleguim et al., 2024) and uneven legal institutionalization across municipalities (Wütrich et al., 2026). Building on this literature, the present analysis focuses on the documentary position of NBS across functionally distinct planning levels and explicitly separates ecological-territorial integration from institutional and governance specification within a single non-scoring protocol. This separation reveals that legal or programmatic institutionalization and territorial-ecological integration may advance at different intensities within the same adaptation architecture.

Table 4

Analytical configurations of integration observed in the corpus

Configuration	Dominant features	Most clearly supported in the corpus	Interpretive caution
Strategic-normative	Guidelines, multilevel integration, principles, and long-term horizon.	NAS	Cross-cutting guidance provides strategic direction; local operationalization depends on additional instruments and mechanisms.
Sectoral-operational	Targets, programs, financing, risk management, and sectoral instruments.	Cities Plan; Transport Plan	Sectoral mainstreaming captures integration within established sectors; broader territorial integration depends on explicit spatial articulation.
Territorial-ecological	Watersheds, watercourses/urban streams, drainage, urban tree cover, green infrastructure, vulnerability, and ecological processes.	Climate Plan Adaptation - Cities; Belo Horizonte; Recife; São Paulo; Manaus	Structural ecological integration requires relationships among green elements, ecological processes, and territory.
Institutional-monitored	Responsibilities, resources, maintenance, indicators, reporting, revision, and learning.	Recife; São Paulo; Manaus	Documented institutionalization captures formal arrangements; material implementation requires separate empirical verification.

Note. Prepared by the authors based on the documentary analysis. Configurations are non-exclusive and unordered; they represent analytical patterns rather than a maturity scale.

5 CONCLUSIONS

Within the selected corpus, NBS are incorporated into Brazilian adaptation instruments through distinct and overlapping configurations. The NAS occupies a primarily strategic-normative position; the federal Cities and Transport plans translate adaptation into sectoral programs and instruments; and the municipal plans combine territorial and ecological articulation, institutional responsibilities, participation, maintenance, and monitoring in different ways. The analysis indicates that term frequency alone provides a limited account of mainstreaming. More informative distinctions emerge from the combination of risk framing, territorial scale, ecological processes, policy articulation, institutionalization, participation, and learning. Documentary mainstreaming and transformation therefore remain separate analytical concepts, while evidence of material implementation requires empirical support beyond documented institutionalization.

The main scientific contribution is to demonstrate how ecological-territorial and institutional dimensions can diverge across different functional levels of a climate-adaptation architecture. Prior research has already established the multidimensional character of NBS governance; this study brings adaptation mainstreaming, NBS governance, policy integration, institutionalization, and SETS into a common comparative frame. Empirically, it identifies four configurations in the selected Brazilian instruments. Methodologically, it provides a non-hierarchical and non-scoring documentary protocol that separates named NBS inclusion, ecological-process integration, territorial articulation, and documented institutionalization.

The conclusions remain bounded by the study design. The research is documentary, uses a purposive sample of information-rich cases, combines instruments from different dates and institutional functions, and relies on a single coder. Supplementary documentation is also unevenly available across jurisdictions, and its coverage was excluded from comparative judgments of implementation capacity. The four configurations represent analytical patterns generated from the selected cases; their prevalence across Brazilian municipalities remains outside the study's inferential scope. Effectiveness, causality, and the degree of material implementation likewise require other forms of evidence. Future research can test the stability and transferability of the configurations in broader samples and combine documentary analysis with interviews, implementation data, and outcome evaluation.

Declarations

DATA AND MATERIALS AVAILABILITY

All primary and supplementary documents analyzed in this study are publicly accessible through the institutional sources listed in the references. Supplementary Appendix provides a dimension-by-document audit matrix covering the seven analytical dimensions for each primary instrument, the strongest retained evidence status used in the reported synthesis, documentary anchors, and source or locator information where identifiable. The supplement makes the interpretive path auditable: NR marks dimensions unused as evidentiary anchors in the reported synthesis, while NI is reserved for dimensions not identified after review of the relevant source material. The study used exclusively public institutional documents and collected no human-participant or personal data.

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Author Contribution

R.F.S. conceived the study, developed the research design, conducted the documentary analysis and coding, interpreted the results, and wrote the original manuscript. V.H.S.A. contributed to the conceptual and methodological development of the study, interpretation of the results, and critical revision of the manuscript. L.G.M. contributed to the conceptual development of the study, interpretation of the findings, and critical revision of the manuscript. All authors reviewed and approved the final version of the manuscript.

Data Availability

The documents analyzed in this study are publicly available from the institutional sources cited in the manuscript. The coding framework and audit matrix supporting the comparative analysis are provided in the Supplementary Material. No confidential, proprietary, or personally identifiable data were used in this study.

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