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Article

Gender Perspectives in Governance for Sustainable Development: A Case Study of Nature-Based Solutions for Water Management in Milan

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Abstract: This paper investigates women's empowerment and their active involvement in governance aimed at promoting sustainable development. The study focuses on examining the roles and processes of co-creation of nature-based solutions (NBS) for water management in Milan. Three research directions were explored: 1) to determine gender-based roles within local governance; 2) to detect semantic groups of NBS based on stakeholders' gender; c) to analyze gender-based linguistic and conceptual patterns of NBS. To achieve our objectives, we converted a sample of audio-video interviews of local stakeholders into textual data along with metadata indicating speakers' roles and gender. Descriptive statistics were applied to explore the governance's roles. We employed a combination of textual analysis and network analysis to identify thematic groups of NBS, and applied a word embedding approach to uncover linguistic patterns indicative of semantic sub-structures. The findings revealed significant demographic diversity. Male stakeholders perceive sustainable development as a process driven by the circular economy and the coordination of territorial authorities, while female stakeholders envision a transformative approach rooted in science, culture, and collaboration. The semantic sub-structure analysis highlighted a tendency among male governance to emphasize specialized skills, whereas female governance placed greater emphasis on problem definition rather than resolution.

Keywords: women's empowerment; nature-based solutions; natural language processing

1. Introduction

The Brundtland Commission, also known as the World Commission on Environment and Development (WCED), introduced the most widely recognized definition of sustainability in its 1987 report "Our Common Future" [1]. This definition intertwines environment and development, highlighting sustainable development as a means of intergenerational equity. The concept of sustainable development extends beyond merely alleviating poverty or improving production and consumption models; it encompasses environmental, economic, and socio-political dimensions, prioritizing the well-being of people. Over time, the Brundtland report has embraced a new interpretative openness, allowing for the enrichment of guiding principles within an evolving global framework. Consequently, the definition of sustainability has evolved to integrate environmental concerns with economic and social developments. Institutions at both national and international levels have set goals to enhance sustainable development by addressing issues such as waste reduction, renewable resource utilization, economic production, and social system improvement. These objectives are encapsulated in the United Nations' Agenda 2030 [2], which outlines 17 Sustainable Development Goals (SDGs) covering areas such as clean energy, poverty reduction, sustainable cities, gender equality, health, and education.

This paper explores sustainable development through two main lenses: the well-being of cities through water resources and governance perspectives, particularly focusing on gender-based management. By analyzing social sustainability within sustainable development practices, the study intersects several SDGs, including those related to health, clean water, industries and innovation, sustainable cities, and gender equality. More properly, this study examines women's empowerment

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and their own active participation in governance structures, emphasizing the gender-based role and managerial visions in environmental management, urban planning, and disaster risk reduction.

The research underscores the transformative potential of *Nature-based solutions* (NBS) and the importance of inclusive governance structures that involve different stakeholders, including residents, local governments, businesses, and academics.

The concept of NBS was introduced by European Commission as "solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions" [3]. The strategic innovation of utilizing NBS lies in global challenges arising from human-induced alterations to ecosystems and the need to mitigate natural threats and disasters, such as pollution, loss of natural habitats, urban expansion, global warming, climate change, environmental degradation, biodiversity loss and compromission of hydrological cycles that lead to extreme events such as floods and droughts [4], impacting on health and quality of life, including fatalities, poor hygiene, and water quality issues [5]. However, the rise of NBS faces several challenges due to governance barriers, policy frameworks, and local context issues. While EU directives attempt to incorporate NBS principles, their implementation varies significantly between countries, highlighting gaps in local governance aspects.

This mismatch impacts the effectiveness of NBS in addressing different urban challenges. In this context, the co-participation of diverse actors with various competencies is crucial. The transdisciplinarity of stakeholders is fundamental for developing an "ecology of knowledge" oriented towards inclusive urban regeneration. This vision of co-creation and co-participation identifies the aspirational characteristics of a virtuous model designed to improve the relevance, acceptance, and equity of NBS implementation. Within this framework, characterized by the development of nature-based strategies to improve urban well-being and address significant challenges and limitations, where local governance plays a fundamental role, our primary focus concerns the integrated management of water resources (IWRM). More precisely, IWRM represents a process that promotes sustainable water development and management to maximize quality of life without harming vital ecosystems. This translates itself into three main goals: a) social equity: ensuring sufficient water quantity and quality for all; b) economic efficiency: serving as many users as possible with available resources; c) ecological sustainability: maintaining healthy aquatic ecosystems. The study of IWRM focuses on the local context as well as its local governance.

In Italy, laws such as L.R. 15 March 2016, No. 4, and R.R. 7/2017 have been enacted to address the hydrological impact of land transformation activities, emphasizing hydraulic and hydrological conservation principles. Various organizations have emerged to support municipalities in implementing sustainable urban drainage systems.

This study aims to investigate the process of co-creation of NBSs on water in Milan by analyzing the dialogue with policy-makers to detect from their visions the future implications of the economic, social, and environmental sustainability related to water.

The research investigates three main questions:

RQ_1: Can women's empowerment within Milan's local governance, through sustainable development practices, be assessed?

RQ_2: What thematic categories for sustainable development of water resources are proposed by Milan's local governance systems, categorized by stakeholders' gender?

RQ_3: Are there linguistic and conceptual patterns within gender-based governance on NBS?

2. Material and methods

2.1. Material

Data collection is a non-probability sample of 101 oral interviews conducted during October 2022 with local governance engaged in sustainable development of metropolitan city of Milam. The sample data comes from a local population of managers and operators involved in local initiatives

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for ecological regeneration in Milan. For each statistical unit, metadata was included concerning the role covered in the local governance and their own gender. The sample consists of 57.43% males and 42.57% females. The interviews were based on four macro-categories of topics proposed by CAP Group, one of the main companies, founded in 1928, that in Lombardy manages the integrated water service in Milan and other municipalities. The company is recognized as the first monoutility in the country's heritage, and is actively involved in minimizing hydraulic risk and addressing urban flooding issues. Its fundamental pillars proposed and that inspired our work are: a) innovation; b) ecological transition; c) people; and d) environment. The aforementioned pillars identify the crucial semantic dimensions of water-related sustainable development that shape our work of listening to local governance. Innovation refers to technologies or processes that can satisfy human needs while minimizing environmental impact and promoting social and economic equity and well-being. This category can be based on the development of sustainable business models, such as circular economies or systems aimed at reducing waste, or processes dedicated to the development of renewable energy sources. Ecological transition aims to reduce the impact of human activities on the environment through production and consumption practices, the use of renewable energy, the development and adoption of cleaner transportation systems, agricultural practices that protect soil and water health, and the reduction of chemical fertilizers and pesticides. It also includes technological advances in support of sustainable development and the implementation of policies that support these practices. People are central to sustainable development, and this includes factors such as education, healthcare, water quality, sanitation, and economic and social justice opportunities. Environment includes the chemical, physical, and biological factors that impact human health and long-term environmental needs.

2.2. Methods

We propose a multi-step model (**Figure 1**) that: 1) converts the interviews into a textual data collection, 2) by adding metadata referring to the gender and profession of interviewees; 3) provides descriptive cross-gender and professions; 4) splits the whole corpus of interviews into two gender-based sub-corpora; 5) and 6) combines textual analysis to network analysis for detecting thematic groups; and, 7) adopts global vectors representation of words for identifying linguistic regularities that we interpreted as semantic dimensions of NBS.

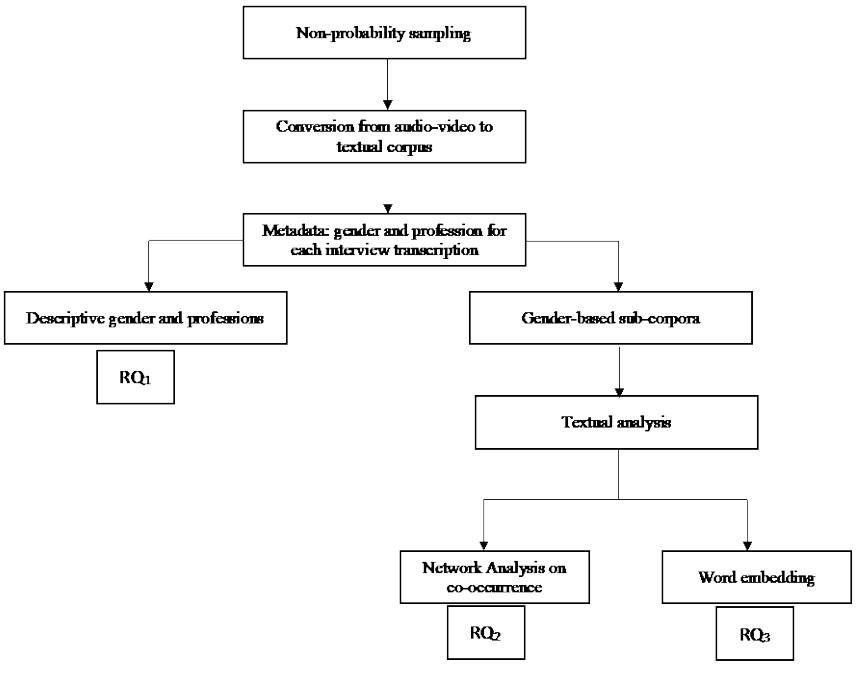

Figure 1. Flow chart of the model.

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Our model can be summarized in seven steps, as described below:

- **Step 1** - *Transformation of video-audios in textual data collection*: an automatic and human transcription services called *Happy Scribe* was used for converting interviews to texts with accuracy between 85 and 99% and available for 120 languages.
- **Step 2** - *Metadata to textual data collection:* we manually annotated gender and profession for each interview.
- **Step 3** - *Gender-based and professions descriptive:* we realized descriptive statistics able to capture gender-based professions and between various pillars: innovation, ecological transition, people, and environment.
- **Step 4** - *Gender-based sub-corpora:* once the metadata was added to each text, we split a corpus based on gender into two gender-based sub-corpora.
- **Step 5** - *Textual analysis:* this phase is preliminary for performing the successive two approaches. The canonical pre-treatment was performed [6-8]: normalization, lemmatization, and removal of stop words for Italian language based on standardized nomenclature ISO 639. We built the lexical table **DTM** (Document Term Matrix) based on a weighting scheme of frequency n_{ij} which counts the number of times the term i^{th} ($i = 1, ..., q$) in the document j^{th} ($j = 1, ..., p$). We converted the **DTM** into a binary matrix **T** where the generic element t_{ij} equals 1 if the i^{th} term appears in the j^{th} document, and it equals 0 if the i^{th} term does not appear in the j^{th} document. In this way, we deleted the weight of relationships between words and texts and focused only on presence or absence of words in the texts. With the scope of detecting the linguistic relationships among the words as semantic trajectories, we multiplied **T** for its transpose, $\mathbf{TT^T}$, by obtaining a new *term x term* or *co-occurrence* matrix **A** which tracks each couple of terms side by side in a certain order.
- **Step 6** - *Network Analysis:* the matrix **A** recalls the properties of Social Network Analysis (SNA) [9], where **A** represents an adjacency matrix that may be formally represented by a graph G (V, E): V is a finite set of nodes represented by the words, and E is a finite set of linkages represented by the co-occurrences. To study sub-groups of words densely interconnected to one another but poorly connected to other parts of the network [10-11] we adopted community detection. Several algorithms have been proposed, but in our model, we used a *fast-greedy* algorithm developed by Clauset *et al*. (2004) [12] as an agglomerative hierarchical clustering method for very large networks, whose main advantage is the stopping criteria for choosing the number of groups based on optimization of *modularity* (*Q*) [10, 13]. The empirical range of its maximization is between [0.3; 0.7]. We separately performed the *fast-greedy* algorithm on gender-based co-occurrence matrices.
  Instead of relying on the more common methods of topic modelling like those used in [14] and [15], some studies have found that the use of textual network analysis to determine thematic groups can be very effective [16, 17].
  Thus, combining steps 5 and 6 we answer RQ_2.
- **Step 7** - *Word embedding:* we used an unsupervised learning algorithm called *GloVe* [18] which combines two main model for learning word vectors: a) global matrix factorization methods, such as latent semantic analysis (LSA) [19], and b) local context window methods, such as the skip-gram model [20] which produce the multi-clustering idea of distributed representations [21]. *GloVe* aims to bypass the well-known drawbacks of previous models, namely the poor capacity of the word analogy task performed by LSA, and the inadequate adoption of the statistics of the corpus in skip-gram methods; since the training is carried out on separate local context windows instead of global co-occurrence counts. The global corpus statistics are captured directly with an accuracy of 75% on the word analogy. It efficiently leverages statistical information by training only on the non-zero elements in the co-occurrence matrix, rather than on the entire sparse matrix or individual context windows. The algorithm is based on a log-bilinear model with a weighted least-squares approach for realizing the logarithm of the words' co-occurrence probability. The ratios of co-occurrence probabilities can be used to determine meanings in the linear sub-structures of the word vector space. These linear sub-structures are captured by the metric of cosine. The model may be outlined as the vector difference between two-word vectors:

  $$e.g., King - man + woman = Queen.$$

  This last step replies to RQ_3.

  As mentioned in the description of the model, the first phase was carried out using the *Happy Scribe* service.

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From steps 3 to 7, we used different packages of the *R* [22] software environment for statistical computing and graphics. More properly, for descriptive statistics, we employed the basic functions of R and *ggplot2* [23] library for data management and visualization. The gender-based sub-corpora were created using the library called *dplyr* [24], which is capable of data manipulation and variables filtering. The steps related to textual analysis, from pre-processing to feature extraction and lexical tables building, were carried out using the functions from the *quanteda* [25] library, as well as the construction of co-occurrence matrices. The network analysis was performed using the *igraph* library [26], while the word embedding was conducted using *GloVe* [27].

3. Results and Discussion

The results are presented in three sub-paragraphs, each adhering to answering each research question.

3.1. RQ1: Women's Empowerment in Governance

As observed in the paragraph describing the material, our data collection is composed of a higher percentage of men: +14.86%. Thus, the sample consists of a prevalence of men with professionals engaged in decision-making with higher-level positions, such as Chief Executive Officer (CEO), where men are 90.48%, General Director, for 85.71%, and Founder, for 69.23%. Women are 93.21% more present as staff of geological support systems in the process of stakeholder engagement and environmental protection. They are even more present as coordinators (78.57%) and chairman of a public or private organizations (53.85%) (see **Figure 2**).

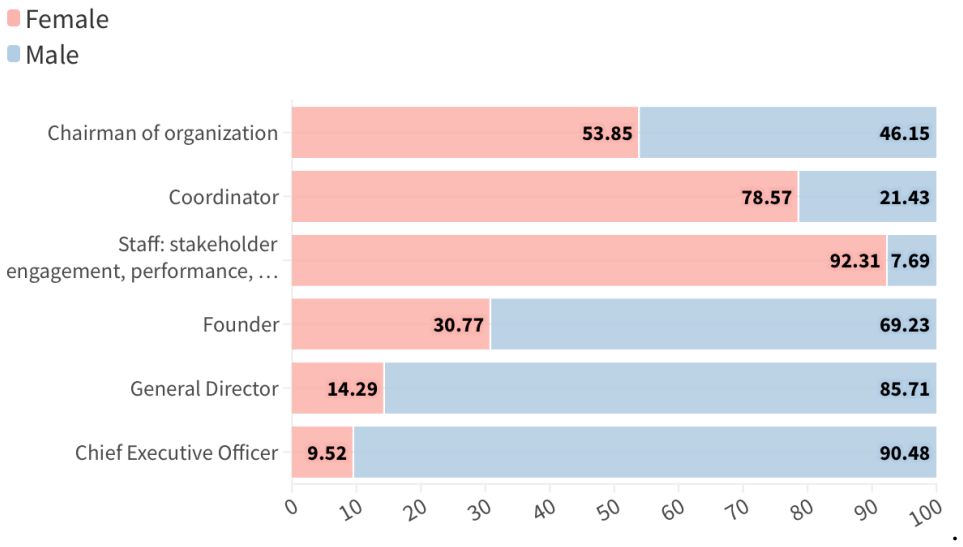

Figure 2. Bar plot of gender-based professional categories (RQ1).

The pillar of innovation is the least frequent among the various professions, with values below 1% (**Figure 3**). The ecological transition is mainly dealt with by CEOs in 63.08% of cases and by founders for 54.45%. The pillar of people is represented by 66.56% of coordinators and 47.98% of public engagement and geology staff, and the environment is strongly linked to the chairman of organizations by 72.61%. The descriptive results highlight a male predominance in decision-making roles, denoting a gender gap in roles of sustainable development management in Milan. In fact, while in the practices of ecological transition are the men engaged, the female governance is more attentive to citizen participation and environmental change.

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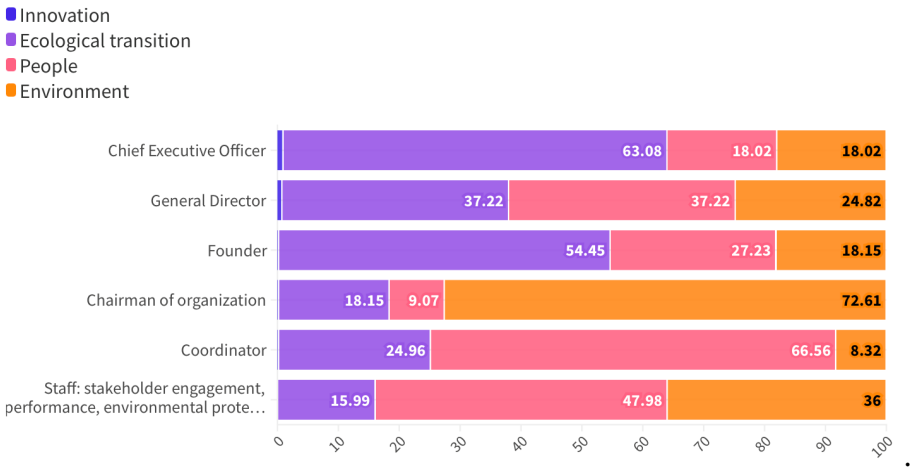

Figure 3. Bar plot of pillar-based professional categories (RQ_1).

3.2. RQ_2: Gender-Based Differences in the Definition of Thematic Groups

The entire corpus is composed of 1,957 types, as number of different words, and 3,866 tokens, which is the total number of words. The lexical richness computed through one of the most used measures the type-token ratio (TTR) is equal to 50.62%, indicating a good lexical variety in describing sustainable well-being of 'water'. Within each pillar, the TTR ranges between 80% and 83%, with a greater variability in the environment and a lesser variability in innovation (**Figure 4**). Under the perspective of gender (**Figure 5**), the TTR suggests almost similar lexical diversity with +1.9% for male sub-corpus. Details on sub-corpora matrices are reported in **Table 1**. Further insights into the characteristics of the texts were performed through indices that measure the number of words that appear only once within a specific corpus and are called hapax (in the plural version of hapax legomena). Often used to study a unique vocabulary used by a specific author, time period, or subculture, it allows us to outline a female context more characterized by semantic elements of sharing through an average hapax value of 0.09. This suggests a gender subculture that conceptually refers to the same theoretical constructs to describe the same topics. The male subculture, on the other hand, denotes a greater propensity to refer to the same topics using sometimes different constructs. This is brought to light by the average hapax value among the interviews equal to 0.45. These results confirm the sparsity data reported in **Table 1**.The exploratory analysis of textual data shows a decrease in the sparsity of the lexical table (as number of empty elements) after dividing the total corpus into two sub-corpora (refer to **Table 1**). In fact, the sparsity drops from 72.85% to a range between 57.29% and 66.30%. This suggests a gender-based argumentative peculiarity. Furthermore, the vocabulary used by women's stakeholder denotes an even lower sparsity, and thus, a higher degree of similarity among the interviewees concerning concerning the pillars of innovation, ecological transition, people engagement, and the environment. By setting a minimum word frequency threshold, where $n_{ij} > 2$, during the feature extraction step, we identified more terms from the female sub-corpus. This finding, allowed us to analyze a larger matrix of co-occurrence in the next steps.

Applying the fast-greedy algorithm to the co-occurrence matrices of the two sub-corpora revealed communities of frequently co-occurring terms within the networks. We have found a different number of communities, depending on whether it is the network of male stakeholders or female stakeholders.

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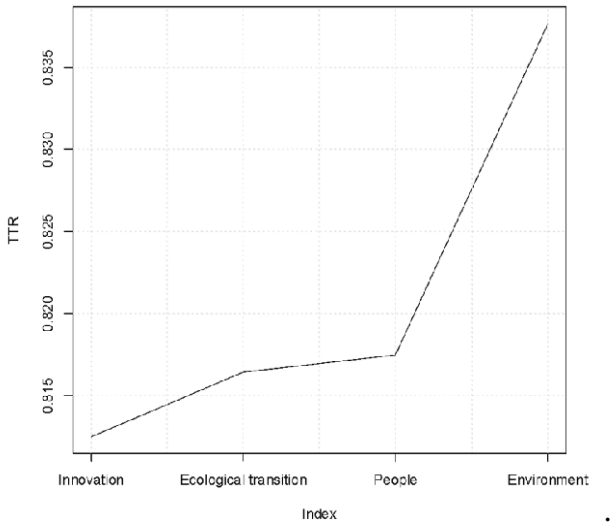

Figure 4. Lexical diversity plot.

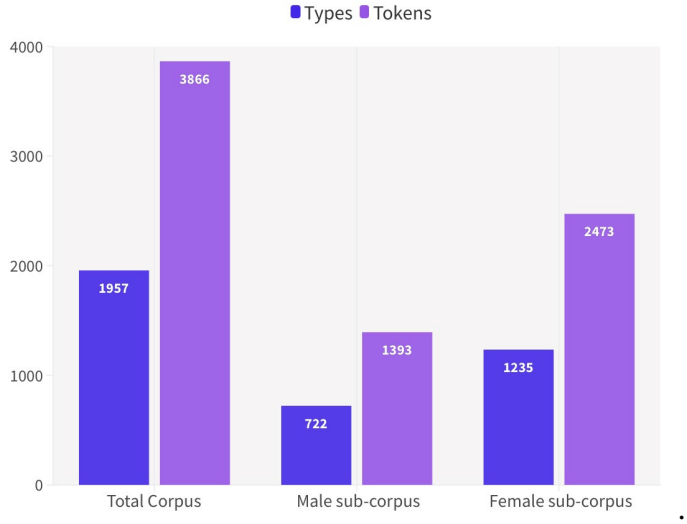

Figure 5. Bar chart of lexical features of corpus and sub-corpora.

Table 1. Statistics on corpus and sub-corpora.

Textual collection	DTM	Sparsity	A
Total corpus	**DTM**$_{101x915}$	72.85%	
Male sub-corpora	**DTM**$_{M\ 58x329}$	66.30%	**A**$_{M\ 329x329}$
Female sub-corpora	**DTM**$_{F\ 43x586}$	57.29%	**A**$_{F\ 586x586}$

The performance of *fast-greedy* algorithm on matrix $\mathbf{A}_M$ showed a good modularity optimization according to Newman & Girvan's empirical indications with Q equals 0.40. For better graphic intelligibility, the visual representation presents two communities of thematic groups based on the most frequent 50 terms (**Figure 6**).

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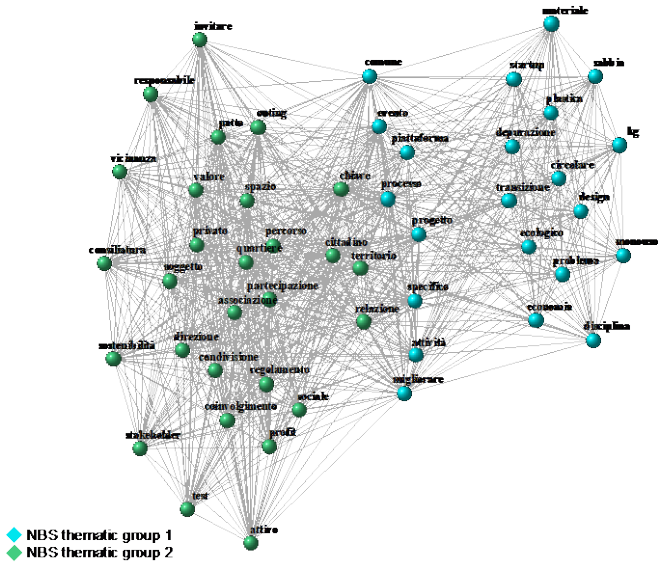

Figure 6. Thematic groups of male sub-corpora (RQ_2).

The first thematic group (turquoise group) identifies a very generalist vision to the sustainable development. It refers to the pollution of plastic, the use of disposable sources, the need of depuration of systems, the circular economy strategies. The second group (green group) is related to the support of local authorities such as municipalities or other stakeholders. Therefore, sustainable well-being is seen as the process of transferring the problem to local authorities.

The community detection on the matrix $\mathbf{A}_F$ presents Q equal to 0.34, falling in the optimal range. As for the previous case, we present the most frequent 50 terms, which the algorithm split into three communities (**Figure 7**). The first cluster (grey group) is characterized by a generalist view of the hydric resources using terms such as pollution, plastics, and sewage systems. The second group (pink group) highlights the need to build a path for services and innovation. The last group (purple group) identifies the welfare, recalling themes as environment, climate change, urban protection, care for people and planet. Female view is mainly related to a process of simplification, transformation, and digitalization of systems aimed at innovation and recycling-based economies. Citizen and cooperation are crucial in the sewage treatment as well as the geological aspect.

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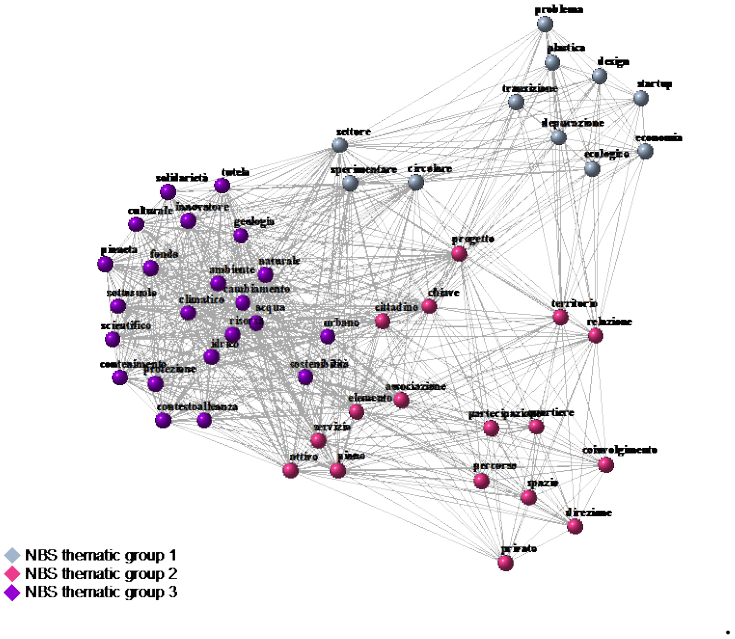

Figure 7. Thematic groups of female sub-corpora (RQ_2).

The gender-based analysis highlights different perspectives on how governance interprets the water issue and intends to plan future strategic resolutions. The male view is represented by a linear process of progress that begins with problem recognition and leads to a series of activities and practices in economy and purification that only the intermediation of the authorities can resolve. The female perspective, on the other hand, revolves around local transformation planning, which includes citizen engagement and concern for environmental protection, subsoil management, and containment practices. From the female viewpoint, welfare emerges from a combination of solidarity, science, and culture.

3.3. RQ_3: Gender-Based Differences in Linguistic and Semantic Regularities

Similar to the network step, we replicated gender-based data analysis, adopting the same word vector differences to capture similarities or dissimilarities. From the vocabularies of male and female sub-corpora, we selected eleven common lemmas with a standardized degree of centrality greater than 0.50 (**Tables 2 and 3**). Through word embedding, we analyzed the Nature-Based Solutions (NBS) encompassing the urban territory, industrial activity, politics, and citizen participation. To understand how these aspects are reflected in language, we explored terms related to locality (local, urban), benefits (benefit, proximity), governance (political, citizen), industry (industrial), and space (quarter, service, territory).

Table 2. Word vectors representation in female sub-corpora (RQ_3).

Word vector difference	Linguistic sub-structure	Probability
Sustainability – local + urban	Recovery	0.61
Sustainability – local + benefit	Business	0.65
Service – proximity + political	To undertake	0.75
Territory – proximity + political	Cartographic	0.70
Territory – local + citizen	Resource	0.72
	Safeguard	0.53
Political – local+ industrial	Neighboring	

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	Valley	0.64
	Po	0.59
		0.59
Sustainability – industrial + neighborhood	Association	0.58
	To involve	0.55
Territory – local + benefit	Plant	0.67
	Winter	0.63
	Project	0.61
	Industrial	0.58
	Ecological	0.52

Table 3. Word vectors representation in male sub-corpora (RQ_3).

Word vector difference	Linguistic sub-structure	Probability
Sustainability – local + urban	Discipline	0.78
Sustainability – local + benefit	Reciprocal	0.68
Service – proximity + political	Biomethane	0.56
Territory – proximity + political	Biomethane	0.70
Territory – local + citizen	Europe	0.59
	Symbiosis industrial	0.58
Political – local+ industrial	Waste to energy	0.60
	Purifier	0.60
Sustainability – industrial + neighborhood	Participatory	0.59
	Sharing	0.68
Territory – local + benefit	Transfer	0.61
	Ecological	0.60
	Plastic	0.67
	Mud	0.61
	Economy	0.53
	Circular	0.53

The word vector representation reveals distinct word vector representations based on gender perspectives within sustainability and urban space. Male stakeholders emphasize regulations, sharing, and policies, particularly focusing on specialized areas like biomethane as a renewable energy source and industrial ecology. Female stakeholders prioritize recovery-oriented activities, business involvement, and protection of urban spaces, with a future-oriented outlook. Thus, while men focus on solutions such as waste-to-energy processes, women tend to concentrate on problems of the territorial aspect, such as Pianura Padana watershed. A convergence between male and female governance is observed regarding the importance of shared urban spaces, resources, and citizen engagement.

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4. Conclusion

In this paper, we investigated the process of co-creation of NBS in Milan by focusing on water resource. We investigated whether the gender of stakeholders could influence the determinants that guide the processes. The analysis focused on women's empowerment in terms of roles within sustainable development practices. In decision-making and policymaking roles a gender gap was observed, with males predominantly occupying higher-level positions such as CEO, General Director, and Founder, while females were more commonly found in roles related to geological support systems, stakeholder engagement, and environmental protection. Females typically held coordinator and chairman positions in public or private organizations. This highlights a disparity in top-level positions related to sustainable development management in Milan, with ecological transition practices being predominantly led by males, while females are more involved in operational roles focusing on public engagement and environmental transformation. The thematic groupings revealed distinct perspectives on sustainable development between male and female governance. Male governance views sustainable development as a linear process, moving from the circular economy to the intermediation of territorial authorities, acting as a bridge. Conversely, female governance sees sustainable engagement as a progressive transformation, emphasizing citizen involvement and highlighting welfare, solidarity, science, and culture as fundamental pillars.

The study analyzed linguistic regularities to detect conceptual structures in male and female discourse within urban territory, industrial activity, politics, and citizen participation domains. In male discourse, emphasis was placed on technical competence and specialization, with a focus on European policies, industrial ecology, and renewable resources. Female discourse exhibited a future-oriented perspective, prioritizing issue identification over solution finding. Despite these gender-based differences, a common vision emerged regarding the sharing of urban spaces and resource management. Females demonstrated awareness of transformational processes involving various contexts and actors, while males focused on support from local authorities and the circular economy. Word embedding techniques highlighted technical resolutions and professional skills in male discourse, whereas female discourse leaned towards recognizing the need for innovation and change across diverse audiences. In conclusion, our study highlights the need for further research considering the intricate nature of gender cultures within local governance. Integrating diverse visions and perceptions into pillars of innovation, people, and ecological transition could enhance environmental, social, and economic developments. This integration has the potential to bolster female empowerment in local governance and maximize the impact of policies in the co-creation process of NBS. Future research could explore the inclusion of various stakeholder categories, such as residents and political authorities. Methodologically, advancements may involve employing neural network approaches to investigate semantic and linguistic patterns further. Techniques like named entity recognition and emotion or tone of voice detection could enhance the identification of demographic diversity features.

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