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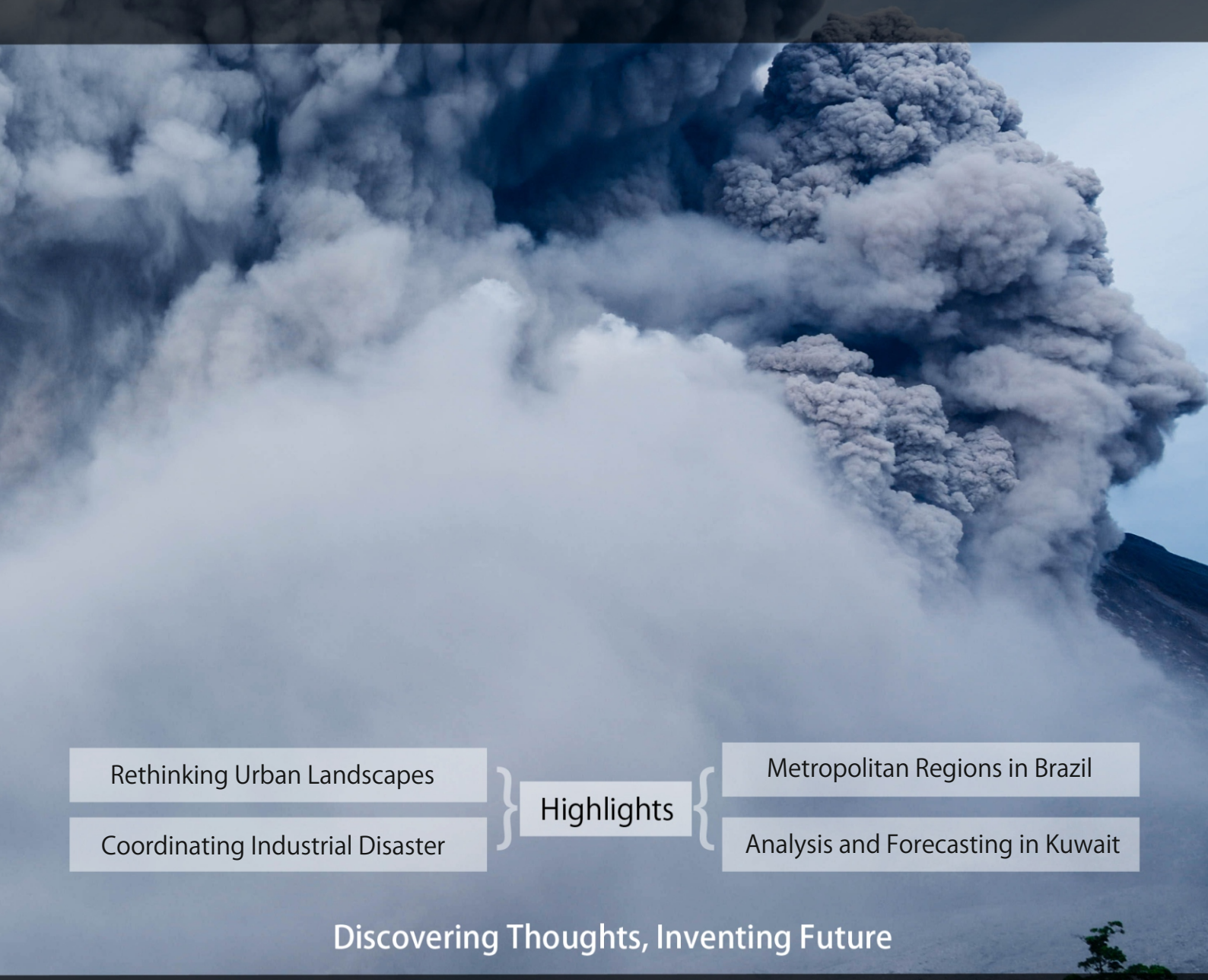

Rethinking Urban Landscapes

Coordinating Industrial Disaster

Highlights

Metropolitan Regions in Brazil

Analysis and Forecasting in Kuwait

Discovering Thoughts, Inventing Future

VOLUME 25 ISSUE 1 VERSION 1.0

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(Post-)Pandemic City: Rethinking Urban Landscapes through Humanized Management

By Letícia Peret Antunes Hardt, Gabriela Stocco Renisz, Victor Augusto Bosquilia Abade, Carlos Hardt, Rafael Gueller Araujo Brandão, Marlos Hardt & Carolina Ceres Sgobaro Zanette

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Abstract- The recent epidemiological events and the associated need for scientific knowledge have increased the number of investigations on the impact of diseases in different areas, but at the level of built scenarios, the problems caused by inadequate infrastructure and urban characteristics in coping with health crises are widespread. Given these issues, the general objective of this research is to assess the application of solutions in the field of humanized management of (post-) pandemic urban landscapes, especially in an international context. A scientometric analysis and a systematic review of secondary sources was conducted in the Lens, Scopus, and Web of Science (WoS) databases, quantifying the results and classifying their characteristics to d elineate the main academic discussions. The literature search yielded a total of 200,032 texts, of which 194 were selected for preliminary analysis after applying filters. This showed that publications on WoS (51.35%) and those with empirical approaches (70.62%) predominate, with Europe (33.51%) being more represented, although the United States (12.89%) published a greater number of articles.

Keywords: scientometrics analysis, systematic review, built scenarios, (post-)pandemic periods, spaces design, urban planning.

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(Post-)Pandemic City: Rethinking Urban Landscapes through Humanized Management

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Keywords: scientometrics analysis, systematic review, built scenarios, (post-)pandemic periods, spaces design, urban planning.

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I. Introduction

This study focuses on the evaluation of alternatives for the humanized future of the contemporary city, considering the period concurrent with and following the 2019 coronavirus disease (Covid-19) pandemic. An increasing number of investigations are being published on the impact of the sanitary crisis on the mental health and well-being of people worldwide. Similarly, the studies highlight how changes in subjects' relational environments, social isolation, and fear of infection, among other reasons, can alter behaviour, including in public spaces (Amério et al., 2020; Ammar et al., 2020; Miller & Smith, 2021; Wang et al., 2025).

At each moment of the pandemic, more *problems* in urban landscapes were being revealed because of the inadequate infrastructure and functionality of cities to cope with health crises. Thus, failures have been identified in several countries, such as the intensification of the viral spread through residential places, poor management of resources, and the needs of the population in terms of urban planning, as well as other issues raised by the pandemic, including the experience of citizens across generations without the effective development of solutions (Chauvin, 2024; Ditrans et al., 2023; Patel, 2020; Zgorska, Kamrowska-Zaluska & Lorens, 2021).

In this context, this research aims to provide an exploratory knowledge base about the humanized landscape and to sistematize scientific data shedding light on the possibilities that apply to post-pandemic scenarios. Thus, a conceptual understanding of the

issues discussed is essential, especially regarding future perspectives for cities and their management.

Therefore, the *general objective* of this study is to assess the application of solutions in the field of humanized management of (post-)pandemic urban landscapes, especially in an international context. In summary, the activities related to achieving these aims should respond to the following *research question:* within a transnational framework, what are the most important principles for the human-focused future of the contemporary city? To achieve the objective and formulate the answers to the query, information from secondary sources was studied, especially studies addressing the topic's scientific and academic state of the art, which ensured the conduct of the study according to the postulates of the theories and concepts discussed below.

II. Theoretical Postulates

The concept of *landscape* is first addressed, which is determined by the relationships between natural and anthropic elements in a spatial, temporal, and social context (Sander et al., 2025). The studies on the theme were gradually expanded and gained a scientific body, being and are used today in an integrated perspective between systems of nature and humankind, in an inter-relational way, considering systemic components to produce a new conceptual approach (Min, 2025; Switalski et al., 2025). It is thus seen as an integrated interpretive and sensory link between natural and human factors.

The topic is also interpreted geographically: it is a form of spatial planning that has multiple aspects, as individuals are considered capable of changing the landscape, and it has emotional effects on people. It is generally associated with what can be observed but is not limited to this condition, referring to immaterial phenomena and processes that are relevant to the interpretation of what is visualized.

However, it also focuses on the expression of characteristics such as space, region, territory, and place and the changes that these environments undergo over time with or without human influence. It is therefore a collective heritage created by the subjectivity of local people and by nature (Min, 2025).

Thus, the term can be used for a variety of situations because the ability to describe a landscape is not a simple act. Its appreciation can be laden with feelings and emotions toward place, but it can also be expressed in a rational and systemic way, evaluating and categorizing natural and human-made features. As a concept, however, it has individual and collective values that make it a subjective influence that is more important than any material value.

On the other hand, its valorization helps improve the quality of life and strengthens people's social and cultural identity (Hersperger et al., 2020). Therefore, not only the landscape but also the urban scenarios and the dynamics of the city, in particular, are permeated by the same relationships, analyses, and territorial views of the individual and society.

The domination of territories historically fostered in humans the ability to shape and change nature, creating a ritual of space (Herrmann-Pillath, 2024). This gave rise to the processes of demographic understanding, population quantification, and urban planning, in which cities were geographically delineated, distinguishing urban from rural perimeters, and using these elementary distinctions to measure their qualitative attributes, thus giving rise to the second relevant concept for the present study: the *city.*

Considering the urbanized areas as transformative agents for global sustainability, Bai (2025) notes that they are places where people live and work, but beyond that they are centers of attraction for society. This 'magnet' effect enables interaction between residents and provides alliances and organizational functions for the group's proper social and cultural development. The concept of demarcated territory highlights the existence of different social actors in cultural construction and appropriation.

The urbanized space can be understood as purely geometric without being so. It relates to architectural elements, economic centers, and social environments, with norms and rules that regulate human activity (Foster et al., 2025). Thus, the concept of habitat has been updated, indicating the creation of a goal of mastering nature. Moreover, urban life is permeated with the collective as the city is full of accumulations and flows of individuals, which is why it becomes necessary to create projects for laws that regulate the rights and duties of citizens and promote politics (Foster et al., 2025).

In this perspective, the city is an agglomeration in a limited area that hosts a sizeable population, where commercial, service, and industrial activities predominate, generating systems of capitalization, and whose community can produce cultural resources for identification (Karam et al., 2025). This definition changes over time, but some elements are evident in the topic's formation and construction.

Currently, the capacity of urban environments to provide technologies to solve social problems has been proven, especially during the recent pandemics. To this end, tools to optimize resources and precision in the provision of public services and the adaptability of government, among others, are being evaluated (Moghayedi, 2025).

Cities need *innovations and technologies* because they are constantly evolving. However, these are difficult constructs to conceptualize as the applications of words have a variety of meanings and can also be interpreted in different ways.

In general, they are associated with knowledge generation. According to Mairesse et al. (2025), innovation can be interpreted as the creation of new realities as it is a process in which something is created that did not exist before and which also gives an unusual function and utility to existing elements. The author emphasizes that this process consists of operations and actions aimed at results; thus, it must be stimulated and developed in a planned direction.

Innovation occurs in a multidisciplinary way; therefore, different innovative practices can be linked to knowledge from different fields (Mairesse et al., 2025). It is a fundamental component for solving social, economic, political, cultural, and other issues in the face of major daily problems. It is thus possible to understand that the innovative process of searching for answers and creating forms of relationships stimulates more effective and efficient changes in society and governance.

Technology, in turn, is based on human action, which is socially conditioned and aims to structure a set of alternatives to achieve defined goals, usually characterized by procedures and tools (Ottone & Grifoni, 2017). It is possible to demonstrate the importance of developing instruments to promote innovation in the search for new outcomes, a particular aspect of technological concepts that provide resources to promote material or intellectual discoveries.

The term 'innovation' is therefore associated with anything that humans invent to make their daily life easier and more enjoyable, considering their subjectivity. This includes artifacts, procedures, or means that help individuals stay alive and feel good, the latter being increasingly valued in today's world (Mairesse et al., 2025).

The progress and innovation in the urban-social and scientific-technical fields in the 1950s changed the everyday life of ordinary people, with more investigations into occupational activities that were defined as being characterized by dehumanizing factors in terms of interaction with community members, especially in the health sector. In the 1970s, debates on *humanization* intensified, focusing on concerns about individual well-being. In addition, contrary practices were associated with hierarchical power relations in the exercise of care and decision-making, as well as with psychological and subjective factors involving acts of depersonalization of the ordinary individual (Girard, 2021).

However, it is not only the health sector that has faced difficulties in dealing with subjectivity and the issue of humanization, as this problem has emerged in various fields (Girard, 2021). For example, in the domain of technology, during the recent pandemic, the monitoring of isolated persons was automated, which reduced the interaction between patients and health professionals to a minimum, leading to a decrease in the interpersonal contact necessary to promote the mental and relational health of isolated persons.

The promotion of computerization and innovation in the surveillance of pandemic infections has brought both advantages and disadvantages, as the excess of technological resources in the provision of care has also led to difficulties in reaching remote regions and in monitoring families in vulnerable situations and without Internet access. These conditions are associated, for example, with the spread of misinformation and communication delays among healthcare staff (Aihara et al., 2025).

In terms of spaces and relationships, humanization is understood as the prioritization of the quality of attention and care for people, their satisfaction, and the relevance of their subjectivity. Girardi (2021) emphasizes that humanitarian action influences the individual's sense of being and the subjective dimension of their performance. These practices are often considered relational technologies linked to the holism of care, as well as the transformation of practices and the quality of support.

In general, this type of policy related to occupations promotes the use of techniques, equipment, and procedures. In conjunction with the use of technological knowledge, they are expressed in dialogues, listening, empowerment, and the management of affection, always committed to people's happiness (Shehayeb, 2023).

Therefore, humanization policies aim to reorganize work processes in healthcare and propose changes in daily service delivery as well as changes in society's performance. The physical and relational environments can exhibit dehumanization, such as in situations where people are housed in static and sterile places that offer little potential for stimuli that promote well-being (Shehayeb, 2023).

These considerations lead to a concern for the influence of the environment on the subjectivity of individuals, requiring the need for a balance between the functional needs of society and the care provided by socialization spaces. Tang (2023) adds that form and design are also humanizing factors in landscapes.

The possibility of humanizing the public space is achievable through an urban process capable of valuing the human scale and allowing citizens to assume a leading role in the design of places of communal use. The authors state that it is crucial for places to meet the desires of their users, and suggests that policies must be geared towards humanizing cities and ensuring citizens' well-being (Rossi & Nardis, 2025).

This position strengthens the social and democratic function of the urbanized space and that the best alternative for municipal development is the one that can improve the quality of life and adequately meet people's basic needs. Thus, the insight that the

environment influences people's behavior and vice versa guides the framework of research methods.

III. Methodological Procedures

Exploratory, descriptive, and synthetic-analytical techniques were applied to define the main scientific-academic debates on humanized landscapes in an international context, particularly considering the recent pandemic period. The methods used were divided into four main phases:

a) *Theoretical Foundation:* Based on exploratory and descriptive techniques for examining secondary sources – literature and documents – with the aim of identifying fundamental theories and concepts for the study.

b) *Methodological Structuring:* Grounded in the same techniques and previous sources, with the aim of identifying methods for conducting the research, especially through the collection of information on academic-scientific articles relevant to the addressed topics.

c) *Classificatory Contextualization:* Framework analysis of innovative and technological solutions to systematize them in an international context.

d) *Discussion of the Results:* Supported by descriptive and analytical techniques for the identification of innovations and technological strategies to substantiate city design, planning, and management processes.

Taking into account the period between 2020, marking the formal onset of the recent pandemic, and 2022, when its effects began to subside, the following international databases were consulted to achieve the previously defined objective: Lens (2020-2022), Scopus (2020-2022), and Web of Science (WoS, 2020-2022). According to Kumar (2025), bibliometrics is a quantitative and statistical methodology that aims to measure scientific publication indexes and the dissemination of knowledge.

This author describes bibliometrics as a method for measuring patterns of written communication as well as for identifying the most active and prolific authors in research on a given topic. In the present study, the systematic review was used to enable the organization of journal contents for the identification of possible innovations and new technologies for the humanization of urban landscapes in the (post-)pandemic period. Therefore, a single string consisting of two parts connected by the Boolean operator AND was used, as shown in Table 1.

Table 1: String used in Journal Databases

("*Urban**" OR" *Urban Management*" *OR* " *Landscap**" *OR* "*Cit**"*OR* " *Humaniz**" OR" *Innovation*" *OR* " *Technolog**") AND ("*Pandemic*" *OR* "*Lockdown*" *OR* "*Social Distanc**")

Source: Prepared through the selection of keywords.

After the initial string search, filters were used for each journal database to identify similar options among the searches so that the results remained consistent. In this phase, pre-tests were conducted within the portals (Table 2) to identify the set of results obtained and refine the filters until usable and high-quality results were found for the present research.

Table 2: Pre-tests Conducted on Journal Databases

LENS
Pre-Test 1:
Initial search: n= 107,296
Application of the filters:
Date (2020, 2021, and 2022): n= 88.982
Type of document(*Journal Article*): n= 63,704
Subject Matter / Field of Study (Psychology; Political Science; Public Health; Sociology; Social Distance; Mental Health; Environmental Health; Psychological Intervention; Environmental Science; Perception; Politics): n= 21,345
Subject Matter / Subject (Health Policy; Psychiatry and Mental Health; Sociology and Political Science; Health (social science); Urban Studies; Social Psychology; Social Sciences (miscellaneous); Public Administration; Environmental Science (miscellaneous); Experimental and Cognitive Psychology): n= 2,493
Language (English, Spanish and Portuguese): No option.
Final application:
Initial search: n= 110,985
Application of the filters:
Type of document (articles): n= 81,200
Date (2020, 2021 and 2022): n= 65,837
Subject Matter / Field of Study (Psychology; Political Science; Public Health; Sociology; Social Distance; Environmental Health; Psychological Intervention; Perception; Politics): n= 20,675

Subject Matter / Subject (Social Psychology; Sociology and Political Science; Public Health, Environmental and Occupational Health; Sociology; Health Policy; Urban Studies; Public Administration): n= 2,789
Keyword Refine (*Public Health; Mental Health; Health Policy; Urban Health*): n= 265
Language (English, Spanish and Portuguese): No option.

SCOPUS

Pre-Test 1:
Initial search: n= 288,123
Application of the filters:
Date (2020, 2021, and 2022): n= 205,092
Type of document*(Article and Review*): n= 169,971
Subject area (Social Sciences; Environmental Sciences; Psychology; Multidisciplinary): n= 56,894
Language (English, Spanish and Portuguese): n= 55,695
Pre-Test 2:
Initial search: n= 42,986
Application of the filters:
Date (2020, 2021, and 2022): n= 38,369
Type of document*(Article and Review*): n= 29,953
Subject area (Social Sciences; Environmental Sciences; Psychology): n= 11,162
Language (English, Spanish and Portuguese): n= 10,771
Pre-Test 3:
Initial search: n= 42,986
Application of the filters:
Date (2020, 2021, and 2022): n= 38,369
Type of document*(Article*): n= 25,727
Subject area (Social Sciences; Environmental Sciences): n= 9,525
Language (English, Spanish and Portuguese): n= 9,196
Pre-Test 4:
Initial search: n= 42,986
Application of the filters:
Date (2020, 2021, and 2022): n= 38,369
Type of document*(Article*): n= 25,727
Subject area (Social Sciences; Psychology): n= 8,295
Language (English, Spanish and Portuguese): n= 7,995
Pre-Test 5:
Initial survey: n= 44,109
Application of the filters:
Date (2020, 2021, and 2022): n= 29,520
Type of document*(Article*): n= 26,473
Language (English, Spanish and Portuguese): n= 25,396
Subject area (Social Sciences; Environmental Sciences; Psychology; Multidisciplinary): n= 11,173
Limit To (Psychology; Cities; Technology; Innovation; Urban Population; Urban Planning): n= 1,655
Exclude (Air Pollution; Air Pollutant; Atmospheric Pollution; Nitrogen Dioxide; Ozone; Nitrogen Oxides; Carbon Monoxide): n= 1,472
Final application:
Initial search: n= 61,603
Application of the filters:
Type of document*(Article*): n= 40,973
Date (2020, 2021, and 2022): n= 37,920
Language (English, Spanish and Portuguese): n= 36,352
Subject area (Social Sciences; Psychology; Multidisciplinary): n= 13,432
Limit To (Psychology; Technology; Innovation; City; Urban Planning): n= 1,479
Exclude (Pneumonia Virus*, Viral Pneumonia; Telemedicine; Government; Teaching; Economics; Distance Education; Medical Education; Severe Acute Respiratory; Coronavirus Syndrome 2; E-learning; Telehealth; Online Learning; Medical Student; Medical Students*): n= 1,158

WEB OF SCIENCE

Pre-Test 1:
Initial search: n= 55,968
Application of the filters:
Date (2020, 2021, and 2022): n= 47,751
Type of document (articles and review articles): n= 40,779
Categories (*Environmental Studies; Psychology Multidisciplinary; Social Sciences Interdisciplinary; Urban Studies; Political Science; Sociology; Regional Urban Planning; Public Administration; Social Issues; Social Psychology; Humanities Multidisciplinary; Behavioural Sciences*): n= 3,433
Language (English, Spanish and Portuguese): n= 3,365
Pre-Test 2:
Initial search: 57,830
Application of the filters:

Date (2020, 2021, and 2022): n= 49,612
Type of document (articles and review articles): n= 42,286
Categories (*Environmental Studies; Social Sciences Interdisciplinary; Urban Studies; Political Science; Sociology; Regional Urban Planning; Public Administration; Social Issues; Social Psychology; Behavioural Sciences*): n= 2,885
Language (English, Spanish and Portuguese): n= 2,842
Pre-Test 3:
Initial search: 57,830
Application of the filters:
Date (2020, 2021, and 2022): n= 49,612
Type of document (articles): n= 37,337
Categories (*Environmental Studies; Urban Studies; Political Science; Sociology; Regional Urban Planning; Social Issues; Social Psychology; Behavioural Sciences*): n= 2,188
Language (English, Spanish and Portuguese): n= 2,159
Final application:
Initial search: n= 27,444
Type of document (articles): n= 22,014
Date (2020, 2021, and 2022): n= 19,936
Language (English, Spanish and Portuguese): n= 19,512
Categories Refine (*Social Sciences Interdisciplinary; Urban Studies; Political Science; Sociology; Regional Urban Planning; Public Administration; Social Issues; Social Psychology; Humanities Multidisciplinary; Behavioural Sciences*): n= 1,503

Source: Prepared through the application of the search procedures

Subsequently, raw data was extracted from the academic texts and articles that better matched the research topic, according to inclusion, exclusion, and thematic criteria could be selected. The following options were considered in all databases:

a) *Type of Archive:* Articles only, to retain the already published and official content, including peer reviewed materials.

b) *Schedule (2020–2022):* Due to the active recent pandemic period.

c) *Languages:* Portuguese, to cover the original language of the present study; Spanish, to address Latin American countries; and English, to highlight the international nature of the study.

The filters were then applied to specific categories provided by each database (Table 3). These procedures were supported by the research protocol (Table 4).

Table 3: Filters Applied to Journal Databases

"*Subject area*" (Terms: *Social Sciences; Psychology; Multidisciplinary*), Keyword "*Limit To*" (Terms: *Psychology; Technology; Innovation; City; Urban Planning*) and Keyword "*Exclude*" (Terms: *Virus Pneumonia, Pneumonia Viral; Telemedicine; Government; Teaching; Economics; Distance Education; Medical Education; Severe Acute Respiratory; Coronavirus Syndrome 2; E-learning; Telehealth; Online Learning; Medical Student; Medical Students)*. The filter "Categories" was chosen from WoS (Terms: *Social Sciences Interdisciplinary; Urban Studies; Political Science; Sociology; Regional Urban Planning; Public Administration; Social Issues; Social Psychology; Humanities Multidisciplinary; Behavioural Sciences*). The filters "Subject Matter" / "Field of Study" were applied to Lens (Terms: *Psychology; Political Science; Public Health; Sociology; Social Distance; Environmental Health; Psychological Intervention; Perception; Politics*), "*Subject Matter*" /"*Subject*" *(*Terms: *Social Psychology; Sociology and Political Science; Public Health, Environmental and Occupational Health; Sociology; Health Policy; Urban Studies; Public Administration) and* Keyword "*Refine*" *(*Terms: *Public Health; Mental Health; Health Policy; Urban Health)*.

Source: Prepared through the application of the search procedures.

Table 4: Search Protocols Applied to Selected Journal Portals

Lens	Scopus	Web of Science
Initial String Total results: n = 110,985	Initial String Total results: n = 61,603	Initial String Total results: n = 27,444
Filter: Type of document Article n = 81,200 | 29,785 excluded	Filter: Type of document Article n = 40,973 | 20,630 excluded	Filter: Type of document Article n = 22,014 | 5,430 excluded
Filter: Publication date 2020, 2021, and 2022 n = 65,837 | 15,363 excluded	Filter: Publication date 2020, 2021, and 2022 n = 37,920 | 3,053 excluded	Filter: Publication date 2020, 2021, and 2022 n = 19,936 | 2,078 excluded
Filter: Categories *Subject Matter / Field of Study* n = 20,675 | 45,162 excluded	Filter: Language Portuguese, English and Spanish n = 36,352 | 1,568 excluded	Filter: Language Portuguese, English and Spanish n = 19,512 | 424 excluded

Lens	Scopus	Web of Science
Filter: Categories *Subject Matter Subject* n = 2,789 | 17,886 excluded	Filter: Categories *Subject area* n = 13,432 | 22,920 excluded	Filter: Categories n = 1,503 | 18,009 excluded
Filter: Keyword n = 265 | 2,524 excluded	Filter: Keyword Limit To n = 1,479 | 11,953 excluded	Partial result: 1,503 articles
Partial result: 265 articles	Filter: Keyword Exclude n = 1,158 | 321 excluded	
	Partial result: 1,158 articles	

Source: Based on the bibliometric procedures adopted.

After extracting information from the retrieved articles, exclusion *criteria* for duplicate studies and epidemiological contexts other than the recent pandemics were established because of the possibility of finding documents that addressed events prior to it. Other articles dealing with the disease were accepted for the reasons already explained.

Subsequently, because of several articles that emerged from the application of the string, the collected data were classified to allow an analysis of the main topics found and how they related to the purpose of bibliometrics. After reading the titles and keywords, the main characteristics of the texts were identified and classified into relevant topics for this study, culminating in the categories described in Tables 5 and 6.

Table 5: Description of Thematic Categories not Relevant to the Study

Information and Media	Addresses the dissemination of information, credibility, manipulation, fake news, and the sharing of data during the pandemic, with articles addressing publications and communications in newspapers, radio, and social media, among other media, with topics not directly related to aspects of cities.
Education	Highlights the influence of the pandemic on education in general, considering both the need to adapt to online courses and the infrastructure of educational institutions, as well as the impact on professionals and students.
Ecology	Presents relevant points for areas of environmental sustainability, such as pollution, and conservation of natural resources such as climate, fauna, and flora, among others, not related to cities and humanization.
Specific Location (Internal or Individual)	Shows the conditions of closed environments with little relation to the community, such as tenements, domestic spaces, kitchens, gardens, asylums, prisons, hotels, and libraries, as well as topics about the individuality of family nuclei, gender issues, and domestic and child conflicts, without addressing the interactions of these subjects or places with the city.
Scientific Methodology	Assesses various forms of scientific production, methods, practices, disclosures, resources, adaptations to the pandemic period, and fraud, among other topics, without direct reference to the keywords of this study.
Mobility and Accessibility	Gathers information on pandemic disruptions in people's interaction with urban mobility. Although this is an interesting topic for the humanized landscape, it offers a very specific perspective that can possibly be used for other opportunities.
Digital World	Lists various ways of using digital tools after social isolation imposed by pandemics, mentioning social media, video calls, electronic materials, artificial intelligence, cyber security, robotics, virtual reality, and the like.
Policy and Management	Discusses party politics and government and civic issues, discussing forms of government, Brexit, and citizen participation in government projects; theories on public administration during the pandemic are also wide-ranging and may contribute to future studies of the humanized landscape.
Professions and Organizations	Examines the impact of social isolation and measures to mitigate the disease effects in the workplace, focusing on specific occupations and adaptations to online services, as well as the impact on facility rental, informal and domestic workers, and coworking and organizations, and the development of digital entrepreneurship.
Economy	Explores the economic impact of the pandemic and links health and economic issues, including increased market values, financial rankings, free market, neoliberalism, financial solidarity, basic income, taxes, and wages.

Security	Investigates issues of workplace safety, child abuse, neglect and maltreatment, domestic violence, dangers of nuclear materials, street crime, organized crime, and overcrowding during the pandemic, which can be addressed in future research.
Medicine and Health	Develops content on strategies for the care of patients with various clinical conditions associated with the disease and the management of physicians and other healthcare workers, such as psychologists, biomedical and nursing staff, in clinics and hospitals, in the context of the pandemic.
Tourism	Considers issues of access to tourist environments and new places and ways of visiting, including discourses on sustainability, the tourism industry, sporting events, accommodation, historic centers, markets, economics, inclusion, travel, recreation, and other related content, with no focus on the city, although this is a topic for further research on the humanized landscape.

Source: Prepared from the search results from the Lens (2020-2022), Scopus (2020-2022), and WoS (2020-2022) databases.

Table 6: Description of the Thematic Categories Relevant to the Study

Isolation and Social Distancing	Deals with social behavior during the pandemic and pays special attention to people's responsibility to integrate into cities in the face of health directives, mentioning interaction at a distance, neighborhood relations, loneliness, and related issues.
Pandemic Impacts on Cities	Reports on the experience of municipalities and public policy, particularly in relation to housing and public administration in the context of the pandemic, focusing on the impact on urban settlements, agglomerations, and slums and on post-pandemic planning, considering effective solutions at this time, with emphasis on the elements of the city and its landscape.
Open Spaces and Green Areas	Provides data to identify open spaces with potential for community interaction during the pandemic crisis and highlights opportunities for the use of natural landscapes and green spaces in the urban environment.
Community Experiences	Discusses community experiences during the pandemic, highlighting the differences between urban structures, government decisions, social interaction in specific places, constraints, well-being, and decision-making in the context of the disease taking into account the perceptions of social groups and their relationships with urbanized spaces.
Smart Cities	Develops concepts for aligning technological, social, economic, and environmental interests to meet the needs arising from the considerations of pandemics, with an important link to technology and innovation, which are fundamental to this study.
Technology and Innovation	Identifies tools and materials used in the context of the recent pandemic as a key criterion for research development to meet community needs and humanize the cityscape.
Human Rights and Public Policies	Targets vulnerable groups such as immigrants, women, and the elderly, among others, in terms of public policies for access to citizenship in their respective places of residence, with content focused on the analysis of inequalities, awareness, vulnerabilities, people on the street, social policies applied to the morphology of cities and related issues, with a strong link to the landscape and its humanization processes.
Humanization	Discusses the subjective aspects of people interacting with the landscape, with information on the psychosocial impact of the pandemic, systemic thinking about the crisis, care planning, psychological suffering of residents in specific locations, crisis management, human behavior, and other content of fundamental interest to this research.
Urban Design and Planning	Identifies ways in which urban areas can survive the impact of the disease; investigates resilient cities, spatial planning and management, use of public spaces, healthcare options, environmental improvements and flexibility; proposes experimental solutions to the health crisis, and eventual technologies and innovations in the urban environment.

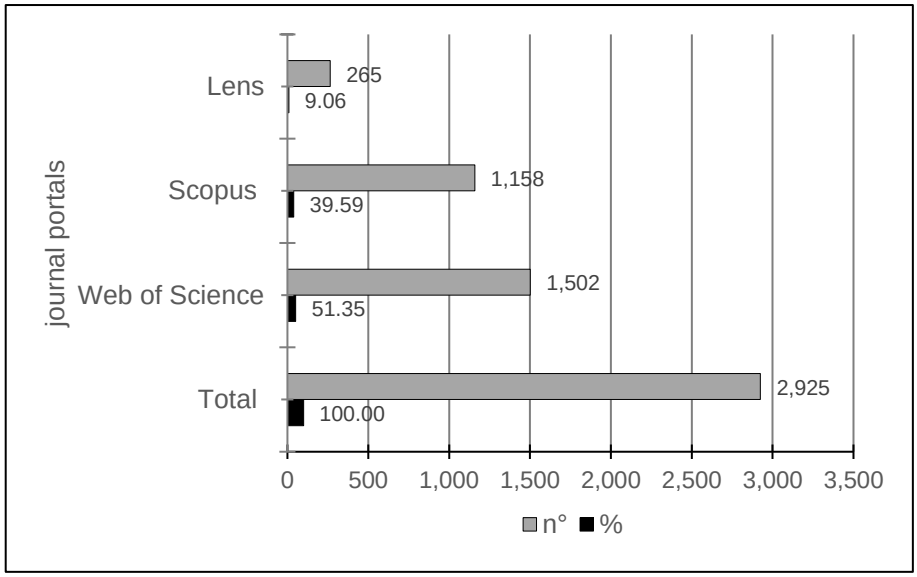
Source: Prepared from the search results from the Lens (2020-2022), Scopus (2020-2022), and WoS (2020-2022) databases.

Text analysis was then performed to assess the main theoretical and practical debates on the topic. As some studies could not be accessed, the bibliometric screening was completed by selecting 149 articles.

After applying all the criteria described, a table was created to systematize the data collected; this also included the study typology, divided into theoretical and empirical studies, and the research countries, which were used to classify the continents to which the publications referred. These results are explained in more detail below.

IV. Bibliometric Results

As mentioned earlier, the bibliometric search without filters returned a total of 200,032 results, of which only 1.46% (2,925) were useful for the topic studied. Most of these articles were eligible for a full reading based on the possibility of using their content came from the Scopus (1,158 [39.59%]) and WoS (1,502 [51.35%]) databases, which returned several studies compared to Lens (265 [9.06%]) (Figure 1).

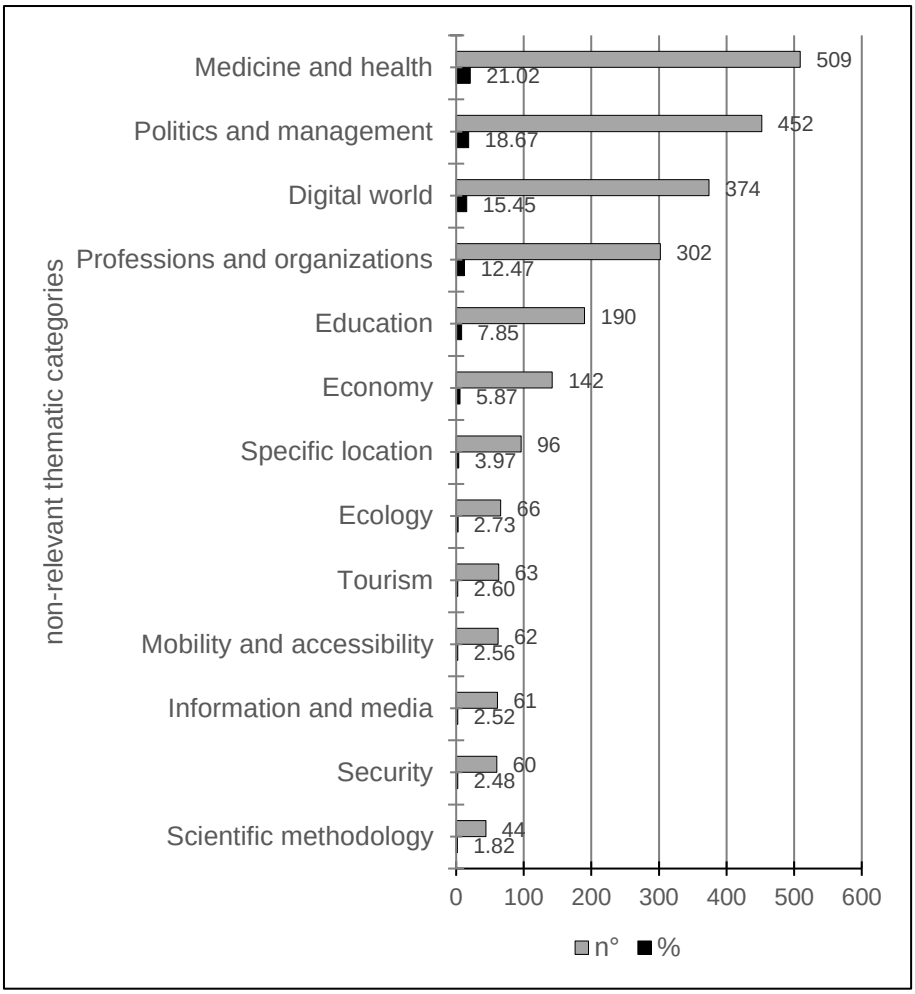


Source: Prepared from data extracted from Lens (2020-2022), Scopus (2020-2022), and WoS (2020-2022).

Figure 1: Chart of Quantities and Proportions of Scientific Articles Found by Journal Portals

The results from both databases of higher proportionality of the bibliometric search represent the most meaningful content in the international literature addressing issues related to the humanized landscape as understood in this study. It is worth noting that the string applied aimed to understand theories, methods, technologies, and innovations related to the thematic. Therefore, it was selected without a population sample or limiting the search to a specific environment, such as central, commercial, or domestic regions in cities, as these were all viable analytical options. Thus, general information was sought to delineate the new approach, which had not been easily found in the literature until then.

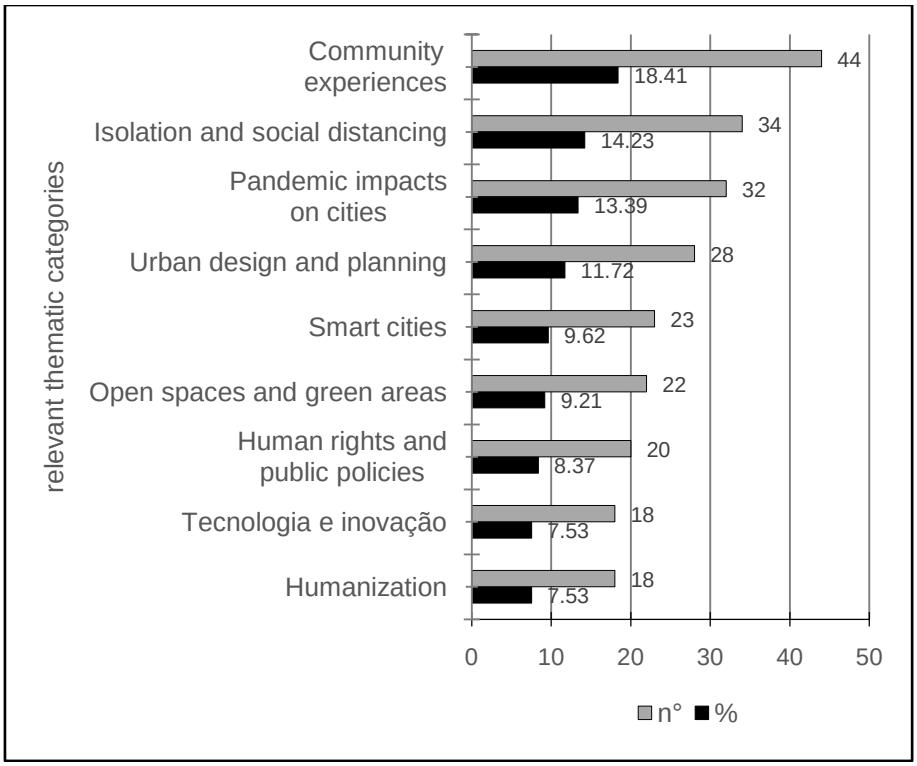
The topics addressed by articles not relevant to the study are shown in Figure 2 and correspond to 2,421 articles (82.8% of the total). As expected, medicine and health account for the largest proportion of articles, with 21.02% (509).



Source: Elaborated from data taken from Lens (2020-2022), Scopus (2020-2022), and WoS (2020-2022).

Figure 2: Chart of Quantities and Proportions of Articles by Thematic Categories not Relevant to the Study

Figure 3 shows the results for the thematic categories relevant to the research, accounting for 239 articles (8.17% of the total). In this context, it is worth highlighting the articles addressing community experiences (44 articles [18.41%]).

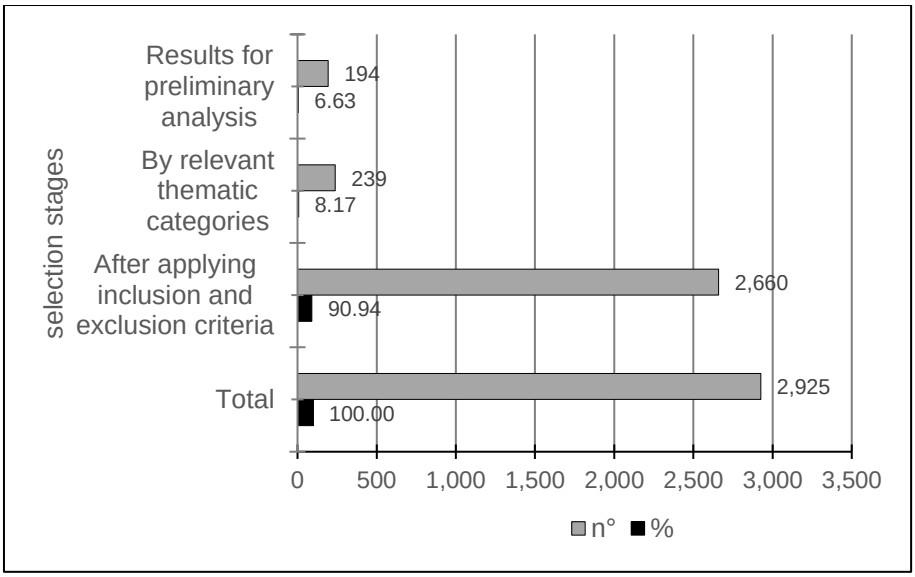


Source: Prepared from data extracted from Lens (2020-2022), Scopus (2020-2022), and WoS (2020-2022).

Figure 3: Chart of Quantities and Proportions of Articles Per Relevant Thematic Categories

The procedures used in the following phases were combined to select and classify articles relevant to the central topics of the investigation. The exclusion criteria resulted in the removal of 265 (9.06%) publications extracted from the databases – 69 because they were duplicates and 196 because they were not suited to the specific context of the health crisis.

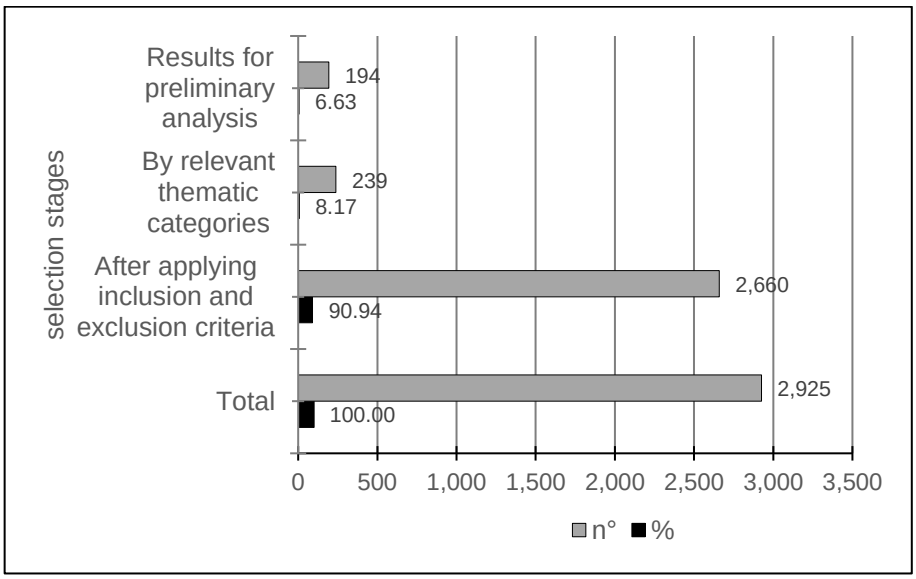
Most of the data met the inclusion criteria, and 90.94% (2,660) of the documents were selected in this phase (Figure 4). The 239 texts in the relevant thematic categories were read to assess their suitability for the study, resulting in 194 articles (81.17% of the previous result).



Source: Prepared from data extracted from Lens (2020-2022), Scopus (2020-2022), and WoS (2020-2022).
Note: Sum of percentages not equivalent to 100.00%

Figure 4: Chart of Quantities and Proportions of Selected Articles per Bibliometric Phases

Of the 194 articles, 137 were empirical studies (70.62%) (Figure 5), which addressed both cities and communities during the pandemic period in different global contexts. On the other hand, only 57 theoretical texts (29.38%) were found, most of which focused on works published during the health crisis and reports of actions taken by the city government.



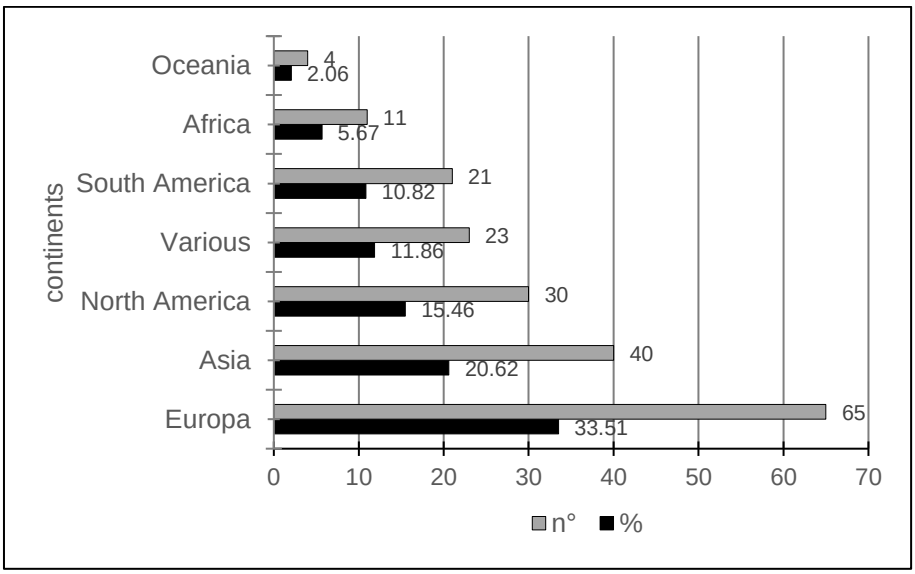
Source: Elaborated from data taken from Lens (2020-2022), Scopus (2020-2022), and WoS (2020-2022).

Figure 5: Chart of Quantities and Proportions of Articles after Preliminary Analysis by Approach Typology

Of the six continents, only Antarctica was not found in the 194 selected articles. Because of the large territorial extent and the significant cultural differences among the regions, America was divided into two subcontinents – South and North – as no article from Central America was found.

Providing information relevant to the analysis of the international context, the journal databases included articles with proportionally different publication locations (Lens: 7 countries, 4 continents, and 2 subcontinents; Scopus: 31 countries, 3 continents, and 2 subcontinents; WoS: 35 countries, 4 continents, and 2 subcontinents).

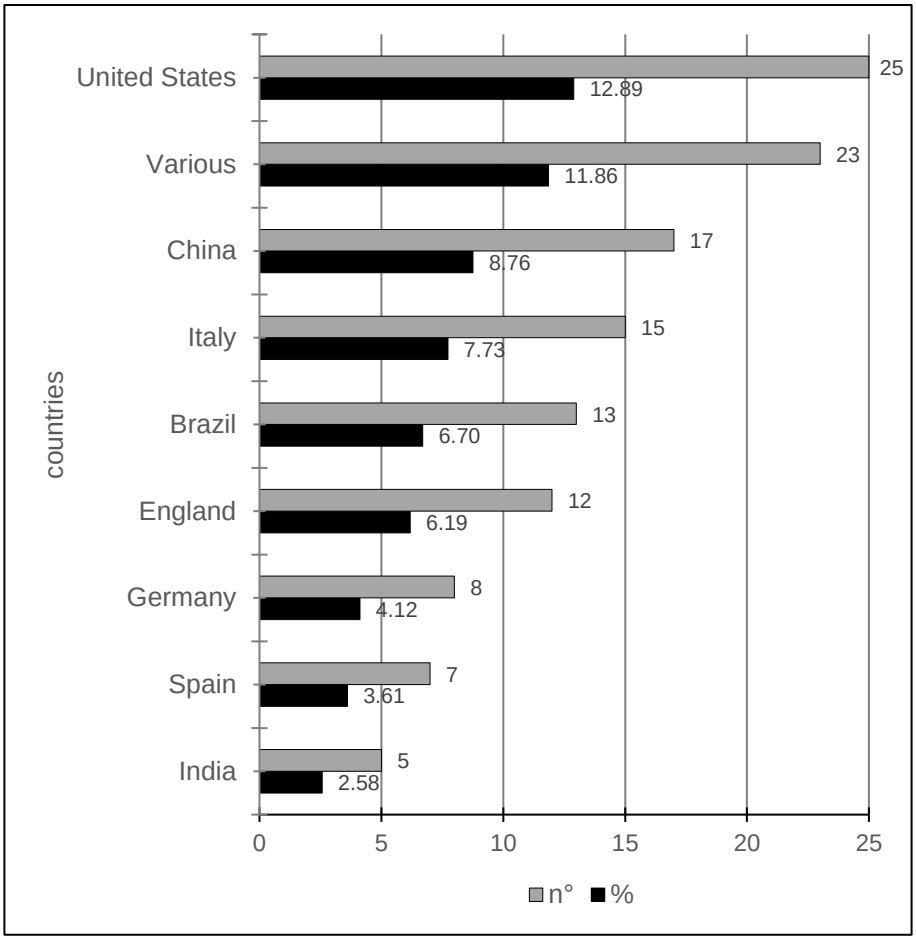
Overall, Europe is the most represented, with 65 texts (33.51%), followed by Asia with 40 (20.62%). The continents with the lowest rates are Africa with 11 (5.67%) and Oceania with 4 (2.06%) (Figure 6).



Source: Prepared from data extracted from Lens (2020-2022), Scopus (2020-2022), and WoS (2020-2022).

Figure 6: Chart of Quantities and Proportions of the Continents Addressed in the Selected Articles

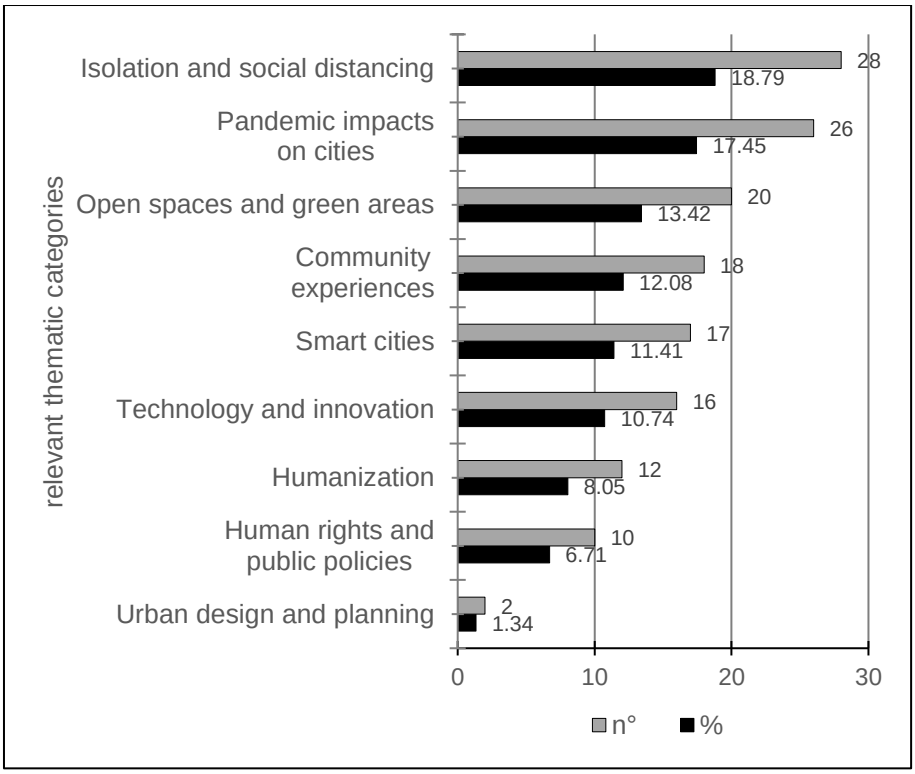
Fifty countries and several cities were analysed in the 196 articles selected. Brazil was in fifth place with 13 studies (6.70%) (Figure 7). However, most of the publications came from the United States, with 25 (12.89%), followed by the 23 articles classified as 'other' (11.86%), which refer to works conducted in more than one country and mostly consist of comparisons between regions on different continents.



Source: Elaborated from data taken from Lens (2020-2022), Scopus (2020-2022), and WoS (2020-2022).
*Note: * = proportion exceeding 2.50% of the total*

Figure 7: Chart of Quantities and Proportions of the Nine* Countries Most Addressed in the Selected Articles

Of the 194 articles included in categories relevant to the topic, 45 (18.83%) were excluded because they were not freely accessible, resulting in 149 (76.80% of the texts selected for preliminary analysis). This reclassified the initial views on isolation and social distancing (28 [18.79% of the available articles]) and on the impact of the pandemic (26 [17.45%]) (Figure 8).



Source: Prepared from data extracted from Lens (2020-2022), Scopus (2020-2022), and WoS (2020-2022).

Figure 8: Chart of Quantities and Proportions of Open Access Articles by Relevant Thematic Category

Reading the articles in their entirety offers several perspectives. However, since it is impossible to individually analyze the contents because they refer to various countries from different contexts, the next section summarises the general results regardless, highlighting the most relevant texts for the frequently addressed thematic categories.

V. Analytical Discussions

Isolation and social distancing were a sudden and radical step in the everyday life of individuals and for society, as well as for trade, transport, education, and professional practice. Amério et al. (2020), Ammar et al. (2020), and Mouratidis (2021) state that the quality of life was changed by the restrictions on movement in the cities during lockdown.

Residents' well-being was also affected by alterations in relationships between them and their neighbors (Marlow et al., 2021), not only due to imposed isolation but also due to the fear of contracting the pathogenic agent, which resulted in high mortality rates from mid-2020 to early 2022 (WHO, 2025). These factors increased people's sense of fear and unease in dealing with the city, increasing the *impact of the pandemic in cities* (Mouratidis, 2021).

Rosa and Mannarini (2021) found that the recent pandemic had a direct impact on the use of *open spaces and green areas* as well as on private places and socio-psychological aspects. The authors confirm that group interaction, communication processes, individual sense-making, and social behavior were changed by that health crisis.

The changes, however, affected not only the individual but also the common sphere. Natural and built spaces were affected by the changes in cities and neighborhoods, as social gatherings almost died out. In general, such environments are affectively remembered by citizens as places for personal and communal reflections, daily activities, and interaction with other groups, creating bonds of belonging (Pipitone & Jović, 2021; Rosa & Mannarini, 2021).

During the recent pandemic, densely wooded areas were widely used, both in economically favoured locations and in informal settlements. In general, residents of residential areas adhered to the recommendations of social distancing, reduced the frequency of central and tumultuous places, and used open spaces that were close to their homes (Zgórska, 2020).

Places with natural landscapes, such as forests, seas, and mountains, reached people's subjective look and proved to be socially safe because of the lower risk of infection. From this point of view, outdoor environments allowed the continuity of physical activities and social interaction from a distance (Mouratidis, 2021; Zgórska, 2020).

This knowledge guides the reasoning that the spatial structure of communities has potential and

awakens the interest of urban planners regarding the search for opportunities to expand functional open spaces for recreational purposes. Together, they make the reuse of degraded land for recreational purposes effective (Zgórska, 2020).

According to Mouratidis (2021), the presence and proximity of places used for recreation are important for maintaining or increasing the quality of life. Because of the risk of infection when traveling– especially on public transport – and mobility restrictions in cities, natural landscapes and green spaces in the neighborhood are seen as being increasingly relevant in the 'pandemic era' (Wolfe, 2011).

As a subjective element, well-being requires components such as life fulfillment, emotional satisfaction, and self-actualization. For example, Mir (2020) points out that the measures required to contain the pathogen disrupted several activities that promoted these conditions, such as recreational activities and social interaction. *Community experiences* with various civic initiatives associated with flexible adaptation to radically new situations have developed the concept of social innovation and increased knowledge in the field of urban resilience (Szemző et al., 2022).

Considering the international literature, the concept of *smart cities* was among the topics of greatest interest for this research, with innovations related to the care of individuals, regardless of the country studied, and proposals for a more inclusive and sustainable urban development process based on technological resources (De Las Heras et al., 2020; Graziano, 2021; Kang et al., 2020).

Technology and innovation adaptations had to be rapid and long-term as the pandemic became a global innovation phenomenon within a few months (Dahlke et al., 2021; Rosa & Mannarini, 2021). The use of information and communication technologies (ICTs) played an important role in people's quality of life as they relied on digital tools to communicate socially, request help, or receive virtual care (Cobelli et al., 2021; Mouratidis, 2021). It is worth mentioning, however, the warning from Miller & Smith (2021) regarding ethics in technological use.

Technological resources also play an important role in preventing new pandemics. When used in urban planning, they suggest that the future lies in the concept of smart cities – in other words, those that use technology to promote quality of life and quickly solve problems in the daily lives of their inhabitants (Yang & Chong, 2021).

Yang and Chong (2021) clarify that smart cities must integrate data and information systems from multiple sources to improve their ability to meet the aspirations of the population. In a pandemic, control and prevention of the spread of the virus or similar contagion agents could be achieved using assistive technologies in the urban structure. To this end, the authors highlight the need for governance initiatives that shape the different modalities of infrastructure in a specialized way and with citizens contributing to and understanding innovation as the demand comes from society itself.

Almost all the statements above, as well as others in the analyzed articles, address *humanization in (post-)pandemic cities.* However, the concept of 'care planning' proposed by Jon (2020) reconizes not only the interdependence of people but also the constant dialectical relationships between built and natural environments,

In terms of *human rights and public policy,* the decisions made in the management of cities during the pandemic period, as well as information about the mental health and well-being of individuals, are of great importance, in addition to alerts about citizens' rights (Gready, 2020; Torres Obregon, 2021). In this framework, aspects of societal vulnerability were reinforced by the disease outbreak, deepening pre-existing socio-economic inequalities (Wu et al., 2021).

Despite limited access to studies on *urban design and planning,* this study contributes to the debate on the basic principles and social aspects related to the design of architectural and urban spaces that can withstand the impacts of a health crisis era (Girardi, 2021; Melone & Borgo, 2020; Mir, 2020). Post-pandemic priorities are also postulated to structure cities so that they can develop and maintain their functionality with as few infections as possible during other severe diseases after Covid-19 (Aboukorin et al., 2021). This debate leads to the final reflections of this article.

VI. Conclusions

The general objective of this study, that is to assess the application of solutions in the field of humanized management of (post-)pandemic urban landscapes, especially in an international context, was achieved. At the same time, the answers to the research question reveal significant trends within a transnational framework, clarifying some of the most important principles for a human-centred future of the contemporary city.

The theoretical approaches to the interaction between landscape and humanization in the urban context served initially as a basis for the bibliometric search, which was also supported by the methodological procedures for texts classification, the results obtained, and the respective analytical discussion. The analysis of the selected articles and the increase in publications on content related to the recent pandemic with different information reveal that the impact of the health crisis has been studied in different areas and on a large scale from 2020 to 2022. It can therefore be assumed that investigations across most scientific fields examined the new topic in a global scale,

enabling the emergence of diverse keywords and multiple thematic categories within the research framework.

The increasing number of studies on the adaptations required for the pandemic indicates that the search for alternatives for the 'humanization' of cities is still at a preliminary stage. In general, the challenge remains to further identify the relationships between human-centred principles and new applied solutions – in other words, to create innovative connections for the area. This is partly because the topic is unprecedented and has been little discussed in the literature.

The present study serves as a basis for overcoming this paradigm. The development of descriptive research on the conceptual definition of the 'humanized landscape' can contribute to future research as it is a topic that has expressive potential for different areas of urban research, despite the still insufficient framework of references focused on this kind of interpretation.

On the other hand, the diversity of the content found gives rise to several possibilities for establishing principles for urban planning. At least in part, it provides important solutions for the humanized future of today's cities.

The need to establish relationships between state administration and specific public measures as a part of the humanization of urban landscapes is also worth mentioning. Greater care for citizens in terms of health and safety in the post-pandemic period is also needed.

Acknowledgments

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Agroecology in Metropolitan Regions in Brazil – Socioterritorial and Socio-Spatial Movements

By Marcelo Gomes Justo

Abstract- This article aims to analyze agroecology in metropolitan regions in Brazil, based on the concepts of socio-spatial and socio-territorial movements. It also draws parallels regarding the presence of agroecology in different metropolitan regions. Another aspect is to continue evaluating these concepts to understand the dynamics of agroecology. The method relies on primary sources from previous research and secondary sources for data comparison. As concluding considerations, the advancement of agroecology depends on the conquest of land and territory -stemming from socio-territorial movements - and on its spatial dissemination, where socio-spatial movements may have an impact. While socio-territorial movements are necessary for agroecology, they are not sufficient on their own. In this case, the concept of socio-territorial movement is explanatory. The expansion of agroecology in metropolitan regions is driven by the actions of movements, associations, and universities. This is a socio-spatial action, such as networks, not merely the presence of socio-spatial movements.

Keywords: *agroecology, metropolitan regions, socio-territorial movements, socio-spatial movements.*

GJHSS-B Classification: *FOR Codes: 070108*

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Keywords: agroecology, metropolitan regions, socio-territorial movements, socio-spatial movements.

I. Introduction

This article seeks to analyze, based on the concepts of socio-spatial and socio-territorial movements, the mobilization around agroecology in metropolitan regions across Brazil. Is agroecology strong enough to become a new sustainable food system in the face of an agro-industrial model that harms the environment? The interest in examining the dynamics of agroecology in metropolitan regions - where the most people live - lies in understanding its potential to promote adequate and healthy diets, based on *in natura* or minimally processed products, as established by the *Food Guide for the Brazilian Population* (2014). In fact, this *Food Guide* was pioneering in presenting to the world the new food classification (*in natura*, condiments, minimally processed, and ultra processed foods), which, for more than ten years, has been driving a scientific revolution in nutrition.

We have a dual objective: to advance the discussion on agroecology in metropolitan regions in Brazil and to evaluate the concepts of socio-territorial and socio-spatial movements to understand the defense of agroecology. The guiding question is: how can the presence of socio-spatial and socio-territorial movements in metropolitan regions contribute to overcoming the dominant food system?

Brazilian metropolises are arenas where contemporary tensions and contradictions converge climate change with environmental racism, hunger and obesity affecting peripheral populations. Metropolitan regions encompass cities with high urban density as well as rural characteristics. Within them, food industries and agroecology movements are in conflict: junk food versus slow food; ultra processed versus *in natura* foods; restaurants led by chefs who are in favor of regional cuisines based on peasant family farming. Agroecology cannot remain confined to market niches; hence the emphasis on the need for popular agrarian reform - through socio-territorial movements - and spatial diffusion. Agroecology can consolidate as a new food system by reaching the masses concentrated in metropolitan regions, since the so-called Green Revolution appeared as the only way to produce food for such large populations. Will this require the joint action of socio-spatial and socio-territorial movements?

Over the past decades, agroecology research and practices have multiplied. Well-known figures as Miguel Altieri, who, since the late 1980s, established agroecology as an alternative agriculture; Eric Holt-Giménez, with the *campesino a campesino* method; Stephan Gliessmann; Eduardo Sevilla Guzmán; and not least Ana Primavesi, they have solidified the academic field of agroecology in the Western world. Other important names, such as Vandana Shiva (2016), have strengthened the discussion on how harmful agribusiness is and underlined that it is peasant family farming that truly feeds the world, with this debate expanding globally. In earlier work, a literature review on agroecology was systematized, grouping a set of its interdependent characteristics: agrobiodiversity, peasant way of life and the role of women, knowledge dialogue, resistance to cooptation by capital, and the action of socio-spatial and socio-territorial movements (JUSTO, 2020). It is common in agroecology literature to elaborate systematizations gathering characteristic elements, especially when drafting public policy recommendations, such as in FAO (2019). It is worth adding that one of the first authors to link agroecology with the socio-territorial movement concept has insisted on its non-cooptation by capitalist agriculture, distinguishing between neoliberal or reformist agroecology and truly emancipatory agroecology

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(GIRARDO; ROSSET, 2017; 2021). *Recampesinization* (to learn the peasant ethos) is a process that has been analyzed and is related to territorial conquests that reposition peasant and agroecological farming in opposition to the process of *descampesinization* (dispossession or to lose the peasant ethos) driven by the "Green Revolution" (FERNANDES, 2019; ULE MUÑOZ; ROSSET, 2022; PLOEG, 2016).

On the other hand, this article aims to contribute to the theoretical discussion on the concepts of socio-spatial and socio-territorial movements (FERNANDES, 2012; HALVORSEN, FERNANDES & TORRES, 2019) and their applications to explain agroecology in metropolitan regions. By comparing data from earlier research with other works addressing agroecology in metropolitan regions, the goal is to deepen the interpretation of how agroecology can be established in these regions through a combination of socio-territorial and socio-spatial movements (JUSTO, 2020; 2023). As Fernandes (2019) underscores, peasant movements have evolved and, recently, in addition to the struggles for land and territory, peasants have fought against food empires and, for healthy food. "Peasantry reinvented food with the concept of food sovereignty and agroecology" (FERNANDES, 2019, p. 207). In collaborative work, the author states that public policies for family farming during the *lulista*[1] period (2003–2016) enabled the "territorialization of agroecological production" (HALVORSEN, FERNANDES & TORRES, 2019, p. 10).

Fernandes (2005) coined the concepts of socio-spatial and socio-territorial movements to bring a geographic perspective into the sociological concept of social movement, adding the spatial dimension to social movements. His main contribution was to characterize some movements as having the conquest of territory as their power, explaining that in socio-territorial movements territory is essential to their existence. "Territorialized movements are those that act across multiple macro-regions and form a network of relations with political strategies that promote and foster their territorialization" (FERNANDES, 2005, p. 31). Based on these definitions, the present work seeks to advance the discussion on the use of these concepts applied to agroecology movements.

The research is based on primary sources and, principally, secondary data such as bibliographic reviews, the IBGE (Brazilian Institute of Geography and Statistics) census, and the national register of organic producers. Secondary data enabled comparisons between previous studies (JUSTO, 2020; 2023) and the situation in other metropolitan regions. The method involved drawing parallels between agroecology and metropolitan regions, based on research on six Land Communes across four metropolitan regions in the state of São Paulo, plus a fifth metropolitan region in another state as a counterpoint. The MST (Landless Rural Workers Movement) has ensured agroecology's entry into metropolitan regions through land occupation, as socio-territorial action. The Land Communes studied are: in the São Paulo Metropolitan Region, Sister Aberta (Perus, SP/SP), Bishop Tomás Balduíno (Franco da Rocha, SP), Bishop Pedro Casaldáliga (Cajamar, SP); in the Campinas Metropolitan Region, Milton Santos (between Cosmópolis and Americana); in the Ribeirão Preto Metropolitan Region, Mário Lago settlement (Ribeirão Preto); in the Vale do Paraíba and North Coast Metropolitan Region, New Hope settlement (São José dos Campos). Additionally, there is the Porto Alegre Metropolitan Region (RMPA), with a set of cooperatives and renowned national production of agroecological rice, which serves as a counterpoint to the Land Communes experiences.

The following section presents a contextualization. Beyond this Introduction, the article has by two main parts: the first exposes and analyzes socio-territorial movements conquering territories for agroecology in metropolitan regions; the second addresses socio-spatial movements related to changes in eating habits toward an agroecological food system.

In recent decades, a colonized notion has consolidated in Brazil. The country has finally "modernized" by overcoming the rural, viewed as synonymous of underdevelopment. Brazil has shifted from rural to urban. The latest population census reports less than 15% of the population living in rural areas. Between the 1950s and the late 1980s, approximately 30 million people migrated from rural areas in the Northeast to major urban centers in the Southeast, constituting one of the largest internal migrations in the Western world in the 20th century, as noted by various scholars.

In truth, the country's structural under-development lies not in the persistence of rural areas, but in the deep concentration of land and wealth, severe social inequalities, the enduring presence of authoritarian and clientelist practices, and the lack of basic infrastructure and sanitation.

Despite the rapid expansion of cities, over 87% of Brazil's 5,570 municipalities have populations of up to 50,000, and 94.15% have fewer than 100,000 inhabitants. Only 326 cities, 5.85% of the total, have populations above 100,000, yet these urban centers account for 57.7% of the national population, according to the Brazilian Institute of Geography and Statistics (IBGE).

There are currently 74 officially recognized metropolitan regions in Brazil. The states with the most are: Santa Catarina (11), Alagoas (9), and Paraná (8). Additionally, five urban agglomerations were identified: three in the state of São Paulo and two in Rio Grande do

[1] It is related to the period of Brazilian´s President Lula and Dilma, both of Labor Party (PT).

Sul. In 2015, the Statute of the Metropolis (Law No. 13,089/2015) was enacted, defining a metropolitan region as a regional unit established by state-level complementary law, comprising a group of neighboring municipalities organized for the integrated planning and execution of public functions of common interest. A metropolitan area is characterized by the continuous expansion of the urban fabric, marked by the integration of road systems and high rates of commuting across residential, industrial, and service areas.

According to IBGE, the most populous metropolitan regions, in descending order, are São Paulo, Rio de Janeiro, Belo Horizonte (and its surrounding metropolitan area), Porto Alegre, Fortaleza, Salvador, Recife, Curitiba, Campinas, Manaus, Vale do Paraíba and Litoral Norte, Goiânia, and Belém. The present research focuses on four of these regions, which together have an estimated population of approximately 28 million people.

In this context, urban agriculture movements have spread across large cities, involving residents, social organizations, and, in some cases, municipal governments. Over the past two decades, cities such as São Paulo, Rio de Janeiro, and Recife have developed public policies to support urban agriculture, while grassroots initiatives led by local communities have established spontaneous urban gardens. These actions bring agroecology and discussions around healthy food systems into urban environments and can be characterized as socio-spatial movements that, at times, begin to engage in territorial disputes[2].

The presence of agroecology in metropolitan regions occurs mainly in two forms: through land reform settlements (independently of being or not defined as Land Communes), which represent socio-territorial movements; and through urban and peri-urban agriculture, which may constitute either socio-territorial or socio-spatial movements (JUSTO, 2019; 2022).

It is also important to highlight the survey conducted by the National Articulation of Agroecology (ANA) on municipal-level initiatives supporting family farming and agroecology. The study identified more than 700 local actions, including public policies, programs, laws, and other measures, across 531 municipalities in 26 states, addressing around 40 different thematic areas. Among them, the city of São Paulo stands out as one of the municipalities with the highest number of initiatives, totaling 15 (ANA, 2021).

a) Agroecology in Metropolitan Regions and the Conquest of Territories: Socio-Territorial Movements

In the early 2000s, the Landless Rural Workers' Movement (MST) developed the concept of Land Communes, agrarian reform settlements in metropolitan regions, with relatively small plots for housing and work, collective food production areas aimed at urban supply, blending rural and urban characteristics, and adopting agroecological and cooperative practices (MATHEUS, 2003). According to Goldfarb (2007), Land Commune expropriations range from 100 to 800 ha (hectare), while those located further inland typically exceed 1,000 ha. Individual plots in these settlements range from 1 to 10 ha, compared to an average of 16 ha in non-urbanized areas. Although the Land Communes were conceived as agroecological, they face the same external pressures as other settlements, which often push against such practices.

We are addressing initiatives with two decades of existence. The comparison centers on to be a Land Commune (which means families originating from urban areas or marked by an urban ethos, managing relatively small plots, seeking cooperation and agroecology), as well as the socio-territorial actions of the MST in every case; and, how the exchange of knowledge and experiences allows traditional peasant agriculture to become agroecological. A key finding shared among the Communes experiences is the recreation of a peasant ethos (JUSTO, 2008) and the viability of a way of life based on their plots production. The case of Porto Alegre, which is not a Land Commune, serves as a counterpoint.

i. *The Land Communes in Four Metropolitan Regions of the State of São Paulo*

This section presents studies on six Land Communes located in four metropolitan regions of the state of São Paulo: Greater São Paulo, Campinas, Ribeirão Preto, and the Paraíba Valley and North Coast. The state has six metropolitan regions, but Baixada Santista and Sorocaba were excluded due to lack of available data.

Together, these four regions comprise a population of approximately 28 million. The São Paulo Metropolitan Region (RMSP) alone accounts for about 10% of the entire Brazilian population, with over 20 million residents across 39 municipalities. Population density varies widely, from 39.7 inhabitants/km² in Salesópolis to 13,715 in Taboão da Serra. The Campinas Metropolitan Region (RMC), established by law in 2000, has 3.5 million inhabitants and includes 20 municipalities. The Ribeirão Preto Metropolitan Region (RMRP), created in 2016, comprises 34 municipalities with a combined population of around 1.7 million. The Paraíba Valley and North Coast Metropolitan Region (RMVPLN), established in 2012, includes 39 municipalities and 2.5 million inhabitants. According to the IBGE Agricultural Census (2017), São Paulo state has 188,620 agricultural establishments, of which 122,555 are family farms and 66,065 are agribusiness operations.

[2] Some São Paulo city cases was analyzed by Justo (2020). Biazoti et al (2021) analyzed the growing of urban agriculture in São Paulo city.

a. *The three Land Communes in São Paulo Metropolitan Region (RMSP)*

This subsection focuses on three Land Communes in the RMSP, analyzed in previous empirical and secondary-source research (JUSTO, 2023), allowing for over a decade of insight. In Cajamar, the Sustainable Development Project (PDS) São Luís, official name, known as Land Commune Bishop Pedro Casaldáliga, was established in 2006 with 29 families on 121 ha. In Franco da Rocha, the São Roque Settlement Project, known as Land Commune Bishop Tomás Balduíno, was also created in 2006, with 61 families on 538.7 ha. Lastly, the Land Commune Sister Alberta is a land occupation in Perus (São Paulo city) on a 117-ha plot owned by a public sanitation company (SABESP), still pending expropriation.

Main results are: former urban dwellers have embraced the identity of peasant family farmers as a way of life; there are varying levels of engagement with agroecology, with most families in a transitional phase; production faces challenges in distribution, with modest outputs (e.g., fortnightly sales of organic produce baskets); and produce partially sustains the settler families' diets. Besides, there are two Social Control Organizations (OCS), one in Bishop Tomás and one in Bishop Pedro, each involving around 30 families.

b. *Land Commune Milton Santos in Americana – SP (RMC)*

Initiated in 2005, the Milton Santos Settlement is located between Americana and Cosmópolis, in the Jacutinga stream basin, and comprises 73 families on 105 ha. The families originated from urban peripheries in Limeira, Sumaré, and Campinas, in line with the Land Commune proposal. In the early years, researchers noted that urban habits created resistance to collective projects and the settlers preferring individual plots. To address this, academic extension efforts promoted the recovery of peasant farming practices (BOMBARDI; MANFREDINI; FERNANDEZ, 2009, p. 137).

In 2015, an OCS was formed with support from the Agroecology Center of ESALQ–USP (University of São Paulo), involving four neighboring families. Subsequently, a cooperative called Cooperflora was created with 12 families to commercialize their production to consumer groups near the settlement. By 2017, they were supplying 50 weekly baskets of seasonal fruits and vegetables (MARQUES et al., 2017).

c. *Mário Lago Settlement in Ribeirão Preto – RMRP*

In Ribeirão Preto city, the Sustainable Development Project *Fazenda da Barra*, better known as the Mário Lago Settlement. An MST land occupation in 2003 originated this settlement and it was officially recognized by INCRA (National Institute of Land Reform) as a land reform settlement on June 20, 2007. It comprises 473 families on 1,549.5 ha. The Land Commune is well known for its agroforestry practices. Gomes (2015) described 264 families living there, with each plot measuring 1.5 to 1.7 ha.

Iha (2015) reflects on the tensions between traditional peasant knowledge and agroecological training. One example is the debate over whether to keep or remove spontaneously growing weeds around crops: agroecological practice values them for soil protection, whereas traditional views see them as neglectful.

d. *Nova União Settlement in São José dos Campos – RMVPLN*

Located in São José dos Campos, the Nova União settlement was formalized by INCRA in 2001 with 64 families on 446.7 ha (average plot size: 5 ha). A study documented how agroforestry *mutirões* (community working together) improved both quality of life and the local landscape (DEVIDE et al., 2020). Settler families mostly came from the metropolitan peripheries of Osasco, São Paulo, and São José dos Campos. In 2006, of the 63 resident families, 18 worked exclusively with livestock; some families were unable to produce due to financial, health, or personal reasons.

From 2012, the state agency ITESP (São Paulo State´s Institute of Land) partnered with APTA (São Paulo's Agribusiness Technology Agency) to train settlers in soil recovery, intercropping, green manuring, and agroforestry systems. Between 2011 and 2012, the Vale do Paraíba Agroforestry Network was created, involving settlers, academics, technicians, and public managers. In 2013, a project to regenerate soil and forest led to the implementation of 32 agroforestry areas (SAFs). The agroforestry *mutirões* involved around 300 people from 2013 - 2014 and had positive impacts on forest corridors, healthier food production and consumption (pesticide-free). Resistance to agroecology remains among settlers who did not participate in the training, while SAF areas have inspired neighboring farmers to begin their own agroecological transition.

ii. *The Metropolitan Region of Porto Alegre (RMPA) - a counterpoint*

The Porto Alegre Metropolitan Region includes 34 municipalities and a population of 4.2 million. In 2020, Rio Grande do Sul had 14 settlements across 13 municipalities, with 364 families cultivating 3,215 ha of rice and other crops. Coopan, a cooperative founded in 1990s, operates in the Capela Settlement in Nova Santa Rita city with 75 members (including 35 youth) and produced 3.5 tons of rice in 2018. In addition to cooperatives and OCS structures, there are 27 groups involving 158 families from RMPA, engaged in vegetable production (ORIGUÉLA, 2019).

According to Origuéla (2019), Rio Grande do Sul is the country's largest rice producer, accounting for nearly 70% of national output. Agroecological rice cultivation in the Porto Alegre Metropolitan Region (RMPA), during the 2016/17 harvest, reached 337,000

sacks over 3,628 hectares, involving 445 families (ORIGUÉLA, 2019). The total production was 513,916 sacks across 5,100 hectares, with 562 settled families. It is estimated to be the largest agroecological rice production experience in Latin America. The cultivated area increased from 468 hectares in the 2003/2004 harvest to 4,886 hectares in 2016/17. The rice fields are managed collectively; thus, family labor is organized through partnerships and collective management. In 2024-2025, they harvested 14,000 tons.

Rice cultivation in Rio Grande do Sul began in the 1960s, characterized by capitalist land renting on large tracts, with industrial machinery and wage labor. With the monetary crisis of the 1980s, this model collapsed. Consequently, family farmers from Santa Catarina migrated to the Porto Alegre Metropolitan Region, renting land to grow rice. These "Catarinas" had credit lines from rice mills in Santa Catarina and introduced pre-germinated seed techniques to the region. Their experience later served as an example for the future settlers to implement rice production in floodplains without the use of agrochemicals. These settlers, who began their land struggles in the 1980s, came mostly from the northwest region of the state and had no prior experience with flooded rice cultivation. Initially, their production in the occupations followed the model of the Green Revolution (ORIGUÉLA, 2019, p. 184). However, their traditional vegetable cultivation was already pesticide-free. The agroecological transition occurred in the late 1990s. There was conflict between settlers who sought organic/agroecological production and others who rented their plots for conventional, agrochemical-based farming. This was resolved in 2008 through legal action by the Public Prosecutor's Office, which prohibited the use of agrochemicals in Banhado dos Pachecos (swamp area) from then on, all rice fields had to be organic. Currently, the Filhos de Sepé Settlement in Viamão is considered an agroecological territory. Finally, the research shows that the yield of agroecological rice production is 85 sacks per hectare, compared to 150 in conventional systems. However, the cost of conventional cultivation is three times higher than that of the agroecological method (ORIGUÉLA, 2019, p. 188).

After the information presented in this first part, some systematization is necessary. Two temporal patterns can be observed: (1) land occupations occurred between 2002 and 2006 and followed the agroecological proposal, initially more as an intention, and later as a practical learning process; (2) the resurgence of agroecology (through extension projects and/or technical assistance) occurred around 2012–2017. Despite some similar processes, the scale of agroecological rice production in the RMPA is unparalleled due to its larger area, which naturally results in greater output. In the case of rice in the RMPA, the agroecological transition occurred in the late 1990s. The secondary data allow us for a decade-long comparison, highlighting the following elements: a process of *recampesinization*; agroecological transition driven by the exchange of knowledge with external agents, aimed at "recovering" peasant practices and/or promoting dialogue between peasant knowledge and agroecological methods; and relatively small-scale production, distribution, and consumption in comparison with the metropolitan scale. It is important to emphasize that without territorial conquest, there would be no grounds for dispute over this theme. On one hand, we observe qualitative achievements and challenges of socio-territorial movements. On the other, we note a great numerical difference in production, particularly due to the larger scale of land and agroecological rice production in the RMPA when compared to ongoing initiatives in the metropolitan regions of São Paulo State.

b) Oligopolies of Production and Distribution Versus Socio-spatial Movements of Agroecology

In this second part, we will outline the contemporary global food system, which is structured around oligopolistic agribusiness control, and how "urban/metropolitan" food systems are characterized by dietary "monotony." From there, we will explain the expansion of socio-spatial movements promoting changes in eating habits and agroecology. This represents a significant socio-spatial shift in the struggle for agroecology, aiming for the conquest of immaterial territories (GIRARDO; ROSSET, 2017; ULE MUÑOZ; ROSSET, 2022).

Two main models mark agricultural production in Brazil: the simple commodity production of peasant family farming, and the capitalist agribusiness commodity production. According to Agriculture census (IBGE), peasant family farming is responsible for 70%, on average, of food production like cereals, vegetables, and fruits. They occupy 20% of the total agricultural area. Capitalistic agribusiness occupies 80% of the total area to produce commodities like soy, corn, coffee, and meat.

Since the 1980s, Oliveira has analyzed Brazilian agriculture and agrarian conflicts through the concepts of the *territorialization of monopoly* and *monopolization of territory*. Peasant agriculture is subordinated to the dominant mode of capitalist production. Subordination occurs when capitalists monopolize production (imposing monoculture) and control land ownership (*territorialization of monopoly*), or when they dictate production methods without owning the land (*monopolization of territory*). Therefore, the struggle for land by peasants represents a way to escape or reduce this subordination. Still, even with access to land, peasants often need to engage in dominant crop cultivation, while managing to maintain a degree of diversity in other plots (OLIVEIRA, 2016). The author

analyzed the recent period in which Brazil solidified its position as a key global player in agricultural trade, specially as the biggest meat producer. Bombardi (2017), examining the same period, shows how transnational agrochemical corporations dominated agricultural production in Brazil, capitalizing on the country's lack of regulations on pesticide and GMO use, conditions far more permissive than those in Europe.

The agribusiness-based food system[3], relying heavily on agrochemicals and ultra processed foods, affects the entire population in unequal ways. We will now consider this global context of corporate control in the agriculture and food sector. According to the *Agrifood Atlas* (2017), major corporations are powerful enough to shape markets and policies, creating extremely unequal relationships between themselves and farmers, peasants, and rural workers around the world. Price pressure from supermarkets and food companies is cited as the main driver of precarious labor conditions and poverty at the base of the supply chain. Loss of soil fertility and biodiversity, pollution, and greenhouse gas emissions are attributed to the rise of industrial agriculture.

Among the academic defenders of agribusiness, notable are the works of Francisco Graziano and Roberto Rodrigues (the latter from a family of landowners). For a critique of the dominant food system in terms of sustainability and the UN 2030 Agenda for Sustainable Development, see: *The State of Food and Agriculture 2023 – Revealing the True Cost of Food to Transform Agrifood Systems* (FAO, 2023).

It is no coincidence that the *Agrifood Atlas* (2017) was published when Brazil had become the "barn" of global agricultural commodities. The report shows that, from the 1980s onward, transnational corporations became global agents with worldwide interests. The ten largest corporations now include five manufacturers and five distributors - six headquartered in the USA, three in Europe, and one in Brazil: Nestlé, PepsiCo, JBS, Coca-Cola, Anheuser-Busch InBev (industry); and Wal-Mart, Cargill, Costco, Kroger, Tesco (distribution).

Since the late 20th century, there has been significant growth in land cultivated with palm oil, corn, sugarcane, and soybeans. In Brazil, seven joint ventures between domestic capital and Western commodity corporations' control 50% of sugarcane mills. The agricultural machinery industry is dominated by three groups - Deere, CNH, and AGCO - which control 50% of the global market.

Another feature of these corporations is their technological investments, setting trends in agriculture digitalization: GPS-guided tractors, soil-monitoring apps, drones for pesticide spraying, and weather-linked sensors. These innovations represent an annual trade market of $30 billion. Pesticide sales have increased sixfold since 1961, reaching $175 billion globally in 2013. In 2014, there were seven major pesticide and seed companies; by 2017, mergers reduced them to four: Monsanto/Bayer, DuPont/Dow, Syngenta/Chem China and BASF. These corporations held over 1,700 plant patents in 2015. Genetic research has heavily invested in "climate genes", plants genetically adapted to climate change.

ADM, Bunge, Cargill, and Louis Dreyfus dominate agricultural commodity trade, managing transportation, processing, and storage through ports, railways, ships, refineries, silos, and factories - together responsible for 70% of global trade. Since 2015, Chinese state-owned Cofco has entered this elite group.

Supermarkets also exert considerable influence over dietary habits (AGRIFOOD ATLAS, 2017). When four corporations dominate seeds, pesticides, and patents; four others control trade; three dominate machinery; and a handful manage retail dismantling this system seems almost impossible. Not to mention the ideological production through agribusiness advertising.

Thus, opposition takes the form of territorial struggle and the search for spaces for new dietary habits. Brazilian eating habits are deeply influenced by this global context. According to Belik (2020), food expenditure by the wealthiest families (earning more than 25 minimum wages per month) is 165% higher than the *total income* of the poorest families (earning up to 2 minimum wages). The main finding is the dietary "monotony" across Brazil - north to south, urban and rural - where just 10 items account for more than 45% of consumption: rice, beans, French bread, beef, chicken, banana, milk, soda, beer, and sugar. As rural incomes rise, diets become more like urban ones.

Belik writes: "Food monotony is the opposite of what is considered an adequate and healthy diet" (2020, p. 9). With rising income, consumption of meat increases, while rice and beans decline. Higher income can reduce consumption of manioc flour, sugar, fresh fish, soybean oil, and increase purchases of beer, olive oil, cheese, fruits, and vegetables. Among the lower-income population, any income increases boosts consumption of these items. Regardless of income, meat is the highest food expenditure. Between 2002 and 2018, *in natura* food consumption fell 7%, while ultra processed food rose 46%. Frozen ready meals grew by 250%. Food retail is concentrated in supermarkets, which capture 93% of revenue.

However, a creative resistance emerges from Brazilian recent culinary. We see a socio-spatial movement involving scholars, politically engaged chefs, and civil society organizations that are connecting people and territories through agroecology. The dominant food system relies on culinary standardization. Dória (2009) analyzes the formation of a "Brazilian cuisine" and the recent interest in healthier

[3] McMichael (2016) defines it as corporate food regime.

"ingredients." For him, Brazilian cuisine is a recent amalgam of Indigenous, African, and European traditions emerging as a set of regional cuisines rather than a cohesive whole.

Dória argues that from the 1970s, a tourism-driven culinary regionalization based on IBGE's 1940s geopolitical divisions prevailed. He proposes a new regionalization based on discontinuous "culinary patches" defined by ingredients:

- *Amazonian Cuisine:* Cassava, fruits, river fish, forest products.
- *Coastal Cuisine:* Fish, seafood, coconut milk (from Ceará to Espírito Santo).
- *Recôncavo Baiano Cuisine:* Palm oil, Afro-Brazilian religious food.
- *Southern Cuisine:* Corn-based dishes (like *cuscuz*), small animal meats, offal.
- *Other Patches: Pequi* in the Center-West, *mate* in the Guarani regions, *pinhão* in Araucaria forests, and *caipira* cuisine (São Paulo, Minas, Center-West) based on corn, pork, chicken, and garden vegetables.

The emerging "ingredient-based cuisine" promotes rooted, popular products with the sophistication of haute cuisine. Dória (2009, p. 66) envisions a future Brazilian cuisine based on biodiversity and native ingredients: "Thus, we can safely say that a Brazilian cuisine, setting aside recipes and ethnic contours to focus on ingredients, is a work yet to be done."

Dória's 2009 prediction has materialized in cooking shows on TV and gastronomy circuits. Notable examples include: cuisine chef Bela Gil: owner of *Camélia Ododó* restaurant, co-founder of *Instituto Brasil Orgânico*, TV host, agroecology advocate, and influencer with over 500,000 followers; chef Rodrigo Oliveira: from *Mocotó* restaurant, nationally and internationally recognized for promoting regional cuisine and distributing thousands of free meals during the pandemic; chef Teresa Corção: founder of *Instituto Maniva* (RJ), fostering relationships between traditional food knowledge and chefs.

On the other end of the social scale, we have chef Tia Nice, from *Organicamente Rango* in São Paulo's south periphery, earned international awards for culinary excellence and social work during the pandemic[4]. Upper class chef Alex Atala and the *Instituto ATA* promote Brazil's biomes and support Organicamente Rango, connecting popular cooking with agroecological food from Parelheiros (an extremely poor neighborhood), recognizing that peripheral communities have long used conventional and unconventional edible plants.

These examples show agroecology's socio-spatial expansion in São Paulo, surpassing earlier analyses (JUSTO, 2019).

We see a socio-spatial movement involving middle - and upper - income consumers who can influence dietary trends. While not all will adopt agroecological diets, such movements expand the reach of socio-territorial actors who supply healthy food to thousands, still small relative to metropolitan inhabitants.

These trends counter the dominant global agribusiness system and manifest as socio-spatial agroecological movements. Academia also plays a role, notably the *Food Gude for Brazilian Population* and the internationally recognized *NOVA food classification system* from NUPENS-USP (Center for Epidemiological Research in Nutrition and Health). Also noteworthy are the efforts of the *Josué de Castro Chair for Healthy and Sustainable Food Systems*, *Rede PENSSAN* (Brazilian Network for Research on Food and Nutritional Security), and various civil society organizations (NGOs) advocating for *in natura* and minimally processed foods, and for new food labeling regulations. TV advertisements such as ACT's (Health Promotion NGO) warning against sugar in soft drinks require massive diffusion to effect real change on nutrition habits.

Socio-spatial manifestations include the growth of *Armazéns do Campo* (MST run stores) in big cities like São Paulo, Porto Alegre, and Campinas. The first was launched in São Paulo in 2016 and now totaling nearly 30 units, accelerated by the pandemic. Other examples include solidarity kitchens in major cities during the pandemic, organized by the Homeless Workers' Movement (MTST), which distribute free meals and cultivate urban gardens. It is agroecology taking root in the city.

Finally, we highlight the Mission *Josué de Castro*, launched in March 2024 to ensure agroecological food access for 5 million people. This mission is led by organizations such as Agroecological National Coalition (ANA), Coalition of Semiarid Region (ASA), AS-PTA – Family farm and agroecology, Coalition of Popular Movements (CMP), *De Olho nos Ruralistas*, Fiocruz (autarchy related to State health system), Small Farms Movement (MPA), Homeless Workers' Movement (MTST), trade unions, *Unisol Brasil* (Cooperative Center) and many others. Then, we have the most relevant socio-territorial and socio-spatial movements, NGOs, trade unions, cooperative center and coalitions forming a public mission spatializing the agroecological struggle.

II. Final Considerations

The possibility of a food system transition depends on the joint action of socio-territorial and socio-

[4] Watch a video called Taking health food to peripheric neighborhood during pandemic. Available at: https://www.youtube.com/watch?v=G3-Dj9UgJhE. Accessed in 09/24/2023.

spatial movements, given that the dominant food system is highly concentrated and, therefore, enormously powerful. The conquest of land and territory by agroecology through the MST and other peasant socio-territorial movements in metropolitan regions is a necessary condition for agroecology to advance, but not a sufficient one.

There are common elements across the experiences of the Land Communes: a process of *recampesinization* (which takes a relatively long time - about 10 to 20 years), peer-to-peer learning and experience exchange among peasants, and the involvement of external agents who engage in dialogue with peasant knowledge, sometimes introducing agroecological elements. There were two significant phases:

1. Occupations occurred between 2002 and 2006, with an initial discourse of agroecology, although less reflected in practice.
2. A resurgence of agroecology - more concretely through extension projects and/or technical support - emerged between 2012 and 2017.

The Land Communes experiences differ from those in the Metropolitan Region of Porto Alegre (RMPA) in terms of size and the external support that allowed the latter to become a national reference. On one hand, we recognize the qualitative achievements and challenges of socio-territorial movements. On the other, there are clear differences in production scale, especially in terms of land area and agroecological rice production, where RMPA stands in stark contrast to the still modest initiatives in the metropolitan regions of São Paulo state.

The concept of socio-territorial movement contributes to interpreting this phenomenon by highlighting the essential need for agroecological agriculture to secure land and territory. Beyond territorialization (which varies in intensity across different metropolitan areas), we observe the socio-spatialization in defense of *in natura* (fresh) or minimally processed food, ideally agroecological. However, the current dynamics go beyond socio-spatial movements and involve social organizations, labor unions, universities, and celebrity chefs.

Thus, the category of socio-spatial movement does not fully capture the complexity of the current context. The socio-spatialization of agroecology creates a network of socio-spatial and socio-territorial movements, NGOs, universities, mission, and famous cuisine chefs.

The agribusiness-based food system is a global network of oligopolies. Brazil is a hotspot in that net. This kind of food system creates a nutritional monotony which is not heathy and neither environmentally sustainable.

Finally, living in large urban centers means consuming trends. We hope that the trend toward an agroecological food system continues to grow.

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Coordinating Industrial Disaster Rehabilitation: Insights from the Rana Plaza Coordination Cell in Bangladesh

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Abstract- The Rana Plaza collapse in Dhaka, Bangladesh, on April 24, 2013, marked one of the deadliest industrial disasters in modern history, claiming over 1,100 lives and injuring more than 2,500 workers. This paper critically assesses the role of the Rana Plaza Coordination Cell (RPCC), established by the Ministry of Labour and Employment, in addressing the multifaceted challenges of disaster rehabilitation. Utilizing a qualitative methodology including focus group discussions, key informant interviews, and analysis of secondary documents, this research examines how the RPCC navigated issues of coordination, data verification, emergency relief, and compensation. Findings reveal that despite initial fragmentation, the RPCC played a central role in mitigating information gaps and facilitating victim support through institutional innovations and stakeholder collaboration. The paper recommends institutionalizing such coordination mechanisms for future industrial disasters to ensure timely, equitable, and efficient rehabilitation outcomes.

Keywords: industrial disaster, rana plaza, disaster coordination, rehabilitation, public administration, Bangladesh.

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I. Introduction

The collapse of the nine-story Rana Plaza building in Savar, Dhaka, on April 24, 2013, remains one of the most catastrophic industrial accidents globally. Housing five garment factories, a bank branch, and various shops, the building's failure resulted in 1,136 deaths and over 2,500 injuries (MoLE, 2016). The incident spotlighted serious gaps in industrial safety compliance, urban planning, and emergency preparedness in Bangladesh. In response, a multitude of actors, including government bodies, NGOs, international organizations, and private sector representatives, mobilized to assist victims.

Among these efforts, the establishment of the Rana Plaza Coordination Cell (RPCC) by the Ministry of Labour and Employment was a pivotal institutional innovation. The RPCC was tasked with ensuring coordination among stakeholders, managing databases of victims, and facilitating compensation and rehabilitation. This paper explores how the RPCC responded to challenges of coordination, information management, and victim reintegration in the aftermath of the disaster.

II. Literature Review

A wide range of literature has addressed the Rana Plaza disaster, yet much of it has focused narrowly on compliance issues or criticized government actions from a distance, leaving a gap in understanding institutional innovations like the Rana Plaza Coordination Cell (RPCC). For instance, Mostafiz, Fahmida, and Akter (2016) examined the post-tragedy roles of the government and the Bangladesh Garment Manufacturers and Exporters Association (BGMEA) but focused primarily on improving workplace compliance rather than evaluating systemic rehabilitation efforts. Similarly, Islam (2015) concentrated on disability inclusion and identified a lack of state mechanisms for addressing survivors with long-term injuries, yet did not investigate coordination mechanisms like the RPCC that emerged to confront such gaps.

Ashfaquzzaman (2017) applied a postcolonial lens to analyze crisis communication during the disaster but lacked engagement with the logistics of institutional recovery. Quadir et al. (2019) assessed quality of life among survivors but did not include RPCC stakeholders in their data collection, leaving out a vital component in the rehabilitation chain. Fitch et al. (2015) focused on psychosocial impacts and PTSD among survivors but again did not connect these outcomes to institutional rehabilitation frameworks.

These gaps highlight a broader issue in the disaster literature: the tendency to analyze post-disaster contexts through either a critical policy lens or victim-centric narrative, without bridging the two through institutional analysis. This paper aims to bridge that divide by focusing on RPCC's organizational role in coordinating relief, managing data, and facilitating recovery. The literature on disaster governance, such as Comfort (1999), emphasizes that integrated information systems and coordination mechanisms are crucial for effective response. The adaptive governance framework (Folke et al., 2005) supports this notion, suggesting that in complex, uncertain situations like industrial disasters,

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flexible, stakeholder-inclusive structures are essential. RPCC's role aligns with this perspective by functioning as a dynamic, evolving body that responded to real-time challenges.

Moreover, disaster sociology scholars such as Tierney (2007) argue that elite and institutional actors often retreat from direct accountability, leaving civil society to fill the gap. This aligns with findings from this study that show limited involvement by BGMEA in initial relief efforts. In contrast, the RPCC's establishment served as a case of what Sylves (2008) terms Integrated Emergency Management Systems (IEMS), where multiple actors coordinate under a unified strategy.

Incorporating theories from public administration, such as Ansell and Gash's (2008) collaborative governance model, the RPCC's multi-stakeholder decision-making process illustrates how institutional innovation can emerge even in a governance landscape marked by fragmentation and mistrust. At the same time, critiques from Weberian bureaucratic theory (Weber, 1947) caution against ad hoc solutions that bypass formal authority, raising important questions about the sustainability of such interventions.

This paper contributes to the literature by documenting a hybrid model of state-led and community-supported disaster response that offers replicable lessons for future industrial crises. It aligns with calls in the broader development and governance literature for embedded, context-sensitive institutional arrangements that balance rapid response with accountability and long-term recovery planning.

III. Research Gap

While various studies critique or analyze specific aspects of the Rana Plaza disaster, few have documented the systemic coordination mechanisms employed by the RPCC. Existing literature rarely includes data directly collected from RPCC officials or beneficiaries, focusing instead on peripheral stakeholders. This paper addresses this lacuna by examining RPCC's operations using primary and secondary sources.

IV. Objectives

The Paper Aims to:

1. Assess the RPCC's role in post-disaster rehabilitation coordination.
2. Identify challenges faced during victim identification, data management, and service delivery.
3. Evaluate the impact of RPCC interventions on compensation, reintegration, and psychological recovery.

V. Methodology

1. A mixed-methods approach was adopted. Primary data were collected via:
2. Surveys of 45 victims using purposive sampling.

- Three FGDs with stakeholders, including union leaders, government officials, and NGO workers.
- Fifteen key informant interviews with RPCC members, medical professionals, and representatives from BGMEA and Rana Plaza Claims Administration (RPCA).

Secondary data included RPCC meeting minutes, NGO reports, government documents, and media archives. Data were analyzed thematically and triangulated across sources.

VI. Background of the RPCC

Bangladesh has established robust systems for responding to natural disasters. However, the Rana Plaza collapse revealed a vacuum in institutional mechanisms for managing industrial disasters. Spontaneous rescue efforts by civilians exposed the absence of trained personnel, coordination, and equipment. Relief distribution was inconsistent and unregulated. Rana Plaza Coordination Cell (RPCC) was created in response to these systemic deficiencies. It aimed to:

- Coordinate rehabilitation services among stakeholders.
- Create a central database for victims.
- Provide timely information and resources to affected families.

Beneficiaries included injured workers, families of deceased and missing persons, and those indirectly impacted (e.g., adjacent residents and rescue workers).

VII. Findings and Analysis

a) Emergency Relief and Medical Support

The initial phase of emergency relief following the Rana Plaza collapse was marked by a highly fragmented response. Numerous NGOs, civil society groups, and individual citizens rushed to assist, but in the absence of central coordination, efforts often overlapped or missed critical needs. As Figure 2 illustrates, food, water, and oral saline were distributed by diverse sources, many of whom were acting independently. According to ActionAid (2013), 86% of the surveyed victims identified food as their most immediate requirement. In-depth interviews revealed that water, rather than oxygen or other medical interventions, was the first demand of those trapped under debris—a reflection of both the nature of the entrapment and the oversight in conventional emergency planning.

While such spontaneous aid is consistent with the emergent norm theory (Turner & Killian, 1987), which posits that during crises, new social norms quickly develop to facilitate prosocial behavior, the absence of structured oversight led to inefficiencies. For example, multiple victims received duplicate aid while others were left out entirely. The RPCC, although officially inaugurated on 7 November 2013 after the primary rescue operation, retroactively documented these early contributions to recognize and channel service providers' continued involvement under government coordination.

The role of the Bangladesh Garment Manufacturers and Exporters Association (BGMEA) was notably limited during this phase, as suggested by both primary data and anecdotal narratives. This aligns with critiques in disaster sociology that emphasize how powerful institutions sometimes avoid engagement in accountability-heavy roles (Tierney, 2007).

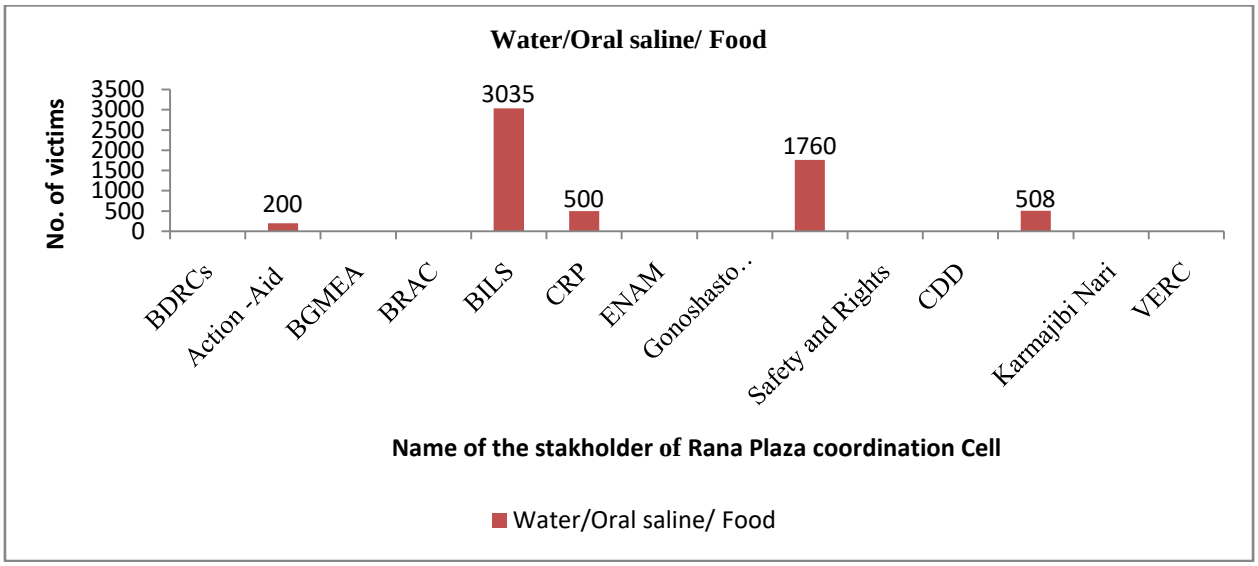


Figure 2: Food/Water/Oral Saline Distribution During Rescue Operations

Following the initial rescue efforts, the focus rapidly shifted to medical treatment. Figure 3 documents the various sources of medical support received. Public hospitals played a central role, yet victims reported unequal access to private healthcare. A striking example is the case of a pregnant survivor denied emergency cesarean delivery at a private hospital due to inability to pay BDT 30,000. She was later pronounced dead at Suhrawardy Hospital in Dhaka. Such incidents reveal the deep structural inequities in healthcare access that disaster victims often face.

These findings resonate with the theoretical framework of structural violence (Galtung, 1969), which argues that social structures can harm individuals by preventing them from meeting basic needs. In contrast to the health equity models that emphasize universal access, Bangladesh's dual healthcare system disproportionately affected poor, marginalized victims of the industrial workforce.

The RPCC played a vital remedial role by compiling lists of injured victims, liaising with public hospitals, and ensuring equitable distribution of treatment support. It attempted to shift the emergency response from an ad hoc relief paradigm to a more institutionally supported and documented framework—a model consistent with the Integrated Emergency Management System (IEMS), which emphasizes coordinated, multi-agency collaboration in disaster response (Sylves, 2008).

Figure 3: Medical Treatment and Support Distribution

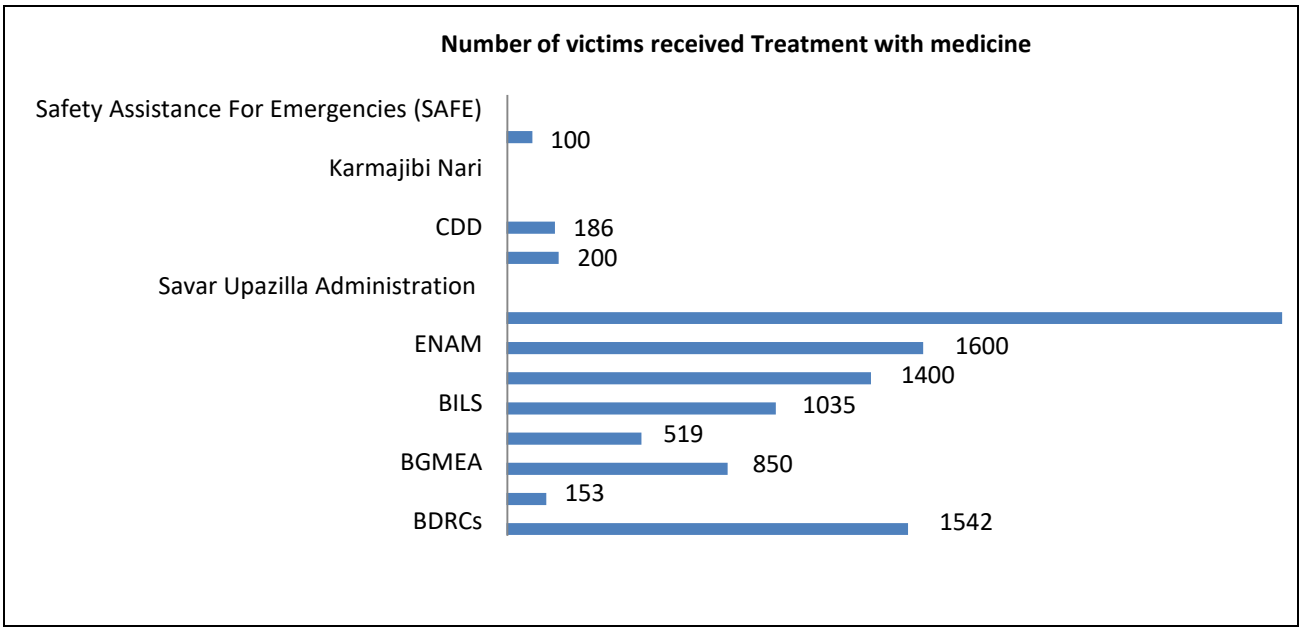


Figure 3: Treatment with Medicine Provided by the Different Organization

b) Victim Identification and Data Management

Conflicting data across agencies severely hampered service delivery in the aftermath of the Rana Plaza collapse. The RPCC played a pivotal role in consolidating disparate lists maintained by local administration, BGMEA, NGOs, and DNA testing facilities. By cross-checking and triangulating these sources, RPCC was able to establish a centralized database that reduced duplication and improved accountability.

Table 1: Number of Victims of Rana Plaza Disaster

SL	Name of Organization	Number of Deceased Victims	Number of Missing Worker	Number of Survivors	Total Worker	Source
1	UNO office	1132	165	1176	**2473**	UNO, 2013
2	DC Office, Dhaka/ MoLE	1134	165	2438	**3729**	DC office, 2013
3	BGMEA	1061	261	2790	**4112**	BGMEA, 2013
4	BILS	1131	--	803	**1934**	CPD, 2014
5	PRIMARK			3600	**3600**	PRIMARK,2013
6	ActionAid	1134	-	1510	**2644**	CPD, 2013
7	CPD	1134	98	2436	**3668**	CPD, 2013

Source: Prepared By Authors

A prominent example involved the Jurain graveyard, where 291 bodies were interred, but only 206 were positively identified through DNA testing—leaving 85 bodies unidentified. Further investigations revealed that lists from the Prime Minister's Office, military bodies, and labor organizations often contained overlapping or inconsistent entries. RPCC's consolidation efforts concluded that the number of confirmed deceased stood at approximately 1,121.

This experience reflects the broader challenges discussed in disaster information management literature. Comfort (1999) argues that in high-stakes emergencies, the lack of an integrated information infrastructure often leads to redundant or contradictory data, complicating timely response. RPCC's strategy mirrors best practices from adaptive governance frameworks, which emphasize the importance of flexible, learning-based approaches to managing uncertainty and complex coordination (Folke et al., 2005).

Moreover, the chaos of conflicting data aligns with Perrow's (1984) Normal Accident Theory, which posits that in tightly coupled, complex systems like post-disaster administration failures are nearly inevitable without systemic safeguards. By centralizing data,

RPCC introduced those safeguards, turning a reactive environment into one where decisions could be guided by accurate information.

However, contrasting perspectives from bureaucratic theory (Weber, 1947) would critique RPCC's approach as ad hoc and vulnerable to politicization, since it bypassed traditional hierarchical structures. Yet, this case also demonstrates the value of collaborative governance (Ansell & Gash, 2008), wherein shared decision-making among stakeholders improved responsiveness despite institutional limitations.

In summary, RPCC's data management initiatives helped restore coherence in an otherwise fragmented response system and underscored the value of coordinated information infrastructure in industrial disaster recovery. Victim Identification and Data Management has been enriched with theoretical perspectives, including Adaptive Governance (Folke et al., 2005), Normal Accident Theory (Perrow, 1984), and contrasting views from Bureaucratic Theory (Weber, 1947) and Collaborative Governance (Ansell & Gash, 2008).

c) Challenges in Reintegration

The paper found that There were a total of 2,438 (RPCC, 2014) survivors in the Rana Plaza incident who were indifferent physical conditions. It is found by the study conducted by ILO and GIZ that 8% of the rescued victims had a permanent disability because of amputation and paralysis, 25 % had severe difficulty in walking. The database of the RPCC also represented this same scenario. So in this situation, it was a tough job to explore and integrate these types of special worker. On the other hand, 59% of the survivor required support for initiating a small business (AAB, 2013). So in this Regard with the help of related stakeholder CRP, DAM, ILO, GIZ, Spandan-B, BRAC, GP, LFMEAB, Taranga RPCC developed interventions for small business support.It was based on market needs and existing pro-poor approaches used and sensitivity was shown to the process of psychological recovery according to the Action Plan of Rana plaza Study found that maximum victims were not willing to join in industry or had a trauma to join in the concrete infrastructure job environment. So to engage them in small business and also to overcome the trauma was a primacy of the job for all. The number of victims covered in this regard is shown in Figure 4. It is seen that career counselling and trauma management was in the significant percentage provided by RPCC in an association of its stakeholder (Figure: 4).

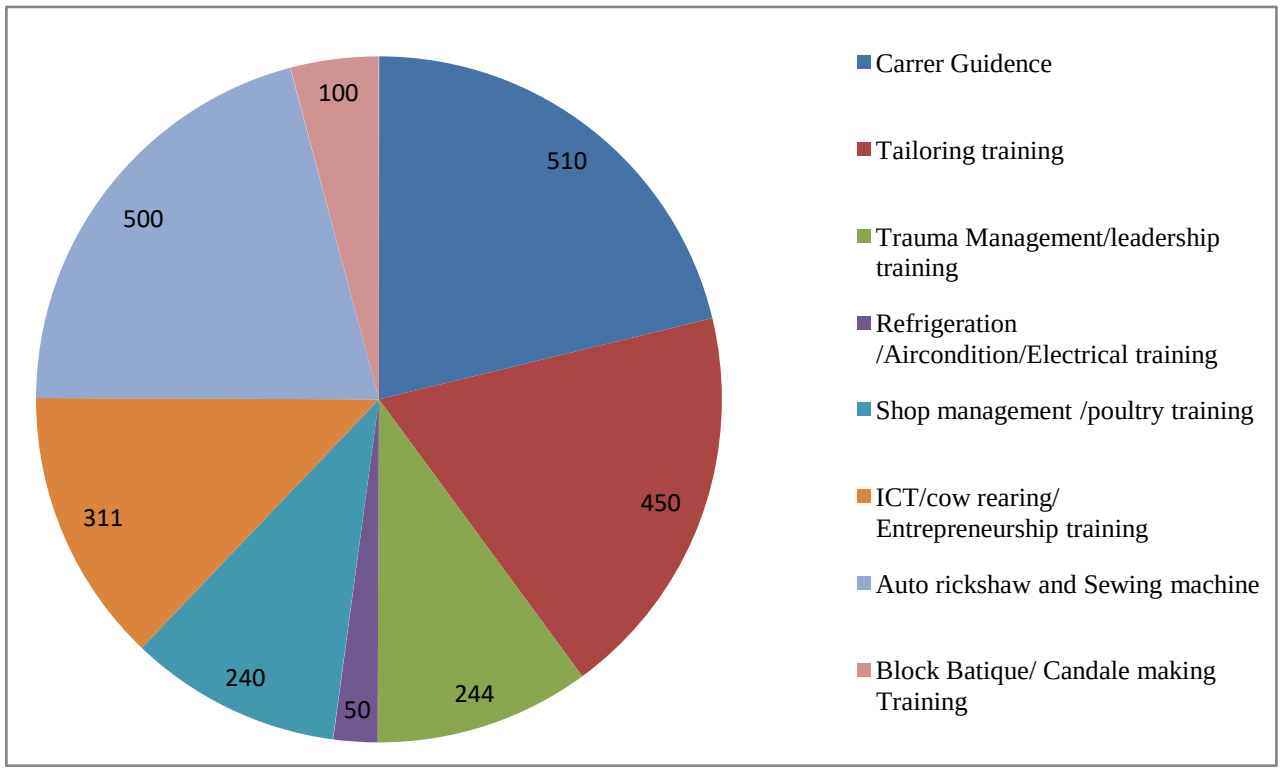


Figure 4: Distribution of No. of Survivors in Different Vocational Training Group

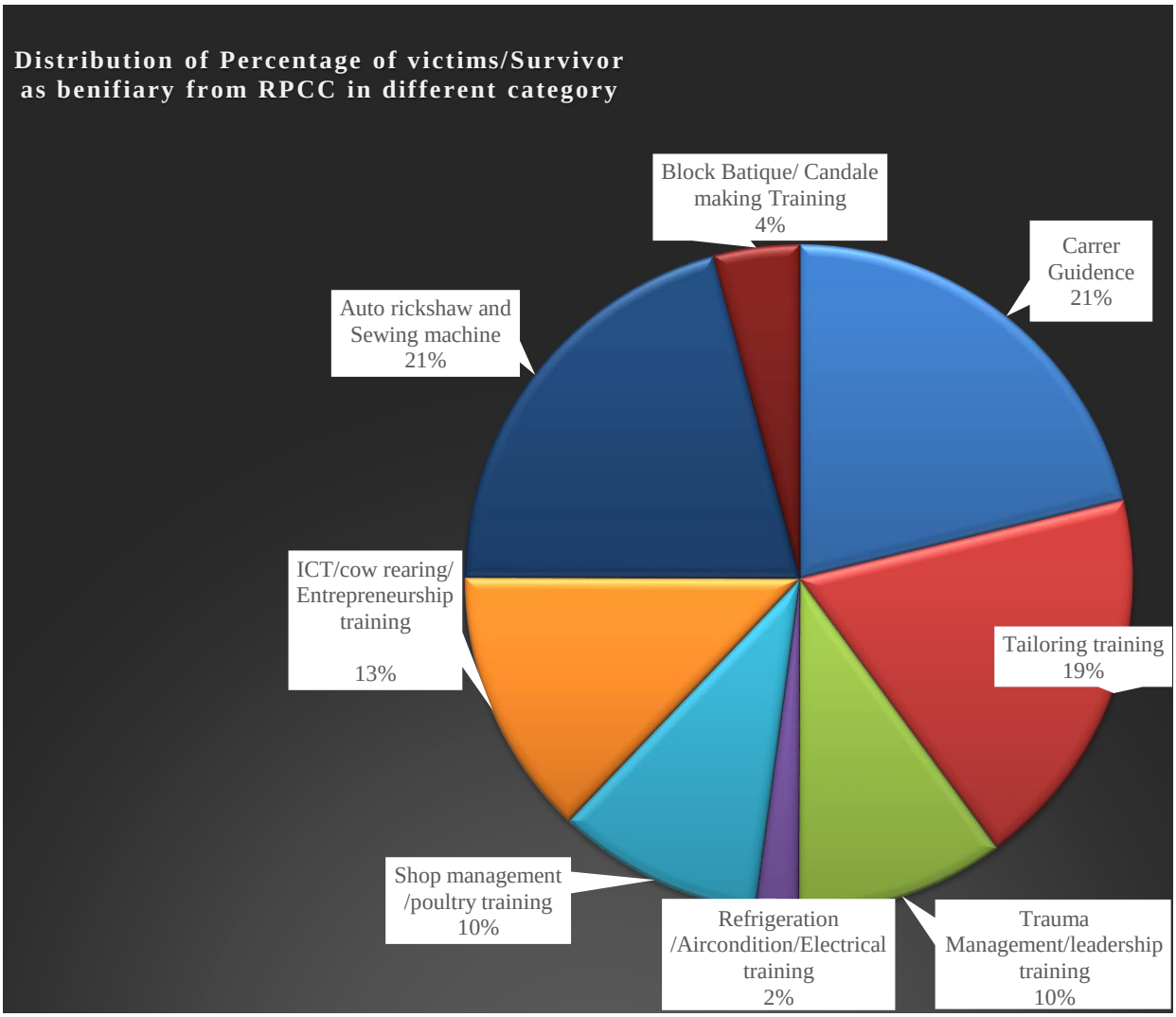
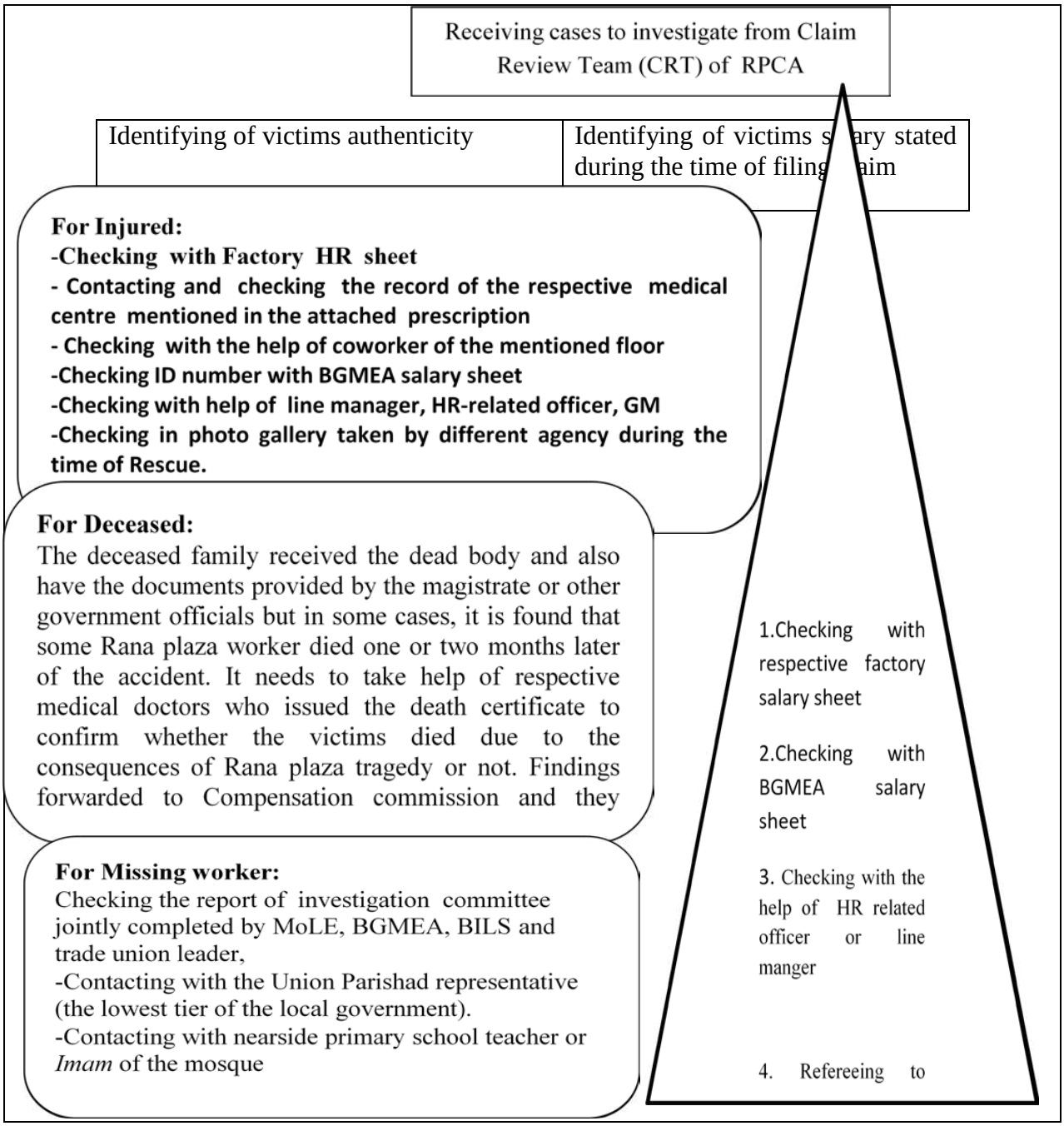


Figure 5: Distribution of Victims/Survivors as beneficiaries

For the victims who psychologically feared to reintegrate in the garments industry, RPCC arranged job placement in the Leathergoods and Footwear sector after necessary counselling and career guidance (Figure: 4). It is found in this paper that during the time of rehabilitation as maximum leathergoods industry was situated in Gazipur and victims were not interested to leave Savar area because they assumed that if once they left Savar they would miss all types of material relief and compensation. Staff of RPCC face trouble motivating the victims to join in COEL, a leather goods industry in Gazipur. It is true for some victims that due to providing huge and long-term relief or only instant material facilities made them a beggars instead of sustainable long-term rehabilitation, which is why they always expected more. It supports the Chambers (1983) on "dole dependency" and Harvey and Lind (2005) on the unintended consequences of poorly managed humanitarian aid. These additions frame the concern that excessive or unstructured relief may hinder sustainable rehabilitation by fostering dependency rather than empowerment. Among the 2,438 survivors (RPCC, 2014), 8% had permanent disabilities. A significant portion (59%) expressed interest in small businesses rather than returning to factory work. RPCC, in collaboration with CRP, BRAC, and ILO, provided vocational training, career counseling, and micro-loans. Despite these efforts, victims were often reluctant to relocate or re-enter formal employment due to trauma. RPCC facilitated job placements in leather and footwear sectors and monitored psychological recovery.

d) Identification of Victims for Compensation and RPCC

RPCC applied verification mechanisms developed during the course of its rehabilitation activities to assess the validity of victims' identities, wage records, and documentation prior to distributing compensation.



Source: RPCC

Figure 6: RPCC in Coordinating Compensation
Prepared by Author

The RPCC investigation team used the ICT as an important tool of the investigation process. Because it was not possible to visit more than a thousand remote places to collect information of the victims. RPCC used the national web portal of the government, with the blog of the union, and the information service centre of A2I project. On the one hand, RPCC received the field-level investigation report signed by the local authority and documents from victims through e-mail to proceed it urgently through the union digital centre (UDC). However, finally, with the help of Rana Plaza Coordination cell $30million was distributed to the eligible victims and their dependents through different instalments.

e) Challenges in Determining Compensation and Role of RPCC

This paper found that three major criteria were fixed to overcome the challenges related to the amount of compensation, which are:

a. *Age* (Here, the age of victims during the time of the accident on 24 April 2013, and major challenge here is that lots of workers joined in Rana Plaza before the age of 18 by hiding their actual age)
b. *Wage* (Wage during the time of Accident or the salary of Last month /March 2013, but some victims joined in the month of March or a week before the accident and some victims used to work using the identity of former worker of Rana Plaza)
c. *Dependent* (How many dependents had on the income of the deceased before the accident and their present age, also and major challenge here is that dependents tend to manipulate documents to avail the total award of compensation). RPCC played a crucial role, as shown in the figure Figure 6. It emerged as challenge in the determination of compensation with this criteria as some decessisd getting more compensation than others. This paper finds the use of ILO Convention 121 as a guiding framework presented limitations, as its global parameters often conflicted with the socio-economic realities of Bangladesh. Scholars like Barder (2009) and de Waal (2007) suggest that standardized international norms may lead to misalignments when applied without localization, particularly in compensation and rights-based mechanisms in post-crisis societies.

VIII. Discussion

RPCC's establishment marked a shift in Bangladesh's disaster management paradigm from ad hoc responses to institutional coordination. Key strengths included:

- Inclusive governance involving government, civil society, and international actors.
- Centralized data systems that minimized fraud.
- Use of digital platforms to overcome logistical barriers.

However, challenges remained. Victim dependency on relief (Chambers, 1983), lack of long-term mental health support, and poor industrial safety compliance still pose risks. To overcome the challenges described by Chambers (1983) regarding "dole dependency," one relevant theoretical approach is the Sustainable Livelihoods Framework (SLF), developed by the UK Department for International Development (DFID, 1999). This framework emphasizes enhancing people's capabilities, assets, and activities needed for a means of living, moving beyond immediate relief to build resilience and long-term economic autonomy. RPCC's small business support, vocational training, and psychological rehabilitation initiatives align with SLF by aiming to shift victims from dependency to self-reliance. However, these efforts could be further strengthened by explicitly adopting livelihood-based planning, tailored to individual capabilities and contexts.

IX. Recommendations

RMG sector contributes to the GDP is over 10% and 82% of export earnings came from this sector (EPB, 2016). So it should be nurtured more carefully as jobs and lives of the worker-related here so after the in-depth analysis this paper recommends to

1. Institutionalization of RPCC as a disaster coordination agency.
2. Develop an industrial disaster policy separate from natural disaster frameworks.
3. Set or prepare a national standard/parameters for compensation with the specific elaboration of calculating the loss of income, definition of dependent, economic assumptions, length of payments, health and benefits considering socioeconomic status/structure of Bangladesh and ILO convention 121.
4. Collect and preserve DNA samples for all deceased to identify the unidentified victims.
5. Establish educational and vocational funds for children of deceased workers.

X. Conclusion

The Rana Plaza Coordination Cell represents a unique model of institutional response in the face of an industrial disaster. While Bangladesh has made notable progress in disaster management, this case underscores the need for dedicated mechanisms tailored to industrial contexts. Learning from RPCC's successes and limitations can help ensure that future industrial tragedies are met with greater preparedness, equity, and accountability.

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Climate Changes and Cultural Responses in the Southeastern Kazakhstan during the Past~50,000 Years

By Botakoz Satayeva, Erbolat Ospanov, Ali Rafet Özkan, Zhaodong Feng & Galymzhan Bekseytov

Ankara Hacı Bayram Veli University

Abstract- The objective of this research is to explore the dynamic relationship between long-term palaeoclimatic fluctuations and patterns of human occupation in southeastern Kazakhstan over the past ~50,000 years. Specifically, grain size-inferred wind intensity variations from the Maibulak (Romantic) loess-paleosol sequence in the Almaty region (Ran et al., 2020) are juxtaposed with stratified cultural horizons identified at the same site (Fitzsimmons et al., 2017). The analysis reveals that wind strength variations preserved in the loess deposits do not appear to have exerted a direct influence on the timing or presence of cultural layers. Furthermore, despite the limited temporal resolution of the Rakhat site dataset (n=12), brGDGT-based reconstructions of mean annual air temperature (MAAT) demonstrate a robust correlation with Northern Hemisphere summer insolation patterns. Furthermore, complementary δ13C-based moisture proxies indicate arid conditions throughout the Last Glacial (MIS 4 to MIS 2), transitioning into more humid phases during the Holocene (MIS 1). The results suggest that southeastern Kazakhstan provided favourable environmental conditions for human habitation during MIS 4 and MIS 3, but likely became climatically restrictive during MIS 2.

Keywords: *loess-paleosol sequence, climate change, culture evolution.*

GJHSS-B Classification: *LCC Code: CC72.3*

Climate Changes and Cultural Responses in the Southeastern Kazakhstan during the Past ~50,000 Years

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Abstract- The objective of this research is to explore the dynamic relationship between long-term palaeoclimatic fluctuations and patterns of human occupation in southeastern Kazakhstan over the past ~50,000 years. Specifically, grain size-inferred wind intensity variations from the Maibulak (Romantic) loess-paleosol sequence in the Almaty region (Ran et al., 2020) are juxtaposed with stratified cultural horizons identified at the same site (Fitzsimmons et al., 2017). The analysis reveals that wind strength variations preserved in the loess deposits do not appear to have exerted a direct influence on the timing or presence of cultural layers. Furthermore, despite the limited temporal resolution of the Rakhat site dataset (n=12), brGDGT-based reconstructions of mean annual air temperature (MAAT) demonstrate a robust correlation with Northern Hemisphere summer insolation patterns. Furthermore, complementary δ13C-based moisture proxies indicate arid conditions throughout the Last Glacial (MIS 4 to MIS 2), transitioning into more humid phases during the Holocene (MIS 1). The results suggest that southeastern Kazakhstan provided favourable environmental conditions for human habitation during MIS 4 and MIS 3, but likely became climatically restrictive during MIS 2. Consistent with the findings of Fitzsimmons et al. (2017), the development of higher-resolution datasets is advocated in order to substantiate links between climatic shifts and cultural dynamics.

Keywords: loess-paleosol sequence, climate change, culture evolution.

I. Introduction

The Southeastern part of Kazakhstan, both geographically and historically, is known as Semirechye (or Zhetysu) due to the presence of seven major rivers. This region occupies the southern part of the Balkhash Lake basin, which is the largest in Central Asia [41; 68]. The direct area of research, where Upper Paleolithic sites are concentrated, is the foothills of the Zailiyskiy Alatau, one of the mountain ranges of the Northern Tien Shan. The northern slopes of this range are characterized by a step-like structure, consisting of two terraced levels. Almost all known archaeological sites are located on the lower terrace and are situated at altitudes ranging from 950 to 1,150 meters above sea level (Ozherelyev et al., 2023).

The Central Asian Arid Zone (CAAZ) is loosely defined as the area stretching from western Kazakhstan to eastern Mongolia (approximately 50-110°E and 35-50°N) and is a result of the combined effects of the Siberian High in the eastern part and the Azores High in the western part. Specifically, westward extension of the Siberian High during cold seasons and eastward extension of the Azores High during warm seasons resulted in a nearly permanent high pressure ridge in the CAAZ where deserts and steppes developed (Feng et al., 2011). The cold-season climate in the CAAZ is presently controlled by the interactions between the Siberian High and the Westerlies and the latter is in turn modulated by the North Atlantic Oscillation (NAO) (Fig. 1A). Specifically, negatively-phased NAO induces the westward and southward expansion of the Siberian High, consequently lowering the winter temperature and precipitation in the downwind areas including the CAAZ (Aizen et al., 2001; Meeker and Mayewski, 2002). The warm season climate in the CAAZ is presently controlled by the interactions between the Asian Low occupying the interiors of Asia and the Azores High reaching the CAAZ (Fig. 1B). Frequent invasion of the polar front is the major mechanism for generating precipitation in the CAAZ (Li, 1991; Lydolph, 1977).

Minerogenic aerosols (or dust) originating in the CAAZ deserts and steppes are entrained into the atmosphere mostly via dust storms under strong wind conditions (Indoitu et al., 2009). They were primarily transported over a long distance to have deposited as pelagic mud in North Pacific (Rea and Hovan, 1995) and also over a short distance to have deposited as loess on the forelands of mountains (Dodonov et al. 2006). The forelands of the Tianshan Mountain chair (see Fig. 1c and Fig. 1d for topographic backgrounds) are the most significant ones in terms of loess distribution in the

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CAAZ (Dodonov and Baiguzina, 1995; Feng et al., 2011). The distribution of CAAZ loess deposits between the well-studied European loess sequences to the west and the extensive Chinese loess plateau region to the east enables researchers to carry out inter-regional paleoclimatic investigations along a west-east transect across the entire Eurasian loess belt of the Northern Hemisphere (Ding et al., 2002; Fitzsimmons et al., 2018; Machalett et al., 2008).

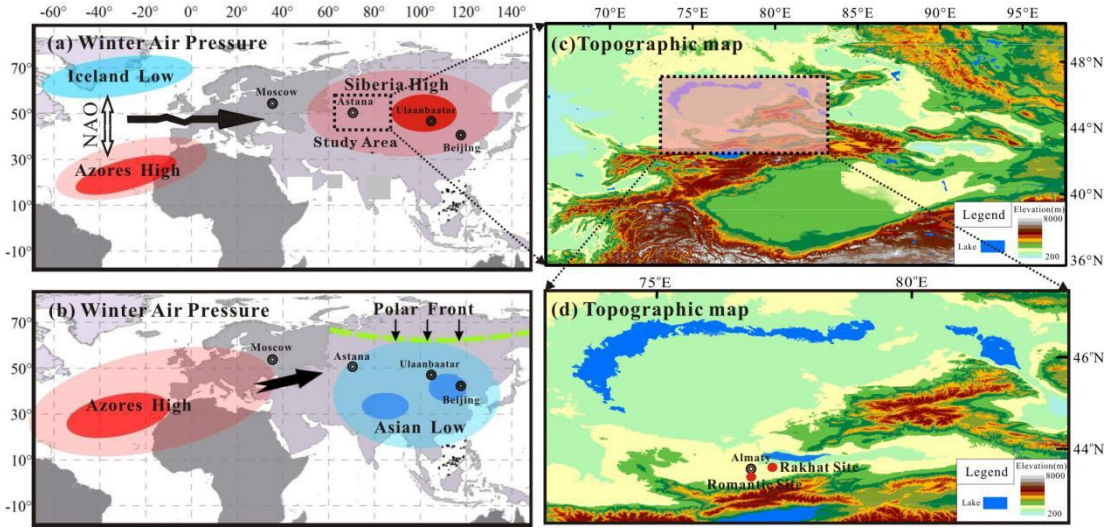

Figure 1: Climatic settings and topographic backgrounds. a: winter air pressure situation in the Eurasian continent; b: summer air pressure situation in the Eurasian continent; c: topographic background of the Central Asian Arid Zone (CAAZ); d: topographic background of the southeastern Kazakhstan (i.e., the focal area of this study).

A recent study on a late Pleistocene loess sequence (i.e., Remisowka site) in Almaty within the southeastern Kazakhstan (Machalett et al., 2008) suggests that besides the prevailing Westerlies and the Siberian High, the polar front activity is another main force of aeolian dust generation and transportation in the CAAZ. They concluded that a steeper (gentler) meridional pressure contrast between southern tropical air and polar air masses, plus the lack (abundance) of moisture during glacials (interglacials), lead to a longer (shorter) seasonal duration, permanency and strength of the polar front on its southern winter position (seasonal domination), involving increased (decreased) and stronger (weaker) cyclonic activity and thus more (less) aeolian transport on orbital timescales. Our recent work (Ran et al., 2020) at a nearby site (Romatic site; also named as Maibulak site in Fitzsimmons et al., 2017) shows that the wind intensity might be indeed stronger during the last glacial than during the recent interglacial (i.e., Holocene). However, our recent work (Ran et al., 2020) also tells a dramatically different suborbital-scale story. That is, the major weak wind-intensity events were chronologically corresponding with the Heinrich (rather cold) Events in the North Atlantic region. The suborbital-scale corresponding relationship might be associated with slowdown or shutdown of the Thermohaline Deep Water Circulation during the Heinrich (rather cold) Events when the Northern Hemisphere was thus drastically cooled. It implies that the southeastern Kazakhstan was most likely in the core of the expanded Siberian High under the drastically cooled conditions and that the resulted low air pressure gradient in the core failed to promote dust storm activities during the Heinrich Events.

The Central Asian Arid Zone (CAAZ) has been reported to have delivered some of the most significant archaeological discoveries in recent decades. Especially, new genetic data indicate that at least two archaic human species (i.e., Neandertals and Denisovans) shared the territories within the CAAZ and possibly interbred with anatomically modern humans as they arrived in the Altai Mountain within the core of CAAZ (Fitzsimmons et al., 2017). They suggested that there was a trend towards increasing occupation of open air sites across the Tianshan piedmont after ~40 ka (ka = thousand years before present), corresponding to more humid climatic conditions including pulses of more intensive dust deposition. They continued to suggest that human occupation persisted into the cold and dry Last Glacial Maximum. But, they seriously cautioned that a need is pressing to develop a much better defined database before making any causal connections between the occupation timings and the palaeo-climatic conditions.

This contribution provides a high-resolution wind-intensity dataset covering the past 50,000 years from the Romantic site near Almaty (Ran et al., 2020) with an attempt to put the reported culture layers from the same site (Fitzsimmons et al., 2017) into a wind-related environmental context. This contribution also

tries to put the reported culture layers from Rakhat site (Necklace et al., 2019) into our recently-obtained palaeo-climatic framework. Again, we (the authors of this contribution) echo the caution by Fitzsimmons et al. (2017) that a need is pressing to develop a much better defined database before making any causal connections between the occupation timings and the palaeo-climatic conditions.

We should also mention that the effects of geographical factors, which are indirectly related to our study and constitute an independent field of research, on various phenomena related to social structure, human relations and personality formation, have been extensively examined in the literature (Ar1, 1999: 219).

II. Literature Review

The present study investigates the interactions between environmental changes and human societies during the Late Pleistocene and Holocene periods in the Semirechye region of southeastern Kazakhstan. This paper examines loess-paleosol sequences from the Romantic (Maibulak) and Rakhat sites, located in the foothills of the Zailiyskiy Alatau (Northern Tien Shan). Climatic Dynamics Wind Activity (based on loess grain-size analysis): Four distinct phases of wind intensity variation over the past ~50 kyr were identified, linked to fluctuations in Northern Hemisphere summer insolation (Berger & Loutre, 1991). Increased wind intensity has been observed to correlate with low insolation periods (e.g., Stages 1 and 3), a phenomenon attributed to the influence of the Siberian High (Ran et al., 2020). Temperature and Moisture (based on brGDGT and δ13C proxies): The brGDGT-based reconstructions demonstrate congruence with global climatic trends: cold phases during MIS 2 and MIS 4, moderate conditions in MIS 3, and warming in MIS 1 (De Jonge et al., 2014). Conversely, the δ13C data indicates aridity during the Last Glacial Period (MIS 4–MIS 2) and increased humidity in the Holocene (Ran & Feng, 2014). Cultural Adaptations Archaeological layers at the Romantic (CH1–CH3) and Rakhat (CH1–CH8) sites demonstrate discontinuous human occupation, yet no direct correlation with wind intensity variations is apparent (Fitzsimmons et al., 2017). The most favourable conditions for human habitation occurred during MIS 3 and MIS 4, whereas MIS 2 (Last Glacial Maximum) likely rendered the region less hospitable (Necklace et al., 2019). Key Findings: The region's climatic changes were driven by global factors (insolation, Siberian High). The presence of cultural layers does not always coincide with extreme climatic events, underscoring the necessity for higher-resolution studies. Southeastern Kazakhstan was identified as a potential habitation zone during cold phases, albeit with fluctuating occupation intensity. Future Directions: The authors emphasise the necessity for refined chronologies and expanded datasets to establish causal links between climate and cultural dynamics (Fitzsimmons et al., 2017).

Primary References: Feng et al. (2011) – Stratigraphy of Central Asian loess. Fitzsimmons et al. (2017) – Upper Paleolithic chronology. Additionally, Ran et al. (2020) provide a reconstruction of wind intensity. Necklace et al. (2019) – Archaeology of the Rakhat site. The present review employs an interdisciplinary approach, integrating geological, paleoclimatic, and archaeological methods to study human adaptation in a changing environment.

III. Materials and Methods

This study employs a multi-disciplinary approach to reconstruct past climatic conditions in southeastern Kazakhstan, focusing on two loess sequences from the Romantic and Rakhat sites. To understand the regional wind intensity variations, grain size analysis was conducted, and a wind-intensity index based on the ratio of coarse silt (20-61 μm) to fine silt and clay fractions (<20 μm) was adopted from Antoine et al. (2013). Chronological data for both sites were obtained through radiocarbon dating of organic materials (charcoal and snails) and optically stimulated luminescence (OSL) dating of quartz and polymineral samples, following the procedures described in Feng et al. (2011) and Fitzsimmons et al. (2018). Bayesian age-depth modeling was applied to construct a robust temporal framework for the loess sequences.

For the Rakhat site, paleoclimate reconstructions were enhanced by analyzing branched glycerol dialkyl glycerol tetraethers (brGDGTs) to estimate mean annual air temperature (MAAT) using transfer functions (De Jong et al., 2014). Carbon isotope (δ13Corg) analysis was utilized to infer moisture variations, as C3 plants dominated the local vegetation. The temperature and moisture data were compared with summer insolation curves (Berger and Loutre, 1991) to assess the climatic shifts over the past 50,000 years. Statistical analyses, including cubic spline interpolation and Bayesian methods, were employed to create the age-depth models for both sites, allowing for a detailed reconstruction of environmental conditions and their potential influence on human occupation in the region.

IV. Results

a) Wind Intensity Sequence at the Romantic Site

The pedostratigraphy and chronology of the Romantic loess sequence, previously outlined by Feng et al. (2011), have been further refined through recent radiocarbon and luminescence dating efforts. The loess-paleosol sequence consists of six distinct units, including mollisol-like paleosols, massive yellowish loess, gleyed loess, and entisol-like palessols, spanning an age range from ~50,000 to ~10,000 years BP. The

integration of charcoal and snail-based radiocarbon dating, along with polymineral pIR-IRSL290 luminescence dates (Fitzsimmons et al., 2018), enables the construction of an age-depth model, revealing a detailed chronological framework for this sequence (Fig. 2).

The grain size-based wind intensity index, following the methodology of Antoine et al. (2013), was employed to reconstruct past wind dynamics. The index, derived from the coarse silt to fine silt/clay ratio, reflects four distinct stages of wind intensity variability during the last ~50,000 years. These stages are marked by significant shifts in atmospheric circulation, with wind intensity peaking during ~50,000–41,000 BP (Stage 1) and ~33,000–23,000 BP (Stage 3), coinciding with low summer insolation periods. In contrast, wind intensity significantly decreased during periods of increasing insolation, such as ~41,000–33,000 BP (Stage 2) and ~23,000–10,000 BP (Stage 4), aligning with a weakening of the Siberian High. These results suggest that shifts in insolation-driven atmospheric dynamics governed regional wind intensity patterns, with implications for dust storm frequency and intensity.

Notably, the cultural occupations at the Romantic site (CH1–CH3) do not appear to have been directly influenced by variations in wind intensity. CH3 (36,600–43,400 cal. BP) occurred during a high wind intensity phase, CH2 (29,000–34,700 cal. BP) during a low intensity period, and CH1 (15,000–21,500 cal. BP) during a time of declining wind intensity. These findings suggest that human occupation may have been independent of loess-recorded wind intensity, although the human groups seemingly avoided the coldest phase of the Last Glacial Maximum (~25,000–20,000 cal. BP).

i. *Temperature and Moisture Variations at the Rakhat Site*

The pedostratigraphy and chronology of the Rakhat site, as defined by Necklace et al. (2019), consists of nine stratigraphic units, including well-developed Mollisols, sandy loess, silty loess, and gravel layers. Cultural layers were identified within several of these units, with ages derived from radiocarbon and OSL dating, resulting in an age-depth model suggesting the presence of human occupations over the past ~70,000 years (Fig. 4).

To reconstruct past climatic conditions, the brGDGT-based Mean Annual Air Temperature (MAAT) and δ13Corg-based moisture proxies were applied to the Rakhat sequence. The brGDGT-based MAAT reconstruction reveals a clear correspondence with Northern Hemisphere summer insolation, reflecting a warm Marine Isotope Stage 1 (MIS 1, ~10,000 years BP), a cold MIS 2 (~25,000–10,000 years BP), and a moderate MIS 3 (~57,000–25,000 years BP). Notably, the temperature pattern during MIS 4 (~73,000–57,000 years BP) suggests another cold phase, consistent with global climatic trends (Fig. 5A).

The δ13Corg data, indicative of soil moisture variations, suggest that the Last Glacial period (encompassing MIS 2, MIS 3, and MIS 4) was marked by relatively dry conditions, while the Holocene (MIS 1) was wetter (Fig. 5B). These findings support the hypothesis that southeastern Kazakhstan provided suitable conditions for human habitation during MIS 4 and MIS 3, with relatively favorable climatic conditions, but was less conducive to human settlement during the cold and dry MIS 2.

Together, these results provide new insights into the relationship between climate, environmental change, and human occupation in southeastern Kazakhstan, underscoring the complex interplay between atmospheric circulation, temperature, moisture, and the survival strategies of early human populations in the region.

The effects of geographical factors, which are indirectly related to our study and constitute an independent field of research, on various phenomena related to political science such as social structure, human relations and political attitudes are widely examined in the literature (Arı, 1999: 219). For example, communities living on the seashore and those living inland or those living in fertile lands and those living in arid regions develop different lifestyles and social structures due to their different socio-economic conditions. This has led many thinkers since Ancient Greece to analyze socio-cultural and political phenomena through geographical factors (Sorokin, 1994: 102). In the historical process, thinkers such as Aristotle, Ibn Khaldun and Montesquieu have systematically addressed various social and political problems from the perspective of geographical determinism (Kışlalı, 1987: 28).

V. Discussion

a) Wind Intensity Sequence at Romantic Site

i. *Pedostratigraphy and Chronology*

We have already reported the pedostratigraphy and chronology (Feng et al., 2011). In brief, the loess-paleosol sequence can be divided into six pedostratigraphic units (Fig. 2A). Unit 1 (0-150 cm) is a mollisol-like paleosol. Unit 2 (150-300 cm) is a massive and yellowish loess unit. Unit 3 (300-400) is a gleyed loess unit. Unit 4 (400-450 cm) is again a massive and yellowish loess unit. Unit 5 (450-700 cm) is an entisol-like palessol. Unit 6 (700-800 cm) is a massive and yellowish loess unit. We obtained six (6) radiocarbon dates on snails and charcoals (Feng et al., 2011). Recently, Fitzsimmons et al. (2018) further studied the middle part (i.e., 2 to 6 m) of Romantic loess section (referred as Maibulak in their papers) and obtained two

sets of luminescence dates at exactly the same depths: one set based on quartz OSL dating and another set based on polymineral pIR-IRSL$_{290}$. The authors (Fitzsimmons et al., 2018) preferred the polymineral pIR-IRSL$_{290}$ dates over the quartz OSL dates. Figure 2A shows that our charcoal dates, which were corroborated by co-existing archaeological artifacts, are in a rather good agreement with the polymineral pIR-IRSL$_{290}$ dates. Consequently, we adopted the snail- and charcoal-based dates and the polymineral pIR-IRSL$_{290}$ dates to establish the age-depth model of Romantic loess section using a cubic spline interpolator with Bayesian statistical methods (Fig. 2B). According to the model, the Romantic loess section was formed between ~50,000 yr BP and ~10,000 yr BP.

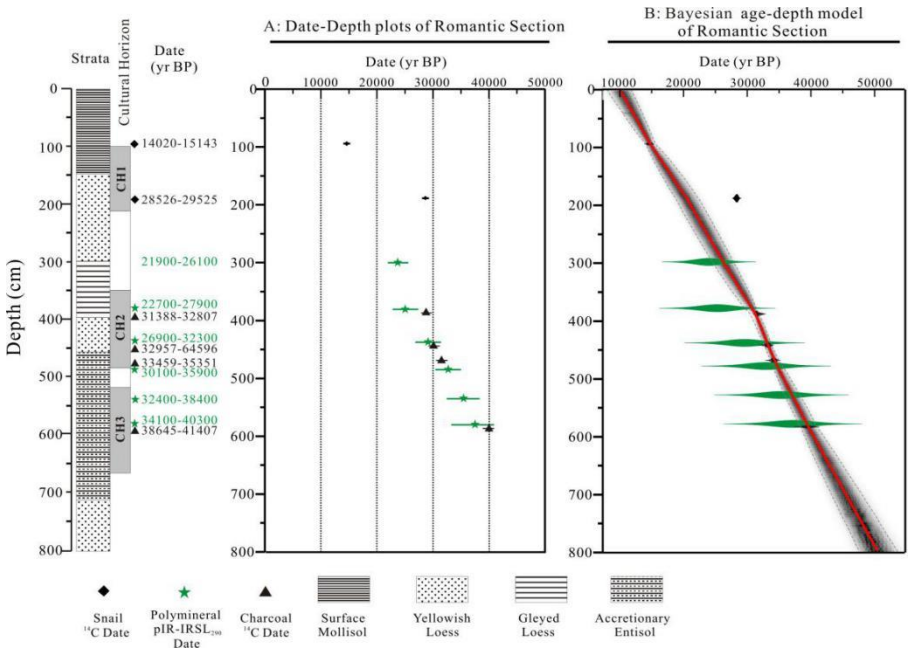

Figure 2: Strata, dates and age model of the Romantic loess section: A: Date-depth plots; B: Bayesian age-depth model (adopted from Ran et al., 2020).

ii. *Wind Intensity Sequence*

To reconstruct the past changes in wind dynamics and in atmospheric circulation, grain size-based wind intensity indices have been adopted by several research teams. Our study employed the index presented by Antoine et al. (2013). The index was defined as the percentage ratio □□□□□□□□ m □□□□□□ m □ of coarse silt fraction (20-61 □m) over fine silt and clay fractions (<20□m). As shown in Figure 3, both the sand percentage (Fig. 3A) and the wind-intensity index (Fig. 3B) exhibit four stages of variations during the data-covering period from ~50,000 yr BP to ~10,000 yr BP. Stage 1 (from ~50,000 to ~41,000 yr BP) was the first wind-intensity increasing period and Stage 2 (from ~41,000 to ~33,000 yr BP) was an extremely low wind-intensity period. Stage 3 (from ~33,000 to ~23,000 yr BP) was the second wind-intensity increasing period and Stage 4 (from ~23,000 to ~10,000 yr BP) was a wind-intensity decreasing period.

We compared the wind intensity in the southeastern Kazakhstan (Ran et al., 2020) with the summer insolation in the Northern Hemisphere (Berger and Loutre, 1991). Our comparison shows that wind intensity variations were generally corresponding with the summer insolation variations. Specifically, the wind-intensity increasing stages (i.e., Stages 1 and 3) were concurrent with the summer insolation decreasing periods. And, the extremely low wind-intensity stage (i.e., Stage 2) and the wind-intensity decreasing stage (i.e., Stage 4) were concurrent with the summer insolation increasing periods. The corresponding relationships can be explained by the insolation-controlled dynamics of the Siberian High. That is, the Siberian High might have become stronger or the duration of the Siberian High-related winter-monsoon domination might have become longer when the summer insolation was decreasing, resulting in more intensive dust storms. In contrast, the Siberian High might have become weaker or the duration of the Siberian High-related winter-monsoon domination might have become shorter when the summer insolation was increasing, resulting in less intensive dust storms (Ran et al., 2020).

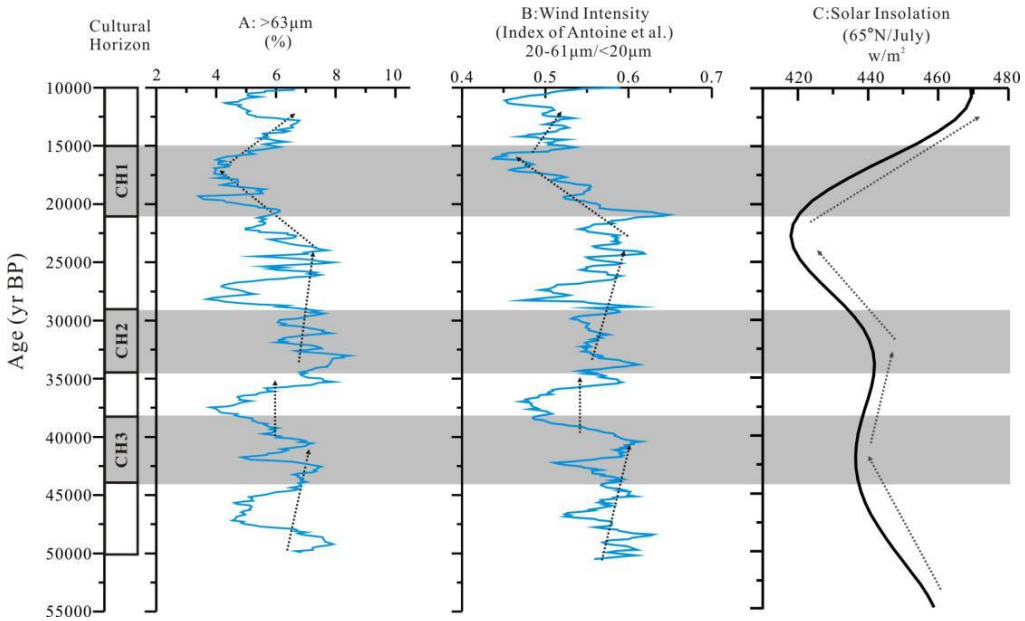

Figure 3: Grain size-based wind intensity index curve of Romantic loess-paleosol sequence (Ran et al., 2020) and the comparison with the summer insolation in the Northern Hemipshere (Berger and Loutre, 1991). A: Sand percentage (>63□□m (%)); B: Wind intensity index; C: Summer insolation in the Northern Hemisphere.

Here, we try to put the reported culture layers (Fitzsimmons et al., 2017) into a wind-related environmental context (Ran et al., 2020). The depths of the three cultural layers at the Romantic site are approximately 1.0~2.1 m (CH1), 3.5~4.8 m (CH2), and 5.2~6.6 m (CH3). And, the ages of the three cultural layers are approximately 15,000~21,500 cal. yr BP (CH1), 29,000~34,700 cal. yr BP (CH2), and 36,600~43,400 cal. yr BP (CH3). Our comparison of the wind intensity chronology with the ages of the three cultural layers shows that the cultural occupations might have not affected by loess-recorded wind intensity. That is, CH3 (36,600~43,400 cal. yr BP) occurred during a period of a high wind intensity; CH2 (29,000~34,700 cal. yr BP) during a period of a relatively low wind intensity; CH1 (15,000~21,500 cal. yr BP) during a period of a dramatically declining wind intensity. However, the human occupation seemed to have avoided the coldest Last Glacial Maximum lasting from approximately 25,000 to 20,000 cal. yr BP, as indicated by the summer insolation in the Northern Hemisphere (Berger and Loutre, 1991).

b) Temperature and Moisture Variations at Rakhat Site

i. *Pedostratigraphy and Chronology*

The loess-paleosol sequence from Rakhat site (Necklace et al., 2019) was pedostratigraphically divided into nine units (Fig. 4A) that were further confirmed in 2019 by one of the authors of this contribution (i.e., Z.-D. Feng). Unit 1 (0-~2 m): a well-developed Mollisol with a rather visible B horizon; Unit 2 (~2-~4 m): a light brown, loose, sandy loess layer; Unit 3 (~4-~8 m): a dark gray, loose, silty loess layer containing three cultural layers (1, 2, 3); Unit 4 (~8-~9.5 m): a dark brown, loose, silty loess layer; Unit 5 (~9.5-~10.5 m): a light brown, loose, sandy loess layer containing a cultural layer (4); Unit 6 (~10.5-~11.8 m): a sandy clay layer containing small gravels and containing three cultural layers (5, 6, 7); Unit 7 (~11.8-~12.3 m): a silty clay layer containing more gravels and containing a cultural layer (8); and Unit 8 (12.3-~13 m): a gravel layer.

Only one charcoal-based radiocarbon date was given in Necklace et al. (2019) and four quartz-based OSL dates were recently obtained (Ran, unpublished dates). We adopted these five dates to establish the age-depth model of Rakhat loess section using a cubic spline interpolator with Bayesian statistical methods (Fig. 4B). If (only if) the age-depth model, based on these five dates, is somewhat acceptable, the Rakhat loess section covers the soil-forming and dust-depositing histories of the past 70,000 years. Again, if (only if) the age-depth model, based on these five dates, is somewhat acceptable, the observed eight cultural layers (CH1~CH8) seemed to have occurred at the following ages (see Fig. 4B): CH1 (~6.6 m) at ~40,500 yr BP; CH2 (~6.8 m) at ~41,500 yr BP; CH3 (~7.0 m) at ~42,900 yr BP; CH4 (~10.0 m) at ~58,600 yr BP; CH5 (~10.8 m) at ~62,600 yr BP; CH6 (~11.2 m) at ~64,700 yr BP; CH7 (~11.6 m) at ~66,700 yr BP; and CH8 (~11.9 m) at ~68,200 yr BP.

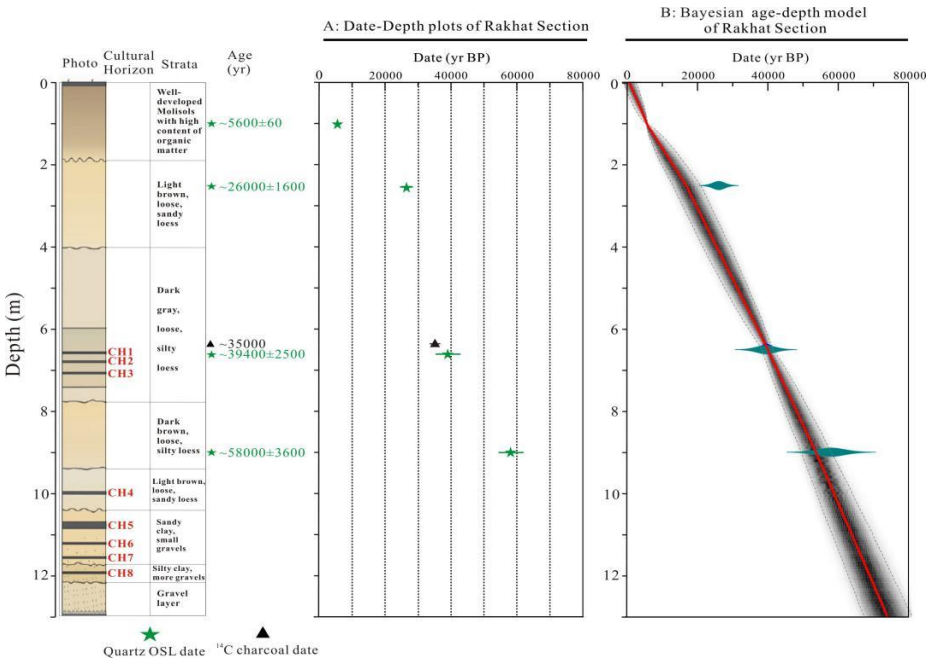

Figure 4: Strata, dates and age model of the Rakhat loess section: A: Date-depth plots; B: Bayesian age-depth model.

ii. *Temperature and Moisture Variations*

Branched glycerol dialkyl glycerol tetraether (brGDGTs) membrane lipids have been widely used to reconstruct past climate and environmental change from natural archives, including loess (Peterse et al., 2012), peat bogs (Zheng et al., 2015), lakes (Sinninghe Damsté et al., 2009; Tierney et al., 2012), and rivers and estuaries (Kim et al., 2010, 2012; Zhu et al., 2011). Specifically, the existing studies on the relationship between brGDGTs in modern soils and modern environmental parameters (i.e., soil pH and atmospheric temperature) show that the variations in the cyclisation of brGDGTs (CBT-index) in soils correlates with soil pH and that the methylation index of brGDGTs (MBT) correlates with both soil pH and mean annual air temperature (MAAT) (Weijers et al., 2007; Peterse et al., 2012; De Jonge et al., 2014). Furthermore, these correlations were quantified by establishing transfer functions between soil brGDGT-based CBT and soil pH and also transfer functions between soil brGDGT-based MBT and atmospheric temperature. Here we applied the newest transfer function built by De Jong et al. (2014) to quantitatively reconstruct the atmospheric temperature variation in Rakhat section during the past 50,000 yr BP (Fig. 5A).

Terrestrial higher plants mainly utilize two principal photosynthetic pathways to fix carbon, i.e., Calvin–Benson (C_3 plants) and Hatch–Slack (C_4 plants) pathways. C_3 plants generally have □□C values in the range of –22‰ to –34‰ with an average of –27‰. C_4 plants generally have $\delta^{13}C_{org}$ values in the range of –10‰ to –16‰ with an average of –13‰ (Deines, 1980; O'Leary, 1988; Farquhar et al., 1989). It has been well documented that temperature is positively correlated with plant isotopic signatures in C_4 dominated ecosystems (i.e., higher temperature, more positive isotopic signatures) (Teeri et al., 1980; Sage et al., 1999; Lorens et al., 2004; Nordt et al., 2007) and precipitation is negatively correlated with plant isotopic signatures in C_3 dominated ecosystems (i.e., more precipitation, more negative isotopic signatures) (Stewart et al., 1995; Bowling et al., 2002; Fessenden and Ehleringer, 2003; Lu et al., 2004). The existing investigations on the relationship between modern soil organic carbon isotopes and vegetation type abundantly demonstrated that when the abundance of C_3 plants is 100%, soil $\delta^{13}C_{org}$ is $\leq -24‰$ and when the abundance of C_4 plants is above 80%, soil $\delta^{13}C_{org}$ is $\geq 16‰$ (Tieszen et al., 1997; Bird and Pousai, 1997). As shown in Fig. 5B, almost all the $\delta^{13}C_{org}$ values are $\leq -24‰$ in Rakhat section, which means that the C_3 plants have been the predominant plants around the Rakhat site. Therefore, the $\delta^{13}C_{org}$ in Rakhat section can be used as an indicator of precipitation or soil moisture (Ran and Feng, 2014; Wang et al., 2019).

The brGDGT-based MAAT (mean annual air temperature) and $\delta^{13}C_{org}$-based moisture variations in Rakhat section during the past 50,000 yr BP are shown in Figure 5. Although the data resolution is rather low (only 12 data points), our reconstruction roughly outlines the climate change in the southeastern Kazakhstan during the past 50,000 years with a high credibility. Specifically, the brGDGT-based MAAT variations indicated a warm MIS1 (Marine Isotope Stage 1 spanning over the past ~10,000 m years), a cold MIS2 ranging from approximately 25,000 to 10,000 years BP

(BP: before the present) and a moderate MIS3 ranging from approximately 57,000 to 25,000 years BP (Fig. 5A). The brGDGT-based MAAT variations seem to have well responded to the summer insolation variations in the northern hemisphere (Fig. 5C). If the summer solar radiation indeed controls the temperature in southeastern Kazakhstan, the climate during MIS4 ranging from approximately 73,000 to 57,000 years BP should be another cold period. The $\delta^{13}C_{org}$-based moisture variations suggest that the entire Last Glaciation (i.e., MIS2, MIS3 and MIS4) was relatively dry and the recent interglacial (i.e., MIS 1 or Holocene) was relatively wet (Fig. 5B).

Again, if (only if) the age-depth model, based on these five dates, is somewhat acceptable, it seemed that the southeastern Kazakhstan was suitable for human habitation during MIS4 (CH8-CH5) and MIS3 (CH4-CH1), but not during MIS2.

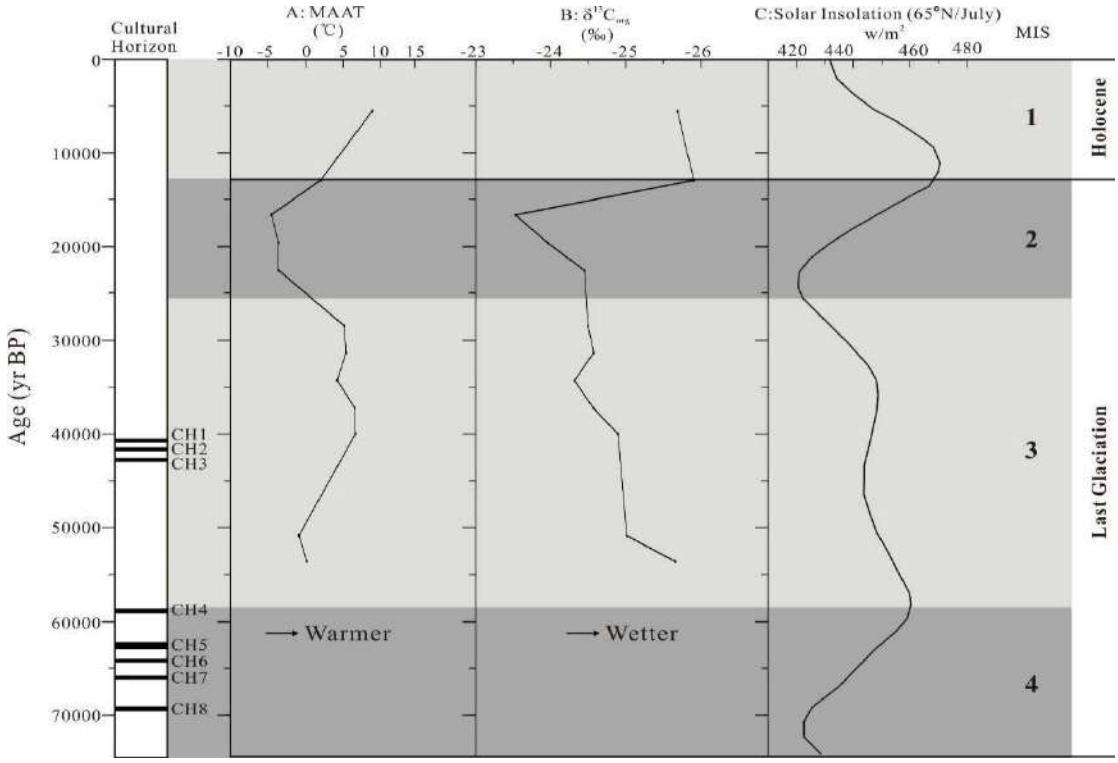

Figure 5: brGDGT-based temperature variations (A) and ^{13}C-based moisture variations (B) of Rakhat loess-paleosol sequence (Ran, unpublished data) and the comparison with the summer insolation in the Northern Hemipshere (Berger and Loutre, 1991).

VI. Conclusions

Three conclusions can be drawn from this contribution. First, our comparison of the wind intensity chronology with the ages of the three cultural layers from Romantic site shows that the cultural occupations might have not affected by loess-recorded wind intensity. For example, CH3 occurred during a period of a high wind intensity; CH2 during a period of a relatively low wind intensity; and CH1 during a period of a dramatically declining wind intensity. Second, although the data resolution from Rakhat site is rather low (only 12 data points), our reconstruction roughly outlines the climate change in the southeastern Kazakhstan during the past 50,000 years with a high credibility. The brGDGT-based MAAT variations from Rakhat site seem to have well responded to the summer insolation variations in the northern hemisphere. That is, the brGDGT-based MAAT variations indicated a warm MIS1, a cold MIS2 and a moderate MIS3. And, the ^{13}C-based moisture variations from the same site display a relatively dry Last Glaciation (MIS 1, MIS2 and MIS3) and a relatively wet Recent Interglacial (i.e., MIS 1 or Holocene). Third, it seemed that the southeastern Kazakhstan was suitable for human habitation during MIS4 (spanning from 73,000 to 57,000 years BP) and MIS3 (spanning from 57,000 to 25,000 years BP), but not during the coldest MIS2 (spanning from 25,000 to 10,000 years BP).

Finally, we (the authors of this contribution) want to echo the caution by Fitzsimmons et al. (2017) that a need is pressing to develop a much better defined database before making any causal connections between the occupation timings and the palaeo-climatic conditions.

Acknowledgments

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Long-Term Shoreline Change Analysis and Forecasting in Kuwait Bay via NDWI and DSAS

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Abstract- Integrating remote sensing and geographic information systems (GIS) can be applied through shoreline monitoring. Coastal environments undergo both natural and anthropogenic processes that drive shoreline changes, making them highly dynamic systems. Kuwait Bay is characterized by its shallow waters and broad intertidal flats, where the tidal activities, wave action, and sediment transportation influence their morphological changes and contribute to critical socio-economic and environmental impacts. This study aims to quantify, calculate, and analyze the metrics of morphological shoreline changes along Kuwait Bay during (1993-2024) and to predict the future shoreline position during 2034 and 2044. Four Landsat sensors (5, 7, 8, and 9) derived from the Google Earth Engine (GEE) platform were used for data acquisition. Shoreline changes were analyzed using the DSAS 5.0 extension in ArcMap 10.4, employing metrics such as SCE, NSM, EPR, and LRR, ArcGIS Pro, and Python (ArcPy library) for shoreline extraction and calculating (NDWI). The highest SCE value was 2889.63 m. As for the NSM, the maximum erosion exceeded that of accretion (2432.94 m and 1482.08 m, respectively). The EPR was 78.64 m/y^{-1} for erosion and 48.09 m/y^{-1} for accretion.

Keywords: kuwait bay, shoreline changes, digital shoreline analysis system (DSAS), normalized difference water index (NDWI), coastal erosion, accretion, remote sensing, coastal vulnerability, land reclamation, coastal management.

GJHSS-B Classification: LCC Code: GC301

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Abstract- Integrating remote sensing and geographic information systems (GIS) can be applied through shoreline monitoring. Coastal environments undergo both natural and anthropogenic processes that drive shoreline changes, making them highly dynamic systems. Kuwait Bay is characterized by its shallow waters and broad intertidal flats, where the tidal activities, wave action, and sediment transportation influence their morphological changes and contribute to critical socio-economic and environmental impacts. This study aims to quantify, calculate, and analyze the metrics of morphological shoreline changes along Kuwait Bay during (1993-2024) and to predict the future shoreline position during 2034 and 2044. Four Landsat sensors (5, 7, 8, and 9) derived from the Google Earth Engine (GEE) platform were used for data acquisition. Shoreline changes were analyzed using the DSAS 5.0 extension in ArcMap 10.4, employing metrics such as SCE, NSM, EPR, and LRR, ArcGIS Pro, and Python (ArcPy library) for shoreline extraction and calculating (NDWI). The highest SCE value was 2889.63 m. As for the NSM, the maximum erosion exceeded that of accretion (2432.94 m and 1482.08 m, respectively). The EPR was 78.64 m/y^{-1} for erosion and 48.09 m/y^{-1} for accretion. These results indicate significant long-term erosion trends, particularly in the northern parts of Kuwait Bay. By the forecast option in DSAS, it was predicted that erosion would continue during the next 2 decades. Continuous retreating of Kuwait Bay's shoreline would affect the coastal ecosystem and habitats by changing sediment dynamics, and threaten coastal constructions and utilities, leading to costly repairs or relocation, and loss of usable land for development and recreation. Understanding the shoreline change is crucial for assessing coastal vulnerability and helps decision-makers plan coastal protection measures and management policies and laws.

Keywords: kuwait bay, shoreline changes, digital shoreline analysis system (DSAS), normalized difference water index (NDWI), coastal erosion, accretion, remote sensing, coastal vulnerability, land reclamation, coastal management.

I. Introduction

Coastal environments are dynamic and intricate systems where land, sea, and atmosphere interact. The natural processes, biological systems, geological features, and human activity, interplay and vary across space and time. Tides, waves, currents, and storm events, shape and continuously modify the shoreline. Erosion, deposition, and sediment transport occur constantly, reshaping landforms like beaches, deltas, and estuaries, as well as storm surges and high-energy wave events can cause rapid and significant change (Bird, 2008) [1]. Coastlines vary dramatically from rocky cliffs to sandy beaches, estuaries to barrier islands each with unique formation processes and sediment characteristics. The type and resistance of rocks, tectonic activity, and sediment supply all contribute to this diversity (Woodroffe, 2002) [2].

Coastal zones are ecologically and biologically complex as they support some of the world's most productive ecosystems mangroves, coral reefs, salt marshes, seagrasses, etc. These ecosystems are highly sensitive to salinity, temperature, tidal range, and human interference (Barbier et al., 2011) [3]. Coastal areas are often densely populated and heavily developed due to their economic and strategic importance. Urbanization, tourism, port construction, and coastal defenses disrupt natural processes and increase risk elsewhere. Pollution, land reclamation, and sand mining degrade ecosystems and accelerate erosion (UNEP, 2006 [4]; Pilkey & Cooper, 2012 [5]). Coastal environments are on the front lines of climate change. Rising sea levels, increasing storm intensity, and ocean acidification threaten infrastructure and ecosystems. Coastal flooding, saltwater intrusion, and ecosystem collapse are growing concerns (IPCC, 2023 [6]; Nicholls & Cazenave, 2010 [7]). Changes in coastal environments occur on different timescales: short-term (tides, storms), seasonal (monsoons, sediment cycles), and long-term (sea-level rise, tectonic changes (FitzGerald & Hughes, 2019) [8].

Coastal processes are ubiquitous and multi-factorial, making understanding all the factors contributing to the proper management of shorelines mandatory. Many authors have focused on the importance of evaluating coastline variations, particularly in areas prospective for large-scale tourism, industrial, or residential facilities. According to Ding and Wang (2008) [9], Hakkou et al. (2018) [10], and Kumar & Jayappa, (2009) [11], shoreline changes are usually caused by the availability of sediment, fluctuating sea levels, rivers, the strength of winds, tidal currents, and wave heights of a region. Measuring and comprehending these processes form the basis for the knowledge of engineers and policymakers because it

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sorts out the characteristics of erosional environments and their pace of degradation or advancement (Boak and Turner, 2005) [12].

Various approaches were applied to analyze the shoreline changes. For example, Ahsanullah et al., (2021) [13] conducted a study to measure the shoreline changes along Karachies closeline from 1972 to 2020. They extracted the shoreline manually and using Normalized Difference Water Index (NDWI) and Erase tool in ArcGIS to quantify the erosion/accretion along the shoreline. In contrast, Zoysa et al., (2023) [14] investigated Oluvil, Sri Lanka shoreline change from 1991 to 2021 and evaluated the impact that the construction of Harbor's had on the coastline using NDWI and digital shoreline analysis system (DSAS). The results of both studies highlighted the importance of practicing sustainable coastal management.

The study of shoreline includes cyclonic activity, waves, and tides push sand in the landward direction, consistently providing coastal evolution with successive changes. Such settings can, at times, either promote or retard the erosion or, on the other hand, promote or inhibit accretionary events, whether climatically or tectonically generated relative changes in sea levels. All along the coastlines fed by rivers and/or offshore sources is significant in stabilizing or changing the profiles as outlined by [10]. These dynamics, therefore, justify the use of prediction models and other analyses in making accurate future shoreline predictions.

a) Studies on Kuwait Coastline

An investigation by (El–Anbaawy, 2017) [15] was set to evaluate the marine environment impact of Al-Sabiyah desalination plant inlets and outlets in Kuwait's Arabian Gulf water. One of the key factors that was mentioned is current movement and went on explaining how the tidal currents in Kuwait Bay shown in Figure (1) is responsible for controlling sediments distribution and morphodynamics.

The desert-like environment of the country and its climatic conditions contribute to managing the challenges along the coastline of Kuwait. Kuwait has a desert climate and topographical features, with a geographical indication of Iraq in the north, Saudi Arabia in the south, and Arabian Gulf in the east. The general inclination of the country descends gradually from the Arabian Gulf in the Northeast towards the Southwest with an altitude of 20m – 300m above sea level. Relatively low rains and high evaporation rates add to sedimentary and hydrological problems, increasing coastal space sensitivity. Kuwait has a 499-kilometer clay coastline. In the last decades, anthropogenic impacts on the coastline have increased significantly due to industrial, recreational, and residential constructions.

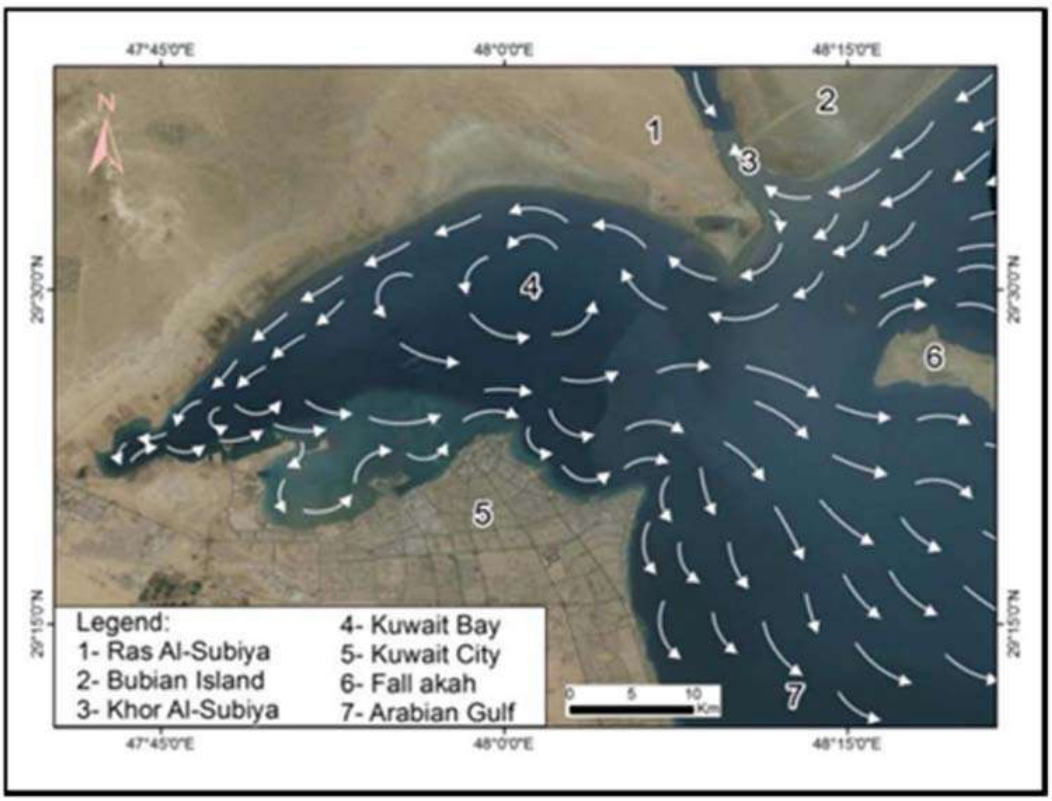

Figure 1: A Map Showing the Anticlockwise Current Movement of Kuwait Bay (after El–Anbaawy, 2017)

Some of the leading activities are the development of seven commercial and oil seaports and the development of oil refineries, including the Mina Abdullah refinery. The aforementioned changes have interfered with natural sedimentation and the hydrodynamic systems where shoreline surveillance is required to contain the impacts positively. A recent study done by (Al-Attar & Basheer, 2023) [16] used on-screen digitizing to extract the entire Kuwait coastline and divided it to four zones and used DSAS to measure the rate of erosion/accretion, and results showed that Zone 2 (Kuwait Bay) showed the highest shoreline change rate where the overall trend is accretion.

Several researches showed how human activities have transformed the Kuwaiti coastline morphology. Sedimentation processes, which are also disturbed through land reclamation, industrial addition, and growth of human city centers, worsen erosion or accretion trends. For example, dredging related to port construction leads to seabed changes, which change the energy of waves and sedimentation (Hassan, 2016) [17]. Existing and planned oil refineries and other related industries aggravate these conditions, contributing to the shoreline's shallowness.

These or similar difficulties still need to be encountered even to this present time despite the advancement in technology in shoreline study. Low-cost and high-resolution data acquisition, particularly on areas of rugged coastline such as Kuwait Bay, could be costly. However, proper integration of ecological or hydrodynamic and socio-economic data is key, although practiced insufficiently often. Modern technologies can offer more possibilities for constructing a numerically more accurate forecast of coastline changes, chiefly machine learning.

b) Significance of Kuwait Bay

Kuwait Bay (the main focus of this study) is a large, semi-enclosed water body located in the north-eastern part of Kuwait, opening into the northwestern Arabian Gulf. Its shallow waters and tidal variations contribute to complex water circulation patterns, which influence salinity, sediment transport, and habitat formation. The bay serves as a natural harbor, providing a sheltered zone for maritime and shipping activities (Al-Rashidi et al., 2009) [18]. Kuwait Bay supports diverse marine ecosystems, including mangroves, coral assemblage, salt marshes, mudflats, and seagrass beds. These habitats serve as breeding and nursery grounds for a variety of marine organisms, including crustaceans, mollusks, and benthic invertebrates commercially important fish species (e.g., mudskipper, mullets) (Al-Yamani et al., 2004 [19]; Khan et al., 2002 [20]). The bay's intertidal zones include salt marshes and sabkhas (coastal salt flats), which are important for halophytic vegetation and specialized fauna. These habitats contribute to nutrient cycling, shoreline stabilization, and biodiversity conservation [20]. The bay is a key stopover site for migratory birds along the Central Asian Flyway. It supports various bird species including flamingos, herons, terns, and sandpipers (Evans, 1994 [21]; Al-Abdulrazzak, 2007 [22]). Mudflats and shallow water provide feeding and roosting grounds for these birds during migration and wintering periods.

Kuwait Bay is integral to Kuwait's economy, being in proximity to major infrastructure such as Shuwaikh Port and Kuwait City. The bay supports vital industries, including shipping, oil refining, and fisheries. Historically, it has supported artisanal fishing and remains a key area for maritime trade and oil exportation [19]. Due to its shallow and semi-enclosed nature, the bay is particularly vulnerable to environmental degradation and pollution [20]. Pollution, habitat loss, overfishing, and coastal development have adversely affected biodiversity in Kuwait Bay. Oil spills, particularly during the 1991 Gulf War, caused extensive damage to marine and coastal ecosystems (Price, 1998 [23]; KISR, 2021 [24]).

Shoreline change analysis is central in establishing the dynamics of coastal environments, especially in regions known for erosion and/or accretion, such as Kuwait Bay, which is greatly influenced by tidal activities, wave action, and sediment transportation processes. Kuwait Bay is known to be a sensitive area that undergoes gradual changes for various reasons that are either natural or anthropogenic activities (El-Raey et al., 1999 [25]; Al-Mansoori, 2020 [26]). Kuwait Bay is relatively shallow and contains comparatively large intertidal flats, which will make this area very sensitive to changes in the quantity and distribution of currents and sediments.

Previous studies on Kuwait Bay have primarily focused on shoreline mapping or sediment transport, often lacking comprehensive, long-term assessments that incorporate both spatial and morphological dimensions. This study addresses this gap by combining (NDWI) and (DSAS) to conduct a 31-year shoreline change analysis (1993–2024), while also integrating morphological characteristics of the coast. This dual approach not only quantifies the rates and directions of shoreline movement but also examines how morphological changes, such as erosion-accretion patterns, and coastal shape dynamics, evolve over time. Furthermore, the study provides predictive shoreline positions for 2034 and 2044, offering a forward-looking perspective that supports coastal management, hazard mitigation, and infrastructure planning in the face of environmental and anthropogenic pressures. To date, no published work has combined both temporal shoreline change modeling and morphological correlation at this scale in Kuwait Bay.

Due to its previously indicated ecological, environmental and socio-economic significance, Kuwait

Bay requires constant assessment of shoreline changes to aid efficient coastal management (Sheppard et al., 2010 [27]; Al-Dousari et al., 2015 [28]).

Data collection by conventional means, including field surveys, is often lengthy, expensive, and exhaustive in large study areas (Natesan et al., 2015 [29]). These limitations made it essential to apply remote sensing and Geographic Information System (GIS) techniques, particularly in monitoring studies. Planetary, frequent coverage remote sensing is employed to monitor the shorelines, and multispectral satellite images are used for the analyses. Implementation of ArcGIS enhances the capability of evaluating shoreline changes and displays stunning outcomes with great precision (Ruiz-Beltran et al., 2019 [30]). Easy access to satellites has also contributed to using remote sensing and geospatial information systems in the shoreline study (Qiao et al., 2018 [31]; Salmon et al., 2019 [32]). Satellite data offers a relatively cheaper and faster image acquisition method than actual field surveys since they are applicable in large areas over an extended period [30]. Those refinements like NDWI improve how shorelines can be identified, or the rate of changes quantified. These developments simultaneously enable the evaluation of the natural and human impacts and enhance management decisions [31; 32]. Shetty et al., (2015) [33] provided compelling data showing that applying GIS and remote sensing is essential in understanding morphological changes along a shoreline.

(DSAS) has also been typically used in assessing shoreline change and quantifying erosion and accretion trends along specific or particular coastal profiles (Thieler et al., 2009) [34]. Scholars focusing on the Arabian Gulf have also shown that shoreline configuration and ability to maintain such aspects are affected by anthropogenic activities such as land reclamation and urbanization [25; 26].

It is observed that the Kuwait Bay shoreline under analysis influences reflects both natural processes and anthropogenic factors. Such influences can only be understood through modern approaches such as remote sensing and geographical information systems, which help manage coastline. Such approaches can help researchers to collect data on short-term temporal changes and help planners to construct strategic long-term planning for Kuwait's sustainable coastal development that will not have adverse impacts on the coastal ecosystems and socio-economic resources.

This study aims to investigate and predict shoreline changes along Kuwait Bay by quantifying and analyzing the morphological changes along the shoreline of Kuwait Bay using (NDWI) and (DSAS) and estimating the condition of the shoreline in 2034 and 2044 using historical records and analysis to determine possible changes in the morphology of the bay. In the same context, this study evaluates Kuwait Bay's potential future shoreline change as influenced by wave and tidal forces and the modified physical coastal development through construction and reclamation activities. These changes present social and economic impacts on the environment, which, for example, lead to habitat alteration or enhanced vulnerability to coastal hazards and have implications on coastal resources. Hence, identifying and assessing these changes are relevant for reasonable management and utilization of the coastal zone.

c) Study Area

This research is limited to the northern coast of the Arabian Gulf, from Ras Al-Sabiyah to Ras Al-Ard (Fig. 2). The geographical extent of the study area is defined by the following coordinates: Top at 29.580582°, with Bottom at 29.299879°, Left at 47.700196°, Right at 48.199582°. The coordinate system used is WGS84 (EPSG: 4326). The study area is approximately 850 square kilometers (km^2), with a length of roughly 50 kilometers, a width ranges from 16 to 20 kilometers, and average depth of 2 to 5 meters [19; 20]. This area where Kuwait Bay is located has limited water depth and ample intertidal areas and, therefore, is very sensitive to variation in the hydrodynamic and sedimentation processes.

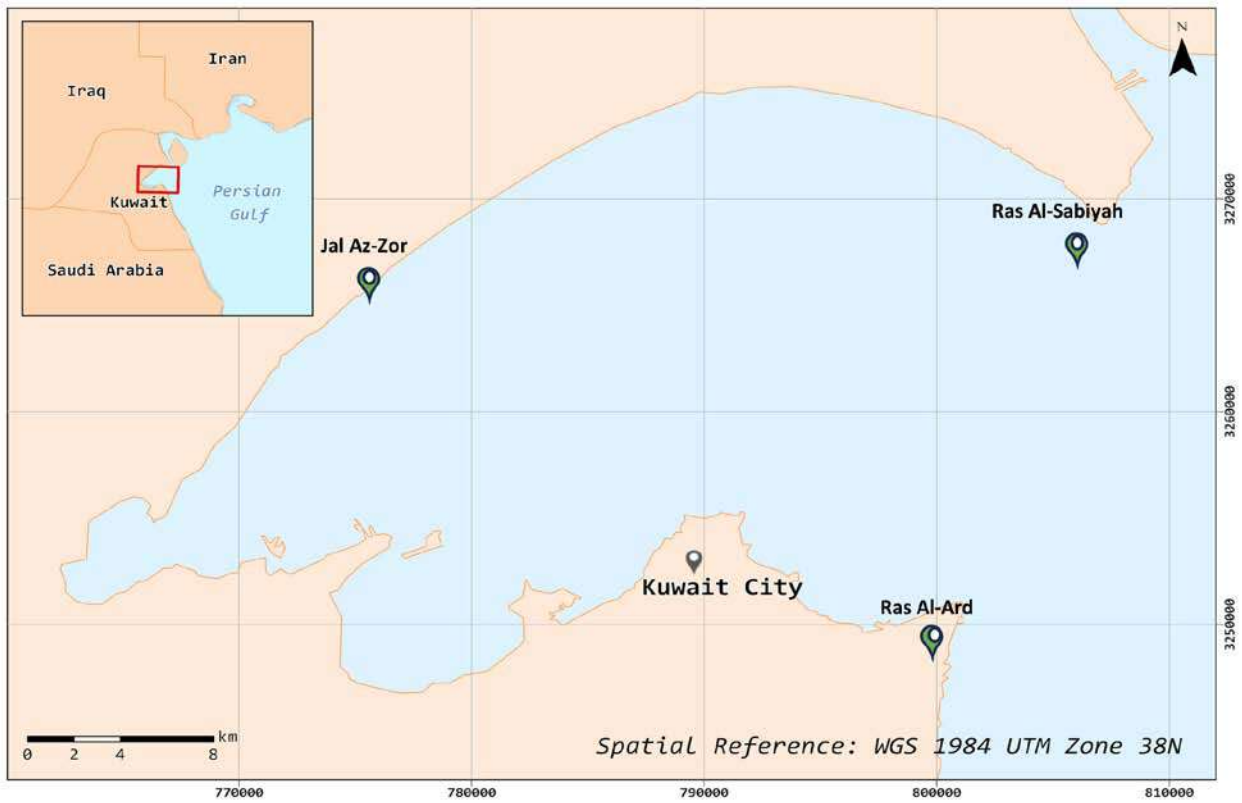

Figure 2: Geographic extent of the study area along Kuwait Bay, between Ras Al-Sabiyah, Jal Az-Zor, and Ras Al-Ard.

Kuwait Bay is significant due to its proximity to Kuwait City, making it highly vulnerable to urban and industrial pressure. Also, it hosts commercial port, fisheries and recreational zones, which makes it play a crucial role in the country's economic and ecological systems.

d) Morphology

The geographical features include tidal flats, sand bars, deltas, shallow coastal shelves, and lesser depths that define the morphology of Kuwait Bay and thereby regulate sediment mobility and hydrodynamic environments. These morphological features depend on the dynamic natural processes of tidal currents, wave actions, sediment procession, transport, and other anthropogenic activities such as reclamation of land, dredging, and coastal development. Morphological analysis is essential for the assessment of the functional characteristics of the bay at the evolutionary level. For instance, sediment redistribution affects currents in which sea organisms can live and breed and changes in coastal evolution that affect fishing, recreational purposes, and the stability of coastal structures.

Most of the changes are gradual and steady, while others are discrete and, as such, call for keen monitoring and assessment. This project provides more study of shoreline change and morphology to understand the dynamics of the bay to support sustainable management and planning endeavors [27; 28]. A significant portion offshore of Kuwait Bay seems to have been shaped and modified by tidal processes, wave energy, and sediment transport [27]. However, actions like coast development and land reclamation have greatly affected it, making it difficult to determine the shore formation [26; 28]. They make Kuwait Bay a suitable area in which to examine the interactions between natural and anthropogenic processes that shape the coastal systems within which the DSAS application may assist in identifying many of these relationships further by coastal development and land reclamation, which add uncertainty to its shoreline change [26; 28].

This project emphasizes the significance of understanding the aspects of coastlines as a means of mitigating the priced dangers and conserving valuable coastal habitats. This current study used satellite data and shoreline extraction techniques to determine future shoreline trends of Kuwait Bay.

II. Methodology

The method applied to this study includes the following steps to measure and assess shoreline transformation in Kuwait Bay using the (DSAS): data obtainment, preliminary data processing, obtaining the shoreline, and performing the analysis according to the DSAS.

a) Data Collection and Processing

Landsat images derived from the Goggle Earth Engine (GEE) platform were used for the study; the spatial and temporal analysis was from 1993 to 2024. Imagery from four Landsat sensors, the Landsat 5, 7, 8, and 9 missions, were chosen for the analysis to capture as many temporal samples as possible during this period. Therefore, all images were selected based on figures showing the least cloud cover for shoreline analysis (Wulder et al., 2019) [35]. These are shown in (Table 1), which indicate the particular datasets and the corresponding acquisition dates.

Table 1: Landsat Datasets and Acquisition Dates.

Year	Landsat Mission	Dataset	Acquisition Date
1993	Landsat 5	LANDSAT/LT05/C02/T1	6/12/1993
1994	Landsat 5	LANDSAT/LT05/C02/T1	3/27/1994
1995	Landsat 5	LANDSAT/LT05/C02/T1	3/30/1995
1996	Landsat 5	LANDSAT/LT05/C02/T1	6/11/1996
1997	Landsat 5	LANDSAT/LT05/C02/T1	5/13/1997
1998	Landsat 5	LANDSAT/LT05/C02/T1	4/7/1998
1999	Landsat 5	LANDSAT/LT05/C02/T1	8/16/1999
2000	Landsat 7	LANDSAT/LE07/C02/T1_L2	4/20/2000
2001	Landsat 7	LANDSAT/LE07/C02/T1_L2	3/6/2001
2002	Landsat 7	LANDSAT/LE07/C02/T1_L2	2/21/2002
2003	Landsat 7	LANDSAT/LE07/C02/T1_L2	4/29/2003
2004	Landsat 7	LANDSAT/LE07/C02/T1_L2	2/27/2004
2005	Landsat 7	LANDSAT/LE07/C02/T1_L2	3/17/2005
2006	Landsat 7	LANDSAT/LE07/C02/T1_L2	3/20/2006
2007	Landsat 7	LANDSAT/LE07/C02/T1_L2	7/29/2007
2008	Landsat 7	LANDSAT/LE07/C02/T1_L2	3/25/2008
2009	Landsat 7	LANDSAT/LE07/C02/T1_L2	3/12/2009
2010	Landsat 7	LANDSAT/LE07/C02/T1_L2	7/21/2010
2011	Landsat 7	LANDSAT/LE07/C02/T1_L2	3/2/2011
2012	Landsat 7	LANDSAT/LE07/C02/T1_L2	3/4/2012
2013	Landsat 8	LANDSAT/LC08/C02/T1_L2	5/18/2013
2014	Landsat 8	LANDSAT/LC08/C02/T1_L2	3/18/2014
2015	Landsat 8	LANDSAT/LC08/C02/T1_L2	4/6/2015
2016	Landsat 8	LANDSAT/LC08/C02/T1_L2	3/23/2016
2017	Landsat 8	LANDSAT/LC08/C02/T1_L2	3/10/2017
2018	Landsat 8	LANDSAT/LC08/C02/T1_L2	4/14/2018
2019	Landsat 8	LANDSAT/LC08/C02/T1_L2	6/4/2019
2020	Landsat 8	LANDSAT/LC08/C02/T1_L2	3/2/2020
2021	Landsat 8	LANDSAT/LC08/C02/T1_L2	4/6/2021
2022	Landsat 9	LANDSAT/LC09/C02/T1_L2	4/17/2022
2023	Landsat 9	LANDSAT/LC09/C02/T1_L2	4/4/2023
2024	Landsat 9	LANDSAT/LC09/C02/T1_L2	4/6/2024

Thus, from 2004 to 2012, the available data was from Landsat 7, which had a scan line error (Markham et al., 2004) [36]. Nevertheless, in the study period, Landsat 7 data were utilized with additional corrections to deal with data loss due to this scan line error. All Landsat imagery shown in Figure (3) was collected in the WGS84 coordinate system and reprojected into WGS 1984 UTM Zone 38N (EPSG: 26 238 for spatial analysis shown in Figure (3).

Since the data acquired through GEE was preliminarily preprocessed, they underwent radiometric, atmospheric, and geometric corrections, ensuring the reliability of the satellite images analyzed (Chander et al., 2009) [37]. Figure (4) shows the breakdown of the study's methodology.

b) Shoreline Delineation

For shoreline Delineation, the NDWI calculation was integrated with vector conversion methods through Python ArcPy (Zou et al., 2016) [38]. Different stages of the shoreline extraction processes are illustrated in (Fig. 5).

The shoreline extraction processes followed these steps:

- *Data Preparation:* Landsat7 and Landsat8 data in Surface Reflectance (SR) bands was preprocessed and retrieved in geo-Tiff format using GEE. These files were stored in an input folder comprising subfolders for each category.
- *NDWI Calculation:* To improve water feature detection, the NDWI was calculated for the expression below (McFeeters, 1996) [39]:

$$\boldsymbol{NDWI} = (Green - NIR)/(Green + NIR) \quad \text{Eq. 1}$$

Green means Band 2, and NIR means Band 4 in the Landsat 5 & 7 datasets were used.

- *Binary Classification:* For the NDWI raster a reclassification was made to convert the raster into a binary format where the threshold was set to zero (0). These were then classified as water where the NDWI values are > 0, and as land where the values are less than zero. This binary classification made the distinction between aquatic areas and land areas much easier to make.
- *Shoreline Extraction:* The digital binary raster was then converted to vector polygon style by using the "Raster to Polygon" function with the help of reference (Wang et al., 2014) [40]. It also shaped the possibility to represent the water bodies in the form of polygons. An area filter erased any shallow internal water body and any island of under 100,000 m^2 to home in on prominent coastal features.

The uncertainty in the extracted shoreline positions was accounted for by considering the spatial resolution of the satellite imagery and the classification method used for NDWI. For Landsat images (30 m resolution), a standard pixel-based buffer of ± 50 m was applied on either side of the extracted shoreline to represent positional uncertainty, following common practice in similar coastal change studies.

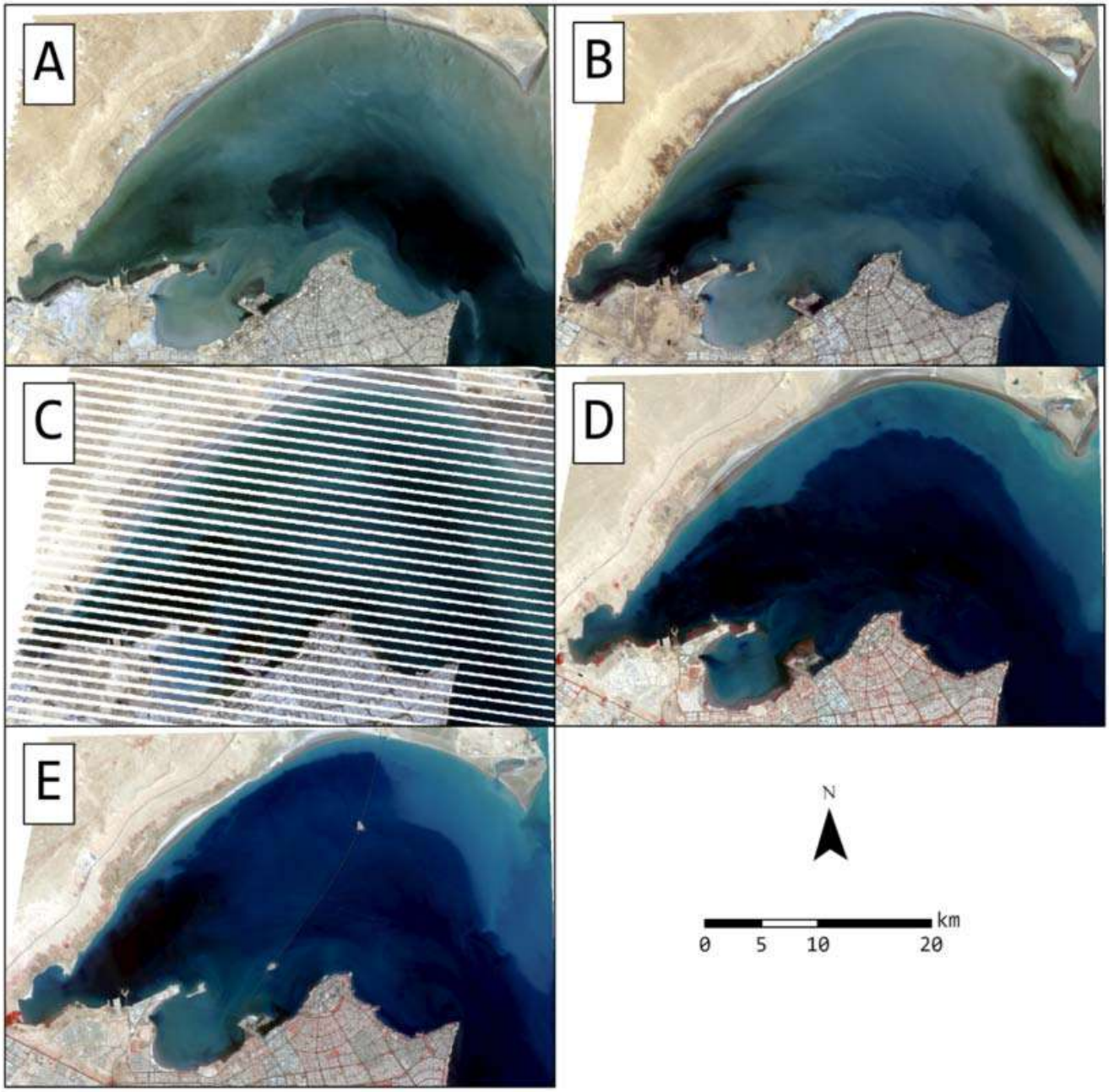

Figure 3: Landsat imagery of the study area used in the analysis: (A) Landsat 5, (B) Landsat 7, (C) Landsat 7 with scan line error, (D) Landsat 8, and (E) Landsat 9.

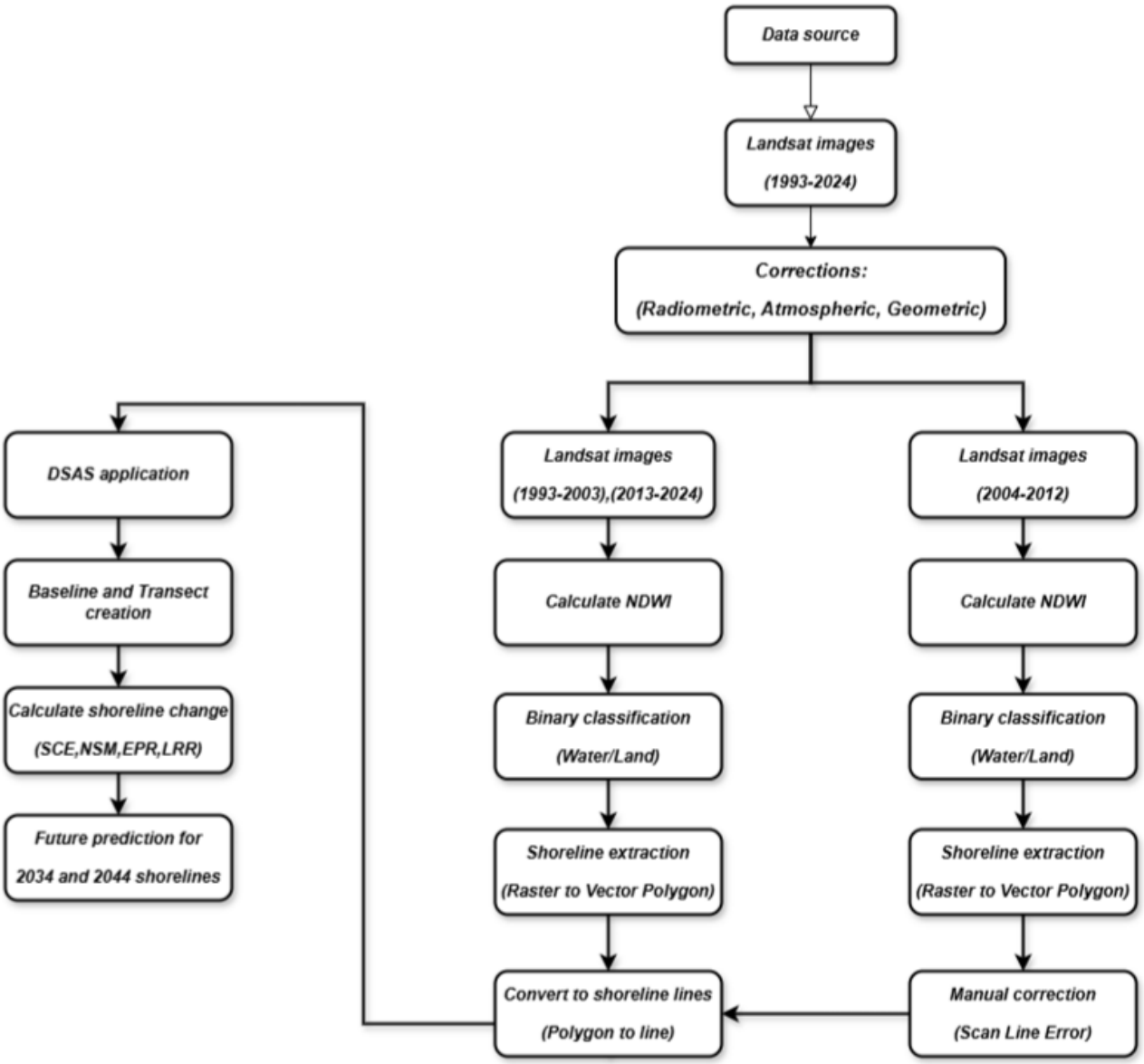

Figure 4: Flow chart of the overall methodology approach in this study.

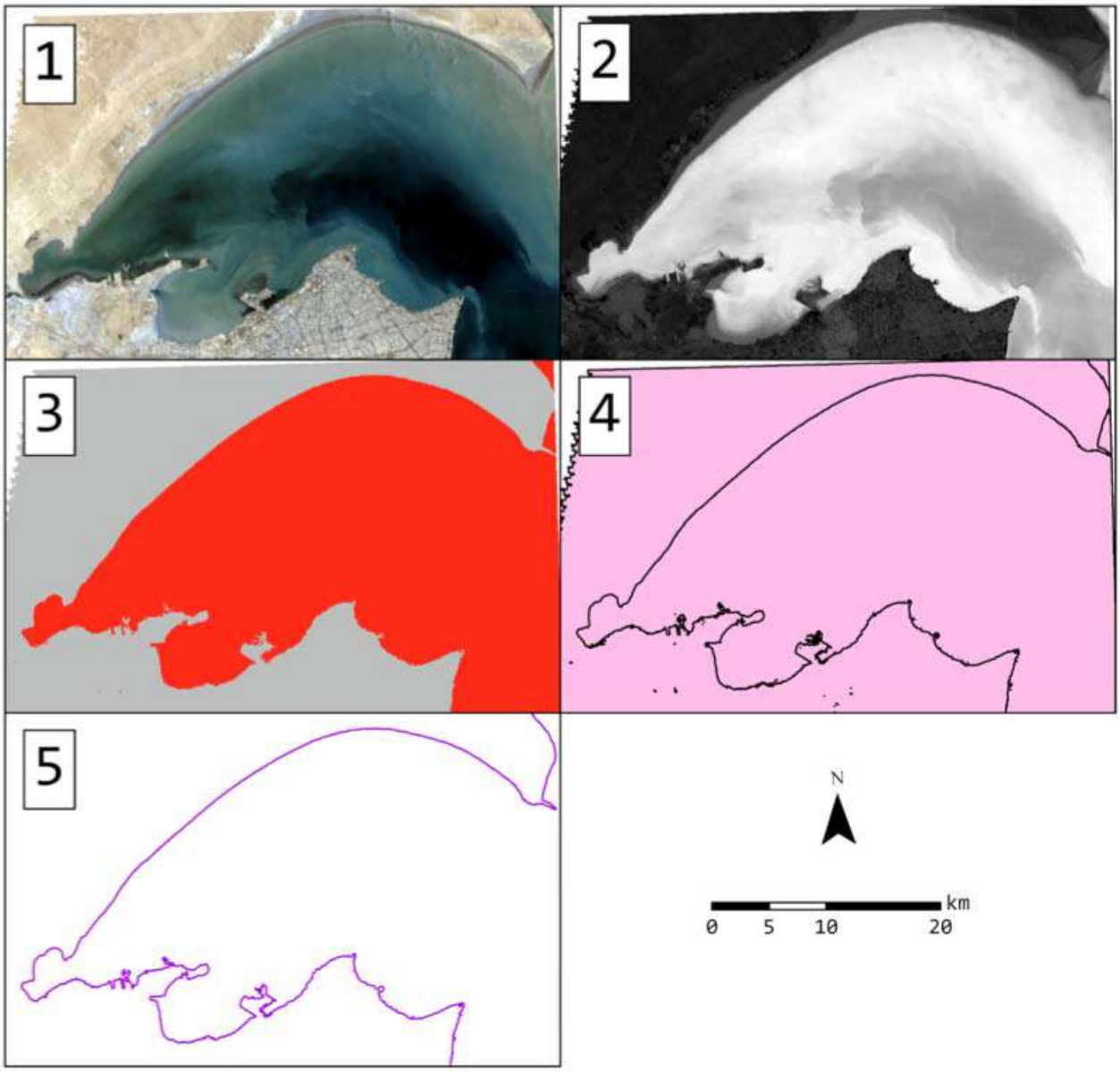

Figure 5: Different stages of the shoreline extraction processes: (1) Original satellite imagery, (2) NDWI raster calculation, (3) Binary classification of water and land, (4) Conversion of water areas into polygons, and (5) Final version of the shoreline after manual corrections.

- *Conversion to Shoreline Lines:* The obtained water polygons were then converted to line features using the "Polygon to Line" tool which provided precise edge of water and land. This step was necessary for additional analysis of the shoreline in DSAS.
- *Manual Correction:* Shorelines identified using the Landsat 7 data acquired between 2004 and 2012 were needed to be corrected due to the scan line error. Some of these corrections entailed checking the extracted shorelines against the NDWI raster to determine if the correct boundary of the shoreline was represented during this period.
- *Quality Assurance:* At each stage of shoreline extraction, there were intermediate controls that included confirmation of the binary classification before conversion to polygons and lines. This made the extracted shoreline data credible through these following steps.

c) *(DSAS) Application*

The shoreline vectors were then exported and imported into ArcMap 10.4 to run the (DSAS) extension developed by the United States Geological Survey [34]. The analysis of the shoreline using the DSAS tool provided information on different aspects of change indices such as Shoreline Change Envelop (SCE), Net Shoreline Mvement (NSM), (EPR), and Linear Regression Rate (LRR).

The Shoreline Analysis Process Followed these Steps:

1. *Baseline and Transect Creation:* An initial line parallel to the shoreline was created, and cross-sections of the transect were created one hundred meters apart. These transects extended typically to the coastline and acted as topographic controls to determine historical shoreline shifts [34].
2. *Shoreline Change Metrics:* In order to measure shoreline changes, DSAS determined the following statistics:

- *(SCE):* Quantifies the extent of the shoreline across the particular transect by establishing the distance between the two extreme positions of the offshore and the inland shores.
- *(NSM):* Determines the vertical reach of shoreline positions along each cross-shore transect.
- *End Point Rate (EPR):* Expresses the amount of shoreline change over one year in average real-time, established in the formula:

$$EPR = \frac{Net\ shoreline\ \ Movement}{Time\ \ intervals\ \ (Num.of\ \ years\ )} \qquad \text{Eq. 2}$$

- (LRR): This measures the rate of change over time through a linear regression analysis of all the shoreline positions in a transect and gives a lasting numeric value for the trend [34].

1. *Predicting future Shoreline Positions:* Potential future shoreline changes were forecast using the forecasted shoreline positions and the DSAS tool, specifying 2034 and 2044 as the predicted years. This project was based on past activity and gave information about the likely future activity of the shoreline.

In DSAS, a transect uncertainty buffer was incorporated to reflect these compounded errors, ensuring that the computed rates of shoreline change (e.g., EPR, LRR) include confidence intervals. These considerations ensure that the derived trends and forecasts are statistically robust and spatially realistic.

In this study, shorelines were extracted using the NDWI method from Landsat imagery (30 m resolution) via Google Earth Engine. While a formal DSAS-style shoreline uncertainty table was not constructed, the methodology followed key principles in line with DSAS standards.

Specifically:

- A consistent shoreline proxy (NDWI) was applied uniformly across all years (1993–2024).
- Transects were spaced evenly, and a buffer of ±50 meters was used around the extracted shoreline to account for spatial variability and uncertainty.
- The selected buffer incorporates known sources of error, including sensor spatial resolution, image georeferencing accuracy, NDWI thresholding sensitivity, and potential tidal variability.

Based on published literature and Landsat metadata, positional uncertainty for Landsat imagery is approximately ±15 meters. Therefore, the applied ±50 m buffer is considered sufficient to accommodate these combined uncertainties.

Shoreline positions were extracted from Landsat imagery (1993–2024) using the NDWI method in Google Earth Engine. It was considered that the effects of cloud cover, tidal stage, and image resolution on shoreline mapping accuracy are as follows:

- *Cloud Cover:* Cloud presence can obscure the shoreline and affect classification. To address this, the standard cloud masking functions available in Google Earth Engine was applied to exclude cloudy pixels. Additionally, the image collection was filtered to select only those scenes with low cloud cover (typically less than 10%), ensuring that only clear-sky images were used for shoreline extraction.
- *Tidal Stage:* Landsat imagery is acquired at varying tidal stages, which can introduce horizontal displacement of the shoreline. Although tidal data were not explicitly incorporated into the analysis, the use of multiple images across a long-time span, combined with a consistent NDWI threshold, helps reduce the influence of short-term tidal variations. Furthermore, a ±50 m buffer was applied around each shoreline to account for potential positional shifts, including those caused by tidal fluctuations.
- *Image Resolution:* The 30-meter spatial resolution of Landsat imagery limits the ability to detect fine-scale shoreline features. While this introduces some positional uncertainty, using the same resolution and NDWI extraction method across all years ensures methodological consistency. The ±50 m buffer also compensates for potential misalignment due to resolution limitations.

Table (2) indicates the differences and significance of the used indices.

Table 2: Differences among the Indices used along with their Significance.

Method	Full Name	Purpose in Shoreline Extraction	Main Advantage	Main Limitation	Type
NDWI	Normalized Difference Water Index	Precisely delineates water bodies to extract shoreline	High accuracy in detecting water–land boundaries, especially in coastal zones	May misclassify built-up areas or shadows	Automated (Remote Sensing)
NDVI	Normalized Difference Vegetation Index	Identifies vegetated land; indirectly separates land/ water	Useful where vegetation clearly marks land areas	Inaccurate in barren or sandy coastlines	Automated (Remote Sensing)
Digitizing	Manual Digitizing (On-Screen)	Manual tracing of shoreline from imagery	Allows expert-based corrections in complex cases	Time-consuming, subjective, and not scalable	Manual (GIS)

III. Results and Discussion

a) Shoreline Extraction Results

The selected shorelines from the shoreline extraction had considerable spatial and temporal changes along Kuwait Bay from 1993 to 2024. Here, 32 shorelines were extracted from the Landsat imagery with low cloud coverage years and high data quality. These shorelines show different degrees of coastal erosion/ accretion, with clear trends demonstrated in regions affected by both natural and human activities.

Several shorelines are depicted in Figure (6) for each of the years under analysis in the study area. The dashed lines in the given color spectrum express the shoreline for different years, based on which one can understand the shifting of the coastline. The extracted area of interest is illustrated at higher magnification to highlight the changes along Kuwait Bay's northern shoreline, where the erosion and accretion features are noted.

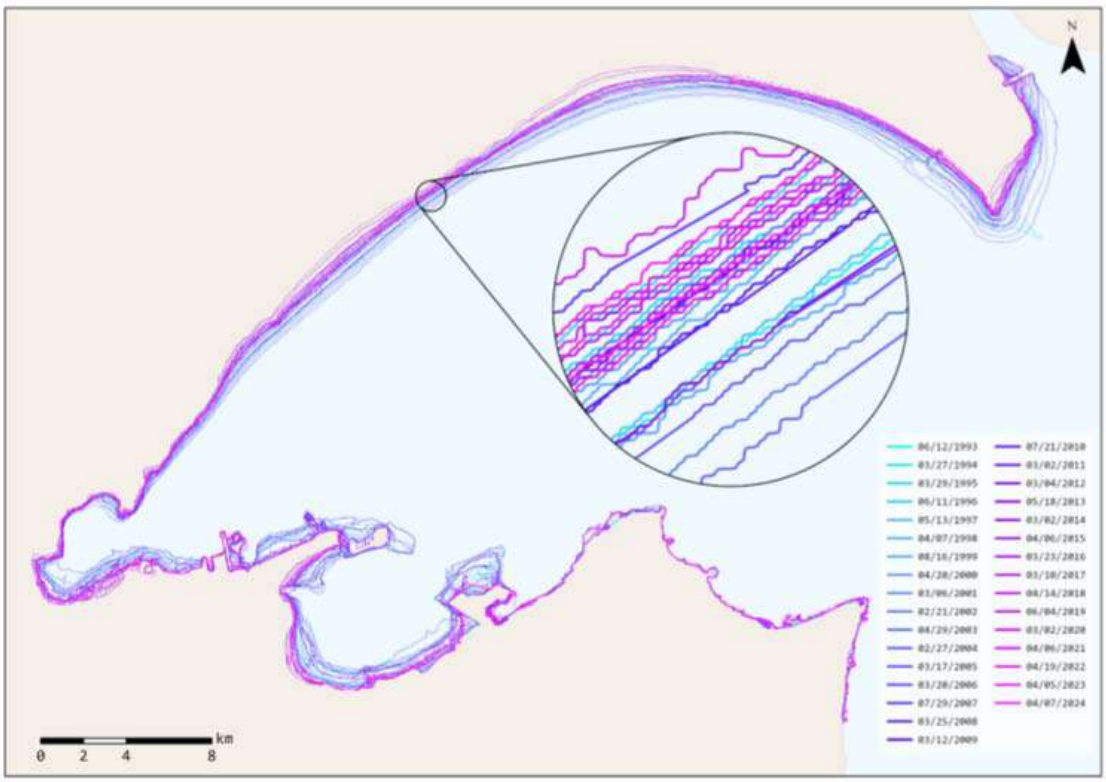

Figure 6: Extracted shoreline positions for Kuwait Bay from 1993 to 2024.

b) Digital Shoreline Analysis System (DSAS) Result

i. *Baseline and Transects*

The concept of baseline and transect generation included establishing an initial line (baseline) along the Kuwait Bay shore by using a Buffer with 50 meters radius and forming cross-sectional lines (transects) with spacings of 100 meters between each transect since the accurate measurement of shoreline shift over time was crucial. Those cross-sections were used as the yardstick for all changes in shoreline positions. Figure (7) shows the baseline and the transects generated over the study area. The transects are laid down at equal intervals, giving a detailed measure of the coastal change from one end of the study period to the other.

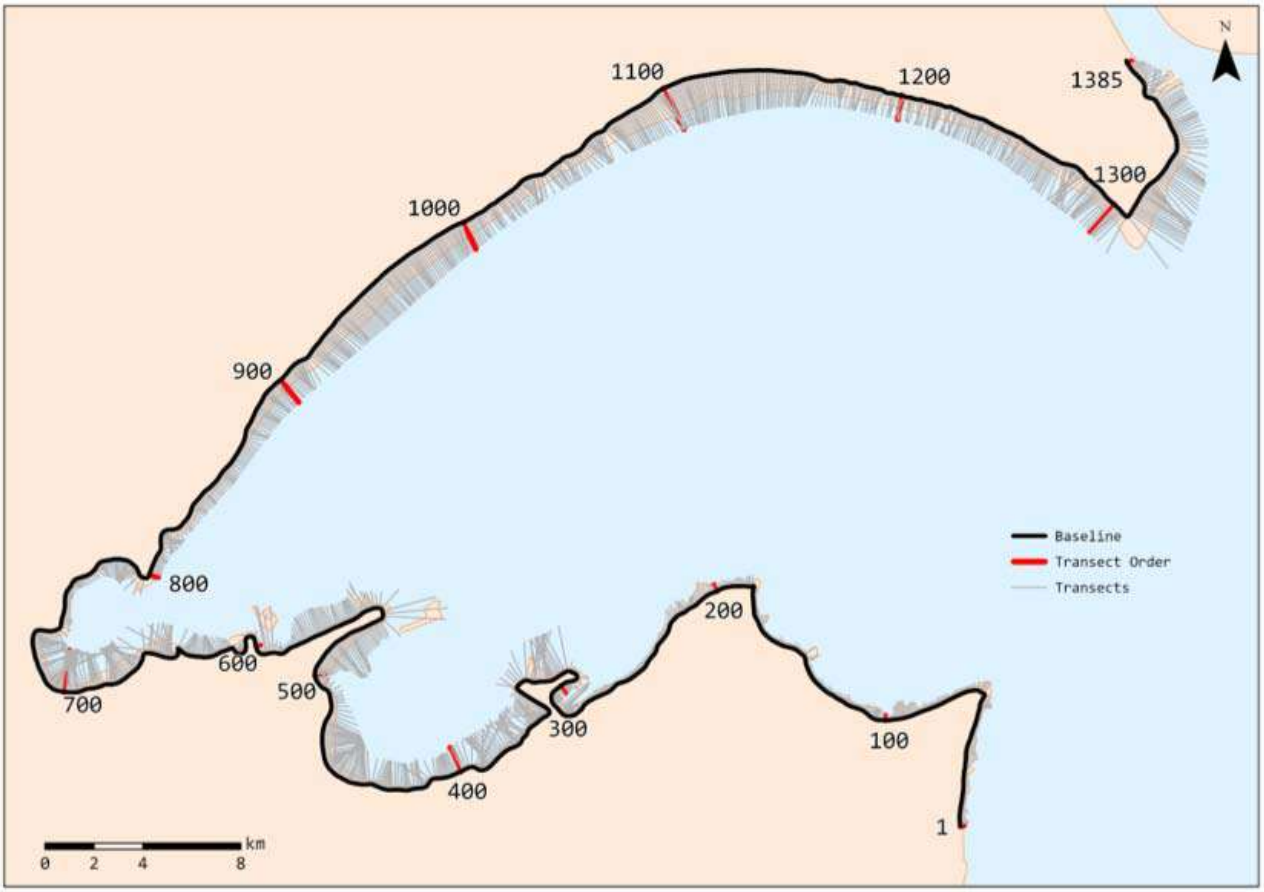

Figure 7: Baseline and transects generated for shoreline analysis across Kuwait Bay.

ii. *Shoreline Change Metrics*

The Shoreline Change Metrics describe the overall nature of changes that occurred along the Kuwait Bay shoreline from the early 1993 to middle of 2024. Four main parameters derived with the help of the DSAS tool are as follows: 1) (SCE), 2) Net Shoreline Movement (NSM), 3) (EPR), 4) (LRR). The outcomes of these quantifiable indices have been computed on the basis of 1384 transects conducted along the coast.

1. (SCE).

The SCE quantifies the distances between the most landward and seaward shoreline positions along each of these transects. The average SCE value of the study area is 7 meters, which shows that there is a huge fluctuation in the shoreline position all over the region. The highest SCE obtained was 2889.36 meters at transect ID 710 while the lowest was 25.04 meters at transect ID 162.

- Total number of transects: 1384.
- Average SCE: 895.77 meters
- Maximum SCE: 2889.36 meters (Transect ID: 710)
- Minimum SCE: 25.04 meters (Transect ID: 162)

These values indicate that the fluctuations of coastline direction in some parts of this region have experienced substantial number of changes in shoreline position, which may be attributed to natural factors as well as human-made interventions such as land filling.

2. (NSM)

The NSM is defined as the difference in shoreline position between the first and last recognized shorelines. The mean value of NSM average is -318.7 meters which suggests that every NSM site experiences general tendency of shoreline erosion. A comparison of transects indicated that 79.19% of the transects showed negative NSM values (erosion) while 20.81 % revealed

positive NSM values (accretion). At the same time, the loss of material is maximal at the transect ID 540 (-2423.94 meters,) while the gain of material is maximum at the transect ID 351 (1482.08 meters) (Table 3).

1. Total number of transects: 1384.
2. Average NSM: -318.7 meters
3. Maximum Erosion (Negative NSM): Transect ID: 540:
4. Maximum Accretion (Positive NSM): 1482.08 meters (Transect ID: 351)
5. Percent of transects with erosion: 79.19% (1096 transects)
6. Percent of transects with accretion: 20.81% (288 transects)

Table 3: Shows the resultant values of NSM, EPR, and LRR.

Metric		Value	Transect ID.
NSM	Max. Erosion	-2423.94 m	540
	Max. Accretion	1482.08 m	351
	Average	-318.7 m	-
EPR	Max. Erosion	-78.64 m/yr	540
	Max. Accretion	48.09 m/yr	351
	Average	-10.34 m/yr	-
LRR	Max. Erosion	-29.71 m/yr	549
	Max. Accretion	65.04 m/yr	351
	Average	-7.27 m/yr	-

3. (EPR)

The EPR gauges the pace of shoreline change throughout the study period. The average EPR is -10.34 m/year; the calculations also indicate that erosion prevails along the coastline. 70.01% of the transects indicated statistically significant erosion, while only 8.96% indicated statistically significant accretion. The highest negative erosion rate was -78.64 m/year at transect ID 540, and the highest accretion rate was 48.09 m/year at transect ID 351.

- Total number of transects: 1384.
- Average EPR: -10.34 m/year
- Maximum Erosion Rate: Debris depth declined at a mean rate of -78.64 m/year (Transect ID: 540).
- Maximum Accretion Rate: 48.09 m/year (Transect ID: 351)
- Percent of erosional transects: 79.19% (1096 transects)
- Percent of statistically significant erosion: 70.01%
- Percent of statistically significant accretion: 8.96%

These findings underscore the need for further erosion control efforts because at least half of the coastline is eroding at potentially damaging rates that may be proven to be devastating in the long run to local ecosystems and artificial structures within the coastal areas.

4. (LRR)

The LRR determines the long-term rate of motion of the Shorelines by fitting a least squares regression line through all the shoreline positions exposed by the cross-section marriage. Therefore, these results suggest a general withdrawal of the shoreline with an average likelihood ratio estimate of -7.27m/year. The average erosion percentage for all the transects is 48.19%, of which 14 transects indicate a statistically significant erosion rate ranging from -0.03 m/year to-29.71 m/year at transect ID 549. However, statistically significant erosion is found in only 11.78% of the transects, the maximum accretion rate being 65.04 meters per year at transect 351.

- Total number of transects: 1384.
- Average LRR: -7.27 m/year
- Maximum Erosion Rate (LRR): Approximately -29.71 m/year erosion rate was estimated at Transect ID: 549.
- Maximum Accretion Rate (LRR): 65.04 m/year (Transect ID: 351)
- Percent of erosional transects: 79.12% (1095 transects)
- Percent of statistically significant erosion: 48.19%
- Percent of statistically significant accretion: 11.78%

Representations of SCE, NSM, EPR, and LRR with their respective figures depicting the changes along transects are presented in Figure (8). These figures and maps illustrate the changes that occurred throughout the study period and the exact location where these changes appeared.

Figure (9) compares the total eroded area, which covered approximately 47 Km^2, from 1993 to 2024 against the total accreted area, which was 4 Km^2. The comparison highlights how erosion plays a major role in determining the morphology of the bay. The great extent of land loss has further emphasized the weaknesses of some of the sectors, especially in the northern and western part, which showed high sensitivity to both tidal forces and wave impacts.

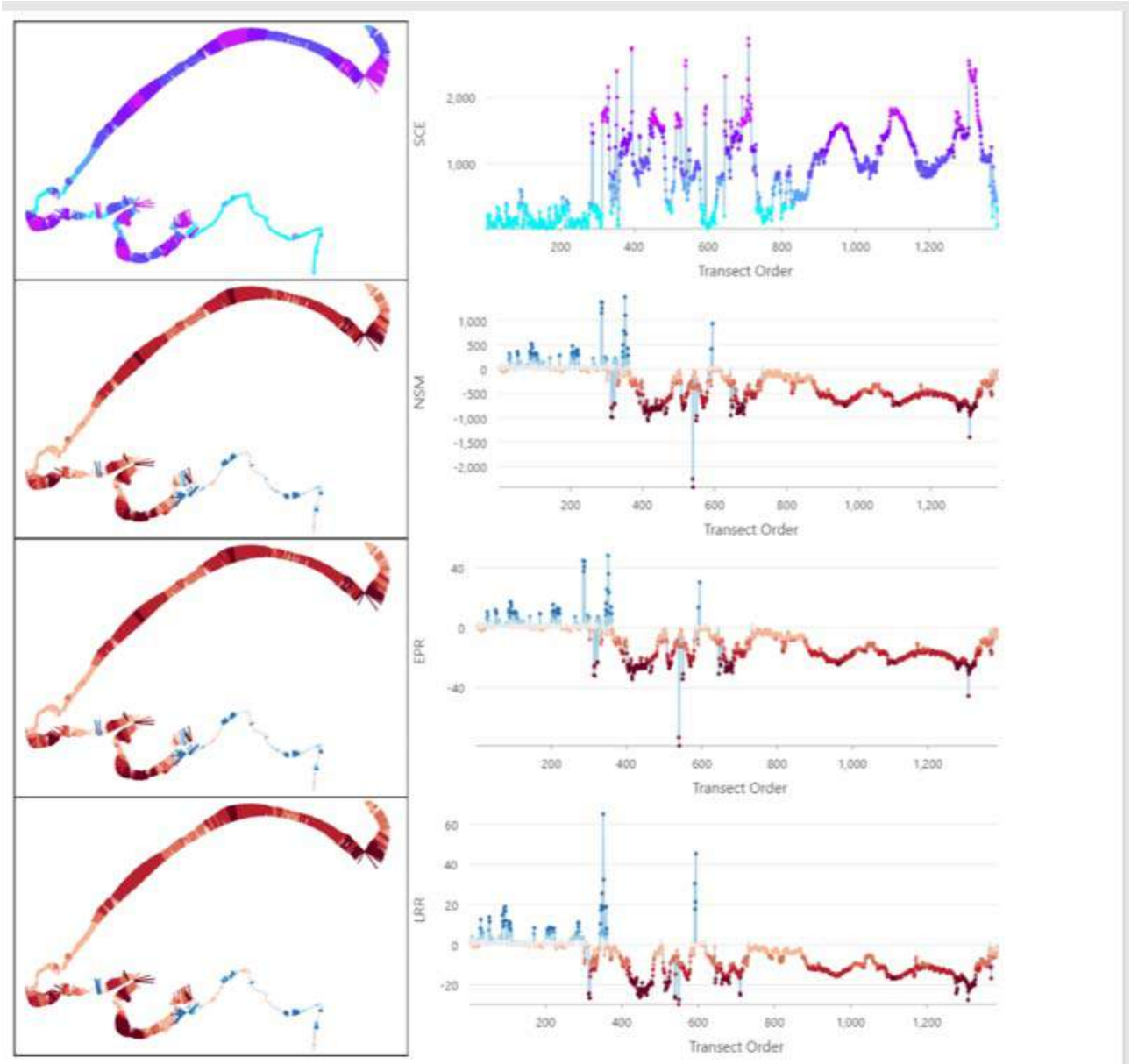

Figure 8: Visualizations of Shoreline Change Metrics for Kuwait Bay, including Shoreline Change Envelope (SCE), Net Shoreline Movement (NSM), End Point Rate (EPR), and Linear Regression Rate (LRR).

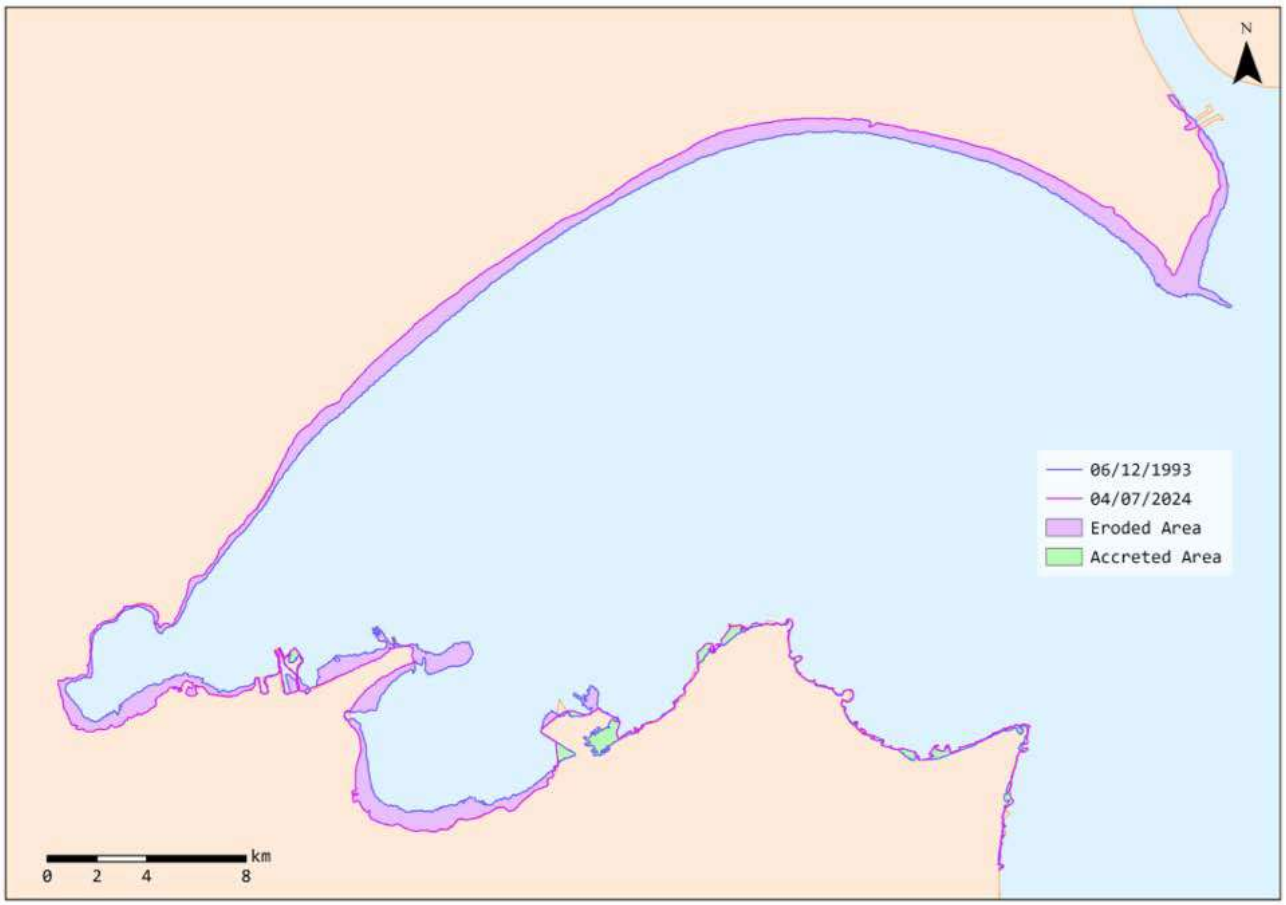

Figure 9: Total eroded and accreted areas between 1993 and 2024.

To identify temporal changes along the shorelines of Kuwait Bay, geographical data sets obtained from remote sensing data were grouped into 5-year periods starting from 1993 to 2023. This approach observed the patterns of erosion and accretion over time and indicated natural processes as well as human intervention on the specific sections of the coastline.

Figure (10) provides a bar chart of the total area of erosion and accretion every 5 years to compare the extent of shoreline response at different time scales. The graph displays extensive slippage between 1993 and 1998, followed by intervals of slippage and buildup, the most significant buildup occurring from 2003 to 2008. The time between 2018-2023 also shows considerable addition and rise, indicating that sedimentation or some other stabilizing factor can occur in a few regions.

Figure (11) illustrates potential and actual site erosion and accretion zones for each 5-year segment to identify the areas of conspicuous variability. Whereas the red color on each map shows the vulnerable or the eroding sectors, the green color reveals the sectors where the coastline is gaining land. It hence acquires the attribute of an accretion zone, all of which visually depicts how different parts of the coastline are changing. Most of the map intervals, especially periods, show comparatively much erosion, particularly on the northern coastal strip, the later periods indicate relatively much accretion on the southern and the western stretch.

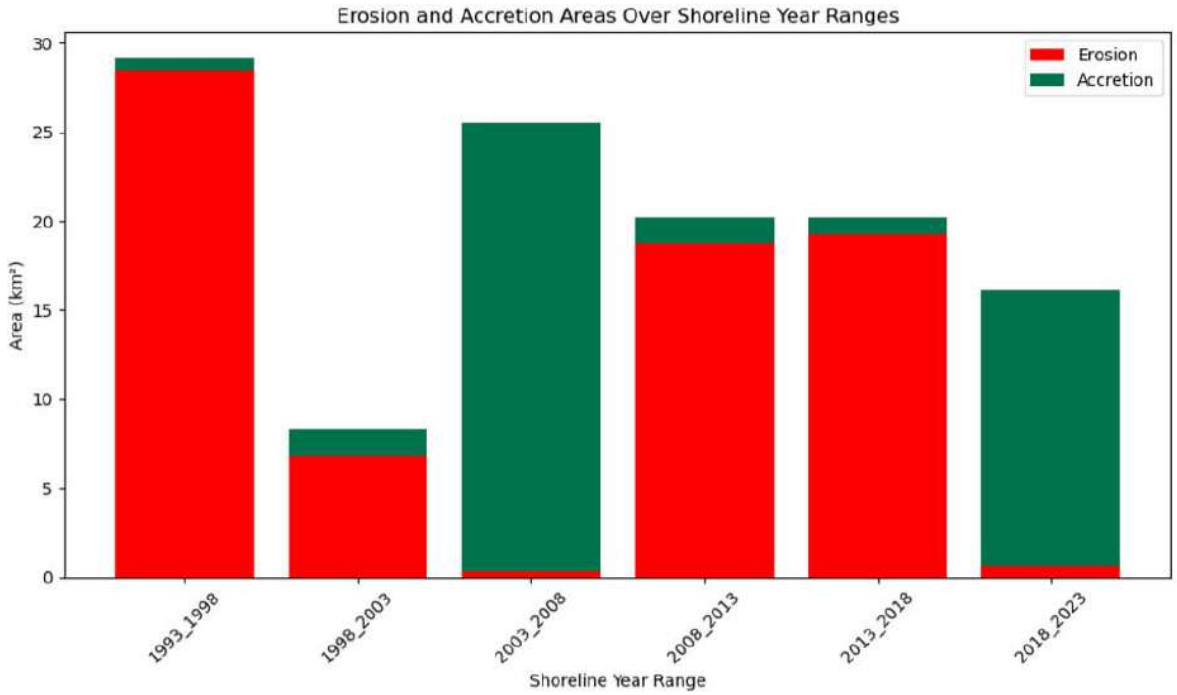

Figure 10: Erosion and accretion areas over 5-year intervals in Kuwait Bay (1993-2023), showing the variation in coastal change across different periods.

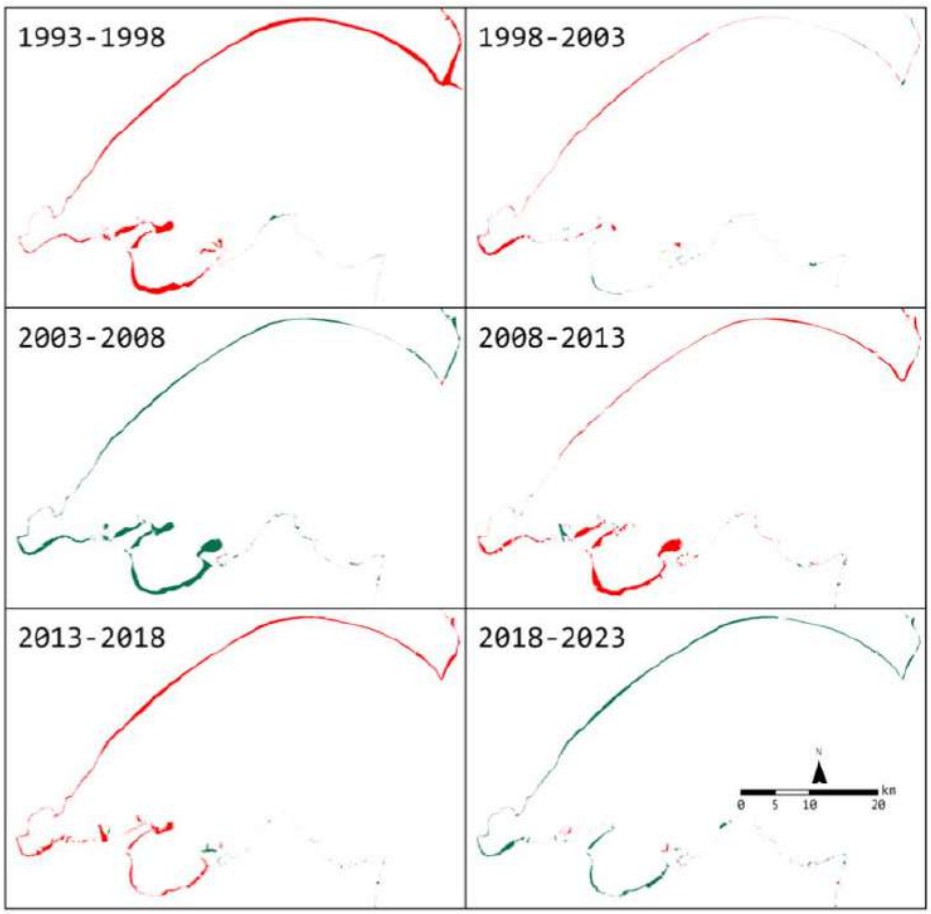

Figure 11: Maps showing spatial distribution of erosion (red) and accretion (green) zones along the Kuwait Bay coastline for each 5-year period from 1993 to 2023.

As shown in Figure (11), erosion predominantly occurred in the northern strip, highlighted in red, and accretion in the southern western parts, highlighted in green. These spatial patterns agree with the findings by Khalaf et al. (1984) [41], who suggest that Kuwait's geomorphology, for example, shallow intertidal flats, plays a pivotal role in the distribution of sediments. High wave energy and the movement of sediments off the shoreline are possible reasons for the northern strip's erosion.

c) Shoreline Future Prediction (2034 and 2044)

Applying the DSAS, pro forma shoreline positions for 2034 and 2044 were estimated using past beach erosion and accretion rates. Specifically, the following forecast of shorelines shows the further development of the coast and delineates stable and actively eroding beaches. Figure (12) shows the future prediction of 2034 and 2044 shorelines generated from the 1993 to 2024 shorelines change rates.

1. *Eroding Location:* Ras Al-Sabiyah, the northern part of Kuwait Bay, specifically Ras Al-Sabiyah, is predicted to experience significant erosion. The forecasted shorelines for 2034 and 2044 show clear landward movement compared to the 2024 shoreline, indicating that this area is likely to undergo continued erosion in the future. The historical analysis suggests that Ras Al-Sabiyah has been subject to considerable coastal retreat, and these future projections confirm that the trend is expected to continue, potentially leading to substantial land loss by 2044.
2. *Eroding Location:* Jal Az-Zor shoreline: The area in the central western part of Kuwait Bay illustrates the inundation model for the projected shorelines in 2034 and 2044 concerning 2024, indicating shoreline erosion. This area is susceptible to forces like tidal action and sediment loss, which have led to coastal retreats in other parts of the bay; further retreat can thus be expected in the next few decades.
3. *Stable Location:* Ras Al-Ard: The future scenario of the shorelines of 2034 and 2044 indicated that some parts of the area are experiencing erosion and others experiencing accretion. However, the overall observation shows little to no changes in shoreline in the next two decades. The stability of the region could be due to the morphological shape of the shoreline and the availability of coastal protection measures.

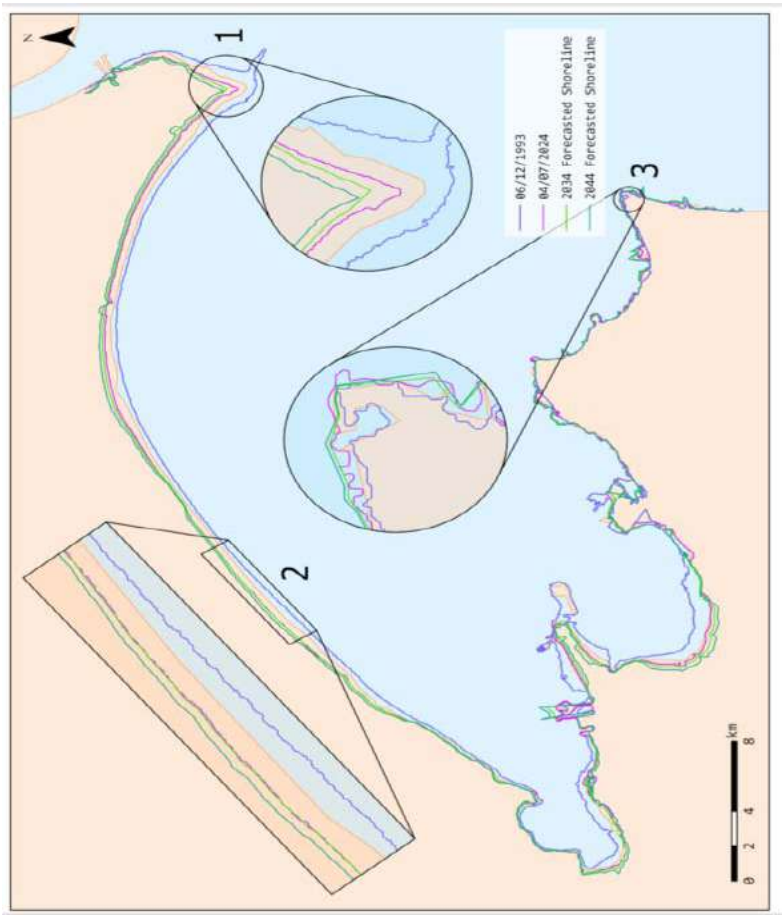

Figure 12: Forecasted shorelines for 2034 and 2044 compared to historical shorelines from 1993 and 2024 in Kuwait Bay.

IV. Conclusions

During the period between 1993 and 2024 some parts of the bay, particularly, the northern part witnessed large variation in the shoreline movement. Erosion has dominated along most of the coast, which addresses a crucial problem that would continue on long-term consideration. Ras Al-Sabiyah and Jal Az-Zor retreat is expected to persist through 2044. With such landward retreating in this region the area is encountering a long-term loss of land and possible destruction of the coastal structure.

Continuous retreating of Kuwait Bay's shoreline is highly expected to contribute to habitat loss for the biodiversity characterizing the Bay, affect its coastal ecosystem through changes in sediment dynamics, threaten coastal homes, roads, ports, and coastal utilities leading to costly repairs or relocation, and loss of usable land for development and recreation. Therefore, crucial concern should be focused on providing future erosion control measures.

On the other hand, regions including Ras Al-Ard have remained relatively stable, whereby little changes along the shorelines are expected to occur within the next few decades. Such stability indicates that natural processes like depositional environments of sediments and coastal morpho-dynamics of Ras Al-Ard provide shelter from strong tidal forces to help stabilize the shoreline. These stable areas might help define "natural," unaltered recovery from coastal change and may require less intervention.

The automated DSAS analysis included transects over Om Al-Namil Island, which submerges during high tide and reappears during low tide. This caused artificially high erosion or accretion values at specific transects (transects 540 and 549). While this is a limitation of the automated methodology, it highlights the challenges of analyzing dynamic coastal systems where tidal variations influence shoreline visibility. Future studies may refine this by manually excluding all the islands close to the mainland and any temporary features that may interfere with this type of analysis.

The southern part of Kuwait Bay shoreline in Shuwaikh Port area, is experiencing a noticeable gain of land (accretion), due to the morphological shape of the shoreline and the tidal currents movement that are redepositing the sediments in this area, in addition to the construction of Shaikh Jaber Causeway and Jaber bridge (Doha Link), which required land reclamation in some parts of the area.

V. Recommendations

To improve the assessment of shoreline changes, it is highly recommended in future studies to combine detailed datasets and highly predictive models. Moreover, future research should be implemented to assess the actually current-wise and future-wise encountered implications and adverse impacts due to the continuous retreat of the shoreline in environmental, ecological, developmental and socio-economical aspects. Integrated developmental management plans and strategies are highly suggested when conducting any commercial or developmental projects in the study area or similar significant crucial coastal zones taking into consideration their vulnerable and susceptible nature to both natural and anthropogenic activities in order to sustain their unique characteristics.

For future studies, calculating and analyzing the future effects of bridges on the bay's shoreline and the current movement is suggested.

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Authors' Contribution Statement

Dr. Adeeba Al-Hurban provided and developed the intellectual, comprehensive, geological and geomorphological background of the study site and encouraged Bader Saeed to investigate and predict shoreline changes along Kuwait Bay using GIS and remote sensing tools and techniques. Bader Saeed quantified and analyzed the morphological changes along the shoreline of Kuwait Bay by using the Normalized Difference Water Index (NDWI) and Digital Shoreline Analysis System (DSAS) and estimating the condition of the shoreline in 2034 and 2044 using historical records and analysis to determine possible changes in the morphology of the bay. Both authors contributed to the final version of the manuscript by revising it critically. Both authors are accountable for all aspects of this work and approve of the version to be published.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Global Lessons for Local Action: Contaminated and Rehabilitated Site Inventories in Rio de Janeiro, Brazil

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Abstract- The management of contaminated and rehabilitated sites is a critical component of contemporary environmental governance, particularly in regions characterised by intensive industrial, logistics, and urban development. In this context, the present study adopts a qualitative, exploratory, and comparative approach to analyse the structure and implementation of Contaminated and Rehabilitated Area Inventories (CRAI) worldwide and situates these experiences within the Brazilian context. First, an international comparative overview was conducted, examining consolidated registries in countries in different continents to identify global best practices and gaps in standardisation. This assessment is subsequently contextualised within the Brazilian framework, evaluating disparities and recent advancements among key state-level systems, with particular emphasis on the Rio de Janeiro State (RJ) as a representative case study. International experiences reveal significant variation in institutional arrangements, regulatory frameworks, and technological maturity. Despite this diversity, global trends point toward greater transparency, geospatial integration, and the use of standardised classification systems for managing contaminated sites

Keywords: *contaminated soil, contaminated grownd water, public health, hazardous chemicals, environmental management.*

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Global Lessons for Local Action: Contaminated and Rehabilitated Site Inventories in Rio de Janeiro, Brazil

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Abstract- The management of contaminated and rehabilitated sites is a critical component of contemporary environmental governance, particularly in regions characterised by intensive industrial, logistics, and urban development. In this context, the present study adopts a qualitative, exploratory, and comparative approach to analyse the structure and implementation of Contaminated and Rehabilitated Area Inventories (CRAI) worldwide and situates these experiences within the Brazilian context. First, an international comparative overview was conducted, examining consolidated registries in countries in different continents to identify global best practices and gaps in standardisation. This assessment is subsequently contextualised within the Brazilian framework, evaluating disparities and recent advancements among key state-level systems, with particular emphasis on the Rio de Janeiro State (RJ) as a representative case study. International experiences reveal significant variation in institutional arrangements, regulatory frameworks, and technological maturity. Despite this diversity, global trends point toward greater transparency, geospatial integration, and the use of standardised classification systems for managing contaminated sites. In recent years, Rio de Janeiro has made significant progress by institutionalising its CRAI, integrating it into the State Environmental Information System, and strengthening state-municipal coordination. As a result, by 2025 the state recorded 481 contaminated sites and 44 rehabilitated areas. However, most sites remain in the early or intermediate stages of management, underscoring persistent challenges related to remediation capacity, technical standardisation, and intergovernmental coordination. Overall, the study advances knowledge beyond existing literature by integrating international best practices of CRAI frameworks with state-level Brazilian governance. The findings offer evidence-based insights to strengthen the management of contaminated sites, highlighting opportunities for regulatory harmonisation, enhanced risk communication, and more informed decision-making in land-use planning and environmental remediation.

Keywords: contaminated soil, contaminated grownd-water, public health, hazardous chemicals, environmental management.

I. Introduction

Soil and groundwater contamination constitute one of the most pressing challenges in contemporary environmental management, particularly in densely urbanised and industrialised regions, where historical land use has generated complex environmental liabilities that require long-term remediation. Worldwide, more than one million contaminated sites have been identified, most of them in developed countries. Approximately 83.5% of these sites are located in Europe and 10.5% in the Americas (Zhang et al., 2025). This distribution highlights the relevance of soil and groundwater contamination and the need for robust legislation, standardized methodologies, and centralized inventories to support remediation planning and ensure public transparency. However, several challenges exist in managing contaminated sites through inventories, including data complexity and integration across regions, legacy pollution, and the lack of unified global guidelines for pollutants (Carré et al., 2017; Chen, Gao, Li, 2025). Inventories of contaminated sites have been developed worldwide to support effective environmental management, exhibiting diverse structures, regulatory frameworks, and technological characteristics. Despite this progress, systematic analyses of these inventories remain scarce. Understanding the similarities and differences between these systems is crucial for identifying best practices and learning from existing systems to improve management approaches. Recently, several countries have made significant progress in improving their systems, incorporating new tools, enhancing public access, and strengthening legislative frameworks.

Contaminated site inventories are fundamentally critical, not just for meeting legislative and reporting mandates (EU Directive 2004/35/EC), but because they constitute the essential scientific baseline for addressing complex societal challenges (Crutzen, 2002). From a scientific perspective, these inventories are affected by data heterogeneity, as a mix of qualitative and quantitative records, varying detection limits, and spatial inaccuracies (Wang et al., 2021). This challenge is compounded by the issue of legacy pollution, where historically contaminated sites continue to pose persistent threats (Sun et al., 2021). Socially, the importance of these inventories is inseparable from the growing concern over environmental justice (Bullard, 1990); contamination disproportionately impacts vulnerable communities, making the inventory a key tool for identifying and rectifying socioeconomic inequalities

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in remediation (Walker, 2012). Furthermore, integrating emerging concepts like public health implications (Hu et al., 2020) and leveraging technological innovations such as AI-based mapping and remote sensing is vital. These advancements can help overcome institutional fragmentation and provide the high-resolution, dynamic data necessary to transform static lists of polluted sites into actionable information for protecting public health and ensuring a truly equitable environment (Tuia et al., 2023).

According to the European Environment Agency (EEA, 2024), most European countries have already established national, centralised inventories of contaminated sites, while others operate decentralised systems managed at the regional level, reflecting a high regulatory maturity. Italy, for example, launched its national database in 2020, made it publicly accessible online in 2023, and, beginning in 2025, has offered consultation through Web Map Services (WMS) and data downloads via Web Feature Services (WFS), in line with international standards. In China, the Law of the People's Republic of China on the Prevention and Control of Soil Pollution, in force since 2019, requires local governments to report contaminated land and mandates the creation of a national soil-environment database and a catalogue of construction land under risk control and remediation (NPCRC, 2019). These instruments are intended to support environmental management and remediation planning (NPCRC, 2019; FAO, 2021). In the Americas, in addition to Brazil, Mexico has established a publicly accessible national inventory of contaminated sites, providing a centralized database integrated with ArcGIS Web System (SEMARNAT, 2025). This initiative is strengthened by the Programa Nacional de Remediación de Sitios Contaminados (PNRSC) from 2021 to 2024, which aims to keep the sites updated and identify trends in contamination (SEMARNAT, 2021).

In Brazil, the main regulatory framework for contaminated areas is the National Environmental Council (CONAMA) Resolution No. 420/2009, which establishes criteria and reference values for soil quality and defines guidelines for the management of areas contaminated by anthropogenic chemical substances. Article 38 of this resolution stipulates that competent environmental agencies must make information on identified contaminated areas publicly available, preferably through their institutional portals, while respecting legal confidentiality when applicable (CONAMA, 2009). The resolution also provides for broad dissemination of information on contaminated areas through formal communication to property owners, land registries, and municipalities, as well as through mechanisms for transparency and risk communication, including the publication of detailed reports on institutional portals (CONAMA, 2009).

Since 2013, the Government of the Rio de Janeiro State, through the State Environmental Institute (INEA), has published information on contaminated sites licensed for remediation, as well as those already rehabilitated, on the GeoINEA Portal (INEA, 2025a). Furthermore, Article 7 of the Rio de Janeiro State Environmental Council (CONEMA) Resolution No. 92, of June 24, 2021, requires municipalities to submit information on their environmental governance structures and licensing procedures to INEA. Building on this framework, INEA Resolution No. 306, of December 9, 2024, formally institutionalised the Contaminated and Rehabilitated Areas Inventory of the State of Rio de Janeiro (CRAI-RJ). Article 4 of this resolution establishes that INEA must ensure public access to information on contaminated and rehabilitated areas through the State Environmental Information System (SEIMA) and the Annual Diagnostic Report on Contaminated and Rehabilitated Areas in the State of Rio de Janeiro, thereby strengthening environmental transparency and governance (INEA, 2024).

The specific research gap about CRAI in the global literature motivated us to address this study. In this context, this article aims to comparatively analyse Contaminated and Rehabilitated Area Inventories (CRAI) at the international level and within Brazil, and to discuss their evolution in the Rio de Janeiro State. Specifically, it seeks to: (i) identify the main structural, regulatory, and technological elements that characterise advanced registration and management models; (ii) assess the alignment of CRAI-RJ with national guidelines and international best practices; (iii) examine the spatial distribution, types of contamination sources, and management stages recorded in the Rio de Janeiro State; and (iv) discuss recent advances, persistent challenges, and opportunities for consolidating the inventory as an instrument of environmental governance.

II. Methodology

This study adopts a qualitative, exploratory, and comparative approach with the objective of analysing Contaminated and Rehabilitated Area Inventories (CRAI). Initially, a comprehensive international review was conducted to identify best practices and gaps in the standardisation of contaminated site registries, providing a foundation for assessing Brazilian systems within a broader global context. The selection of CRAI involved an extensive review in English and Portuguese languages of scientific and institutional databases, including Scopus, Web of Science, Google Scholar, governmental repositories, and technical reports published up to October 2025. The corpus comprised normative acts, official reports, scientific articles, and legal guidelines.

The selection prioritised countries that offer digital consultation mechanisms, georeferenced site

data, contaminant reporting, and legislative support for CRAI implementation. To ensure a broader perspective and a view of all continental regions, international inventories from Brazil, Mexico, the Netherlands, the United States, Italy, Austria, China, Taiwan, and Australia were selected. In the African continent, South Africa also maintains a national contaminated land inventory, established under the National Environmental Management: Waste Act 59 of 2008 (RSA, 2009). However, during the period of this study, the official institutional website was inaccessible (IWMP, 2025), and information regarding the structure and operational framework of the inventory could not be obtained; consequently, this country was excluded from the comparative analysis.

To examine similarities and specific features across CRAI systems, a set of key elements was defined and organised into thematic axes, as summarised in Table 1. This methodological design enables an in-depth comparative analysis and a critical assessment of the effectiveness of these inventories across different socioeconomic and institutional contexts.

Table 1: Criteria analysed in different CRAI, organised by thematic axes.

Thematic Axis	Criteria
1. Institutional Structure	Territorial scope
	Location and access platform
	Agency responsible for the registry
	Legal/normative basis
2. Format and Technology	Tools used (Excel, web system, GIS, report)
	Integration with other environmental databases
3. Access and Transparency	Year of first publication
	Existence of online query mechanism
4. Technical Content	Recorded area classifications
	Main information fields recorded
	Publication of aggregated statistics
5. History and Evolution	Year in which the regulation establishing publication requirements was created
	Recent reforms and modernisations (last five years)

Source: Authors, 2025.

Subsequently, a detailed review of legal and regulatory instruments related to contaminated site management at the federal, state, and municipal levels in Brazil, with particular attention to the Rio de Janeiro State was conducted. After that, a systematic assessment of the Contaminated and Rehabilitated Areas Inventory of Rio de Janeiro (CRAI-RJ) was carried out.

The CRAI-RJ, which is georeferenced and integrated into the State Environmental Information System (SEIMA) and accessible via the GeoINEA and Ambiente + platforms (INEA, 2025b), was analysed in terms of site distribution, contamination sources, and management stages as defined by CONAMA Resolution No. 420/2009. The categories considered were: Suspicious Area (AS), Contaminated Area under Investigation (AI), Contaminated Area under Intervention (ACI), Area under Monitoring for Rehabilitation (AMR), and Rehabilitated Area for Declared Use (AR).

III. Results and Discussion

a) *Contaminated and Rehabilitated Area Inventories: International Overview*

The synthesis of information contributed to the identification of best practices and strategies that can be applied in other regions, aiming to improve public environmental policies and promote environmental justice (Hoelting et al., 2024). These Contaminated and Rehabilitated Areas Inventories serve as an official instrument for the means of disseminating information. Although approaches vary across geographic and socioeconomic contexts, CRAI generally share structural similarities and some key aspects. Table 2 presents these criteria from Brazil, Mexico, the Netherlands, the United States, Italy, Austria, China, Taiwan and Australia CRAIs as examples of structured inventories.

Table 2: Comparison of CRAI from Brazil, Mexico, Netherlands, United States, Italy, Austria, China, Taiwan and Australia.

Thematic axis	Criteria	Brazil	Mexico	Netherlands	United States	Italy	Austria	China	Taiwan	Australia
1. Institutional structure	Territorial scope	National	National	National	National	National	National	National	National	State/Regional
	Location and access platform	BDNAC, IBAMA website	GeoPortal SEMARNAT	Bodemloket and Atlas Leefomgeving	The main one is the National Priorities List (NPL), EPA website	MOSAICO, ISPRA website	Altlastenatlas, Altlasten Portal	Soil Environment Information Publicity Platform	Soil and Groundwater Pollution Remediation Website	Local EPA, NTEPA websites
	Agency responsible for the registry	Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) in coordination with state and municipal entities	Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT)	Ministry of Infrastructure and Water Management (Ministerie van Infrastructuur en Waterstaat) in coordination with local authorities	Environmental Protection Agency (EPA) and state and local entities	Italian Institute for Environmental Protection and Research (ISPRA) in coordination with regional entities	Bundesministerium für Land- und Forstwirtschaft, Klima- und Umweltschutz, Regionen und Wasserwirtschaft (BMLUK) in coordination with regional entities	Ministry of Ecology and Environment (MEE) in coordination with province entities	Environmental Management Administration (EMA)	Environment Protection Authority (EPA) and Northern Territory Environment Protection Authority (NTEPA)
	Legal/normative basis	CONAMA Resolution No. 420/ 2009	NOM-147-SEMARNAT/SSA1-2004	Wet bodembescherming (Wbb), 1987, replaced in 2024 by Omgevingswet (Environmental and Planning Act, 2024)	Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), 1980; Hazardous and Solid Waste Amendments (HSWA), 1984	Legislative Decree 3, No. 152/2006, Art. 251.	Altlastenatlas-VO (BGBl. II Nr. 232/2004)	Order No. 42 of the Ministry of Environmental Protection, 2016	Soil and Groundwater Pollution Remediation Act 2000	National Environment Protection (Assessment of Site Contamination) Measure, 1999
2. Format and technology	Tools used (Excel, web system, GIS, report)	Excel, web system, GIS and reports (varies according to state methodology)	Web system, GIS and reports	Web system and GIS	Web system and GIS	Excel, web system, GIS and reports	Web system, GIS and reports	Excel, Web system, GIS and reports	Web system and GIS	Web system, excel and GIS
	Integration with other environmental databases	Partial	N/A	Yes	N/A	N/A	N/A	Yes	N/A	Yes
3. Access and Transparency	Year of first publication	2010	N/A	N/A	N/A	2023	N/A	2018	2002	1999
	Existence of online query mechanism	Available in some states	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
4. Technical content	Recorded area classifications	Suspected contaminated area, contaminated area under investigation, contaminated area under intervention, area under monitoring for rehabilitation and area rehabilitated for declared use	Area with contaminated soil and area with remediated soil	Area with available data and unknown status, area under investigation, area under remediation, area investigated/ remediated and area with known history	Areas are not separated into management sequence classes; each area belongs to a specific program that maintains its own management system, covering investigation, remediation and monitoring	Area awaiting evaluation, potentially contaminated area, contaminated area and non contaminated area	Area with history of potentially polluting activity, area with history of potentially polluting activity that underwent evaluation and confirmed contaminated area	Suspected contaminated area, confirmed contaminated area, risk-level classification of contaminated areas, contaminated area under detailed investigation and contaminated area under risk assessment	Restricted-use area due to groundwater contamination, area under control, area under remediation	Western Australia is the only state that has a structured classification: Report not substantiated, possibly contaminated – investigation required; not contaminated – unrestricted use; contaminated – restricted use, remediated for restricted use, contaminated – remediation required; and decontaminated
	Main information fields recorded	Area identification, current activity and responsible party, contaminant type, cause of contamination, affected medium, total or affected area, control, intervention and rehabilitation measures, area status, and general administrative information	Area identification, contamination type, cause of contamination, remediation methods, surface area of remediated and contaminated land by state	N/A	Varies depending on the management program. For the national priority Superfund program: area identification and history, contaminants, affected medium, area status, registration context, and administrative information	Identification of the area, responsible party, competent authority, registration date, reason for registration, progress of remediation and intervention processes, national priority and administrative information	Area identification, activity, status, area description, contamination assessment, priority classification, remediation measures, monitoring and control, administrative information	Area identification, current activity and responsible party, contaminant type, cause of contamination; affected medium, total or affected area, control, intervention and rehabilitation measures, area status, and general administrative information	Area identification and activity, contaminant type and concentration, affected medium, total area and area currently monitored, area status, and registration history	Varies depending on the management program. In general, it involves area and activity identification, contaminant type, and contaminated site management
	Publication of aggregated statistics	At state level	Yes	N/A	N/A	At regional and national level	At regional and national level	N/A	At national level	At regional and national level
5. History and Evolution	Year in which the regulation establishing publication requirements was created	2009	N/A	N/A	N/A	2020	N/A	N/A	2001	1999

	Recent reforms and modernizations (last five years)	Changes in contaminated area classification criteria and modernization of web and GIS systems in some states	Availability of data extraction	N/A	N/A	Creation of the national information system on contaminated sites (MOSAICO)	Changes in contaminated area classification criteria and modernization of the GIS system	N/A	Modernization of the GIS system and availability of data extraction	Recent improvements included more advanced search functions, more detailed interactive maps, standardized data formats across states, and automatic integration of technical reports into GIS systems. There was also greater alignment with the NEPM and the PFAS NEMP
	References adopted	IBAMA, 2022	SERMANAT, 2025	Rijkswaterstaat, 2025	US EPA, 2025	ISPRA, 2025	Umweltbundesamt, 2025	SCPC, 2017; SEIPP, 2021	MET, 2025	ACT Government (2025); NSW Government (2025)

Note: N/A - no answer found
Source: Authors, 2025.

The international comparison revealed a substantial variation in the institutional and regulatory structure among the analyzed countries, although all have converged towards digital, georeferenced, and continuously updated registries of contaminated areas within their territories. Regarding the disclosure of information on territorial scope, the majority of countries operate with unified systems of national scope. With the exception of Australia, which maintains separate inventories for each regional jurisdiction, all countries operate unified national databases that centralize information across the entire territory under a federal or national authority. However, segmented models, where different programs or information portals maintain their own databases, are observed in countries such as the Netherlands and the United States. This decentralization of information publicity does not necessarily compromise the technological maturity of these nations. This diversity underscores that no single institutional model exists, but rather a universal need for a specific legal/normative basis to make the CRAI available, with Environmental Protection Agencies or an equivalent ministerial body being the central entity responsible for the registry in almost all cases.

All analyzed systems provide public access through online portals, unequivocally demonstrating a global trend toward transparency. However, the data presented in Table 2 show that the depth of data integration and technological sophistication vary. Across all countries, recent reforms have focused on modernising GIS infrastructure, improving digital interfaces, enhancing data extraction in multiple formats, and refining criteria for classifying and prioritising sites. These developments indicate a global shift toward integrated, transparent, and methodologically robust registries, which are becoming increasingly essential for environmental governance, remediation planning, and land-use decision-making in densely urbanised and industrialised regions. Despite different levels of platform development, the analysed systems share core features such as georeferencing, contaminant registration, and the monitoring of site status. Countries such as the Netherlands, the United States, Australia, and Taiwan operate systems based on web systems and GIS, with recent reforms focused on advanced search functions, detailed interactive maps, and format standardization. Australia and China, for example, demonstrate integration with other environmental databases. This modernization indicates a global focus on transforming the inventory from a static list into a dynamic and interoperable tool. It is noteworthy that the difference in CRAI accessibility maturity is evident in the year of first publication; Taiwan and Australia established public access in 2002 and 1999, respectively, while Italy only published its national system in 2023, and Brazil still offers CRAI consultation only at the state level.

A critical difference observed in the CRAI systems lies in how countries categorize contaminated areas, which directly influences monitoring and reporting. Brazil, Italy, Austria, and Taiwan utilize structured classification systems that follow the progression of areas through the contaminated land management stages (Suspected Area, under Investigation, under Intervention, Rehabilitated), allowing for systematic monitoring until the areas achieve rehabilitation. Additionally, the recording of detailed information is a common practice, including area identification, contaminant type, cause of contamination, and the current remediation status. The publication of aggregated statistics is also a practice adopted in several countries (Mexico, Italy, Austria, and Taiwan), which is essential for reporting and for macro-level assessment of management policy. In contrast, the United States manages contaminated areas through multiple national programmes, including Superfund (National Priorities List – NPL), RCRA Corrective Action, and the Underground Storage Tank (UST) programme (US EPA, 2025). These frameworks classify and prioritise sites according to factors such as the type and degree of contamination, risks to human health and the environment, the source of pollution, and the operational history of the contaminating activity.

Finally, this comparative approach makes it possible to identify best practices and persistent gaps in registry standardisation, thereby informing the evaluation of Brazilian CRAI in a global context.

b) Contaminated and Rehabilitated Area Inventories: Brazilian Overview

Article 6 of CONAMA Resolution No. 420/2009, currently under revision, reinforces the responsibility of state and municipal environmental agencies to maintain and update their registries and to integrate them into the National Database on Contaminated Areas (BDNAC), with the goal to standardise and disseminate information at the national level (CONAMA, 2009).

According to the National Program for the Remediation of Contaminated Sites (2020), consultation of the BDNAC revealed that information on contaminated sites is available only for the States of São Paulo, Minas Gerais, and Rio de Janeiro, through links that redirect users to the respective state inventories. Pernambuco is also mentioned and discussed in the publication, although it does not have a specific inventory directly linked within the BDNAC framework.

The Environmental Agency of Pernambuco State (CPRH) hosts, on its website, a contaminated sites registry that is integrated into the Plan for Prevention, Preparedness, and Rapid Response to Environmental Emergencies Involving Hazardous Substances (Plano P2R2). Access to most information requires a login, and publicly available data are limited to spreadsheets listing contaminated sites associated with chemical accidents, organised by municipality and contamination source. Additional spreadsheets provide records of chemicals associated with commercial and industrial activities, incident histories, pollutant potential and facility size, as well as information on the transport of hazardous substances (CPRH, 2025).

In institutional terms, São Paulo, Rio de Janeiro, and Minas Gerais each have state environmental agencies responsible for managing their registries. São Paulo has the most consolidated model, supported by Decree No. 59,263/2023, whereas Minas Gerais still operates under Joint Normative Deliberation COPAM/CERH No. 02/2010. Rio de Janeiro, in turn, has advanced with INEA Resolution No. 306/2024, which coordinates the actions of the state agency with municipal authorities, thereby reinforcing the integrative character of environmental management.

In Brazil, instruments for registering, monitoring, and remediating contaminated sites have undergone gradual improvements, driven by the consolidation of state environmental policies and the implementation of geospatial information systems. With regarding to format and technology, all three states maintain digital and georeferenced registries, but differ in the complexity of their tools. Rio de Janeiro stands out for its diverse instruments, combining Excel spreadsheets, web-based systems, GIS platforms, and technical reports, which reflect recent efforts toward technological integration and improved transparency. São Paulo operates a GIS-based system with real-time reporting, demonstrating a high level of maturity and operational continuity. Minas Gerais uses Excel and GIS, but does not provide real-time updates, limiting both efficiency and public dissemination, which is conducted solely through periodic reports referred to as inventories.

In terms of access and transparency, São Paulo and Rio de Janeiro offer public online consultation mechanisms. In contrast, Minas Gerais does not yet provide this functionality, thereby limiting access for civil society and the scientific community. As for technical content, the three states converge in their use of management categories that range from suspected contaminated areas to sites rehabilitated for declared use, with São Paulo presenting the most detailed classification of remediation stages.

From a quantitative perspective, São Paulo accounts for the most significant number of registered sites (7,051), followed by Minas Gerais (762) and Rio de Janeiro (525). This discrepancy reflects both São Paulo's higher level of industrialisation and more extended history of contamination, as well as the robustness of its system for identifying and updating data. The lower numbers observed in Rio de Janeiro and Minas Gerais indicate that their systems are still being consolidated, with ongoing improvements, particularly in terms of integration with municipal databases.

c) Contaminated and Rehabilitated Area Inventories: Rio de Janeiro State Overview

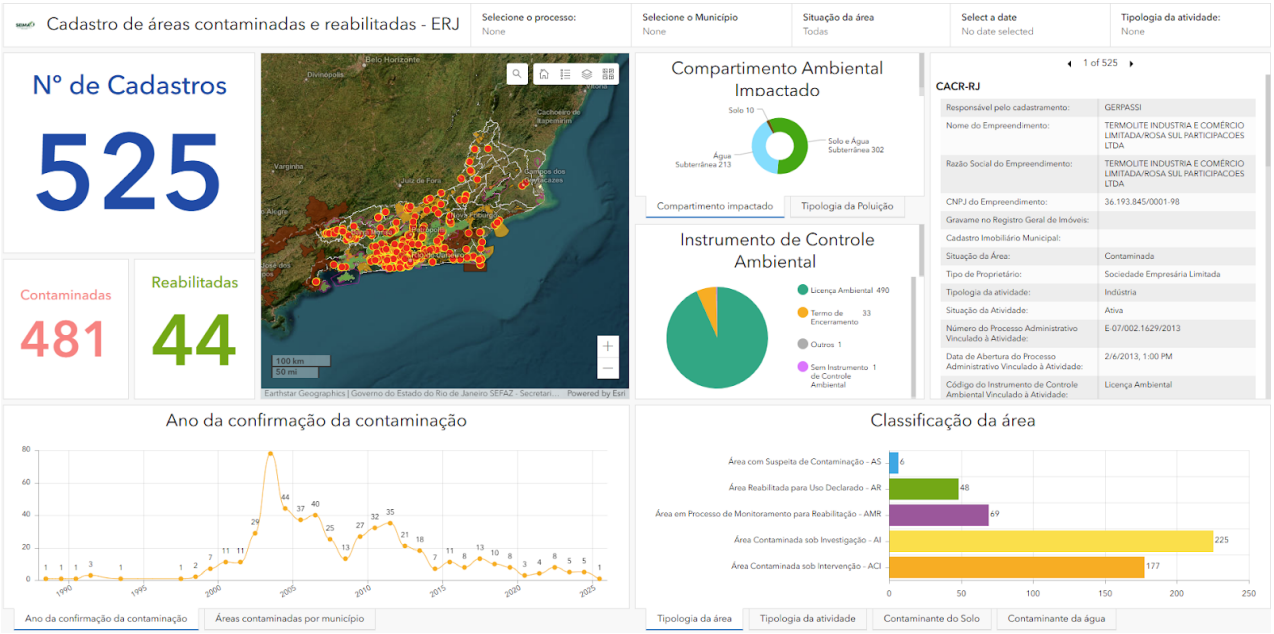
Within this national context, the State of Rio de Janeiro stands out as an example of a system in consolidation, whose evolution over the past decade illustrates efforts to improve mechanisms for registering, monitoring, and ensuring transparency of information on contaminated sites. In 2013, the state released the first edition of CRAI-RJ. This initial report listed 151 contaminated sites, classified by type of activity: industrial facilities, waste landfills, passenger transport facilities, and fuel stations (INEA, 2025c). As technical and institutional arrangements evolved, the registry was progressively improved and, by its fourth edition, included more than 328 registered sites and a georeferenced version accessible through the GeoINEA Portal, which enables the integration of environmental data and the download of interactive maps (ARÊAS et al., 2017; INEA, 2025a).

The 2023–2025 Strategic Plan of the State Environmental Institute (INEA) established the development of support systems for managing contaminated and remediated sites as a strategic priority (RIO DE JANEIRO, 2023). Based on this guideline, in 2023, the Environmental Liabilities Recovery Management Unit (GERPASSI) was created within the Directorate for Post-Licensing and Environmental Inspection (DIRPOS). In partnership with the Territorial Management and Geospatial Information Unit (GERGET), GERPASSI developed specific procedures

for implementing a new registry system for contaminated sites in the state.

The consolidation of contaminated site management in Rio de Janeiro has been accompanied by significant regulatory advances, aimed not only at creating and maintaining CRAI-RJ but also at standardising procedures for identifying, investigating, and rehabilitating such sites. One of the main milestones in this process is INEA Resolution No. 306, of December 9, 2024, which regulates the creation and maintenance of CRAI-RJ in accordance with Article 38 of CONAMA Resolution No. 420/2009 (CONAMA, 2009; INEA, 2024). This regulation formalised the management of the registry under GERPASSI and established technical and operational guidelines for integrating environmental information.

The consolidation process required compiling information from INEA's administrative systems, both physical and digital, including the Electronic Information System (SEI), which supports environmental licensing. This process established CRAI-RJ as a strategic instrument for information sharing and for strengthening territorial environmental management in the state. Standardised electronic forms were developed, including fields for cadastral identification, type of activity, current and intended land use, characterisation of pollutant chemical substances, risk scenarios, remediation measures, and implemented interventions. Approximately 500 administrative procedures were reviewed, and their data were updated in SEIMA (as illustrated in Figure 1), the GeoINEA Portal, and the Ambiente+ platform (INEA, 2025a; INEA, 2025b).



Source: INEA, 2025b.

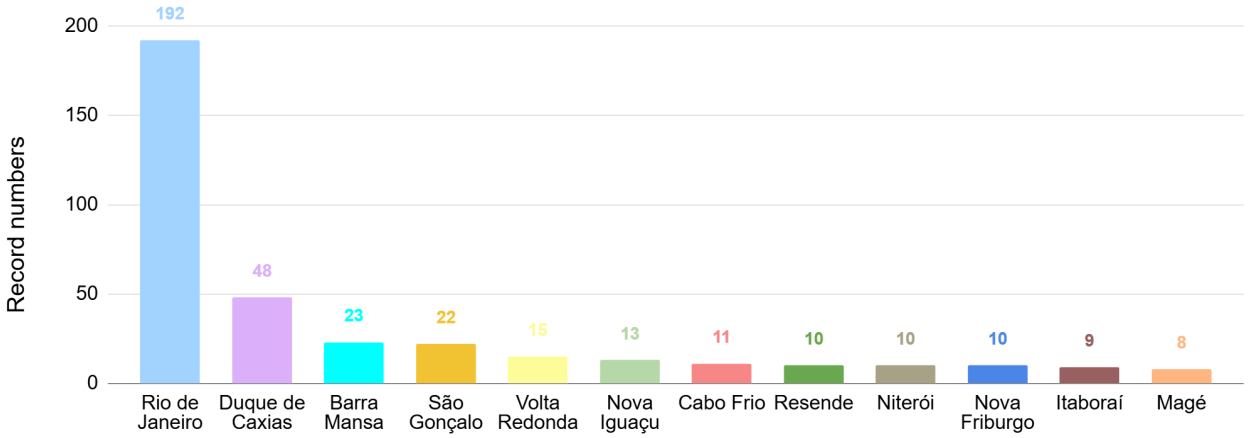
Figure 1: Control panel ("dashboard") of the SEIMA portal.

Operation of the registry is carried out through SEIMA, which enables GERPASSI technicians and municipal agencies to register and update information within their respective jurisdictions (INEA, 2025b). Data validation occurs in a specific module of the ArcGIS Enterprise platform, ensuring the integration of local data into the state system and promoting standardised information and shared management of contaminated areas across the State of Rio de Janeiro.

Currently, sites in the registry are georeferenced as points, but the next version is expected to represent them as polygons. According to the Environmental Company of São Paulo State (CETESB, 2014), this change will enable a more accurate spatial characterisation of diffuse pollution scenarios, in which contaminant releases occur over extensive areas that may encompass multiple properties or urban and rural zones.

The CRAI-RJ database incorporates historical records, procedural updates from approximately 500 administrative processes, and contributions from municipal agencies, thus ensuring comprehensive coverage of environmental liabilities across the state. As of November 2025, the State of Rio de Janeiro had recorded 481 contaminated areas and 44 remediated areas, distributed across 60 municipalities. Most contaminated and remediated areas are concentrated in municipalities within the Rio de Janeiro Metropolitan Region, an area characterised by high population density and a strong presence of industrial, logistics, and petrochemical activities, which are sectors historically associated with the generation of

environmental liabilities. This spatial distribution reveals a direct relationship between the intensity of anthropogenic activities and the incidence of contamination, especially in urban and industrial centres such as Rio de Janeiro, Duque de Caxias, and São Gonçalo.

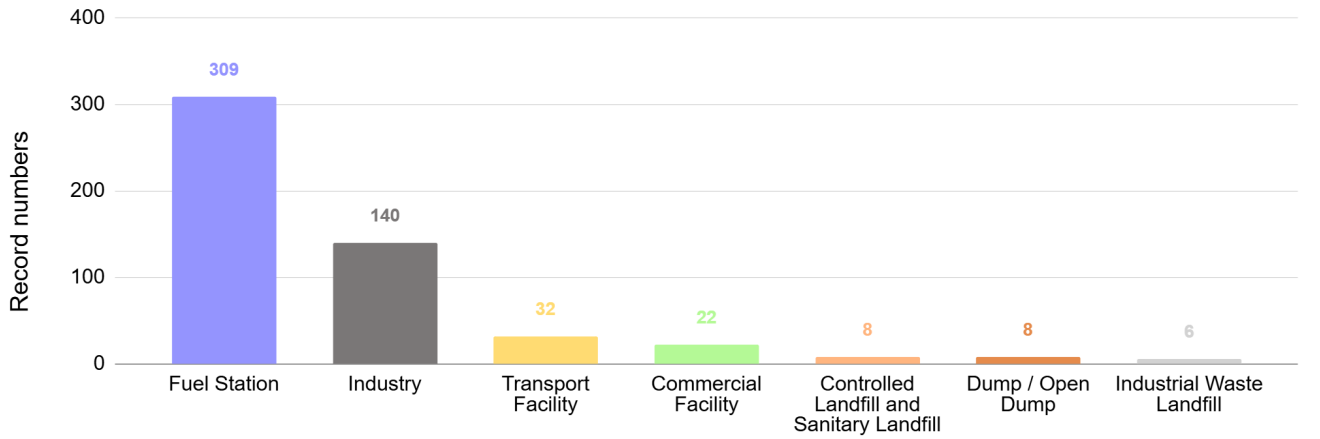


Source: Authors, 2025.

Figure 2: Geographic distribution of contaminated and remediated areas by municipalities in the state of Rio de Janeiro.

The Rio de Janeiro municipality accounts for the largest share of records, with 194 occurrences, corresponding to approximately 37% of the state total, followed by Duque de Caxias (48 areas), Barra Mansa (23), and São Gonçalo (22) (Figure 2). This spatial pattern reflects the historical concentration of potentially polluting industrial and service activities in metropolitan areas and along major road and logistics corridors. These cities also exhibit cumulative effects of rapid urbanisation and industrialisation, historically characterised by weak environmental controls and inadequate management of hazardous waste and chemical substances, as highlighted in the literature (Panagos et al., 2013; Garcia et al., 2021). In this context, the State Register of Contaminated Areas plays a strategic role as a tool to support territorial planning, environmental management, and the definition of priorities for the investigation, monitoring, and remediation of environmental liabilities.

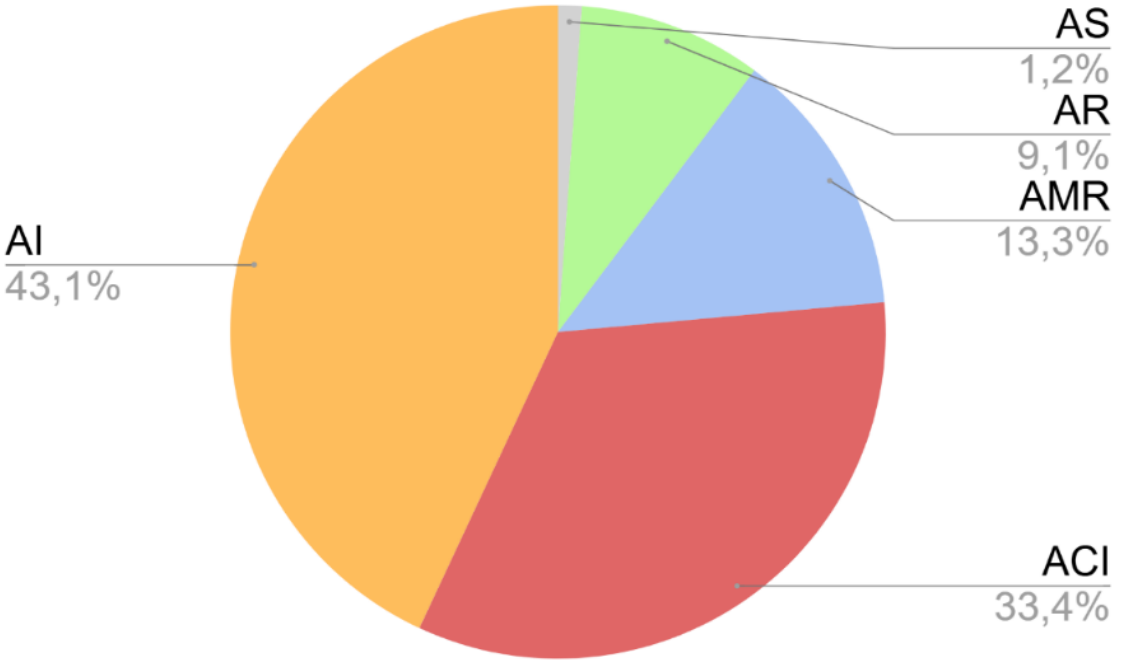
Regarding contamination sources, fuel stations account for the most significant proportion of contaminated areas in the State of Rio de Janeiro, totalling 309 cases (Figure 3), which corresponds to approximately 59% of all records. This result is directly related to the widespread distribution of these facilities and the high frequency of incidents involving leaks of fuels and lubricating oils, the primary sources of soil and groundwater contamination associated with this type of activity.



Source: Authors, 2025.

Figure 3: Contaminated and remediated areas: the type of activity responsible for contamination.

The predominance of areas in the initial (AS, AI) and intermediate (ACI) stages of the contaminated land management process (77.7%) underscores the complexity and long-term nature of environmental remediation in the state. It also reveals operational, institutional, and technical barriers that hinder the transition to more advanced stages, such as long-term monitoring and complete rehabilitation of sites. Although there are records of remediated areas in the State of Rio de Janeiro (9.1%), their proportion remains modest relative to the total number of registered sites, especially when compared with states such as São Paulo, where more than 30% of contaminated areas have already been officially remediated (CETESB, 2025).



Source: Authors, 2025.

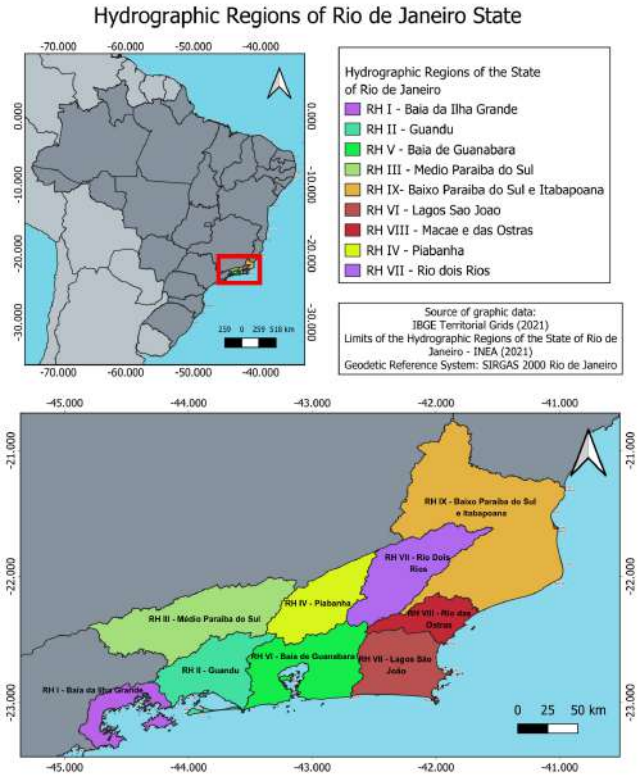
Figure 4: Classification of contaminated and remediated areas registered in CRAI-RJ.

The predominance of areas in the initial (AS, AI) and intermediate (ACI) stages of the contaminated site management process (77.7%) reinforces the challenging nature of environmental remediation in the state. It reveals operational, institutional, and technical barriers that hinder the transition to more advanced stages of the process, such as final monitoring and complete rehabilitation of the site. Furthermore, although there are records of remediated areas in the State of Rio de Janeiro (9.1%), their proportion remains modest in relation to the total, especially when compared to states such as São Paulo, where more than 30% of registered contaminated areas have already been officially remediated (CETESB, 2025).

Technical Capacity-Building and Municipal Integration

Since August 25, 2021, municipalities in the State of Rio de Janeiro have been responsible for licensing and registering contaminated sites under their jurisdiction (INEA, 2025b). Of the 92 towns in the state, 77 reported conducting environmental licensing, and 54 stated that they specifically license contaminated site remediation (INEA, 2025c). Integrating data on contaminated areas managed by these municipal authorities into CRAI-RJ is therefore a critical requirement.

To support this integration, a series of technical training sessions was launched in 2024, covering nine hydrographic regions and their respective municipalities (Figure 5). These activities aimed to disseminate INEA Resolution No. 306 and its guidelines for registering and identifying evidence of contamination.



Source: Adapted from INEA, 2025.

Figure 5: Hydrographic regions of the Rio de Janeiro State and their location in Brazil.

The training programs were closely aligned with INEA's Strategic Plan, particularly the initiative to "offer training in guidelines for identifying environmental liabilities," and with the guidelines of the State Secretariat for the Environment and Sustainability (SEAS) and INEA presented in the State Strategy and Action Plan for Biodiversity in Rio de Janeiro (EPAEB-RJ). This plan was developed in alignment with the Kunming–Montreal Global Biodiversity Framework, whose Specific Objective 4.4 calls for the reduction of environmental contamination. Action Line 2 of EPAEB-RJ emphasises the need to train municipal and state technicians to identify contamination and pollution, collect samples, and expand analytical capacity for contaminants (INEA, 2024).

IV. Conclusion

The comparative assessment of contaminated and rehabilitated area inventories shows that Brazil, particularly the State of Rio de Janeiro, is moving towards a more integrated and transparent governance framework for soil and groundwater contamination, while still facing significant structural and operational challenges. By aligning CRAI-RJ with national regulations and international best practices, Rio de Janeiro has moved beyond a fragmented, case-by-case approach and established a more systematic architecture for registering, georeferencing, and monitoring environmental liabilities. The incorporation of standardised management categories, the integration of online platforms, and the explicit engagement of municipal authorities collectively enhance the state's capacity to identify priority areas, support regulatory enforcement, and inform land-use and territorial planning.

Fuel stations, logistics corridors and industrial clusters emerge as central nodes of contamination, reinforcing the need for sector-specific regulation, preventive controls, and long-term monitoring instruments. Strengthening the interface between contaminated site management, environmental licensing, and urban planning remains essential to prevent the re-production of environmental liabilities and to reduce socio-spatial inequalities in exposure to contaminated land. In view of the comparative framework with states and/or countries with greater maturity in contaminated land management, it is noted that for Rio de Janeiro to overcome the current operational stagnation in the effective rehabilitation of these areas, it is necessary to emulate governance innovations, namely the adoption of dedicated financial mechanisms and robust intersectoral integration among urban planning, health, and environmental agencies.

The consolidation of CRAI-RJ and other Brazilian inventories offers a strategic opportunity to deepen geospatial integration, expand public access to environmental information, and foster more participatory forms of environmental governance. Future research could explore the social and territorial dimensions of contaminated sites in greater detail, including their interactions with housing markets, infrastructure expansion, and environmental justice claims. From a policy perspective, for the contaminated land management policy to be effective and just, it must consider the integration of socio-economic vulnerability indices into the CRAI data. This measure is crucial to ensure that the inventory transcends its diagnostic function and establishes itself as a driver of Environmental Justice, prioritizing remediation in vulnerable areas where exposure to contaminants exacerbates existing socio-spatial inequalities. Thus, technological advancement and operational improvement must be directed towards mitigating disproportionate exposure risk and ensuring territorial equity.

Overall, the consolidation of contaminated site inventories, coupled with municipal integration, transparency, and standardised operational procedures, constitutes a strategic instrument for environmental governance. It supports the prioritisation of remediation actions, informs urban and regional planning in vulnerable areas, strengthens preventive and corrective measures, and contributes to the sustainable management of environmental liabilities.

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Associates are authorized to organize symposium/seminar/conference on behalf of Global Journal Incorporation (USA). They can also participate in the same organized by another institution as representative of Global Journal. In both the cases, it is mandatory for him to discuss with us and obtain our consent. Additionally, they get free research conferences (and others) alerts.

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We accept the manuscript submissions in any standard (generic) format.

We typeset manuscripts using advanced typesetting tools like Adobe In Design, CorelDraw, TeXnicCenter, and TeXStudio. We usually recommend authors submit their research using any standard format they are comfortable with, and let Global Journals do the rest.

Alternatively, you can download our basic template from https://globaljournals.org/Template.zip

Authors should submit their complete paper/article, including text illustrations, graphics, conclusions, artwork, and tables. Authors who are not able to submit manuscript using the form above can email the manuscript department at submit@globaljournals.org or get in touch with chiefeditor@globaljournals.org if they wish to send the abstract before submission.

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3. Ensure corresponding author's email address and postal address are accurate and reachable.
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7. Manuscript submitted *must not have been submitted or published elsewhere* and all authors must be aware of the submission.

Declaration of Conflicts of Interest

It is required for authors to declare all financial, institutional, and personal relationships with other individuals and organizations that could influence (bias) their research.

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Unless specified in the notification, the Editorial Board's decision on publication of the paper is final and cannot be appealed before making the major change in the manuscript.

Acknowledgments

Contributors to the research other than authors credited should be mentioned in Acknowledgments. The source of funding for the research can be included. Suppliers of resources may be mentioned along with their addresses.

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Preparing your Manuscript

Authors can submit papers and articles in an acceptable file format: MS Word (doc, docx), LaTeX (.tex, .zip or .rar including all of your files), Adobe PDF (.pdf), rich text format (.rtf), simple text document (.txt), Open Document Text (.odt), and Apple Pages (.pages). Our professional layout editors will format the entire paper according to our official guidelines. This is one of the highlights of publishing with Global Journals—authors should not be concerned about the formatting of their paper. Global Journals accepts articles and manuscripts in every major language, be it Spanish, Chinese, Japanese, Portuguese, Russian, French, German, Dutch, Italian, Greek, or any other national language, but the title, subtitle, and abstract should be in English. This will facilitate indexing and the pre-peer review process.

The following is the official style and template developed for publication of a research paper. Authors are not required to follow this style during the submission of the paper. It is just for reference purposes.

Manuscript Style Instruction (Optional)

- Microsoft Word Document Setting Instructions.
- Font type of all text should be Swis721 Lt BT.
- Page size: 8.27" x 11'", left margin: 0.65, right margin: 0.65, bottom margin: 0.75.
- Paper title should be in one column of font size 24.
- Author name in font size of 11 in one column.
- Abstract: font size 9 with the word "Abstract" in bold italics.
- Main text: font size 10 with two justified columns.
- Two columns with equal column width of 3.38 and spacing of 0.2.
- First character must be three lines drop-capped.
- The paragraph before spacing of 1 pt and after of 0 pt.
- Line spacing of 1 pt.
- Large images must be in one column.
- The names of first main headings (Heading 1) must be in Roman font, capital letters, and font size of 10.
- The names of second main headings (Heading 2) must not include numbers and must be in italics with a font size of 10.

Structure and Format of Manuscript

The recommended size of an original research paper is under 15,000 words and review papers under 7,000 words. Research articles should be less than 10,000 words. Research papers are usually longer than review papers. Review papers are reports of significant research (typically less than 7,000 words, including tables, figures, and references)

A research paper must include:

a) A title which should be relevant to the theme of the paper.
b) A summary, known as an abstract (less than 150 words), containing the major results and conclusions.
c) Up to 10 keywords that precisely identify the paper's subject, purpose, and focus.
d) An introduction, giving fundamental background objectives.
e) Resources and techniques with sufficient complete experimental details (wherever possible by reference) to permit repetition, sources of information must be given, and numerical methods must be specified by reference.
f) Results which should be presented concisely by well-designed tables and figures.
g) Suitable statistical data should also be given.
h) All data must have been gathered with attention to numerical detail in the planning stage.

Design has been recognized to be essential to experiments for a considerable time, and the editor has decided that any paper that appears not to have adequate numerical treatments of the data will be returned unrefereed.

i) Discussion should cover implications and consequences and not just recapitulate the results; conclusions should also be summarized.
j) There should be brief acknowledgments.
k) There ought to be references in the conventional format. Global Journals recommends APA format.

Authors should carefully consider the preparation of papers to ensure that they communicate effectively. Papers are much more likely to be accepted if they are carefully designed and laid out, contain few or no errors, are summarizing, and follow instructions. They will also be published with much fewer delays than those that require much technical and editorial correction.

The Editorial Board reserves the right to make literary corrections and suggestions to improve brevity.

Format Structure

It is necessary that authors take care in submitting a manuscript that is written in simple language and adheres to published guidelines.

All manuscripts submitted to Global Journals should include:

Title

The title page must carry an informative title that reflects the content, a running title (less than 45 characters together with spaces), names of the authors and co-authors, and the place(s) where the work was carried out.

Author details

The full postal address of any related author(s) must be specified.

Abstract

The abstract is the foundation of the research paper. It should be clear and concise and must contain the objective of the paper and inferences drawn. It is advised to not include big mathematical equations or complicated jargon.

Many researchers searching for information online will use search engines such as Google, Yahoo or others. By optimizing your paper for search engines, you will amplify the chance of someone finding it. In turn, this will make it more likely to be viewed and cited in further works. Global Journals has compiled these guidelines to facilitate you to maximize the web-friendliness of the most public part of your paper.

Keywords

A major lynchpin of research work for the writing of research papers is the keyword search, which one will employ to find both library and internet resources. Up to eleven keywords or very brief phrases have to be given to help data retrieval, mining, and indexing.

One must be persistent and creative in using keywords. An effective keyword search requires a strategy: planning of a list of possible keywords and phrases to try.

Choice of the main keywords is the first tool of writing a research paper. Research paper writing is an art. Keyword search should be as strategic as possible.

One should start brainstorming lists of potential keywords before even beginning searching. Think about the most important concepts related to research work. Ask, “What words would a source have to include to be truly valuable in a research paper?” Then consider synonyms for the important words.

It may take the discovery of only one important paper to steer in the right keyword direction because, in most databases, the keywords under which a research paper is abstracted are listed with the paper.

Numerical Methods

Numerical methods used should be transparent and, where appropriate, supported by references.

Abbreviations

Authors must list all the abbreviations used in the paper at the end of the paper or in a separate table before using them.

Formulas and equations

Authors are advised to submit any mathematical equation using either MathJax, KaTeX, or LaTeX, or in a very high-quality image.

Tables, Figures, and Figure Legends

Tables: Tables should be cautiously designed, uncrowned, and include only essential data. Each must have an Arabic number, e.g., Table 4, a self-explanatory caption, and be on a separate sheet. Authors must submit tables in an editable format and not as images. References to these tables (if any) must be mentioned accurately.

Figures

Figures are supposed to be submitted as separate files. Always include a citation in the text for each figure using Arabic numbers, e.g., Fig. 4. Artwork must be submitted online in vector electronic form or by emailing it.

Preparation of Eletronic Figures for Publication

Although low-quality images are sufficient for review purposes, print publication requires high-quality images to prevent the final product being blurred or fuzzy. Submit (possibly by e-mail) EPS (line art) or TIFF (halftone/ photographs) files only. MS PowerPoint and Word Graphics are unsuitable for printed pictures. Avoid using pixel-oriented software. Scans (TIFF only) should have a resolution of at least 350 dpi (halftone) or 700 to 1100 dpi (line drawings). Please give the data for figures in black and white or submit a Color Work Agreement form. EPS files must be saved with fonts embedded (and with a TIFF preview, if possible).

For scanned images, the scanning resolution at final image size ought to be as follows to ensure good reproduction: line art: >650 dpi; halftones (including gel photographs): >350 dpi; figures containing both halftone and line images: >650 dpi.

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Tips for writing a good quality Social Science Research Paper

Techniques for writing a good quality homan social science research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of homan social science then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow here.

6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.
Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

19. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.

20. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

21. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

22. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium though which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

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Informal Guidelines of Research Paper Writing

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.

Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.

The following approach can create a valuable beginning:

- Explain the value (significance) of the study.
- Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- Report the method and not the particulars of each process that engaged the same methodology.
- Describe the method entirely.
- To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- Simplify—detail how procedures were completed, not how they were performed on a particular day.
- If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- Resources and methods are not a set of information.
- Skip all descriptive information and surroundings—save it for the argument.
- Leave out information that is immaterial to a third party.

Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- Present a background, such as by describing the question that was addressed by creation of an exacting study.
- Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- Do not include raw data or intermediate calculations in a research manuscript.
- Do not present similar data more than once.
- A manuscript should complement any figures or tables, not duplicate information.
- Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."

Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

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Introduction	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
Methods and Procedures	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
Result	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
Discussion	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
References	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring

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