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Review Paper

Driving Factors Influencing Watershed Management and Sustainability: A Systematic Review

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Abstract
Watershed management and sustainability have gained significant global attention due to escalating environmental, socio-economic, and governance challenges. This study presents a Systematic Literature Review (SLR) aimed at identifying and synthesizing key driving factors that influence watershed management and sustainability. A comprehensive search was conducted exclusively in the Scopus database, covering publications from 2013 to 2023. Through PRISMA-based screening and thematic analysis of 193 relevant studies, a total of 37 driving factors were identified. These factors were classified into three main domains: biophysical (7 factors), socio-economic (13 factors), and institutional (17 factors). The findings reveal that institutional factors are most prominently emphasized, followed by socio-economic and biophysical dimensions. This synthesis provides a holistic understanding of the complex and interconnected elements that drive watershed sustainability. The insights derived are intended to inform future research, support evidence-based policymaking, and strengthen integrated watershed management practices across diverse geographic and socio-political contexts. The search employed multiple keyword combinations, including "watershed", "catchment", "river basin", "drivers", "influencing factors", and "determinants", ensuring broader thematic coverage within the Scopus database.

Keywords
Watershed Management, Sustainability, Driving Factors, Systematic Review, Governance

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1. INTRODUCTION

Watersheds represent critical biophysical and socio-ecological systems that provide essential ecosystem services such as water supply, climate regulation, and soil conservation (Tesfay Abraha et al., 2024). The sustainability of these functions is vital for human well-being and environmental integrity (Han and Liu, 2024; Huang et al., 2020). However, these systems are under increasing pressure due to anthropogenic drivers, including population growth, economic development, land use change, and the impacts of global climate change (Cunha and Cunha, 2023; Kåresdotter et al., 2022; Nasr and Orwin, 2024; Panondi and Izumi, 2021; Zhou et al., 2019). These challenges necessitate management approaches that are integrative, adaptive, and focused on long-term sustainability.

Previous reviews on watershed management often focused on narrow disciplinary domains or case-specific issues, with limited integration across socio-environmental, institutional, and economic dimensions. Moreover, few studies applied a systematic approach guided by PRISMA protocols to synthesize multi-factorial drivers. This review addresses these gaps by presenting a comprehensive, thematically organized synthesis of 193 articles published over the past decade. Integrated Watershed Management (IWM) has been promoted as a comprehensive response to these issues, emphasizing the coordinated management of natural resources within watershed boundaries and addressing the dynamic interactions among biophysical, socio-economic, and institutional components (Nasiri Khiavi et al., 2024; Tang and Adesina, 2022).

Although the urgency of sustainable watershed management is widely acknowledged, its practical implementation is often hindered by the complex and interconnected nature of influencing factors. These factors span across multiple

domains: biophysical (e.g., climate, soil, hydrology, land use change), socio-economic (e.g., livelihoods, education, community participation), and institutional (e.g., policies, governance, stakeholder coordination). Many studies offer partial insights by focusing on individual dimensions or case-specific contexts, limiting broader applicability. Despite the increasing number of publications on watershed-related issues, there is a lack of comprehensive, systematic synthesis that identifies, categorizes, and integrates the key factors influencing watershed management and sustainability.

A few researchers have explored multi-domain frameworks, but limited effort has been made to consolidate this knowledge into a structured, evidence-based overview. There is no rigorous systematic review that captures the full complexity of these interacting drivers across global literature in the past decade. Therefore, this research intends to fill that gap by conducting a systematic literature review (SLR), drawing on peer-reviewed studies indexed in the Scopus database between 2013 and 2023.

The objectives of this research are to: (1) conduct systematic literature searches and filtering from the Scopus database, based on predefined inclusion and exclusion criteria following the PICO/PICOS framework and PRISMA 2020 protocol; (2) extract and synthesize information on factors influencing watershed management and sustainability from the included studies; (3) identify, categorize, and analyze key driving factors across biophysical, socio-economic, and institutional domains; and (4) provide a critical discussion of the identified factors, including their potential interrelations and implications for watershed governance. This study distinguishes itself by applying a PRISMA-guided SLR with domain-specific classification and regional insight, offering a robust foundation for both research and policy-making

2. EXPERIMENTAL SECTION

2.1 Study Design and Framework

This study adopts a Systematic Literature Review (SLR) approach to identify and synthesize key driving factors that influence watershed management and sustainability. The review follows the PRISMA 2020 protocol to ensure transparency and replicability, and applies the PICO/PICOS framework to guide the formulation of the research scope and screening strategy. As a limitation, the study relied solely on Scopus-indexed articles and English-language publications, which may exclude relevant research in other languages or indexed elsewhere.

- Population/Problem (P): Watershed management and sustainability
- Intervention/Issue (I): Driving or influencing factors
- Comparison (C): Not applicable
- Outcome (O): Identification and synthesis of relevant factors
- Study design (S): Peer-reviewed articles, proceedings, and technical reports (2013–2023) indexed in Scopus

To enhance coding consistency, team members conducted cross-validation of thematic classifications during full-text analysis, although formal inter-coder reliability was not statistically measured.

2.2 Search Strategy

A systematic search was conducted using the Scopus database, selected for its comprehensive multidisciplinary coverage and high indexation quality. The search included publications from January 1, 2013 to December 31, 2023, in English only, and this yielded 419 initial records. The search strategy used Boolean operators to combine terms such as “watershed management” OR “river basin governance” OR “catchment sustainability” AND “driving factors” OR “influencing elements” OR “indicators”.

2.3 Inclusion and Exclusion Criteria

Selection criteria were clearly defined to ensure methodological consistency: Inclusion Criteria:

- Published between 2013 and 2023
- Written in English
- Indexed in Scopus
- Peer-reviewed journal articles, conference proceedings, or trusted technical reports
- Explicitly discuss factors influencing watershed management or sustainability across biophysical, socio-economic, or institutional domains
- Empirical studies, case studies, literature reviews, and meta-analyses

Exclusion Criteria:

- Publications before 2013
- Non-peer-reviewed materials (e.g., editorials, news, opinions)
- Studies without clear reference to influencing factors
- Purely technical articles lacking management implications
- Duplicate entries

2.4 Study Selection Process

During the screening and eligibility assessment, a total of 419 records were initially identified from the Scopus database. After title and abstract screening, 243 articles were assessed for full-text eligibility. Of these, 50 articles were excluded and as a result 193 articles were included in the final qualitative synthesis. The selection process is depicted in Figure 1, adhering to the PRISMA 2020 framework, to ensure transparency and reproducibility in reporting (Page et al., 2021).

2.5 Data Extraction and Synthesis

Data were extracted manually, focusing on:

1. types and definitions of influencing factors;
2. study location and context; and
3. supporting evidence and frequency of occurrence in the literature.

Table 1. Reasons for Excluding 50 Articles During the Full-text Eligibility Assessment

Reason for Exclusion	Number of Articles (n)
Not discussing driving factors	30
Focused purely on technical methods	17
Inappropriate article type (e.g., conference abstracts, editorials)	3
Total	50

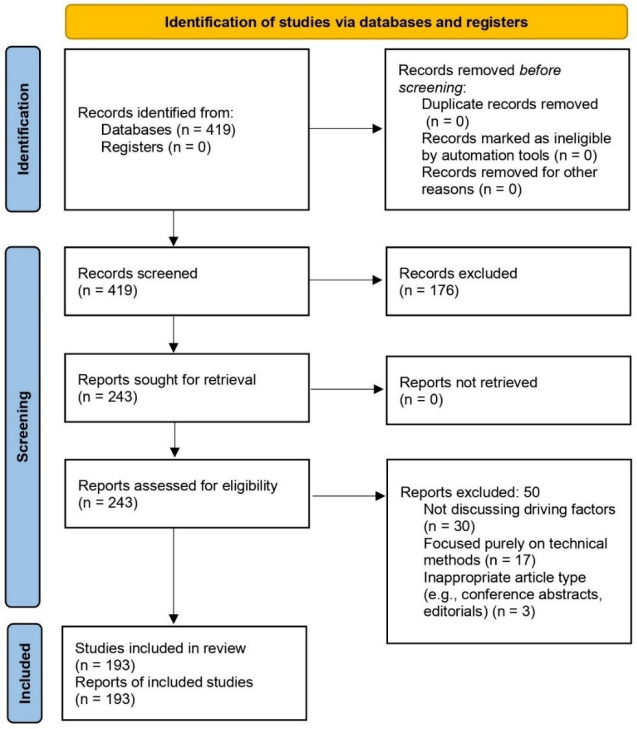

Figure 1. PRISMA 2020 Flow Diagram Illustrating the Selection Process of Articles for Inclusion in the Systematic Literature Review on Driving Factors of Watershed Management

Table 2. Top Five Journals Publishing Studies on Watershed Management and Sustainability Among the 193 Articles Included in the Review

Rank	Journal Title	Total of Article
1	Sustainability	21
2	Water	14
3	Environmental Management	9
4	Modeling Earth Systems and Environment	8
5	Applied Water Science	7

Thematic synthesis was applied to classify the 37 identified factors into three domains: environmental (biophysical), socio-economic, and institutional (governance). Both inductive (emerging from the data) and deductive (based on predefined concepts) coding approaches were used. Factors appearing in multiple studies were considered highly relevant. The resulting synthesis captures the multidimensional nature of watershed management and offers structured insight into dominant themes across global contexts.

2.6 Overview of Included Studies

A total of 193 peer-reviewed studies, published between 2013 and 2023, were included in this systematic literature review. These studies span a broad disciplinary spectrum, including environmental sciences, hydrology, social sciences, and public policy. Methodological approaches vary widely, ranging from empirical case studies, stakeholder surveys, and GIS-based spatial analyses, to systematic reviews, meta-analyses, and hydrological modeling techniques.

The articles were published in over 100 journals, reflecting the interdisciplinary nature of watershed-related research. Table 2 presents the top five journals most frequently appearing in the reviewed articles. Notably, Sustainability and Water-both published by MDPI-contribute a significant share. However, Table 3 shows that the overall leading publisher by number of articles is Springer, followed by MDPI and Elsevier. This highlights a concentration of articles in a few MDPI journals, whereas Springer and Elsevier maintain a broader portfolio of journals on environmental and sustainability topics.

Table 3. Most Frequent Publishers of the Included Articles, Reflecting Institutional Trends Across Environmental and Sustainability Research

Rank	Publisher	Total of Article
1	Springer	68
2	MDPI (Multidisciplinary Digital Publishing Institute)	45
3	Elsevier	35
4	Taylor & Francis	19
5	Wiley	7

From a geographical perspective, the selected studies cover a wide range of watershed locations across Asia, Africa, the Americas, and Europe. Countries most frequently studied include Ethiopia, China, India, Indonesia, and the United States (see Table 4 for study locations most commonly reported). Some studies have a global or conceptual focus, while others examine regional watershed systems such as those in the ASEAN region or transboundary basins. Author affiliations represent more than 40 countries, indicating a broad international contribution to this field (see Table 5 for countries based on affiliation of authors).

Table 4. Most Commonly Reported Countries or Regions as Study Locations in the Selected Articles

Journal Title	Total of Publication
Ethiopia	16
China	14
India	11
Indonesia	9
USA (United States of America)	8

Table 5. Top Five Countries Based on Institutional Affiliation of Authors

Author's Affiliate Country	Total of Publication
China	41
Ethiopia	25
India	22
Indonesia	19
USA (United States of America)	17

Publication trends over time show a significant increase in scholarly interest. As shown in Figure 2, 147 articles were published between 2018–2023, compared to just 46 between 2013–2017. This rise reflects growing academic concern over watershed sustainability, climate-related vulnerabilities, and environmental governance reforms worldwide.

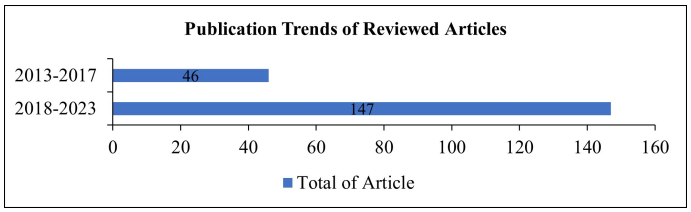

Figure 2. Publication Trends of Reviewed Articles Over Two Periods (2013–2017 And 2018–2023), Showing Increased Attention to Watershed Management Drivers

3. RESULTS AND DISCUSSION

Through thematic synthesis of the 193 selected studies, this review identified 37 driving factors that consistently influence the management and sustainability of watersheds. These factors reflect the complexity and interdependence of watershed systems, and were classified into three thematic domains: Environmental (Biophysical), Socio-economic, Institutional (Government).

Each factor was identified based on its recurrence, empirical support, and explicit discussion in the reviewed literature. These factors are not mutually exclusive and are often found to interact in real-world settings, underscoring the need for integrated watershed governance. Each factor is presented below, grouped by domain, along with brief justification and representative citations.

3.1 Environmental Aspects (Biophysical)

These factors relate to the natural physical and biological characteristics of the watershed and the ecological processes they regulate.

1. Forest Cover Area: Forest cover significantly regulates water yield, flow dynamics, and water quality in watersheds. While deforestation increases runoff and sediment load, maintaining a minimum of 30% forest cover-such as observed in Jambi, Indonesia-enhances hydrological stability and groundwater recharge (Cecílio et al., 2019; Li et al., 2017; Piffer et al., 2021; Tarigan et al., 2018). Spatial distribution of forests and their interaction with climate variability influence ecohydrological responses (Wei et al., 2017; Yeh and Liaw, 2016, 2015). Effective forest management, including restoration of native vegetation and incentive-based policies, is crucial for maintaining watershed resilience (Sun and Vose, 2016).
2. Land Use Patterns (LULC) and Land Use Suitability: Land use and land cover changes directly influence surface run off, infiltration, and erosion processes (Kumar et al., 2022; Leta et al., 2021; Sadhwani et al., 2022). Unsuitable land conversion accelerates land degradation and water pollution, while suitability-based land use planning supports sustainability (Chen et al., 2013; Liu et al., 2023b; Ngondo et al., 2021; Tankpa et al., 2021).
3. Soil Characteristics and Erosivity Rate: Soil texture, organic matter, and structure influence infiltration, sediment transport, and nutrient retention (Bekele and Gemi, 2021; Guduru and Jilo, 2023; Majoro et al., 2023). Areas with high soil erodibility demand targeted conservation to minimize watershed degradation (Balasubramani, 2018; Fenta et al., 2016; Molla and Sisheber, 2017).
4. Geological and Geomorphological Conditions: Watershed geomorphology-such as slope, lithology, and terrain configuration-affects runoff generation, erosion risk, and groundwater potential (Bhat et al., 2022; Girma et al., 2020; Rahman et al., 2021). Integrated planning should account for these structural factors (Chhillar and Joshi, 2022; Grabowski et al., 2014; Noe et al., 2022; Roccati et al., 2018).
5. Carrying Capacity of Land and Water: Carrying capacity defines the sustainable limits of human activity in a watershed. Overexploitation leads to ecological degradation and resource conflict (Dai et al., 2020; Deng et al., 2021; Jia et al., 2018; Jiao et al., 2015; Luo et al., 2021; Wang et al., 2018; Wei et al., 2021; Woldesenbet, 2022; Xu et al., 2023).
6. Rainfall and Climate Change: Rainfall patterns and

climate change modify watershed hydrology, affecting water availability and increasing flood or drought risks. Adaptive management is needed to address these dynamic pressures (Ani et al., 2022; Tarekegn et al., 2021; Tercini et al., 2021).

7. Quality, Availability and Continuity of Water Resources: Sustainable watershed functions depend on the quantity and quality of water. Land use, pollutant loads, and management practices influence turbidity, nutrient levels, and temporal flow consistency (Alexandratos et al., 2019; Bellin et al., 2016; Bunney et al., 2021; Gao et al., 2023; Hubbart, 2020; Li and Huang, 2013).

3.2 Socio-Economic Aspects

These factors relate to the characteristics of the human population, economic activity, and community behavior that influence watershed pressures and sustainability outcomes.

1. Population Growth and Pressure: Rapid population growth increases land and water demand, exacerbating land conversion, pollution, and ecosystem stress (Ahmad and Haie, 2018; Almeida et al., 2018; Ceola et al., 2019; Magel and Francis, 2022; Martin et al., 2017; Syafri et al., 2020; Yu and Duffy, 2018). Effective demographic governance is needed to mitigate resource strain.
2. Education, Knowledge, Participation, and Community Awareness: Community knowledge and awareness improve conservation behavior, while participatory approaches strengthen watershed interventions (Acharya and Prakash, 2019; Chen et al., 2023; Jacobs et al., 2016; Pradhan et al., 2021; Robinson et al., 2015; Rojas et al., 2020; Wang et al., 2013).
3. Population Wellbeing Level: Indicators of wellbeing such as health, income, and access to services influence local engagement in sustainable watershed practices (Akinsete et al., 2019; Ju et al., 2022; Knieper and Pahl-Wostl, 2016; Liu et al., 2020; Núñez-Razo et al., 2023; Wang et al., 2022).
4. Water Access and Fair Use of Water: Equitable water access ensures social justice and reduces competition among users. Governance mechanisms are needed to support allocation and conflict resolution (Alexandratos et al., 2019; Núñez-Razo et al., 2023; Syafri et al., 2020; Tang and Adesina, 2022; Villicaña-García and Ponce-Ortega, 2017).
5. Gender Equality and Women's Empowerment: Gender equity supports inclusive decision-making and strengthens resilience in watershed communities (Dessalegn et al., 2022; Hlahla, 2022; James et al., 2021; Kumar and Kumar, 2024; Lucier and Qadir, 2018; Lundberg, 2018; Ngarava et al., 2019; Silva Rodríguez de San Miguel, 2019).
6. Land and Water Dependency: High dependence on land and water resources for livelihoods increases pressure on watershed systems. Diversification of income sources is crucial (Hubbart, 2020; Katusiime and Schütt, 2020; Leta et al., 2021; Mengistu et al., 2022; Núñez-Razo et al., 2023; Syafri et al., 2020).
7. Community/Government/Industrial Land Ownership Status: Ownership arrangements influence land use behavior, conservation incentives, and stakeholder conflict (Bhardwaj et al., 2021; Huang et al., 2022a; Katusiime and Schütt, 2020, 2023; Liu et al., 2023a; Piemonti et al., 2013; Ulibarri and Escobedo Garcia, 2020).
8. Conservation Local Wisdom: Indigenous ecological knowledge offers culturally embedded strategies for watershed protection (Asmamaw et al., 2020; Chen et al., 2023; Haenn et al., 2014; Hartman et al., 2016; Iniesta-Arandia et al., 2015; Nugroho et al., 2023; Thapa et al., 2022b; Yousry et al., 2022).
9. Natural Resource Utilization Conflicts: Resource competition often leads to social tension and mismanagement. Conflict-sensitive watershed planning is necessary (Armah et al., 2014; Cai et al., 2013; Chaudhary et al., 2015; Hubbart, 2020; Leta et al., 2021; Schellens and Belyazid, 2020).
10. Adoption of Conservation Technology by Society/Government/Industry: Uptake of conservation technologies enhances ecological resilience, especially when adopted across society, government, and industry actors (Daloğlu et al., 2014; Ding and Sun, 2023; Li et al., 2022; Ramteke et al., 2020).
11. Community Income and Unemployment Levels: Income instability often drives unsustainable exploitation. Promoting local employment can reduce ecological pressure (Mengistu and Assefa, 2021; Montoya-Zumaeta et al., 2019; Retallack, 2021; Stein et al., 2017; Syafri et al., 2020; Yu et al., 2021).
12. Human Development Index (HDI): Communities with higher HDI levels are more capable of engaging in sustainable watershed governance (Amorocho-Daza et al., 2023; Bilbao-Ubillos, 2013; Couto et al., 2020; Lucia and Grisolia, 2021; Mengistu and Assefa, 2021; Núñez-Razo et al., 2023; Tang and Adesina, 2022).
13. Gross Regional Domestic Product (GRDP): GRDP reflects the economic output of a region. Integrating economic growth data into watershed planning is vital to balance development and conservation (Andualem et al., 2023; Núñez-Razo et al., 2023; Wang et al., 2023; Zhou et al., 2019).

3.3 Institutional Aspects (Governance)

These factors relate to rules, policies, institutional capacities, and governance mechanisms that regulate how individuals, communities, and authorities interact with natural resources within watershed systems.

1. Conflict Resolution Mechanism: Effective mechanisms for addressing resource-related disputes strengthen in-

stitutional trust and support long-term watershed sustainability (Cai et al., 2013; Chu et al., 2015; De Bruyne and Fischhendler, 2013; Oftadeh et al., 2017; Roozbahani et al., 2015; Silva et al., 2022; Xu and Hui, 2021).

2. Utilization of Technology and Innovation: The use of geospatial tools, remote sensing, and advanced hydrological models improves monitoring and planning (Harshadeep and Young, 2020; Miao et al., 2017; Tan and Zou, 2023). Technology facilitates data-driven and adaptive watershed governance (Agboola, 2014; Spiller et al., 2015).
3. Availability, Openness and Service Information: Open access to watershed data enables public participation and institutional accountability (Chen et al., 2023; He and James, 2021; Narendra et al., 2021; Núñez-Razo et al., 2023; Sudriani et al., 2023; Yonariza et al., 2019).
4. Watershed Management Regulations at Regional Level: Clear, enforceable regional regulations are essential for ensuring coordination among authorities and responding to ecological realities (Rajaei et al., 2021; Sulistyaningsih et al., 2021).
5. Law Enforcement Regulations: Strict and consistent environmental law enforcement deters illegal activities and enhances compliance (Al-Faraj and Scholz, 2015; Brown and Quinn, 2018; Khan et al., 2017; López-Ballesteros et al., 2019; Sanchez et al., 2023; Skidmore et al., 2023).
6. Collaboration and Coordination: Cooperation across agencies, sectors, and communities enhances governance quality and integrates diverse perspectives (Anghileri et al., 2013; Basuki et al., 2022; Cairns et al., 2017; Hedelin et al., 2023; Pei et al., 2022; Scott, 2015; Shifflett et al., 2019; Snorek et al., 2022; Song et al., 2023).
7. Community Involvement and Participation: Inclusive community engagement builds legitimacy, encourages local stewardship, and supports adaptive management (García Alba Garciadiego, 2023; Marks et al., 2014; Narendra et al., 2021; Perera et al., 2023; Vargas et al., 2019).
8. Watershed Management Transparency and Accountability Mechanism: Transparent decision-making processes reduce corruption and improve trust in watershed programs (Armas Vargas et al., 2023; Cutts et al., 2018; Gisladottir et al., 2022; Mason, 2020).
9. Human Resource Capacity in Watershed Management Agencies/Institutions: The competence of watershed agency personnel influences the success of management plans and policy enforcement (Kristensen et al., 2013; Li et al., 2021; Roestamy and Fulazzaky, 2022).
10. Monitoring and Evaluation (M&E) Management: Robust M&E frameworks support adaptive management, accountability, and continuous improvement (Anghileri et al., 2013; Asbjornsen et al., 2015; Bhardwaj et al., 2021; Bremer et al., 2020; Liu et al., 2023a; Narendra et al., 2021; Rajaei et al., 2021).
11. Licensing and Supervision of Land and Water Use: Regulatory licensing ensures that land and water exploitation aligns with environmental standards (Brontowiyono et al., 2022; Erfani et al., 2015; Falkenmark et al., 2014; Genova and Wei, 2023; Katusiime and Schütt, 2023; Ngondo et al., 2022).
12. Integration of Regional Spatial Planning Regulations: Embedding watershed priorities in spatial plans strengt hens policy coherence and reduces land-use conflicts (Alvez et al., 2022; Bafarasat et al., 2022; Campbell, 2016; Hou et al., 2021; Indset, 2023; Li and Lu, 2020; Solarek and Kubasińska, 2022).
13. Synchronization of Regulations between DAS-Related Managers: Policy coherence across administrative levels reduces fragmentation and improves efficiency (Albrecht, 2023; Genova and Wei, 2023; Kauffman, 2015; Lim et al., 2022; Luo et al., 2023; Mohammed et al., 2022; Sadeghi et al., 2023; Yousry et al., 2022).
14. Research, Development and Community Service Collaboration: Partnerships between universities, agencies, and communities enhance innovation, policy relevance, and public engagement (Agramont Akiyama et al., 2022; Ayre et al., 2018; Bhattarai et al., 2020; Bouckaert et al., 2022; Dobbs et al., 2016; Huang et al., 2022b; Núñez-Razo et al., 2023; Pradhan et al., 2021).
15. Disaster Mitigation Capacity and Systems: Institutional preparedness for disasters such as floods or droughts determines watershed resilience and recovery (Asdak et al., 2018; Cai et al., 2013; Davenport and Seekamp, 2013; Lane et al., 2023; Mansour et al., 2022; Peng et al., 2022; Qiu et al., 2017; Rehman et al., 2019; Thapa et al., 2022a).
16. Availability and Sharing of Funding between Managers: Adequate and equitably distributed funding supports sustainable implementation and stakeholder collaboration (Kafle et al., 2015; Lakshmisha and Thiel, 2023; Narendra et al., 2021; Núñez-Razo et al., 2023; Rai et al., 2018; Rezaei-Moghaddam and Fatemi, 2023; Tang and Adesina, 2022).
17. Facilities and Infrastructure Related to Watershed and Water Resources Management: The availability and quality of infrastructure such as monitoring tools, irrigation systems, and conservation facilities influence implementation success (Andualem et al., 2023; Meng et al., 2021; Nowak et al., 2022).

The 37 identified driving factors were thematically categorized into three primary domains: biophysical (7 factors), socio-economic (13 factors), and institutional (17 factors). Table 6 presents a structured summary of these factors, along with concise descriptions that highlight their relevance to watershed sustainability. This classification serves as the analytical foundation for the subsequent discussion and implications.

Table 6. Summary of the 37 Identified Driving Factors Grouped by Domain and Description

Driving Factor	Domain	Brief Description
Forest Cover Area	Biophysical	Forests regulate water yield, flow, and sediment; maintaining ≥30% cover improves resilience.
Land Use Patterns and Suitability	Biophysical	LULC changes impact erosion and runoff; planning based on suitability enhances sustainability.
Soil Characteristics and Erosivity	Biophysical	Soil texture and stability affect infiltration and sedimentation; key to land degradation control.
Geological and Geomorphological Conditions	Biophysical	Terrain, slope, and lithology shape hydrological processes and groundwater dynamics.
Carrying Capacity of Land and Water	Biophysical	Exceeding ecological limits leads to degradation; defines sustainable human activity thresholds.
Rainfall and Climate Change	Biophysical	Climatic variability alters hydrological cycles; necessitates adaptive watershed planning.
Water Resource Quality and Availability	Biophysical	Sustainable management requires maintaining water quality, availability, and flow consistency.
Population Growth and Pressure	Socio-economic	Population expansion intensifies demand on land, water, and ecosystem services.
Education, Knowledge, and Awareness	Socio-economic	Awareness and participation improve community stewardship and conservation success.
Population Wellbeing	Socio-economic	Income, health, and service access influence capacity for sustainable watershed practices.
Water Access and Equity	Socio-economic	Fair distribution prevents user conflict and supports social sustainability.
Gender Equality and Women's Empowerment	Socio-economic	Inclusion enhances decision-making and community resilience.
Land and Water Dependency	Socio-economic	High livelihood reliance increases ecological pressure; diversification is key.
Land Ownership Status	Socio-economic	Ownership affects land use decisions, incentives, and stakeholder dynamics.
Local Ecological Wisdom	Socio-economic	Indigenous knowledge provides culturally embedded conservation practices.
Resource Use Conflicts	Socio-economic	Competition leads to degradation; conflict-sensitive planning is needed.
Conservation Technology Adoption	Socio-economic	Technology improves resilience when adopted by society, government, and industry.
Income and Unemployment Levels	Socio-economic	Economic insecurity drives unsustainable practices; job creation mitigates this.
Human Development Index (HDI)	Socio-economic	Higher HDI communities more effectively engage in governance and sustainability.
Gross Regional Domestic Product (GRDP)	Socio-economic	Regional economic performance must align with ecological planning.
Conflict Resolution Mechanisms	Institutional	Mediation systems support stability and long-term cooperation.
Technology and Innovation Use	Institutional	Advanced tools improve monitoring, planning, and policy design.
Information Availability and Openness	Institutional	Data transparency enhances participation and institutional trust.
Regional Watershed Regulations	Institutional	Strong local rules provide ecological alignment and coordination.
Law Enforcement	Institutional	Effective enforcement ensures compliance and deters illegal activities.
Coordination and Collaboration	Institutional	Cross-sector cooperation integrates diverse perspectives and improves outcomes.

Community Participation	Institutional	Inclusive engagement builds legitimacy and adaptive capacity.
Transparency and Accountability	Institutional	Transparent governance reduces corruption and builds public trust.
Human Resource Capacity	Institutional	Skilled personnel are essential for planning and implementation success.
Monitoring and Evaluation	Institutional	M&E frameworks support adaptation and continuous learning.
Licensing and Supervision	Institutional	Regulatory control ensures resource use complies with sustainability standards.
Integration in Spatial Planning	Institutional	Aligning watershed priorities in spatial plans reduces conflict.
Cross-agency Regulation Synchronization	Institutional	Harmonized policy across levels prevents fragmentation.
R&D and Community Engagement	Institutional	Research partnerships foster innovation and inclusive policy development.
Disaster Preparedness and Mitigation	Institutional	Institutional readiness enhances watershed resilience to climate extremes.
Funding Availability and Distribution	Institutional	Adequate and fair financing supports long-term implementation.
Infrastructure for Watershed Management	Institutional	Physical infrastructure underpins success in water conservation and distribution.

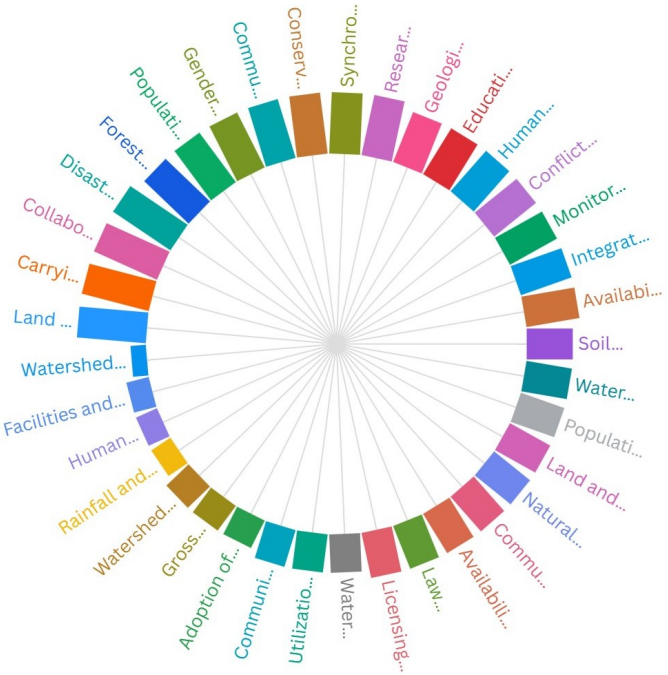

Figure 3. Overview of the 37 Driving Factors Influencing Watershed Management and Sustainability Across Biophysical, Socio-Economic, and Institutional Domains

To complement the synthesis of findings, the 37 identified driving factors influencing watershed management and sustainability are organized by domain-biophysical, socio-economic, and institutional-and visually presented in Figure 3. Each factor is accompanied by the number of supporting studies, providing insight into its relative prominence and scholarly attention in the literature.

To further illustrate the distribution of factors across domains, Figure 4 presents a comparative visualization. The pie chart (Figure 4 (left)) displays the proportional emphasis on each domain, while the tree map (Figure 4 (right)) depicts all 37 factors, classified by domain.

3.4 Interrelationship Between Factors and Aspects

Watershed systems represent complex socio-ecological entities where no single factor operates in isolation. The synthesis of 193 studies reveals robust interlinkages among biophysical, socio-economic, and institutional domains. These interactions play a critical role in shaping watershed conditions, influencing both ecosystem services and governance effectiveness.

3.5 Environmental-Socioeconomic Interactions

Changes in land cover, rainfall, or soil quality (biophysical) often translate into altered agricultural productivity, livelihood vulnerabilities, and public health risks (socio-economic). Conversely, socio-economic pressures-such as poverty, rapid urbanization, or agricultural expansion-intensi fy deforestation, land degradation, and water pollution. For instance, land conversion driven by population pressure not only disrupts hydrological balance but also reduces the resilience of dependent communities.

3.6 Socioeconomic-Institutional Interactions

Community awareness, education, and income levels influence how local actors participate in decision-making and

Figure 4. Distribution of the 37 Identified Driving Factors for Watershed Management and Sustainability. Figure 4 (Left): Pie Chart Showing The Proportion of Factors by Domain-Environmental (7), Socio-Economic (13), and Institutional (17). Figure 4 (Right): Tree Map Visualizing Each Factor Within Its Corresponding Domain, with Area Scaled to the Number of Supporting Studies

adopt conservation practices. Simultaneously, institutional arrangements-such as access to information, land tenure systems, and legal enforcement-determine the incentives and constraints shaping economic behaviors. Gender equity, stakeholder participation, and conflict resolution mechanisms are institutional levers that can amplify or suppress the socio-economic drivers of sustainability.

3.7 Institutional-Environmental Interactions

Institutional structures directly influence watershed biophysical integrity. Policies on spatial planning, licensing, and land-use regulations shape erosion risks, forest cover stability, and water quality. Moreover, enforcement capacity and inter-agency coordination affect the implementation of biophysical conservation strategies. Investments in infrastructure or monitoring systems also reflect institutional commitment to managing biophysical complexity.

3.8 Complex Cross-Domain Interactions

Many sustainability issues require understanding multi-aspect dynamics. For instance, the successful adoption of erosion control technology may depend on land suitability (environmental), farmers' economic capacity and education (socio-economic), and institutional support through incentives and training. Likewise, disaster mitigation (environmental) is reinforced by institutional preparedness, early warning systems, and active community participation.

3.9 Implication for System Thinking and Modeling

Understanding these interdependencies is essential for integrative watershed governance. Approaches such as MIC-MAC (Matrice d'Impacts Croises Multiplication Appliquee a un Classement) offer structured tools to assess driver-dependence relationships among factors. By analyzing influence pathways, decision-makers can identify leverage points

that generate systemic improvements across domains.

3.10 Synthesis of Main Findings

This systematic review identified 37 driving factors influencing watershed management and sustainability, categorized into environmental (7 factors), socio-economic (13 factors), and institutional (17 factors) domains. The dominance of institutional factors suggests that governance mechanisms-ranging from regulation enforcement to inter-agency coordination-play a foundational role in enabling or constraining sustainability efforts. As visualized in Figure 4 (left and right), institutional factors are the most frequently emphasized in the reviewed literature. This emphasizes the crucial role of institutional arrangements in ensuring policy implementation, managing stakeholder conflicts, and mobilizing resources.

Furthermore, the interconnectedness between factors across domains reflects the complex and dynamic nature of watershed systems. Integrated approaches are essential for effective intervention planning. For instance, deforestation (biophysical) is closely linked to population pressure (socio-economic) and weak enforcement (institutional). Conversely, successful watershed initiatives often exhibit alignment between community participation, supportive governance, and biophysical suitability.

3.11 Implications of the Review

a. For Research: This review provides a foundational typology of 37 empirically grounded factors that can be adopted as a conceptual framework in future empirical studies, including factor prioritization using tools like MICMAC, system dynamics modeling, or scenario-based simulation.
b. For Policy: The findings offer a comprehensive reference for policymakers to evaluate existing watershed governance frameworks. Institutional weaknesses-particularly in transparency, coordination, and funding-emerge as key intervention points. Integrating traditional knowledge, promoting gender equity, and enhancing participatory planning can improve policy relevance and inclusivity.
c. For Practice: Practitioners, including watershed managers and community-based organizations, can use the results to identify leverage points for improving intervention effectiveness. Emphasis should be placed on multisector collaboration, continuous monitoring, and adaptive learning mechanisms.

Notable regional contrasts emerged, such as the emphasis on community-based governance in Southeast Asia compared to technocratic watershed planning in Sub-Saharan Africa. Similarly, methodological diversity was observed, ranging from GIS-based modeling to qualitative stakeholder assessments.

3.12 Strengths and Limitations of the Review

A key strength of this study lies in its rigorous, transparent methodology based on the PRISMA 2020 protocol, inclusion of only peer-reviewed and Scopus-indexed sources (2013–2023), and thematic synthesis across a large sample size (193 studies). The classification into three domains facilitates understanding across disciplines and enhances the usability of findings. However, several limitations should be acknowledged:

- Database limitation: Only Scopus-indexed studies were included, potentially excluding relevant literature from other databases.
- Language bias: Articles not published in English were excluded.
- Diverse contexts: The included studies vary in regional focus, methods, and case specificity, which may limit generalizability.
- Descriptive synthesis: While comprehensive, the review does not quantify the relative influence of each factor-a gap that can be addressed in future research through empirical validation.

3.13 Future Prospects

Based on the findings, the following strategic recommendations are proposed:

1. Strengthen Institutional Governance: Prioritize the development of regulatory frameworks, inter-agency coordination, and participatory governance. Invest in institutional capacity-building, transparency mechanisms, and law enforcement related to watershed conservation.
2. Promote Integrated and Adaptive Management: Foster cross-sectoral coordination among biophysical, socio-economic, and institutional stakeholders. Adaptive strategies should anticipate changes in land use, climate variability, and social dynamics to enhance system resilience.
3. Support Empirical Modeling and System Analysis: Apply tools such as MICMAC analysis and system dynamics modeling to quantify relationships among factors, identify leverage points, and guide evidence-based interventions tailored to specific watershed contexts.
4. Empower Local Communities and Recognize Indigenous Knowledge: Strengthen the role of local stakeholders in planning and monitoring activities. Respect and integrate local knowledge systems and practices that support sustainable resource use.
5. Align Economic Development with Ecological Limits: Integrate indicators such as carrying capacity, GRDP, and HDI into planning frameworks to ensure that economic activities within watersheds remain within sustainable ecological thresholds.

This review is limited by its reliance on a single database and English-only sources, which may affect inclusiveness. Future studies should consider multilingual sources and tri-

angulated methodologies. Importantly, integrated watershed governance aligned with SDG 6 and SDG 13 is vital in the face of escalating climate risks.

4. CONCLUSIONS

This systematic literature review has synthesized evidence from 193 peer-reviewed studies published between 2013 and 2023, leading to the identification of 37 driving factors that influence watershed management and sustainability. These factors were thematically categorized into environmental/biophysical (7 factors), socio-economic (13 factors), and institutional/government (17 factors) domains. The review confirms that watershed systems function as complex socio-ecological entities, where effective management requires understanding and managing the interactions between environmental processes, community dynamics, and institutional governance. Notably, institutional factors dominate the discourse, highlighting the centrality of governance, regulation, coordination, and stakeholder engagement. This underscores that technical solutions alone are insufficient; sustainable watershed management must be driven by coherent policy frameworks and inclusive implementation mechanisms. The results offer a structured knowledge base that can inform integrated watershed governance, facilitate the design of adaptive management strategies, and support empirical research for policy refinement.

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