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Case Report

Sustainable Water Management and the 2030 Agenda: Comparing Rain Forest Watersheds in Canada and Brazil by Applying an Innovative Sustainability Indicator System

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Abstract: Watershed management varies greatly across the world. Local conditions are generally dictated by how watershed management is regulated at national, regional, and local scales. Both multisectoral and community-based participatory involvement in watershed management can positively impact the quality and effectiveness of outcomes. This localization can also be vital to the achievement of the UN's Sustainable Development Goals. In recent years, the term "sustainability" has become overused, has limited quantifiable meaning, and can create "fuzzy" targets. We suggest that an outcome that focuses on "thrivability" is more appropriate; this refers to the ability to not only sustain positive conditions for future generations but to create conditions that allow for all living things (present and future) to have the ability and opportunity to thrive. A thrivability approach aligns with the 2030 Agenda's ultimate goal: prosperity for all beings on earth. This study uses a thrivability lens to compare two study sites. Primary and secondary data were collected for both the Regional District of Nanaimo (RDN), Canada, and Hydrographic Region VIII (HR-VIII), Brazil, and have been input and analyzed through our Thrivability Appraisal to determine each region's watershed thrivability score. The Thrivability Appraisal uses seven sustainability principles as the overarching framework. These are then related to four individual subcomponents of watershed health and three common interest tests based on primary environmental perception and secondary technical data as inputs. Assuming the centricity of water for prosperity, the final scoring is a culmination of the 49 total indicators. A comparison is then drawn to the regions' capacity to achieve the eight targets for UN Sustainable Development Goal (SDG) 6. The outcome illustrates each region's water management strengths and weaknesses, allowing for lessons to be learned and transferred to other multijurisdictional watersheds.

Keywords: IWRM; SDG 6; thrivability appraisal; sustainability indicator system

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1. Introduction

Due to the levels of human impacts on the environment, which have outweighed natural changes with speeds comparable to those of geological phenomena, the literature across a range of disciplines has discussed the potential that the time we live in should have its own name—the Anthropocene [1]. The concept of Anthropocene recognizes that human actions have affected all terrestrial and aquatic ecosystems and that innovative approaches are needed to understand impacts, adapt outcomes, and mitigate the changes humans have forced on the planet [2].

To bring about societal change at an impactful level and with the speed needed to mitigate and adapt to earth's transforming systems, a reorientation and restructuring of policies, regulations, and practices at all institutional levels toward more effective governance systems is required [3]. However, the complexity of local, regional, national, and international governance structures creates challenges in moving collectively to create positive change. To both respond to this and offer pathways forward, the 17 United Nations (UN) Sustainable Development Goals (SDGs) have been conceived "to galvanize governments and civil society to confront the interlinked social, economic, and ecological challenges of the Anthropocene" [4].

The importance, difficulties, and limitations of evaluating and monitoring change in socio-environmental systems (SES) towards sustainable development have been extensively debated in technical and academic literature [5–8]. However, developing an adequate set of indicator systems that can be used as decision-support tools to guide planetary society to a sustainable path future is recognized as a worthwhile effort by the scientific community [9,10].

The UN 2030 Global Agenda represents a concerted political agreement that establishes 169 targets to be achieved (or substantially moved forward) by 2030, framed into 17 ambitious and interlinked Sustainable Development Goals (SDGs) [11–13]. The overall objective is to promote prosperity for the whole planet. During the 2030 Agenda formulation process, academia advocated that existing knowledge about the drivers, dynamics, and limitations of social change processes at all scales must guide the SDGs implementation efforts [4]. Previous research has also examined the complex interconnections, synergies, and trade-offs among SDGs [11,14–20] and agrees that the SDGs provide meaningful, integrated indicator systems.

In this context, the purpose of this article is to present "Thrivability Appraisal", an indicator system developed as an extension to the 2030 Agenda. It serves as a potential tool for integrated environmental assessment, focusing on integrated water resources management (IWRM) and, more specifically, on SDG 6 (Clean Water and Sanitation for All). The methodology is based on a holistic, integrated conceptual approach that encompasses factors associated with ecosystem resilience, including the seven sustainability dimensions involved in environmental management and develops from the foundational position that democratic governance and poverty alleviation are fundamental to reaching prosperity at local, regional, national, or global levels [21]. The Thrivability Appraisal indicator system has been applied at local and regional levels in several watersheds in Brazil [22–24].

This work presents the application of this sustainability indicator system to two SESs located in rain forest biomes, which are also United Nations Educational, Scientific, and Cultural Organization (UNESCO) designated Biosphere Reserves: Brazil (Atlantic Rain Forest Biosphere Reserve) and Canada (Mount Arrowsmith Biosphere Region).

The two studied sites are both representative of rainforests as defined in each bioregion. Rio de Janeiro's VIII Hydrographic Region (HR-VIII) (located in UNESCO's Atlantic Forest Biosphere Reserve) and the Regional District of Nanaimo (located in UNESCO's Mount Arrowsmith Biosphere Region) (Figure 1). As mandated by the Man and Biosphere Programme (MAB), all biosphere reserves must serve as demonstration sites for three core functions, including environmental protection, logistical provisioning for scientific research and education, and sustainable development [25].

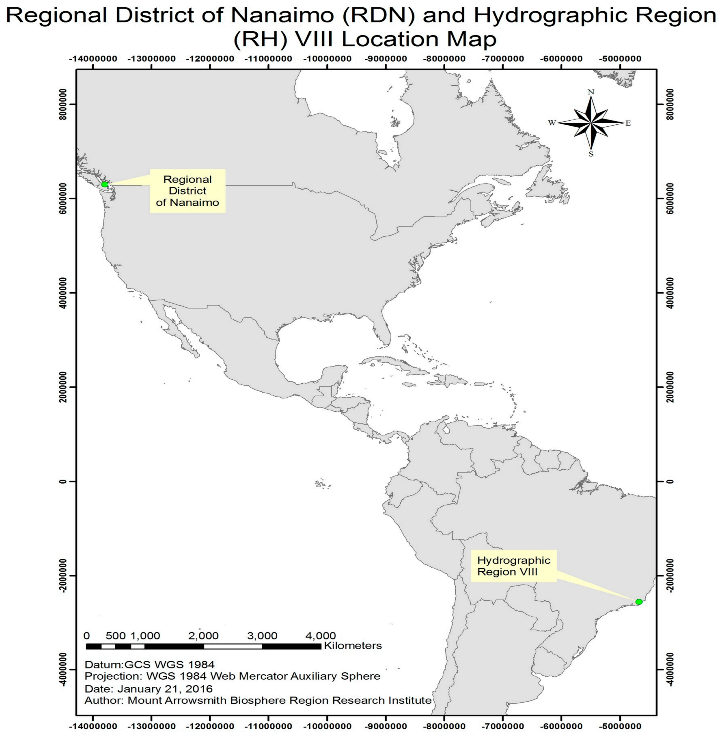

Figure 1. Regional District of Nanaimo (RDN) and Hydrographic Region (RH) VIII Location Map.

The HR-VIII covers the Macaé River Basin, the Ostras River Basin, the Imboassica Lagoon Basin, and other small coastal creeks and wetlands, thus comprising the Brazilian case study site. Formerly covered by the Atlantic Rain Forest and related ecosystems, HR-VIII's territory involves six municipalities with diverse political and administrative perspectives (Macaé, Nova Friburgo, Casimiro de Abreu, Rio das Ostras, Conceição de Macabu, and Carapebus). The Atlantic Rain Forest Biosphere Reserve, in its mountain areas (composed of rough rocky terrain and steep river valleys), is rather well conserved, mainly due to Conservation Areas that protect the headwaters of the Macaé River and its main tributaries. On the other hand, coastal areas of estuarine alluvial plains (with low and sprawling sandy riverbeds, subjected to frequent floods in the rainy season) have been highly impacted by accelerated growth and industrial activities driven by the offshore petroleum exploitation in Campos Basin over the past few decades. The Macaé River Basin is imperative to the Brazilian energy sector, as it supplies all the necessary water for the Campos Basin activities (responsible for almost 70% of Brazil's oil and gas production), thermoplants, and harbor and gas terminal facilities installed therein.

The upper regional territory is organized into small rural settlements, where economies rely upon family tourism, agriculture, and livestock. The lower region of HR-VIII has a dense and unequal urbanization pattern in which subnormal agglomerations coexist with luxurious buildings and industrial facilities. The heterogeneity regarding natural resources, resource dynamics, watershed users, infrastructure providers, and external forces on both resources and social actors characterizes a complex SES. The more densely populated and wealthier lower region holds political power [21] despite its profound social inequalities.

The Regional District of Nanaimo (RDN) is one of 27 regional districts in British Columbia, Canada. This form of government is unique to British Columbia and is best described as a federation composed of municipalities, electoral areas, and Treaty First Nations, each of which has one or more representatives on a regional district Board of Directors. Regional districts provide services of shared interest across the partners: water management, transit, solid waste, sewage treatment, and parks services are often managed at the regional level. Each incorporated municipality or First Nation government retains responsibility for other services within its boundaries, while the regional district manages the unincorporated areas.

The RDN was incorporated in 1967 and includes the municipalities of Nanaimo, Lantzville, Parksville, and Qualicum Beach, as well as seven unincorporated Electoral Areas; the total population is estimated at 170,367 [26]. The district is governed by a 19-member Board: 12 directors are from the incorporated municipalities and serve as locally elected officials within these municipalities, and seven are elected officials from the electoral areas. The RDN is situated within the territories of several First Nations, including three with Reserve Lands within the RDN: Snuneymuxw First Nation, Snaw-Naw-As First Nation, and Qualicum First Nation.

The Regional District of Nanaimo (RDN) covers approximately 208,000 hectares of land on the central east coast of Vancouver Island, ranging in elevation from approximately 2000 m to sea level, and contains a wide range of ecosystems and biomes from coastal to high alpine terrains. Approximately 10% of the RDN's land base is within the provincially designated Agricultural Land Reserve (ALR), and the remainder is a mix of forested mountainous areas, settlements ranging from low-density rural development to higher-density urban settlements, parks, riparian areas, and high connectivity to the Salish Sea.

When we think about sustainable water management (the focus of SDG 6), the adoption of integrated water resources management (IWRM) processes and participatory governance models, together with water cleanliness and accessibility, is often at the center of development issues [27–29]. Academic and technical literature have pointed out the lack of adequate indicator systems to deal with the multiple types of interactions between SDG 6 and the other SDGs [30,31], integrating the inherent complexity of SES and sustainability assessments themselves [32].

When water scarcity issues are considered, monitoring data other than that derived from national statistics needs to be taken into account. Water security indexes obtained by both modeling or remote sensing quantification techniques are not directly comparable, depending on boundary system conditions and specifications [33]. In water accounting, "traditional hydrometric data archives suffer from data gaps, incomplete time series, and poor spatial resolution, often leading to poor quality databases" [34] (p. 2). Recent situations have added to this complexity: addressing inequality and poverty while simultaneously envisioning sustainable future alternatives in the Anthropocene has reached a new level of importance driven by the COVID-19 pandemic [35]. Regarding IWRM, holistic approaches that involve interdisciplinary processes and frameworks are seen as essential to achieving sustainable water resources management [36].

In a broader holistic perspective, the concept of thrivability is said to go beyond sustainability and to embrace "the qualitative growth that supports full prosperity in partnerships" [37] (p. 830). Recognizing that little is known about how thrivability works in practice, these authors applied it in a conceptual study of entrepreneurial ecosystems. The complexities implied in evaluating sustainability actions, along with the major implications of building new development and well-being social and economic paradigms proposed by the 2030 Agenda, inspired the authors to design the thrivability assessment methodology [21]. Testing this innovative qualitative indicator system within two forested study sites justifies the work presented herein.

2. Materials and Methods

The Thrivability Appraisal is an adaptation of the principles used by long-enduring institutions for governing sustainable resources described in the literature, considering the interrelation of the seven sustainability principles [38] with the three principles for water governance derived from the literature about IWRM [39] along with the guiding questions of the common interest [40]. The conceptual framework is described in full detail elsewhere [21,41]. For each of Ostrom's seven sustainability principles, four individual subcomponents have been defined. Finally, each was then subjected to three common goods interest tests, bridging collaborative governance issues into the SES evaluation. Primary and secondary data were used as the inputs to determine final scoring (Figure 2).

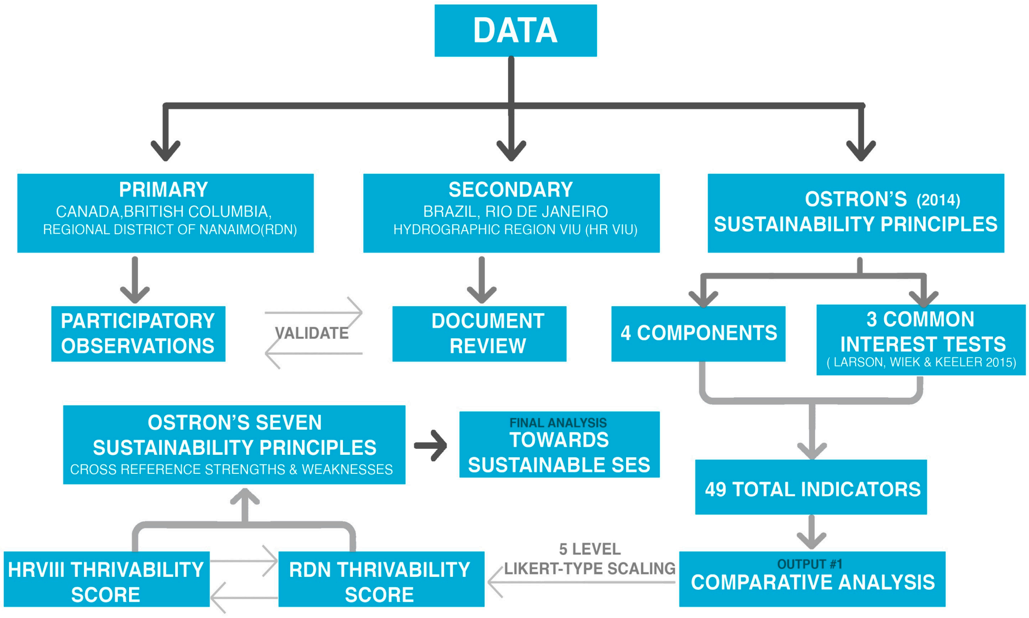

Figure 2. Schematic representation of Thrivability Appraisal methodology.

Primary data were collected over a span of fifteen years through participatory observation of watershed committees and similar working groups that deal with water management in Brazil and Canada. In Brazil, the Macaé River Watershed Committee (WSC) and Advisory Council of Environmental Protection Area Macaé de Cima (APA Macaé de Cima in Portuguese) were chosen as key informants. Survey delivery was conducted either through individual meetings, by email, or through joint meetings with two or more representatives of the chosen organization or agency (the preferred format was selected by the interviewees). The qualitative research profiled in this study was conducted between September 2015 and February 2016. In Canada, participatory observations during meetings and seminars involving watershed and environmental organizations and local stakeholders related to water and biodiversity conservation in the RDN were conducted between September 2015 and November 2015. The researchers have each been involved in participatory management initiatives in their respective nations for more than a decade.

Secondary data were collected through document and archival reviews of legal and official environmental frameworks in Canada and Brazil (laws, bylaws, watershed management plans, PA management plans, official community plans, and minutes of environmental participatory forum meetings). Additionally, bibliographic research into studies relating to democratic governance and participatory environmental management was completed, with a focus on academic work relating to environmentally threatened areas and watersheds.

In Canada, among the thirty contacted key informants, twenty-one responded to the survey: eight from governmental institutions, seven from NGOs and universities, five from private corporations, and one from a First Nation government. In Brazil, among the forty-seven contacted key informants (twenty-seven representatives from the Macaé River WSC and twenty representatives from the Advisory Council of APA of Macaé de Cima), twenty-four answered the survey: six from governmental institutions, eleven from NGOs and universities, and five from the private sector. The different views and interests represented by the study participants suggest a great number of complex interactions in both regions. Due to the qualitative nature of this study, data collected are assumed to be both accurate and appropriate as informed by working professionals within the two SES.

To define each principle's subcomponents and common interest tests, we selected socioeconomic and environmental currently employed indexes, indicators, parameters, and practices to address IWRM external connections and causal links, according to the DPSIR framework: "driving forces", "pressures", "states", "impacts" on socio-environmental systems, and societal "responses". The detailed indicator system scoring criteria are available for download on the Mount Arrowsmith Biosphere Region Research Institute's website at the following link: https://mabrri.viu.ca/sites/default/files/complete-scoring-criteria-for-thrivability-appraisal.pdf (accessed on 26 August 2023).

Based on the environmental perception of interviewed key informants, a strength and weakness analysis proceeded by applying a Likert-type scale to compare the thrivability characteristics of the two study areas' Socio-Environmental Systems (SES). Likert scales are commonly used in IWRM, not only in academic studies [42]. We defined a five-level scale criteria to create a hierarchy of priorities from the thrivability appraisal outputs, resulting in a thrivability scale. If the total scoring of any sustainability principle is equal to or below 20, it is considered a "very poor" result and is presented in red; if the total scoring of any sustainability principle is between 20 and 40, it is considered a "poor" result; if the total scoring of any sustainability principle is between 40 and 60, it is considered a "regular" result; if the total scoring of any sustainability principle is between 60 and 80, it is considered a "good" result; and if the total scoring of any sustainability principle is above 80, it is considered an "excellent" result. When looking at subcomponents or common interest tests, any score of zero is considered a major challenge to overcome.

Thrivability appraisal methodology was linked to the targets of SDG 6 by calculating the modes of 51 responses based on their perception of interrelatedness when relating thrivability scores for each principle according to three interaction criteria [11]: 0—consistent (no significant positive or negative interactions); 1—enabling (creates conditions that further the target); 2—reinforcing (aids the achievement of the target); and 3—indivisible (inextricably linked to the achievement of the target). Participants were chosen from a wide range of educational backgrounds, including forestry, natural resources, protection, environmental and agriculture engineering, aquaculture and fisheries, geoscience, geography, architecture and planning, biology, ecology, meteorology, recreation, tourism and sustainable leisure management, sociology, anthropology, history, fine arts and creative writing, health, psychology, criminology, physics, IT and computer science, civil, mechanics, materials, chemistry, and production engineering and business management. The range of participants was intentionally broad to ensure diversity. Participants included students, staff, and faculty from both VIU and IFF, respectively. A schematic representation of bridging thrivability appraisal with SDG 6's targets is shown in Figure 3.

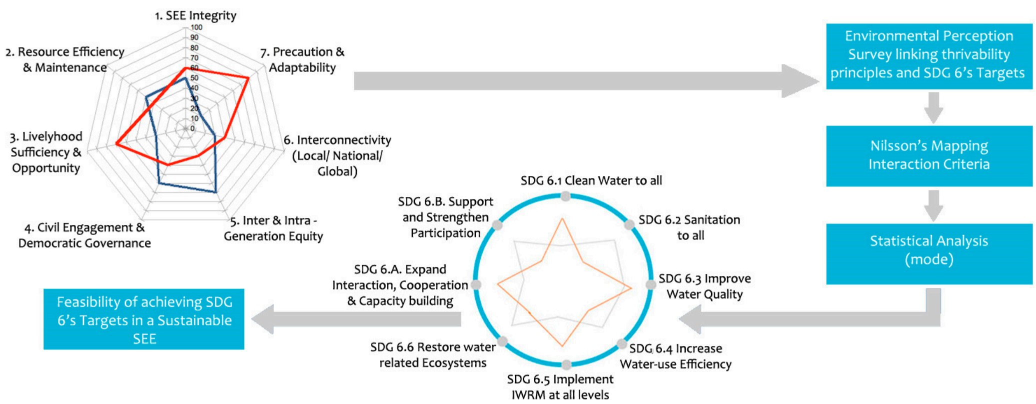

Figure 3. Schematic representation of bridging thrivability appraisal scoring with SDG 6's target achievement.

3. Results and Discussion

The current picture of environmental degradation induced by human activities characterizes what current academic literature is referring to as the "Anthropocene", a period in which human influences have introduced instability in the terrestrial system at both a degree and speed unprecedented in human and geological history [43].Considering the possibility that humanity has already ventured beyond the edges of ecosystem resilience, as a way to sustain our civilization, the literature suggests the adoption of profound changes in current development paradigms to approaches that encompass regenerative economies and highly innovative designs that profoundly reshape all aspects within political, environmental, economic, and sociocultural contexts [44]. The implementation of sustainable models of development requires the identification of challenges and efforts that are needed to tackle problems relating to a variety of interconnected social, economic, and environmental factors. Along with this, the temporal dimensions of long-term sustainability must also be considered [45,46].

Despite the general acceptance of sustainability principles across levels of government and environmental entities, questions have certainly been raised on the vagueness of definitions and the lack of actions that truly achieve stated targets. Many academics have also been critical of the lack of rigor often characteristic of activities conducted under the umbrella of "sustainability" [47,48]. In its broadest sense, the "sustainable" part of the sustainable development paradigm implies that everything that is done now must not harm future generations. However, the precise meaning of "sustainable" and what it embraces varies depending on who is using the term and in what context [49]. The conceptual inaccuracies associated with its polysemy can even be considered an ideological operation to reconcile the irreconcilable, that is, unlimited economic growth with the maintenance of environmental integrity at the planetary level [47]. The multidimensional character of sustainable development minimally involves economic, environmental, and social dimensions, known as Elkington's triple bottom line [48]. Similarly, the term sustainability is also present in various discussions linked to educational, economic, social, and environmental issues. The words "sustainable" and "sustainability" have perhaps become so overused as to lose all meaning [48–50].

The concrete challenges for promoting sustainable development and/or sustainability are often as heterogeneous and complex as the diversity of human societies and natural ecosystems around the world. In response to the criticisms circling definitional vagueness and terminology overuse are literally hundreds of attempts to define indicators and appropriate methodologies to evaluate sustainability in defined territories. Those efforts often combine global, national and local level initiatives, such as the Well-Being Index (IB), the Environmental Sustainability Index (ESI), the indicator systems for sustainable development developed by the Global Scenarios Group (GSG), the Living Planet Index (LPI), the Sustainability Panel (SP), the Genuine Progress Index (GPI), and the Global Reporting Initiative (GRI), aimed at corporations and nongovernmental institutions. Other indicator systems are focused on unsustainability, such as the State Failure Task Force (SFTF). To be inclusive, the range of indicator components has become very broad, but further analysis reveals that a significant number of those initiatives represent research or environmental defense groups' points of view, which may share a narrow or homogeneous vision of sustainable development and contemplate a large number of aggregated indicators in order to reflect their own concept of sustainability or to support a particular development model [48–51].

Bohringer and Jochem conducted a comprehensive study of sustainable development indexes [51]. The authors concluded that all of them could not fulfill fundamental scientific requirements, thus being practically useless or even misleading to policymakers. The author's criticism focused on normalization as well as the weight and aggregation processes employed to build such indexes.

Pires et al. evaluated 170 sustainability indicator systems related to water use and management using the DPSIR framework and found that among the indicator systems studied, 146 did not fully encompass the main sustainability dimensions [9]. They ranked the remaining 24 indicator systems that fulfilled the majority of their sustainability criteria. According to their analysis, the Water Poverty Index—WPI [52] was ranked highest among those able to provide core information for IWRM, followed by the Climate Vulnerability Index—CVI [53] and the Water Reuse Index—WRI [54].

WPI comprises five dimensions: resource (R), access (A), management capacity (C), water uses (U), and environmental influences regarding water issues and extreme climatic events (E). It is usually applied at regional or local scales [55,56]. CVI was conceived parallel to WPI and links water resources with human vulnerability assessments, considering three dimensions of vulnerability, including exposure to natural disaster and climate variability (E), sensitivity to health, food and water access (S), and adaptive capability (C) linked to graphic profile, livelihood strategies, and social networks within the community [53,57]. Inspired by CVI, a climate change vulnerability index was designed to aid as a decision support tool to increase adaptive capacity to climate-related extreme events in urban coastal areas [58]. The WRI measures the cumulative water withdrawn during its passage downstream within a watershed. High WRI values indicate a potential increase in the competition for multiple water uses, as well as pollution and public health problems [54,59]. WRI and other indicators developed for assessing water reuse and its impacts on multiple-use watersheds are described elsewhere [60].

Post-2015, when the UN General Assembly endorsed the UN Document A/RES/70/1 "Transforming Our World: the 2030 Agenda for Sustainable Development", the efforts to measure SDG achievement and to rank countries according to their pathways towards sustainability and prosperity resulted in a new sustainability index: the Sustainable Development Goal (SDG) Index. Initial UN recommendations included a set of 230 global indicators to achieve (or at least work toward) the 2030 Agenda at national levels. Criticisms of this model note that the SDG Index comprises between one and five variables per goal for each country, which is widely considered to be too few variables to create a comprehensive and statistically consistent country rank for each SDG. Furthermore, the literature points out the need for data-driven and evidence-based implementation and follow-up processes, which must be scientifically robust tools for decision support and integrative policy-making at the global, regional, national, and subnational levels [61–66], especially since the 2030 Agenda adheres to a strong sustainability conceptual formulation and considers that social and economic development depends on the natural resources and environment [67].

The SDG Index develops from five fundamental assumptions: (i) the number of indicators may evolve if new evidence becomes available; (ii) nonofficial data helps bridge current data gaps; (iii) the 17 SDGs are the final overarching framework; (iv) it is focused on absolute country performance based on distance to invariant sustainable development targets; and (v) the reporting of results needs to be presented in ways that are accessible to a wide audience [68]. As in the case with any composite index, indicator selection is a key factor for the SDG Index construction [69].

It is noted that the lack of country data is a major limitation for SDG Index temporal evaluation. Additionally, annual results cannot be compared appropriately once new variables arise and as data gathering proceeds: the number of global indicators in the four SDG Index and Dashboards Reports to date were 60 (2016), 83 (2017), 88 (2018), and 93 (2019) [61,63]. According to Sachs et al., 2019 [63] (p. 7), "While the SDG Index compares average performance across countries, the purpose of the SDG Dashboard is to identify the policy areas where major progress is needed at the national level. Available time series data is too sparse to estimate country-level rates of change for a sufficient number of variables. Further to this, challenges to the 2030 Agenda's implementation and monitoring are related to existing governance models: data gathering, decision-making and policy design which will require "unprecedented level of co-operation and co-ordination, creating innovative coherent actions in an increasingly fractured geopolitical environment" [70]. Due to the comprehensive nature of the SDGs and the unavailability of data in many countries, creating a complex and multidimensional data analysis and synthesis process is challenging. Beyond the SDG's complex set of interactions that can complicate data gathering processes, other factors can cause gaps in data collection and analysis, adding even further complexity to the design of indicator and monitoring systems regarding SDG's operationalization induced by public policies [71,72].

Focusing on a more comprehensive view of sustainable behavior that embeds a holistic perspective, the theoretical–conceptual framework of a thrivability appraisal integrated indicator system is expressed in the word "thrivability", which combines the verb thrive with the word sustainability; it is intended that this new word is more closely aligned with the 17 interlinked SDGs and better defines what the SDGs are working to achieve. Postulating that water provision for multiple uses is essential regarding development issues and that neither global prosperity nor health is possible without access to fresh water, the thrivability appraisal focuses on SDG 6 and IWRM practices. The thrivability indicator system was conceived at the regional level from qualitative evidence brought forth by survey discourse analysis and tested in two hydrographic regions in the state of Rio de Janeiro [21,41]. The analysis was then applied to of HR-VIII and the Mount Arrowsmith Biosphere Region.

Public policies that enforce sustainability strategies based on intra- and intergenerational justice were chosen to compose that integrated indicator system, which adopts a holistic perspective and is grounded on a strong sustainability conceptual framework. The new system takes available technical data and stakeholders' perceptions into account and addresses recommendations that are adherent to the current academic debate on sustainability assessments and SDG indicators gaps [44,72–78].

The Anthropocene, as defined and discussed by academics, speaks to a world where intertwined human interactions and impacts are shaping natural processes in ways never before seen or experienced. The climate crisis, price shocks of food, forced migration, pandemics, and other socio-ecological dynamics are turbulent examples of the results of complex feedbacks that characterize the Anthropocene. Once we accept that nature is deeply shaped and connected to human actions, we begin to understand that environmental problems cannot be considered simply as a consequence of anthropogenic disturbances in the balance of nature and, further, that these problems cannot be solved if we evaluate the systems separate from human influences [79]. Thus, thrivability appraisal results have no significance if we only examine single indicators, such as cluster principle's scoring or a calculated mean score. The results must be analyzed systemically through a lens that synthesizes clues and directions along with evaluating quantitative results, which are presented in Figures 4 and 5 and synthesized in Tables 1 and 2.

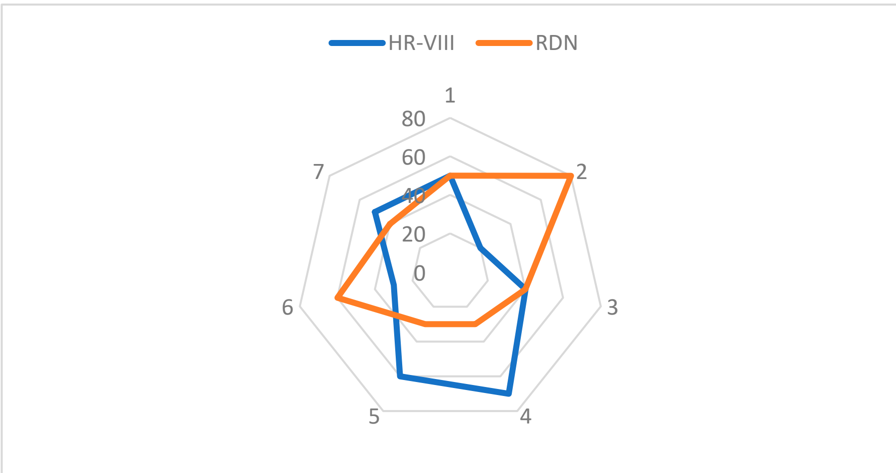

Figure 4. Thrivability appraisal results for Hydrographic Region VIII (Brazil) and Regional District of Nanaimo (Canada). Note: 1 = Social-ecological system integrity; 2 = Resource efficiency and maintenance; 3 = Livelihood sufficiency and opportunity; 4 = Civil engagement and democratic governance; 5 = Intergenerational and intragenerational equity; 6 = Interconnectivity from local to national/global scales; and 7 = Precaution and adaptability.

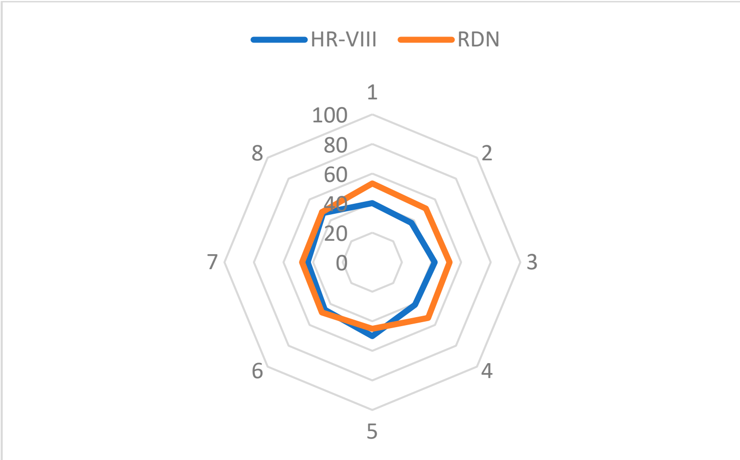

Figure 5. Relationship between thrivability appraisal and SDG 6 targets for Hydrographic Region VIII (Brazil) and Regional District of Nanaimo (Canada). Notes: 1 = SDG 6.1 target (clean water to all); 2 = SDG 6.2 target (sanitation to all); 3 = SDG 6.3 target (improve water quality); 4 = SDG 6.4 target (increase water-use efficiency); 5 = SDG 6.5 target; 6 = SDG 6.6 target (implement IWRM at all levels); 7 = SDG 6.a target (expand interaction, cooperation, and capacity building); and 8 = 6.b target (restore water-related ecosystems).

Table 1. Comparative thrivability appraisal considering overall sustainability principles' scores of HR-VIII and RDN.

Sustainability Principle	Thrivability Scale	
	HR-VIII	**RDN**
1. Social-ecological system integrity	50	50
2. Resource efficiency and maintenance	20	80
3. Livelihood sufficiency and opportunity	40	40
4. Civil engagement and democratic governance	70	30
5. Intergenerational and intragenerational equity	60	30
6. Interconnectivity from local to national/global scales	30	60
7. Precaution and adaptability	50	40

Notes: red = very poor (0–20); orange = poor (up to 40); yellow = regular (up to 60); green = good (up to 80).

Table 2. Modes of environmental perception survey relating thrivability appraisal scoring and SDG 6 targets.

SDG 6 Targets	Thrivability Appraisal Sustainability Principles Interactions (Modes of 51 Responses)						
	1	**2**	**3**	**4**	**5**	**6**	**7**
6.1	2	3	2	1	1	2	1
6.2	0	2	3	0	1	1	1
6.3	3	3	1	1	1	2	3
6.4	2	3	1	1	1	2	2
6.5	1	1	0	3	1	2	2
6.6	3	1	1	1	1	2	2
6.6a	0	1	1	1	1	2	2
6.6b	0	2	0	3	1	2	2

Notes: 0—consistent interaction; 1—enabling interaction; 2—reinforcing interaction; and 3—indivisible interaction.

Table 2 illustrates the values that relate the thrivability appraisal scoring to the SDG 6 targets; due to the broad range of perceptions of our interviewers, we chose to use mode as the most representative way to score the data. This analysis shows that while the efficiency and maintenance of resources are the largest challenge in the Brazilian case, they represent the strongest point in the Canadian case. Expressive differences were also found in interconnectivity from local to national and global scales, with the Canadian case exhibiting a better performance. The situation was inverted when civil engagement and democratic governance were the focus. In Brazil, water is a common good; watershed committees are deliberative and have their own budgets to apply in watershed restoration. On Vancouver Island, water management has jurisdictional complexities, and watersheds tend not to be managed through inclusive, integrated, and funded processes. Through the lens of a precautionary and adaptability principle, the Brazilian case results were slightly better due to protected areas strategically set in watersheds and given that management plans tend to consider the locals' expectations to thrive.

In the cases studied, equal scores were obtained for sustainability principles 1 and 3. Regarding social-ecological system integrity, the main challenges observed through the thrivability appraisal comprise inappropriate land uses, high levels of riparian occupation, unmonitored or regulated water use, and deforestation of riparian areas in both cases. HR-VIII's weakest points were due to failures in the implementation and operation of command-and-control mechanisms and the lack of publicly available data on superficial and groundwater quality. The primary weakness in this Canadian example was the deficiency of protected areas within the watersheds. When talking about livelihood sufficiency and opportunity, both regions failed on common interest tests. In HR-VIII, individuals are directly dependent on unprocessed natural resource extraction (for example, foraging activities for livelihoods or foodstuffs), and traditional populations have problems in finding work and/or a good income. On Vancouver Island, insufficient livelihood opportunities in rural areas are also an issue.

According to the perceptions of interview participants, the achievement of universal and equitable access to safe and affordable drinking water for all (SDG 6, target 6.1) and resource efficiency and maintenance should be related through an indivisible interaction. This result points to an inherent difficulty for HR-VIII regarding the solving of sanitation issues before 2030. Indivisible interactions also link access to adequate and equitable sanitation and hygiene for all and ending open defecation while paying special attention to the needs of women and girls and those in vulnerable situations (SDG 6, target 6.2), and the protection and restoration of water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers, and lakes (SDG 6, target 6.6) to livelihood sufficiency and opportunity (sustainability principle 3). Although the Brazilian and Canadian cases have equal scores regarding sustainability principle 3, RDN's better expectation in achieving SDG 6 6.2 targets can be attributed to Canada's far better performance on resource efficiency and maintenance, which was considered a reinforcing interaction regarding target 6.2.

Additionally, civil engagement and democratic governance were perceived to be indivisible to the implementation of integrated water resources management at all levels (SDG 6, target 6.5) and to support and strengthen the participation of local communities in improving water and sanitation management (SDG 6, target 6.6b). Target 6.5 is the only SDG 6 target in which the Brazilian case performance is expected to surpass the Canadian case. We can attribute this result to regional civil society characteristics but also to Brazilian Environmental and Water Policy as a whole. As expected, SDG 6.6.3 target (improve water quality by reducing pollution, eliminating dumping, minimizing the release of hazardous chemicals and materials, halving the proportion of untreated wastewater, and substantially increasing recycling and safe reuse) was linked to multiple sustainability principles once water quality involves multiple and complex interrelated factors. Once again, HR-VIII's low scoring in resource efficiency and maintenance put it behind the RDN since HR-VIII is only slightly better regarding precaution and adaptability and because the two territories have equal scoring in social-ecological system integrity.

4. Conclusions

The use of a thrivability approach to the research is intended to highlight that processes and approaches should not just be sustainable but should allow people and places to thrive. This approach, along with the core principles of the SDGs, seeks to illustrate that all is related: change in one area (positive or negative) has impacts on other aspects of life on this planet. Overall, good governance, as defined by inclusionary, multidimensional processes, appears to be a better pathway to managing complex systems such as watersheds. Additionally, commitments to the designation of protected areas and truly limiting human impacts in these areas are needed to ensure fragile lands, waters, and resources are not irreparably damaged. Taking a holistic approach to monitoring forested sites that guarantee water and help to mitigate climate crisis is undeniably relevant to public policies and decision-making processes. The thrivability appraisal is the result of a comprehensive IWRM data gathering system. As tested, the indicator system has proved to be a successful tool when used to compare data for both the Atlantic Rain Forest in Brazil and the Pacific Rain Forest in Canada and is likely transferable to other regions that may be similarly lacking detailed information related to IWRM. The case study in Brazil provides transferable approaches that relate to strong water regulations, engagement processes firmly based on democratic governance mechanisms, and an approach to strategically designating conservation areas to protect headwaters from unsustainable development. The Canadian case study highlights the long history of watershed management dating back to the Commission of Conservation in the early part of the 20th century, well-established and respected provincial regulations for watershed and wildlife management, and the strong interest from local governments in protecting the headwaters and watersheds that serve as sources for potable water. It is hoped that this research will open new opportunities for considering interrelated approaches to understanding complex systems and, ultimately, to improvements that lessen the impacts of humans on this fragile sphere.

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