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Review

A Review on the Water Dimensions, Security, and Governance for Two Distinct Regions

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Abstract: Non-arid region countries, including Canada, enjoy abundant water resources, while arid countries such as Qatar struggle to meet their water needs. However, climate change threats to water resources are similar for both climatic regions. Therefore, this article discusses water dimensions, security, and governance for these different regions, i.e., non-arid Canada and arid Qatar, that distinctly respond to their water-related challenges. Limitations of the article include lesser water-related literature availability for Qatar than for Canada. Canada's water resources appear vulnerable to climate change as it is projected to face >0.6 °C above the global average of 1.6 °C for the 20th-century temperature. Qatar is extremely vulnerable to dust storms, and rising sea levels, with the maximum temperature approaching 50 °C during the summer, and flooding during the winter. The sustainable use of water resources needs to address social, economic, political, climate change, and environmental dimensions of water. Other than climate change impacts and high per capita consumption of water, Qatar faces challenges of a rise in population (~29 million as of now), acute shortage of freshwater from rainfall (~80 mm per annum), high evapotranspiration (~95% of the total rainfall), depletion of groundwater, and low agricultural productivity due to infertile lands and water scarcity, all leading to food insecurity. The sustainable use of water resources requires improved regulations for water governance and management. Comparisons of water sustainability issues, dimensions, security, and governance facilitate discussions to improve water governance structures for resource sustainability, food security, and climate change adaptability, and show how one country could learn from the experiences of the other.

Keywords: adaptability; climate change; distant regions; sustainability; water resources

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1. Introduction

Life on planet Earth depends on water to support food and energy production, socio-economic development, and healthy ecosystems [1–3]. However, climate change and population increases have challenged the sustainable management of this precious natural resource. Hurlbert and Diaz [4] evaluated the impacts of climate change on the infrastructures and adaptation potential for water scarcity or drought in the South Saskatchewan River Basin (western Canada) and the Elqui River Basin (Chile) and anticipated that both regions will face extreme weather events including increasing droughts due to climate change. Therefore, sustainable natural resource use requires ingenuity, foresight, and adaptability [5]. As part of future-thinking in the past decade, global- and hydro-politics have emphasized water security in policymaking [6]. Pandey [7] stated achieving water security had to be one of the major global challenges in the age of climate change. The Intergovernmental Panel on Climate Change (IPCC) in its recent report has mentioned that climate change impacts have increased over the past few decades. The temperature has risen, and rainfall intensity has increased but the frequency has reduced. This has resulted in global warming-induced issues including heat waves, glacier melt, sea level rise, uneven rainfall patterns, and flooding, leading to challenges in water resource management, food security, and others [8].

The sustainable management of water resources has thus become a core topic of debate in the context of global warming, the main environmental challenge of today, and is characterized by the rise of global average temperature. The continuous use of natural resources such as burning fossil fuels for heat and energy leads to the excessive emission of greenhouse gases and increases atmospheric temperatures. Greenhouse gases such as carbon dioxide and chlorofluorocarbons accumulate in the atmosphere to trap heat; therefore, global warming has impacted life in non-arid and arid regions in different ways. With continuously increasing temperatures, it has been predicted that permafrost may disappear before the end of the twenty-first century. This will impact the soil hydrological characteristics of countries such as Canada, which have found subsurface layers in the north, high elevations in mountainous areas such as the Rocky Mountains in western Canada, the Chic-Choc Mountains to the east, northern Manitoba, and Ontario contain melting permafrost [9–14]. Global warming also results in more storms and rising sea levels, which pose a threat of flooding in Atlantic Canada and water scarcity and groundwater depletion in the Middle East, including Qatar [15,16]. The two study regions, Canada and Qatar, face identical as well as distinct challenges in finding sustainable solutions to water-related issues [17,18]. Both regions strive to maintain safe drinking water and have planned to expand agriculture, which will put immense pressure upon valuable and scarce water resources [19,20].

1.1. Canada

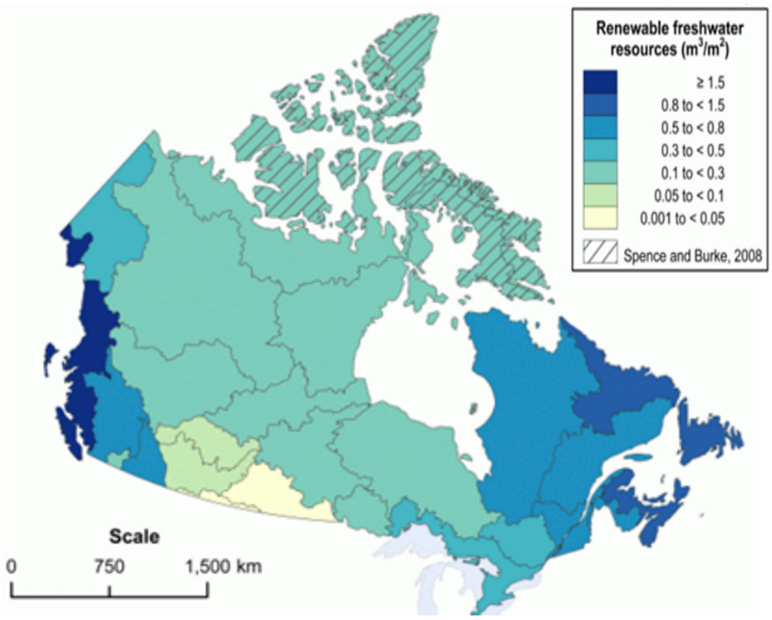
Canada is situated in North America (Figure 1a) and faces some of the most accelerated and intense warming and flooding resulting from global climate change [16,21]. Geographically, Canada is the world's 5th largest country (9.09 million km^2) following Russia (17.05 million km^2), China (9.32 million km^2), and the U.S. (9.16 million km^2). About 9% of Canada's total area (i.e., about 0.89 million km^2) is occupied by freshwater [22,23], and blessed with an abundance of precipitation, rivers, lakes, and groundwater; it holds almost 20% of the world's freshwater resources. All these assets are not available for population use due to potholed scenarios, i.e., 84% of the country's population adjusted in the south, where only 40% of the streamflow is available. The country's total renewable water resources are 3280 km^3/year (surface water: 2900 and groundwater = 380 km^3/year), and divided by the current population of 37.26 million, the per capita water availability is approximately 88,000 m^3/person/year. Per Niagara Falls State Park site data [24], it becomes equivalent for each Canadian to 34 s of flow on the Canadian side of Niagara Falls (Table 1).

Table 1. Water availability for Canadians from the Niagara River flow only [24].

Niagara Falls/River	Niagara Falls on the Canadian Side	Niagara Falls on the U.S. Side	Niagara River
Fall/Flow	2581 m^3/s	287 m^3/s	2868 m^3/s
Per capita (per Canadian per year) fall/flow time	~5 min	34 s	31 s

Global climate change threatens both the short- and long-term sustainability of freshwater resources in Canada and across the globe [25–29]. Although Canada has an abundance of water resources, the country's freshwater systems face mounting pressure from ecosystem degradation, pollution, habitat loss, invasive species, and amongst other threats, climate change [30]. The situation could be averted in future scenarios, through best governance and management, which will require sustainability in water use best suited to the country's ecosystems. The proven vulnerability of Canada to global warming, i.e., >0.6 °C above the global average of 1.6 °C for the 20th-century temperature, may be considered optimistic for future policymaking [31]. The bases of Canada's sustainable water use are its land area (9.09 million km^2) and the diversity of water resources (encompassing spatial and temporal characteristics of heavy precipitation events over Canada) and use across the western, central, and eastern provinces and territories [32,33].

(**a**)



(**b**)

Figure 1. (**a**) The geo-referenced map of Canada showing its location on the globe in North America (the inset) as well as the provincial boundaries and (**b**) spatial distribution of renewable freshwater distribution in Canada [34].

Canada's current opportunity-driven challenges are sourced from future accelerated snow and ice melt, sea-level rise, changing precipitation patterns, seasonal shifts, and impacts on hydrological (surface and groundwater) regimes on urban and aquatic life [32]. Historical patterns show spatial variations and temporal changes in the average precipitation that have increased with inter-annual spatial variability since the middle of the eighteenth century from under 0.5 to 0.6 m/year reflecting up to a 35% increase in the northern and southern parts of the country, and a 10% decrease in the Prairies regions [33]. As shown in Figure 1b, the country has spatially varying freshwater resources providing for its eastern provinces (Newfoundland and Labrador, Prince Edward Island, Nova Scotia, and New Brunswick) and causing freshwater availability challenges for southern parts of the Prairie provinces (Alberta, Saskatchewan, and Manitoba). Most of the agriculture and potable water uses are met with this freshwater [34].

1.2. Qatar

Qatar is an arid country in the Middle East with a rough terrain that comprises a rocky desert and scattered oases formed by depressions and a long Persian Gulf shoreline. To the south, Saudi Arabia is Qatar's only land-bordering country (Figure 2a). Its geographical area is approximately 1.16 million ha (11,581 km^2) including several offshore islands, and this peninsula stretches *circa* 180 km from north to south and 85 km at its widest point. It has an elevation of 100 m above sea level in the south, decreasing to less than 50 m in the north. The arid climate of Qatar deprives it of freshwater resources caused by insufficient rainfall and depleted groundwater resources (Figure 2b) [35,36], and the country relies on desalination, groundwater, and treated sewage effluent (Figure 2c; Ref. [37]). Water from the two major basins is unsuitable for agriculture, but it is suitable from the three minor basins (i.e., Doha, Aruma, and Abu Samra), which are about 450 m deep, and cover 30% of Qatari territory with good quality water for irrigation [38].

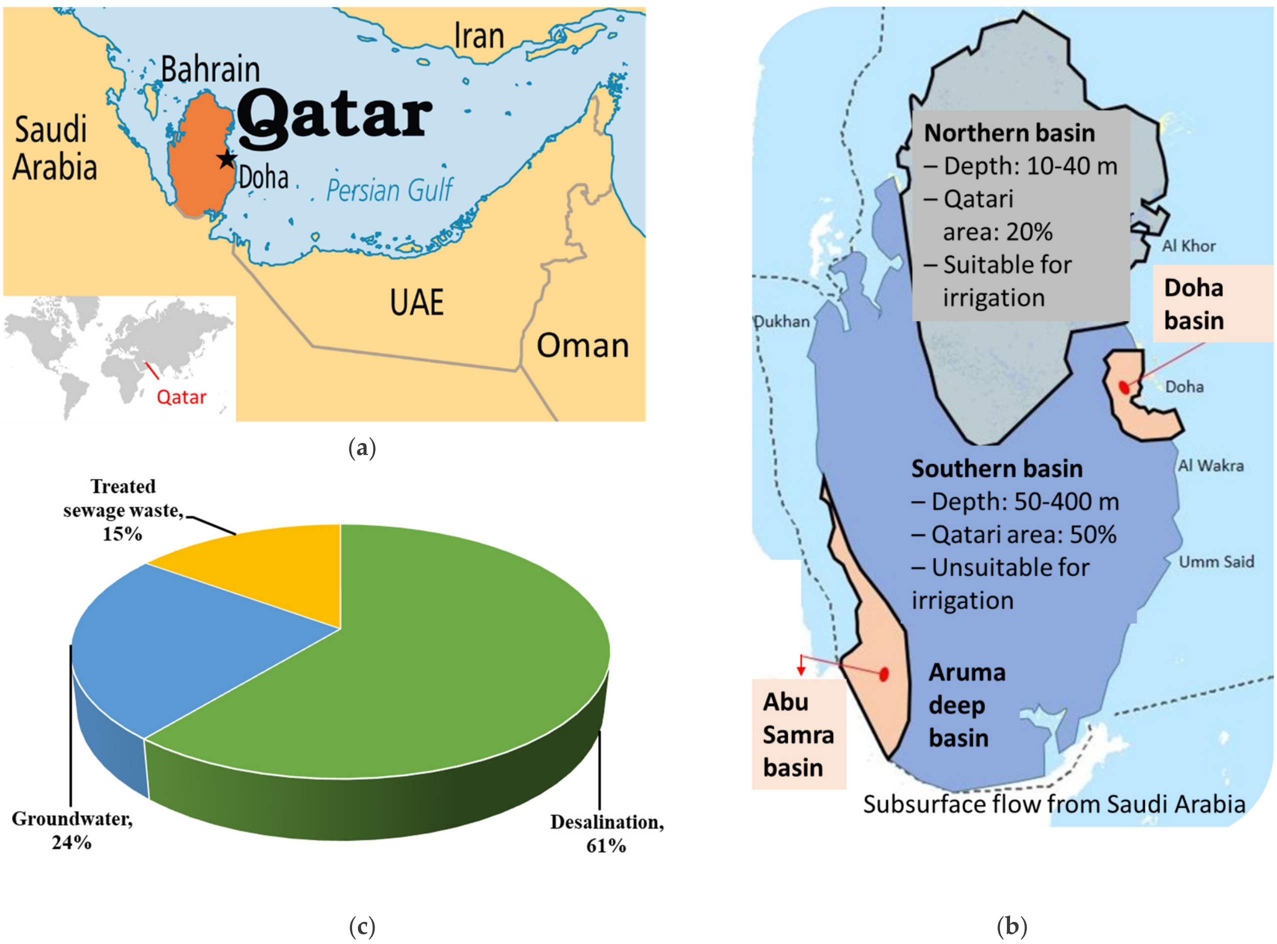


Figure 2. (**a**) The geo-referenced map of Qatar showing its location on the globe (the inset), in the Persian Gulf, and on the only land border of Saudi Arabia; (**b**) characteristics of five groundwater basins of Qatar [38]; and (**c**) the country's reliance on desalination, groundwater, and treated sewage effluent [39].

Qatar experiences varying water evaporation phenomena throughout the year. A total average annual rainfall of approximately 80 mm [39] coupled with extreme summer months of over 40 °C temperature results in >2000 mm/year evaporation, i.e., >10 mm/day in June as compared to <2 mm/day in December [40]. The majority of Middle Eastern countries including Qatar are categorized as arid climatic regions. A study conducted during the 1960s reported that the region had run out of water to meet its food needs by the 1970s [41]. The current state of the water balance of Qatar (Table 2) for the period 2008–2016 reflects an increase in water stocks (total recharge from rainfall, inflow from Saudi Arabia, artificial recharge, and irrigation returns) from 108 to 172 million m^3; however, the water balance decrease remained relatively unchanged between 266 and 269 million m^3 per year for the same period [42]. Based on the 9-year data in Table 2, recharge from water injections, obstructions, and high evapotranspiration results in an average annual negative water balance of 110 million m^3.

Table 2. Water balance components (million m^3) of Qatar [42].

Year	Municipal and Industrial Abstraction	Agricultural Abstractions	Outflow to Sea	Irrigation and Well Recharge	TSE Injection	Recharge from Rainfall	Water Balance
2008	−23	−226	−18	67	7	27	−158
2009	−19	−228	−18	70	24	66	−99
2010	−19	−229	−18	70	26	21	−141
2011	−20	−229	−18	70	26	66	−95
2012	−20	−230	−18	70	25	63	−121
2013	−20	−230	−18	83	36	52	−96
2014	−21	−230	−18	83	43	35	−106
2015	−21	−230	−18	61	57	68	−81
2016	−21	−230	−18	61	61	48	−97
9-year average	−20	−229	−18	71	34	50	−110

Despite scarce freshwater resource availability, as in Canada, everyone living in Qatar not only has 100% access to safe water, but they are among the world's top largest water consumers per capita [37,43]. The only difference is that water availability for use in Qatar is not all fresh, as about 61% of the total water supplies comes from seawater desalination (mostly used as drinking water), 24% from groundwater abstraction (mainly for agriculture purposes), and 15% from sewage effluent treatment plants (for landscaping irrigation and agricultural use) [39].

1.3. The Importance and Scope of This Review

Literature and scholarly discussions suggest exploring modified styles of governance for the sustainable management of water resources, water security, and adaptation to global change [4,44–58]. The challenges of water governance vary from region to region [4], but the essence of potential solutions to water-related challenges remains the same for different regions, including the two extremes (non-arid versus arid). Therefore, the scope of this article is to review and discuss the challenges of water resource dimensions, security, and governance for two extreme scenarios, i.e., non-arid Canada and arid Qatar under the impacts of climate change and sustainable development. In these contexts, this article makes a novel contribution to the literature on water dimensions, security, and governance. The Canadian context is discussed before Qatar's because of more available literature for Canada, with major sections of the article being water dimensions, security, and governance.

Bearing in mind that the supply of water is essential for life on earth, the future scope of this review article is to replace the current approach of relying on conventional households and communities to manage water services with sustainable and advanced methods of coping with issues of water scarcity. This will of course need more support from public funds and better use of financial instruments that have proven their worth in other sectors. With these approaches, the world can achieve the goal of universal access to safe, sustainable, and resilient services and protect food security and public health.

1.4. Definitions and Concepts Used in This Review

This section presents the definitions and concepts to set the context of the discussion of this review. Fundamental and applied institutions of water are called water dimensions, e.g., there are four essential water institutions/dimensions including the social dimension (equitable use), economic dimension (efficient use), political dimension (equal domestic opportunities), and environmental dimension (sustainable use) [57]. The environmental dimension not only includes sustainable use, but also climate change aspects. The social dimension is all about the fair distribution of water resources and services to effectively fulfill the needs of socio-economic groups. Unfortunately, around the world, water resources and services are not evenly distributed in both rural and urban areas. The economic dimension that dictates overall economic growth is dominated by the efficient allocation and use of water resources. The economic dimension also directs the role of governments in poverty alleviation and economic growth, as efficient water governance in a country can control per capita incomes. For the economic dimension, we need to look into the cost of producing water from desalination plants and analyze the indirect return from using this water and its impact, if any, on the environment. Another important factor will be the impact on the health of the consumer and its relation to the overall cost of desalination.

"Water security" concepts have attracted researchers to investigate and evaluate applications such as human health, water quality, and sustainability of water supply for human uses and activities [59]. The World Economic Forum described water security as "the gossamer that links together the web of food, energy, climate, economic growth, and human security challenges that the world economy faces over the next two decades" [60]. Sample definitions of water security may be found in the literature [61,62], but most of the current literature produced in Canada defines water security by extending water's disciplinary application [63–65] to Indigenous Ways of Knowing [66]. In simple words, water security is sustainable access to adequate quantities and acceptable quality of water to ensure human and ecosystem health on a watershed basis. Numerous indicators of water quality, but fewer indicators of water quantity, exist, although demands for supply and resource inventory prevail when discussing water security [65]. The water security definition sets grounds for sustainable planning and continuous governing of water resources to ensure enough good quality water for sustaining humans, animals, plants, and other organisms of an ecosystem at a watershed level. Water security is about benefitting from water availability for both humans and ecosystems while limiting potential risks. In other words, water security is the sustainable and consistent presence of sufficient and acceptable quality water for humans and the ecosystem, as well as safeguarding resources for future generations [67].

Water governance is making and implementing decisions/policies on quantity, quality, time, procedure (infrastructure), and the right to water by people. Water governance is critical to water security and the long-term sustainability of Earth's freshwater systems [68]. Over time, the definition of water governance has been disputed by practitioners and researchers alike [29]. Therefore, international debates in conferences and the literature have discussed opinions from various schools of thought to adopt and interpret water governance from varying agreed-upon and conflicting perspectives [69]. Political, social, economic, and administrative systems designed to use and manage the water of a watershed refer to water governance that involves laws, statutes, rules, and regulations to ensure the rights and obligations of ecosystem members about the use of available water. According to the Stockholm International Water Institute of the United Nations Development Programme (SIWI-UNDP), good water governance addresses the formulation, establishment, and implementation of water policies, legislation, and institutions, and clarifies the roles and responsibilities of government, civil society, and the private sector concerning water resources and services [70]. Water governance is recognized as a critical contributor to the long-term sustainability of water resources [71].

From a management perspective, water governance has been referred to as process and outcome, for example, it has been defined as the system that determines who gets water, when and how, and who has the right to water and related services and their benefits [72]. Jiménez et al. [29] have reviewed the term's use, to reveal how the concept of water governance is understood, referred to, and implemented in practice by different stakeholders. The definition of water governance was also rephrased by Bakker and Cameron [73] as the processes of political, organizational, and administrative setups through the interest of the stakeholders as articulated by communities through their interests, their input, and decisions. This definition was adapted from Rogers and Hall [74], who made decisionmakers accountable for decision making and implementation of the development and management of water resources, as well as the delivery of water services, as per the definition of water governance by Bakker [75] and Norman et al. [76].

2. Methodology

For this article, a comprehensive literature review has been conducted to encompass "Water Dimensions, Security and Governance for Two Distinct Regions". The non-arid Canada and arid Qatar regions were taken as the two distinct regions for this review. These two regions historically face identical as well as distinct challenges in finding sustainable solutions to water-related issues as learned from the literature. Access to safe drinking water and planning to meet agricultural water needs have been the major challenges for these regions. Addressing these challenges has resulted in immense pressure upon the valuable and water resources of these countries and worldwide. Peer-reviewed publications were searched through the Scopus database covering the period 1986–2022. Library databases and collections of the University of Prince Edward Island and University of Doha for Science and Technology were also searched to review the related literature. Keywords for the database search were limited to the English language. Journals, conference proceedings papers, and book chapters were selected for the source type. Canada and Qatar-specific articles, conference papers, book chapters, books, and reviews were selected for the document type. Selective keywords included water policy, water governance, water dimensions, water security, food security, sustainability, resource management, safe drinking water, adaptability, climate change, arid versus semiarid environments, water resources, and others.

3. The Water Dimensions

Canada has been peacefully resolving its transboundary water issues with its only neighbor the U.S. [77], and is not involved in any water politics with regard to transboundary water disputes unlike other countries, e.g., the U.S. and Mexico, India and Pakistan, India and Bangladesh, and Iraq, Syria, and Turkey who are in conflict for the use of water of the Rio Grande [78], Indus [79], Ganges [80], and Tigris-Euphrates [81] Reivers, respectively [82]. Although most water conflicts revolve around water quality versus quantity and surface- versus groundwater, the Canada–U.S. transboundary water issues have been resolved for water quantity and surface water challenges [77]. This may be because the water quality and groundwater issues are challenging to resolve, as a community-wide approach is needed to save the surface- as well as groundwater from pollution. Within Canada, the political dimension controls the rights of the water stakeholders in society for opportunities in decision-making processes to enhance the chances of effective implementation and conflict resolution. With all racial groups, including visible and non-visible minorities, and Indigenous people, water governance activities are key to a stable political system in numerous countries. Wilson et al. [83] are of the opinion that in addition to acknowledging the political dimensions of water security, Canada needs to engage with its Indigenous peoples for broader hydro-social relationships through holistically using traditional freshwater resources including mountain creeks and springs.

The environmental dimension speaks about meeting the water and the related needs of the current generation without compromising the ability of future generations to fulfill their water needs. Canada is fortunate enough to have sufficient availability of freshwater resources, but it is not exempted from its responsibilities for their sustainable use. Emphasis is needed to safeguard them from deterioration due to pollution caused by anthropogenic activities including conventional agriculture, urban sprawl, and enhanced industrial activities to fulfill the needs of the increasing population. Furthermore, some indirect environmental effects can pose challenges to adopting sustainable agricultural practices, such as supplemental irrigation and increased greenhouse emissions [19]. However, Notaro et al. [84] suggested that the use of modern, automated, and energy-efficient water supply systems can eliminate water leakages, and thus adverse environmental impacts of agriculture on the environment. Bhatti et al. [19] presented an overview of climate change-induced hydrological variations in Canada for irrigation strategies and concluded that supplemental irrigation should replace the least efficient surface irrigation systems. Farmers in the Canadian Prairie provinces seldom use basin irrigation for agriculture. This may not be a potential step for farmers of other provinces of Canada and Qatar where irrigation is operated using advanced irrigation systems such as drip and sprinkler methods, but rather for developing countries where basin irrigation is broadly practiced.

Qatar is not fortunate in terms of the availability of an abundance of freshwater resources. The social, economic, political, and environmental dimensions remain the responsibility of the government, which efficiently manages the equitable use of water, providing equal domestic opportunities for the sustainable use of the available water. However, water-related issues remain on the surface. For example, because of less rainfall, there remain limited freshwater resources, which in combination with unsuitable agricultural land, prohibit farmers from practicing conventional agriculture, thus forcing the government to import a huge proportion of food items annually [85]. The literature [39,85] further concludes that groundwater in Qatar is dominantly used for agriculture purposes, i.e., 24% from groundwater abstraction is mainly for agriculture, whilst domestic and industrial water needs are met with treated water, e.g., 61% of the total water supplies comes from desalinated seawater mostly used as drinking water. Furthermore, 15% of the total water is produced from sewage effluent treatment plants for landscaping irrigation and agricultural use. As Mustafa [85] resolved for Qatar, the near-absolute reliance on food imports and water desalination makes it a stand-alone scenario with the main strategy being to achieve food security.

4. Water Security

Canadian water security can only be assured by ensuring sustainability in water use for all aspects of change (environmental, societal, and climatic). With regard to Canada's water security, it is essential to understand its physical and regional geography, i.e., the culture, economy, people, and many other factors contributing to the environment of that region. The overall Canadian population is not uniformly distributed: the southern border is more heavily populated in comparison to regions with less favorable physical conditions in the north. Physical conditions play a vital role in determining population size, as people opt to settle in areas with promising opportunities and favorable environments. Canada has six regions, and it is necessary to understand the physical geography of each of these with respect to their regional geography. Starting from the west, British Columbia's coastline allows it to be an ideal place for tourism. In the Prairie region, it can be seen how important mining is in its regional geography, which solely results in the opportunities in its physiogeographic regions of the Interior Plains and Cordillera. The location of Ontario and the presence of the Great Lakes allow it to have a favorable temperature, experience all four seasons, and receive a good amount of annual precipitation. This physical geography is the reason behind Ontario's dense population, as it attracts people by creating opportunities. An important characteristic of Quebec's physical geography is the forest products of the Canadian Shield. The lands of the Cree and Innuit also lie in Quebec, and therefore many Cree and Innuit individuals are present in Quebec's population. Atlantic Canada's physical geography allows it to play an important role in Canada's fishing and tourism industry. In addition, the arable land of Atlantic Canada allows it to play a significant role in the agriculture sector, producing crops such as potatoes, berries, and apples. The Territorial North exhibits a consistent cold environment, hence categorizing itself in the sparsely populated zone.

A growing body of literature has historically reported inconsistent pressures of water insecurity on Indigenous peoples compared with non-Indigenous peoples [86–91]. The literature has also addressed water security for Indigenous peoples from the lenses of research and policy [92–96]. Wilson et al. [83] presented a detailed discussion on the water security issues of the Indigenous peoples of Canada by relating them to the quality component of water security that is always discussed in terms of the treatment of drinking water before it is supplied to the household for domestic use. The literature has reported that such water treatment is the only solution for safe storage but remains objectionable for Indigenous people [97]. The chlorination of water might not have been objectionable because of scientific reasons but rather for political reasons by the First Nations of Canada [98]. As Linton [98] suggested, the water crisis may be resolved by reinvesting water with social content, thus altering the way the water is seen.

Water security is a major challenge in Qatar, as outlined in the Qatar National Research Strategy [99]. The Qatar Foundation [99] presents three pillars for water security including (a) desalination and water treatment, (b) water quality and reuse, and c) groundwater aquifer recharge. The objectives of these three categories are to (i) reduce desalination energy consumption and cost by 40%, (ii) increase water quality and reuse by 30%, and (iii) elevate the groundwater table to the 1980 levels, respectively. Strategies to achieve the objective of reducing desalination energy consumption and cost by 40% are promoting the use of (i) high-performance hybrid systems, (ii) reverse/forward osmosis, (iii) solar thermal desalination, and (iv) new membrane materials. Strategies to achieve the objective of increasing water quality and reuse by 30% are (i) the quality of raw water, (ii) optimized treatment processes, and (iii) assured quality for different users. Strategies to achieve the objective of elevating the groundwater table to 1980 levels are (i) computational subsurface modeling, (ii) soil characterization and water/contaminant interaction, and (iii) groundwater assessment.

Social aspects of water security in the Gulf States including Qatar do not appear in the literature, as for the Levent region which includes Lebanon, Syria, Iraq, Palestine, and Jordan [100]. Engineering and technical approaches focus on desalination plants [101], while the recent literature [27,102–104] suggests not overlooking policy action in the context of food security concerns raised during the geopolitical blockade of Qatar. Qatar, in recent years, has realized the importance of food security for its national sovereignty and has developed many strategies to achieve this, despite many regional and international problems. Having the balance between implementing these strategies and creating and/or using water resources efficiently is also another challenge regarding food security in this nation. Water is further needed for expanded landscaping in Qatar. The plantation of 9 million trees for a net zero carbon emission FIFA World Cup will need additional water, especially during the initial years of root establishment of these trees. Proper irrigation scheduling based on a scientific approach to plant water requirements and the application of the right amount of water at the right time have a sustainable way of water use in Qatar.

5. Water Governance

Water governance is essential for efficient water management [28], having a due place under natural resource management [29]. Bakar and Cook [105] argued that water governance in Canada is characterized by a high degree of fragmentation because of decentralized approaches to environmental governance. It is broadly understood that collaborative environmental governance comprises approaches that are characterized by deliberation among various actors and a desire to achieve consensus in environmental decision making [106–108]. Climate change challenges will increase water use, needing special consideration in the sustainable use of water resources to address quantity and quality issues of drinking water, and the municipal water supply needs for society other than drinking, such as industrial and agricultural use.

Hussein and Lambert [37] produced a very informative discussion on water issues and governance in Qatar. According to them, no problems have been reported about the water supply in the country. This can be taken as good governance of water in Qatar, despite its scarcity in this arid region with the continuous expansion in water consumers. A prominent example of good water governance has been quoted as, "Urban water supply in Qatar largely comes from desalination, which increased from 35% of total consumed water in 1990 to 59% in 2014 [109]. Almost all the fast-increasing water demand of the past decade, when the population doubled between 2007 and 2011, has been met by increasing desalinated water quantities. This trend has remained since, although at a slower pace over the past decade, yet still with a growth of 38% between 2012 and 2017 [110]".

Food security initiatives outlined in the Qatar National Food Security Program (QNFSP) [111] and Qatar National Vision 2030 (QNV-2030) [112] will need an abundant backup supply of irrigation water. Limited groundwater resources may hinder this supply. However, regional challenges such as the blockade imposed on Qatar in 2017 and the restricted imports and skyrocketing prices of food items have raised serious concerns about food security and food self-sufficiency in the country. Additional food demand due to the increased population, visitors, and foreign workers add to the need of safeguarding Qatar's food security and self-sufficiency.

The productivity of outdoor agriculture in Qatar is greatly hindered by threats of extreme summer temperatures, poor quality and scarce irrigation water, and non-fertile soil. The productivity of indoor agriculture (i.e., greenhouse farming) has the potential to contribute to the QNFSP and QNV-2030 efforts to attain food self-sufficiency in Qatar [111–113]. Greenhouse farming is actively promoted by the government, but conventionally operated greenhouses are less productive than modern greenhouses. The conventionally operated greenhouses will thus be unable to fulfill the country's food demand, while efficiently managed greenhouses facilitating indoor and controlled agriculture in such situations have the potential for success and can ease the demand for additional water for agricultural activities [20].

5.1. Drinking Water

The sustainable use of water resources requires regulations for the management of water systems that provide numerous benefits to society in terms of water-related services important for human well-being [114,115]. The human right to equitable access to safe drinking water was first recognized back in 2010 by the United Nations (UN) General Assembly and the Human Rights Council and is seen as binding international law [66,116]. More recently, the UN's Sustainable Development Goal #6 targets "universal and equitable access to safe and affordable drinking water for all" by the year 2030 as part of a global agenda to which all nation-states are signatories [117]. Irvine et al. [118] discussed transferrable principles to revolutionize drinking water governance in First Nations communities in Canada and identified specific challenges facing First Nations drinking water management in Canada that will serve to protect the health, promote culture, and move toward equitable governance structures and sustainable practices.

The management of drinking water involves the supply of the water and advisories about the quality of the drinking water. International bodies to which a country has membership emphasize its member countries must take care of the environment and people in one way or the other. Canada has membership in international bodies including the United Nations, G8 (the Group of Eight), and the Organization for Economic Co-operation and Development (OECD), among others. Only Canada in the G8 and the 37-member OCED does not have legally enforceable federal drinking water standards [105]. Four out of ten provinces meet voluntary federal standards; fewer than half of Canadian provinces and territories require "advanced" treatment of surface water, which is standard practice in the European Union and the United States [119].

All levels of government in Canada and First Nations share the responsibility to implement multi-barrier protection of drinking water [120]. About 100 First Nations communities survive on boil water advisories in Canada [121]. The recommendation to boil water means that the water in your area does or may contain disease-causing bacteria. Advice may include information about food, drink, or how to make ice cream; washing dishes; or hygiene such as brushing teeth and bathing [122]. In 2007 alone, there were 1766 boil water advisories across Canada in small towns, cities, and townships, some of which had been in place for more than 5 years, as well as 93 boil water advisories for First Nations communities [123]. According to the Conservation Ontario report, Canada's groundwater reserves are not completely mapped, and groundwater quality monitoring is highly variable across the country, thereby risking the water rights of more than 10 million Canadians who depend on groundwater for drinking water.

Groundwater is one of the purest sources of drinking water. Climate change-induced high temperatures and low rainfall in arid zone countries, such as the Middle Eastern countries including Qatar, cause high rates of evapotranspiration and low groundwater recharge [124,125]. Specifically, for the Middle Eastern countries including the Arabian Peninsula and Iraq, low rainfall has resulted in periodic droughts [126–129]. As mentioned earlier, Qatar encompasses a dry and hot peninsula that does not have fresh surface water resources such as streams or rivers. Its only freshwater source remains the groundwater, with an annual groundwater recharge from a meager rainfall of about 72 million m^3 [130]. Climate change impacts on rainfall, groundwater, and communities are not new but have been reported for countries in the north and northwest of the Arabian Peninsula including Syria, Africa, Lebanon, Jordan, and Morocco [130–133]. Therefore, arrangements for drinking water from groundwater sources will remain challenging for countries in this region; however, the climate change impacts bring rainy clouds to Qatar and make a new pattern of intense rainstorms leading to continuous groundwater recharge at a large scale.

Drinking water safety plans ensure the quality of drinking water meets the World Health Organization (WHO) drinking water standards. The WHO water safety plan approach for drinking water management represents an alternative preventative management framework to the current conventional and reactive drinking water management strategies [134]. This approach has seen successful implementation throughout the world and has the potential to address many of the issues with drinking water management [135]. Bereskie et al. [136] conducted a strengths-weaknesses-opportunities-threats (SWOT) analysis of drinking water management and governance in Canada at the federal, provincial/territorial, and municipal levels, and proposed a modified water safety plan (defined as the plan-do-check-act (PDCA)-WSP framework), established from water safety plan recommendations and the principles of PDCA for continuous performance improvement. Their PDCA-WSP framework aims to strengthen Canada's current drinking water management and to fit and integrate into existing governance structures.

5.2. Municipal Water Supply Other Than for Drinking

The municipal supply of water is important for sustainable community development and needs an efficient structure for water supply systems. An efficient municipal water supply system can protect public health; meet industrial, commercial, and residential needs; and maintain environmental quality [73]. Narain [137,138] emphasized that good governance provides the base for the efficient functioning of organizations, reinforcement of existing rules and adapting of new rules, conflict resolution, trust development for sustainability, and accountability of functions involved in water supply decisions. Different business models for water supply infrastructure in Canada have been presented by Bakker and Cameron [73] (p. 488), along with principles for good governance pertinent to water supply management, as explained by Joe et al. [139].

This energy–water interaction with limited water resources is especially peculiar across the globe, but also in extremely high use rates, such as in Qatar, which provides a unique case in terms of extreme water scarcity and excessive water use [18]. For the areas of extensive water use, the low water quantity and quality often result in the decline of human well-being, which may lead to social tensions, disputes, and potentially acute conflicts, especially in urban environments where the population density and water demand are extremely high [140]. Therefore, a comprehensive system of water supply can avoid water conflicts. For example, Sun et al. [141] constructed a comprehensive national-scale water assessment and management system through system dynamics by developing five subsystems (economy, population, water supply and demand, land resources, and water pollution and management) that affect the sustainable utilization of water resources. Their system, according to the authors, provides a balanced development program to achieve not only steady economic growth, but also a demographic dividend by protecting arable land resources, maximizing the sewage treatment rate, and improving the reutilization efficiency of water.

Municipal water supplies other than drinking water in Qatar are sourced from wastewater treatment and water desalinization plants. It is believed that desalination is a more expensive option than wastewater treatment and reuse in terms of energy use [142]. According to UNESCO's World Water Assessment Program (WWAP), desalinization expenditure can be controlled through recycling and reusing, which lead to lower water demand and preservation of the water supply stock [143]. Another solution for controlling expenditures on water treatment and supply systems is to consider centralized versus decentralized systems. Simply, a centralized water treatment approach comprises a conventional treatment system combining processes of coagulation, flocculation, sedimentation, filtration, and disinfection to treat wastewater in a central location before distributing treated water for municipal use. On the other hand, a decentralized system treats water at the point-of-entry (PoE) and/or point-of-use (PoU). The PoE and PoU are installed at the individual home or business to treat potable water, as the PoEs treat the raw water before it enters the property or home, while PoUs are installed to treat water where needed, such as kitchen and bathroom taps [144].

Leigh and Lee [145] considered transitioning away from centralized water systems toward decentralized as one of the potential solutions to address municipal water supply issues. They suggest integrating or introducing multifunction systems with approaches of water reclamation, gray water recycling, and rain and/or stormwater harvesting. Sherawat et al. [146] explained that the efficient planning and implementation of regulations can lead to sustainable water resource management. This may include, for the municipal water supply, the allocation of treated water based on the quality needed to achieve the best water resource management and reuse, for example, as toilet flushing uses an estimated 20 to 30% of the household water consumed, lower quality water can be used in toilets.

5.3. Water for Agriculture Use

Approximately 80% of water used for both agriculture and potable use is sourced from local groundwater. The gross domestic product from agriculture in Canada averaged CAD 33,383 million (Canadian dollars) from 1997 until 2020, reaching an all-time high of CAD 48,264 million in December of 2020, from a record low of CAD 23,668 million in June of 1998 [34]. Climate change impacts over the past few years have increased discussion about the use of groundwater in rainfed regions of Canada for supplementary irrigation, which poses several challenges for water and resource managers.

The use of water for agriculture changes along the stretch of this widely non-uniform region concerning weather, soil, and the environment that favors different agriculture sectors. For example, the Prairie provinces of western Canada, where most of the arable land and cattle herds are found, are predominantly semi-arid, and therefore pressure on water resources can be substantial [147]. About three-quarters of irrigated land in Canada is in the Prairies, primarily Alberta and Saskatchewan, where in Alberta alone, with its large base of cropland, the beef cattle sector needs one-quarter of the water, leaving three-quarters for crop irrigation use [148]. Water used for the beef sector includes drinking, cleaning, waste disposal, and processing of products as well as for the production of feed crops and forages [149]. Eastern Canada, especially Atlantic Canada, has started realizing that supplementary irrigation is needed for crops during the summer months to optimize field crop production. Governance of agricultural water use must consider scenarios of climate change and their varying impacts on Canadian agricultural baskets. For agriculture, an abundance of water is available in the shape of surface- and groundwater resources. Therefore, water availability is not a challenge, but the required energy to pump groundwater and distribute irrigation water is. This can be addressed by adopting high-efficiency drip systems for horticultural crops, sprinkler irrigation systems for field crops, drip irrigation systems for row crops, and overall upgrading the existing water supply system to an energy-efficient supply system, i.e., systems with good quality sources, leak-proof distribution, and renewable energy sources, can ensure sustainable agriculture in Canada [150].

Global warming has created a dry continental climate, which harms crop production and yield. It is quite impossible to reverse the effects of global warming, but Canada can try its best to keep the situation from getting worse. The best way to overcome global warming is to decrease the country's overall greenhouse gas emissions. A major contributor to global warming is coal and fossil fuel production, and its use should be curtailed. This will have a positive impact on the country in its fight against global warming, and once increases in annual temperature are under control, any approach to natural resource management, such as water resource management, would suffice for decades.

For Qatar's agriculture sector, Bilal et al. [15] suggested that the use of desalinated water and wastewater reuse will reduce the country's dependence on groundwater. Darwish and Mohtar [35] divided water consumption in Qatar based on the sources and uses of water, for example, agricultural operations use groundwater sources; potable consumption is met from desalinated water; and the irrigation of crops and landscaping for parks, lawns, and livestock water needs are fulfilled from treated wastewater. In Qatar, the religious, social, and local marketing trends do not permit the use of treated wastewater for edible agriculture [151]; however, treated water has been used to grow fodder crops in some instances [18]. It is important to look at the usability of water from various resources in Qatar and develop a model to show the relationship between water resources, the economy, environmental impact, human health, and economic efficiency and effectiveness of water use.

6. Conclusions

Despite the limited literature availability about water challenges in Qatar as compared to Canada, this article assessed issues facing the two distinct regions, i.e., arid and non-arid, respectively. This review has stimulated a discussion on how one country could learn from the experiences of the other and vice versa. The characteristics of Canadian water resources are governed by the country's geography and paradigm shift in socio-economic factors. Therefore, challenges in devising sustainable approaches to water use are due to the following: the additional need for water to support economic growth; the importance of acceptable water quality in its provinces and territories; the imperfect water management system; and managing future climate change impacts. Policymakers have to consider factors that predict perceptions of risks associated with global climate change as examined by Stedman [152], and the involvement of the resource industry as described by Briscoe and de Loë [153]. Investments may be prioritized to redesign hydraulic structures and the drainage infrastructure of cities against a backdrop of rising rainfall intensities, and effectively disposing of peak loads. As documented by Bhatti et al. [150], intelligent and modern supplemental irrigation is required to fulfill rising crop water requirements caused by rising temperatures in the rainfed and prairie regions of Canada.

Selected results from the observations of the carried-out reviews include that (i) the modeling and projecting studies indicate no substantial acceleration of climate warming from permafrost degradation during the 21st century in Canada; nonetheless, Canada, similar to other high-altitude cold regions, experiences some of the most accelerated and intense warming resulting from global climate change [13,21]. (ii) The political and institutional dimensions of water governance need to be discussed, which may lead to exploring the relevance of social power that has been overlooked in the past, though it is an important aspect of the water security debate [68]. (iii) The solutions to water issues, such that Indigenous communities in Canada survive on high-risk drinking water systems followed by continuous drinking water advisories, need revisiting to ensure sustainable water security in Canada [86,87]. Canada is successfully managing its water resource issues. Qatar can learn from the experience of Canada as population growth, urbanization, and economic and technological development are putting constant pressure on energy, water, and food resources [15]. Furthermore, climate change, which can cause fluctuations in temperature and total annual precipitation, is one of the greatest risks to energy, water, and food security in Canada and Qatar. Reduced reliance on groundwater is critical to the sustainability of water-dependent sectors such as agriculture as the continued depletion of groundwater leads to saltwater intrusion and land subsidence.

Qatar's deprivation of freshwater resources is caused by low rainfall (~80 mm per annum), high evapotranspiration (~95% of the total rainfall) [154], and more groundwater withdrawal than recharge. This could worsen if water conservation techniques are not promoted. The country is among the world's top per capita water consumer nations, and its water requirements are met by seawater desalination (61%), groundwater abstraction (24%), and sewage effluent treatment plants (14%). This assessment showed the government could save resources on expensive desalination by convincing communities to increasingly use economically viable treated wastewater, e.g., landscaping, etc. Fortunately, Qatar's government has long been aware of the importance of water security, as recognized in the 2012 Qatar National Research Strategy and in 2014 as one of the country's grand challenges. Water conservation needs were experienced with the crucial 2017 blockade (when local food production was planned), and the additional water consumption needs of industrial (real estate) projects (while FIFA 2022 World Cup-related developments were at a full peak), foreign workers/visitors, and extended landscaping/agricultural irrigation. Food self-sufficiency targets set in the QNV-2030 will additionally need more water in the future. It was realized that Qatar would have different difficulties such as social structure, cultural behavior, environmental changes, overall country size/topography limitations, and political pressure in comparison with Canada. However, from assessments of the similarities and differences, it was shown that sustainable solutions for water resource management for both arid and non-arid regions can be similarly achieved through the consideration of water dimensions, security, and governance. The challenge of balancing the infinite demands of water with its finite resources on the planet is and will remain a concern for many countries, including Canada and Qatar, since it is a life-sustaining natural resource [155,156].

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