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ORIGINAL ARTICLE

A critical analysis of the food–energy–water nexus in the Kootenai River Basin

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Abstract

The paper has applied Food–Energy–Water (FEW) nexus in the Kootenai River Basin—a basin located in greater Columbia River Basin shared by Canada and USA—to explore how the institutional, stakeholders, and environmental aspects are represented within the basin. Despite the wide application of FEW nexus, the authors argue that the nexus concept has failed to capture the social dimension such as emotions within the basin. Furthermore, although the FEW nexus is a broader concept encompassing a wide range of actors, the FEW concept was unsuccessful in integrating indigenous and tribal communities into the nexus framework. Finally, the authors assert that FEW nexus should be further explored to incorporate social and environmental dimensions such as the role of various stakeholders, e.g., tribal communities, fishery, and biodiversity, into the nexus framework in the Kootenai River Basin.

Keywords Kootenai River Basin · FEW nexus · Stakeholders · Climate change · Emotions

Introduction

Originating in the Rocky Mountains of British Columbia, the Columbia River flows approximately 2000 km (1245 miles) from the United States (USA) to Canada before emptying into the Pacific Ocean. With a catchment area of 671,000 km^2 (259,000 mi^2)—almost the size of France—the Columbia River is the largest river in the Pacific Northwest and the fourth largest river in the US (Cosens 2016). While 15% of the basin is located in British Columbia, Canada, 85% of the basin lies in the USA, covering some portions of Washington, Idaho, Montana, Nevada, Utah, Oregon and Wyoming (see Fig. 1). Despite the fact that only 15% of the Columbia River Basin lies in Canada, 50% of the peak flow and 38% of the average annual flow originate in Canada (Barton and Ketchum 2012).

The Columbia River Treaty which was signed by Canada and the US in 1961 and entered into force in 1964, is considered one of the most complicated transboundary water agreements in the world (McKinney 2012; Shively and Thompson 2015). The purposes of the Columbia River Treaty were to generate hydropower and to establish flood control facilities in the USA and Canada (Givens et al. 2018). Both countries established entities to coordinate the management process of the treaty (Shurts 2012). British Columbia Hydro, a provincial corporation that generates hydro-electricity in British Columbia, is the Canadian entity, and Bonneville Power Administration and Northwest Division of USA Army Corps of Engineers are the joint USA entities that facilitate the coordination and management of the Columbia River Treaty. Although there is no specific termination date for the treaty, it is up to both countries to either terminate, renegotiate or modify the Columbia River Treaty beginning in 2024 (Bankes and Cosens 2012; Shively and Thompson 2015). Starting 2024, the adopted flood control mechanism

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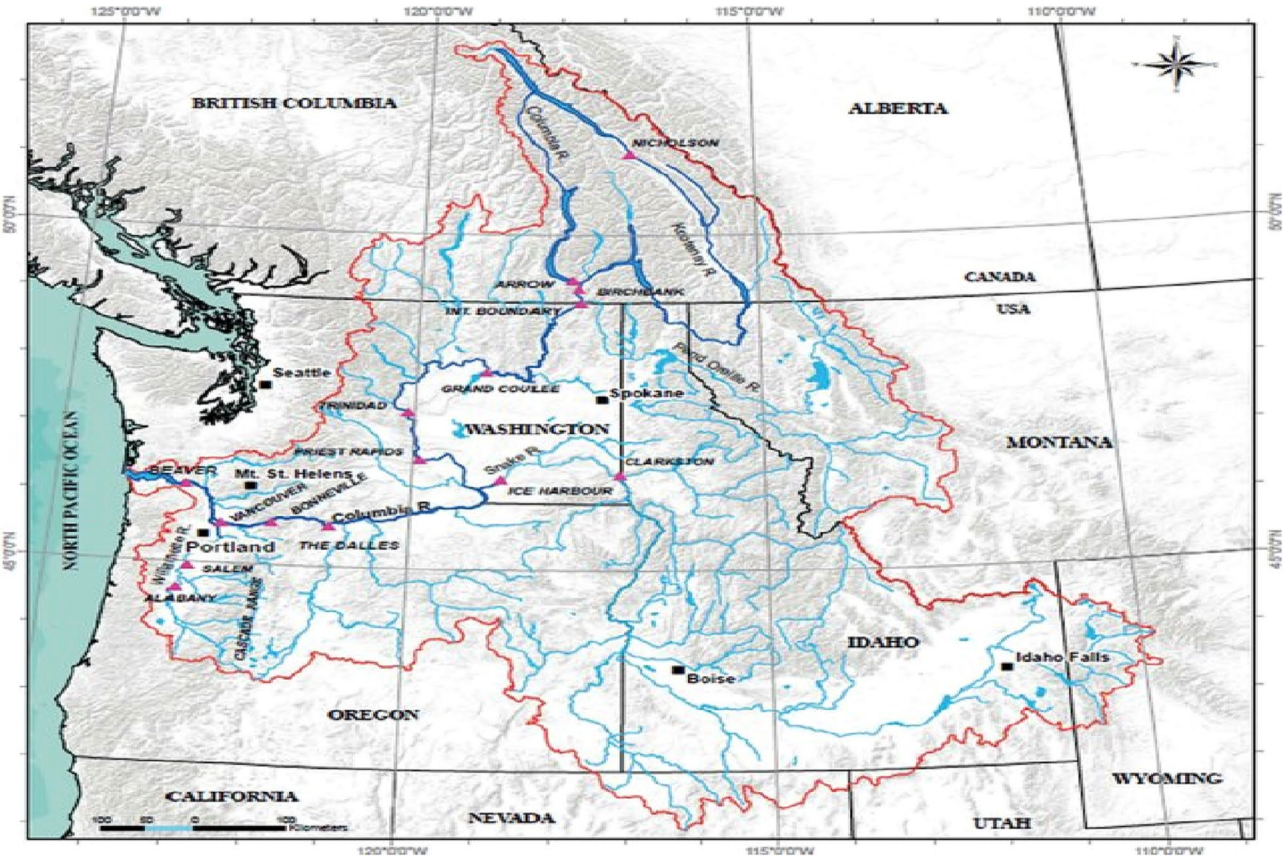

Fig. 1 Columbia River Basin. Source: Jay and Naik (2011)

of the Columbia River Treaty will automatically change, which will affect hydropower generation within the Columbia River Basin (Shively and Thompson 2015). For this reason, the USA and Canada have already started reviewing the treaty to assess management options for the Columbia River Basin (see also Givens et al. 2018).

The basin encompasses a number of sub-basins such as the Yakima River Basin, and the Kootenai (Kootenay) River Basin, to name a few (Anders et al. 2007). This paper will focus on the Kootenai River Basin (see Fig. 2), which has a catchment area of 41,906 km^2 (16,180 mi^2). Almost 70% of the Kootenai River Basin is located in British Columbia; approximately 7% of the basin is situated in northern Idaho, and 23% of the basin is located in northwestern Montana (Anders et al. 2007; Knudson 1994).

Communities within the basin have experienced environmental transformation from water for agriculture and water for energy. In combination with dramatic climate changes, the area is facing a number of severe environmental crisis like degradation of the ecosystem, decline in fish species, and wildlife concerns. Furthermore, the original treaty ignored the effective participation and engagement of indigenous communities whose livelihoods are highly dependent on the river (Cosens and Williams 2012). These issues, including the degradation of habitat, disappearance of fish species, and involvement of multiple communities within the Kootenai River Basin are examined in detail in this paper.

The Kootenai River Basin is home to multiple sectors, including agriculture and hydropower, which can be viewed as important parts of the Food–Energy–Water (FEW) nexus. The FEW nexus serves as the conceptual framework of our analysis. First, this paper explores the USA–Canada transboundary water management relationship through assessing the legal and institutional frameworks within the basin, and delves into the emotions behind different decisions. Next, we use the FEW nexus concepts to evaluate how different stakeholders, such as indigenous and tribal communities, environmental advocates, agriculturalists, industries and fishing communities are engaged and represented in the Kootenai River Basin. Finally, we use the nexus concept to explore environmental considerations in the Kootenai River Basin, with special attention to impacts of climate change and wetland ecosystems. By applying the FEW nexus in such unique location, the authors aim to assess whether the nexus concept can fully explain the current dynamics in the Kootenai River Basin, and make recommendations

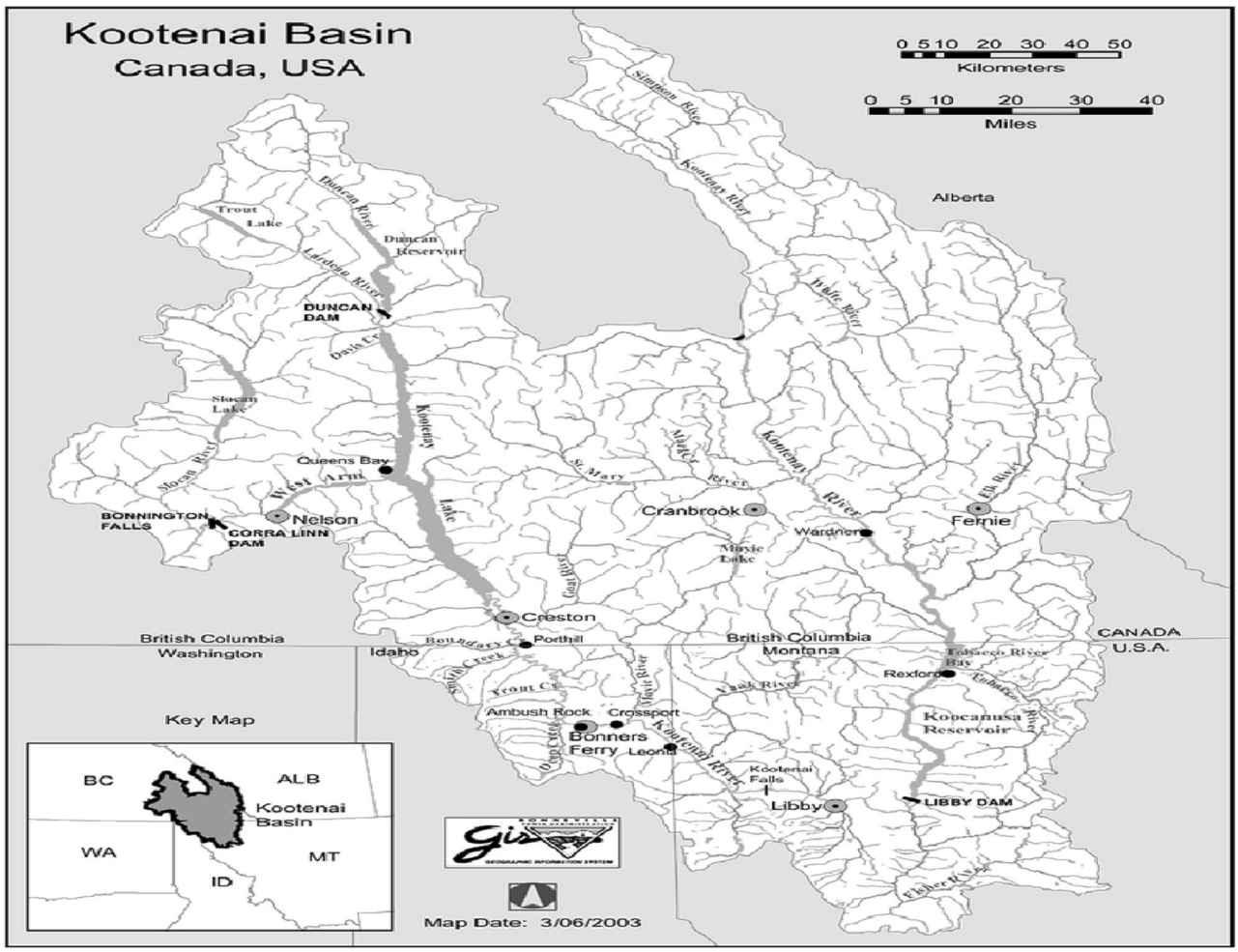

Fig. 2 Kootenai River Basin. Source: Anders et al. (2007)

to enhance the application of the concept in this specific locality. To apply the FEW nexus concepts to the Kootenai River Basin, the authors will examine a variety of resources including journal articles, newspapers, scholarly articles, websites, and reports.

Conceptual framework: Food–Energy–Water nexus

Water is the most important resource for the well-being of humans and nature, and its scarcity due to mismanagement and excessive use threatens the livelihood of people (Brauman et al. 2016; Haddeland et al. 2014; Pushpanjali et al. 2019; Shumilova et al. 2018). Shumilova et al. (2018) note that the world will face a roughly 40% deficit in water supply in 2030 from a '*business-as-usual perspective.*' Moreover, at the global scale, freshwater is unevenly distributed (Rodell et al. 2018). The unfair distribution of freshwater, as noted by Schewe et al. (2013), will be further deteriorated due to the changes in precipitation patterns—in the form of seasonal and inter-annual variabilities. In addition to the severe decline in the quantity of freshwater, Shumilova et al. (2018) assert that the quality of freshwater is compromised due to massive industrial, agricultural, and urban pollution, which further limit the availability of freshwater for ecosystem and human needs (see Pushpanjali et al., 2019). In line with the argument of Shumilova et al. (2018), Rasul and Sharma (2016) contend that the Rio Declaration, "The Future We Want," emphasizes the inclusion of social, economic and environmental crises into economic development. Given the dramatic climate crisis, the Rio Declaration also stresses a holistic approach for managing food, water and energy production in a way that minimizes negative implications on the ecosystem.

While the demand for freshwater is significantly increasing, the available freshwater at a global scale is presumably constant. According to the UN World Water Development Report (UN-WWA 2014), with the increase in population, the demand for water is linked with the high

demand for energy and food production. Water and energy are the two most important driving forces for food production. Shumilova et al. (2018) note that at a global scale, irrigation alone contributes to almost 70% of the withdrawal of freshwater from rivers and aquifers, however, the amount of freshwater withdrawn for the purpose of irrigation varies from one continent to another. Furthermore, almost 30% of the generated energy is utilized for food production and supply chains.

Shumilova et al. (2018) note that roughly 15% of the world's total water withdrawal was used for energy production in 2010 and it is envisaged that the global water withdrawal for energy generation will boom by 20% in 2035 (see also UN-WWA 2014). Thus, the World Economic Forum (2011) has recognized tradeoffs between food, energy and water as the most important development barriers for the growing population in the face of climate change (see also Rasul and Sharma, 2016). It is estimated that the world population will reach 9.8 billion people by 2050, of which 66% of the population will be living in urban and peri-urban areas. The dramatic increase in population will trigger an almost 50% increase in food production (UN-Food and Agriculture Organization (FAO) 2017), roughly 61% increase in energy demand, and 55% increase in water demand (cited in Shumilova et al. 2018).

Tabatabaie and Murthy (2020) believe that to enhance the effectiveness of Food–Energy–Water (FEW) Nexus, the interdependency between three of the sectors should be unraveled. For instance, when producing food, more water and energy are needed, or massive energy is needed to extract water from deep aquifers. According to Muller (2015), FEW nexus was first discussed at the UN Conference on Environment and Development (UNCED) in Rio de Janeiro, Brazil in 1992. Given the rapid population growth rate, globalization, urbanization and the adverse impact of climate changes, FEW nexus became more popular after the "Water Energy and Food Security Nexus-Solutions for the Green Economy Conference" (see also Hoff 2011; Endo et al. 2017; Tabatabaie and Murthy 2020).

Tabatabaie and Murthy (2020) argue that the nexus can be improved by increasing efficiency, decreasing the tradeoffs, and fostering cooperation and governance across the three sectors. As the three components of FEW nexus are inter-linked, the development of one sector will reduce the resources in the two other sectors (chang et al. 2016). Hence, it is very important to develop a sustainable plan that tackle all the needs without compromising or reducing the resources of any components (food, energy and water) (Wicaksono et al. 2017) in the context of Kootenai River Basin.

We chose the FEW nexus as the analytical framework of the paper to demonstrate, as stated by Pardoe et al. (2018), that the FEW nexus can help us to better understand the balance between water for energy and water for food production in the face of climate crisis. Pardoe et al. (2018) argue that the FEW nexus emphasizes on taking holistic and comprehensive approaches in decision planning to address the issues of water, energy and food production. Developing climate-sensitive adaptation strategies can help mitigate the adverse impact of climate change on agricultural, forestry, fisheries, freshwater availability, energy and industrial sectors. In the face of climate change, this paper, therefore, applies the FEW nexus to evaluate if the nexus concept can aid in understanding water uses in the Kootenai River Basin.

Institutions and emotions

The FEW nexus concept draws attention to the interdisciplinary character and interdependence of various factors in the basin, which further underlines topics that have been previously ignored. Leck et al. (2015) posit that political economic has been under-emphasized by the FEW Nexus. This could be the unwillingness of the political parties or the government to cooperate in a shared river basin, e.g., Columbia River Basin. Stirling (2015) further notes that "underlining that transformative social and political changes will be needed in addressing the Nexus successfully and that perhaps the real challenge is in bringing about the new "infrastructures, organizations, behaviors, markets, governance practices and even cultures" are needed.

However, it is not clear to what extent the human factor during the negotiation process is reflected by the FEW nexus. This concept is part of the contemporary mainstream environmental policy literature that assumes that researchers, policy makers and consumers involved in water decisions are all rational actors (Wolfe 2017). As a result, FEW fails to explain how social and historical events affect the emotions that influence people's decisions in complex environmental problems (Wolfe 2017). Emotion plays a fundamental role in the decision-making process (Vess and Arndt 2008; Dickinson 2009) and is fundamental for rational thinking (Mercer 2010). While the field of emotion is still evolving, the related studies from international relations field and political ecology theory may be incorporated.

The goal, here, is to introduce the history of water relations between the USA and Canada in the Columbia River Basin, which led to the signing of the Columbia River Treaty. Emphasis will be placed on the current period of re-negotiating the Columbia River Treaty principles. By presenting examples of behavior of the USA President, the closed Columbia River Treaty negotiation process and the group emotions expressed by Canada and the USA, the goal is to draw attention to the importance of incorporating the concept of emotions to the FEW concepts.

Institutional arrangements

The history of water conflicts between Canada and the USA dates back to 1812. The Oregon Treaty signed in 1846 as well as a number of disarmament agreements had a limited contribution to resolving the conflicts and maintaining peace in the basin (Johnson 1966). However, as both sides intensified their water development projects, disputes over shared water continued. As a result, Canada and the USA signed a 1909 Boundary Waters Treaty with the main goal of preventing potential future conflicts over water. This 1909 treaty established main principles for water sharing between the two countries and triggered the creation of the International Joint Commission (IJC). Canada proposed to have an impartial waterway commission that would function and make decisions independent from the two countries, but this was not supported by the USA whose states wanted to maintain control over the water allocation process. Therefore, the functions of the IJC are rather limited as it provides monitoring and administering services at the level of advisory opinion (McKenzie 2013). Overall, although these attempts contributed to constraining the potential conflict, both the USA and Canada continued to develop their water resources separately.

Several events contributed to a more intensified water partnership between the USA and Canada in later years. First, during the 1930s Great Depression in the USA, President Franklin Roosevelt promoted federal government action that would catalyze economic development and productivity (Vogel 2012). Second, in 1948 this region was struck by a powerful flood, which brought massive destruction all the way to Vanport, Oregon, killing 15 and displacing over 18,000 people downstream (Statesman Journal 2019). Third, in 1951 the USA applied to the IJC for approval to construct the Libby Dam on the Kootenai River. Although the dam would be built on the USA part of the basin, the reservoir would flood about 42 miles of Canadian land (Johnson 1966). This was the first time Canada made a claim for compensation of downstream benefits. Discussions over the Libby Dam included emotional moments, such as when the Chairman of the Canadian section of the IJC claimed that the USA "want(s) us to give them a gold watch for the price of a bit of tinsel" (Johnson 1966, p. 714).

Driven by the urgent need to develop hydropower and to control floods, the USA and Canada asked the IJC to work on the legal framework for potential improvements in the shared basin. This process resulted in signing the Columbia River Treaty in 1961. Based on this treaty, three dams (Duncan, Hugh Keenleyside and Mica) were built on the Canadian side and one (Libby) on the USA side, which also flooded part of Canadian territory. More importantly, the Columbia River Treaty incorporated the "downstream benefit" payments also called the "Canadian entitlement," according to which, in addition to the $64.4 million paid by the USA to Canada for flood control services, the USA would annually share half of the electricity produced downstream with Canada (McKenzie 2013). The two countries agreed that the USA power companies would purchase this electricity from Canada for the first 30 years (1973–2003), which would entitle Canada to an annual economic gain in the range of $120–$335 million (Economist 2018). The Columbia River Treaty was signed to last for 60 years with the requirement of ten years' prior notice for withdrawal or amendments.

With 2024 approaching, discussions between the USA and Canada on the fate of the Columbia River Treaty started in June 2018. In June 2020 the tenth round of negotiations on the Columbia River Treaty were carried out. It is an important period for both countries because, while the Columbia River Treaty has been praised as "one of the most far-reaching water development efforts in North America" (Fisher 1967) and "seen around the world as a model of transboundary cooperation" (Northwest Power and Conservation Council, (NPCC) 2010) there are also many deficiencies that require further consideration.

The role of emotions

The importance of emotions in decision-making can be illustrated in various ways based on the Columbia River Treaty negotiations. First, it is useful to remember that the Columbia River Treaty was signed during the time of President Eisenhower in the USA and Prime Minister Diefenbaker in Canada who were initially "eager to work together" (Economist 2018). On the other hand, it is unclear how the negotiations in the present days will proceed considering the "frosty relations" between Donald Trump and Justin Trudeau (Harper 2019). More uncertainty originates from Trump's recent withdrawal from the Paris Climate Agreement (Economist 2018), from the 12-nation Trans-Pacific Partnership that he called a "bad deal for American businesses, for workers, for taxpayers" (Laurier Institute for the Study of Public Opinion and Policy (LISPP) 2018) and from the nuclear deal with Iran that he also called a "horrible one-sided deal" (Stevens 2018). During discussions on the Trans-Pacific Partnership in particular, Trump called the Canadian negotiators "spoiled" and "difficult to deal with" (Economist 2018). It is unclear to what extent the emotions and attitude of the USA President will further affect the Columbia River Treaty negotiations.

Moreover, after the long talks about greater inclusion of different stakeholders into the Columbia River Treaty, it is suspicious that the negotiation process is closed to the

public and press and that details are not revealed by the officials (NPCC 2010). In addition, the tribal communities from the USA are not part of the negotiation and the three representatives of the First Nations from the Canadian side have only an observer status. The Chief Negotiator from the USA side Jill Smail has commented on this: "our foreign policy judgement is that the best way to manage the USA objectives and conclude a successful agreement with Canada in a timely manner is to limit the USA negotiating team to a small team of federal agencies" (USA Department of State 2018). However, if one examines the members of the negotiation groups from both sides, the main power utilities are the key participants despite not being federal agencies. The question arises: to what extent has the initial agenda of hydropower and flood control, on which the Columbia River Treaty was initially based, shifted towards wider inclusion, and has the perception of the Columbia River Treaty as a "business contract" changed at all (Pearkes and Rowlands 2020)? It is also important to underline that the interests of the USA and Canada are different because of different emotions attached to them. This is mainly related to the principles of Canadian Entitlement and Canadian feeling of environmental deprivation.

USA position–Canadian entitlement

Canadian Entitlement is the main topic of discontent raised by the USA power utilities (The Columbian 2017), which claim that power payments made to Canada are 10 times more than their actual worth (Statesman Journal 2019). This position is also supported by the USA officials. For example, Cathy McMorris-Rodgers and Peter DeFazio, who are part of the treaty negotiation process, claim that if Canadian Entitlement is not changed, "Pacific Northwest ratepayers will lose roughly $1 million every 2–3 days or about $150 million a year" (NPCC 2010).

Canadian position–reparations

On the other side, Canadians think that they should be compensated for historic wrongs done to degraded ecosystems, inundated communities and loss of land behind the dams (Statesman Journal 2019) and that the Canadian side has suffered more from environmental impacts than the USA (Vernon and Farquharson 2018). Moreover, when it comes to the Libby Dam, some claim that it is a "great Canadian giveaway" as Canada does not receive any monetary compensation for its flooded land nor have any management control (Pearkes 2020). Their geographic position and existing infrastructure, on the other hand, give Canada more confidence. For example, representative of Canadian negotiation team Katrine Conroy claims that "there is more at stake for the Americans than for us (Canadians)" (Metcalfe 2018).

Stakeholders

The Columbia River Treaty developed a framework aimed only at hydropower production and flood control activities (Shurts 2012; Shively and Thompson 2015). The framework includes little consideration of environmental aspects, such as ecosystems, wildlife and fisheries. Diminishing environmental values triggers concern among indigenous communities. For them, establishment of the treaty revealed economic, cultural and spiritual losses corresponding to the river and fishery (Shively and Thompson 2015). The fishery has high importance not only for tribal communities, but also represents economic value for the entire region. In addition, the interests of other stakeholders, such as farmers, commercial navigation, commercial recreation, recreational anglers and industries were neglected in the treaty (Shively and Thompson 2015). This section will examine the application of the FEW nexus for stakeholder matters.

Originally, the Columbia River Treaty intended to develop a complex instrument to oversee flood control and hydropower production for both the US and Canada (McKenzie 2013). However, over time, social values, as well as water distribution patterns, shifted. Although hydropower still remains an important sector, other interests like fish species restoration, agricultural expansion and drinking water are becoming equally important. These different uses shape water allocation patterns in the basin and require openness for input from stakeholders for the future planning of the Columbia River Basin (McKenzie 2013).

The Columbia River Treaty governs the construction and operation of dams in both the USA and Canada. Development of additional hydropower activities brings together eighteen different business groups, federal agencies, states and local municipalities (McKenzie 2013). However, few opportunities were developed for facilitating public participation. Public concerns mainly reveal needs for irrigation, drinking water and fish restoration. Raised societal concerns have transformed the initial goals of the Columbia River Treaty to include the strong interests of other parties and perspectives (Shively and Thompson 2015).

While Chang et al. (2016) argue that environmental, societal and economic factors have been adversely affected by the climate changes, Shumilova et al. (2018) and Tabatabaie and Murthy (2020) posit that FEW nexus has excluded many factors such as stakeholders. Tabatabaie and Murthy (2020) state, "Unfortunately, in most regions in the world, important decisions regarding FEW sectors are made without coordination due to institutional arrangements (Chang et al. 2016). Even within each sector, stakeholders are not connected and decisions are made without considering the consequences of those decisions on other stakeholders", *[e.g., farmers, ranchers, fishers* etc.*]*. In line with the argument of Shumilova

et al. (2018), Keairns et al. (2016) argue that to address the challenges of the FEW nexus, we have to consider "multi-dimensions, such as social, environmental, local, national business and technology dimensions.

Anadromous fish and the aquatic environment

Restoration of anadromous fish populations in the Columbia River Basin explicitly reflects the issue of competing interests. The man-made water storage facilities dramatically reduce the river flow which adversely impacts anadromous fish populations (Weaver 1997). Fish are prominent in the region from different perspectives. First, the commercial fishery brings benefits for state economies. Second, the anadromous fish represent a value on the food chain and are part of the ecosystem, representing environmental health. Reduction in the anadromous fish population leads to the disappearance of other species. Third, the fish plays a special role in the culture of indigenous communities. By exclusively focusing on flood control and hydropower, the Columbia River Treaty completely ignores fish (Weaver 1997).

The rights of indigenous communities to the fish are a significant factor to consider. Historically, indigenous communities, known as Yaqan Nukiy, were the first settlers of the Kootenai area. The Yaqan Nukiy is one of four Canadian and two US bands which form the Ktunaxa Nation. The Akisqnuk, Aqam, Tobacco, and Yaqan Nukiy are Canadian bands, and the Salish Kootenai Montana and Kootenai Tribe of Idaho are US bands (Lower Kootenay Band 2020). The traditional area of the Ktunaxa Nation is 70,000 km^2 (27,027 mi^2) within the Kootenai region of southeastern British Columbia and partially covers Alberta, Montana, Washington and Idaho (Lower Kootenay Band, 2020). Indigenous people signed a federal treaty around 1980s (McKenzie 2013). Although signed treaties give these communities some rights to the fish, they had to claim their rights by approaching courts. Finally, after 120 years, the court found that indigenous communities must be considered in the management plan (McKenzie 2013).

By the 1970s, reduction of fish populations jeopardized the interests of many stakeholders along the river, so the Northwest Power Planning Council (NPCC) was created (Weaver 1997). The NPCC represented stakeholders from different groups, however, it was later identified unsuccessful in addressing issues related to fish population decline (Weaver 1997).

Agricultural irrigation and drinking water

Federal funding promoted the growth of irrigation projects, which led to massive water withdrawals from the river. Almost 80% of water withdrawals are used for irrigation (Shively and Thompson 2015). The situation triggers conflict not only between irrigation and drinking water, but hydropower, fisheries, flood protection, and other uses. Even though the agricultural sector guarantees food security in the region, metropolitan water authorities argue that drinking water is the most important use (McKenzie 2013).

The FEW nexus and stakeholders

The FEW nexus is used to analyze the relationship of stakeholders with water in the Kootenai River Basin (see Fig. 3). The stakeholder element of the Kootenai River Basin has gained more attention recently (Shively and Thompson 2015). The nexus reveals the actors' vulnerability to activities which lead to substantial river flow changes in the Kootenai River Basin (see also Shively and Thompson 2015). Primarily, the operation of the energy sector has caused a wide range of environmental and social concerns, particularly the reduction of fish population that was of economic and cultural value to tribal communities. Although stakeholders interact with nexus issues in different forms, cooperation might offer helpful perspectives to elaborate nexus research and enhance its application (Hoolohan et al. 2018).

Factors such as biodiversity, tourism, people, navigation, ecosystem, fishery, water quality, etc. are inter-connected with each other and are classified under the main framework of FEW nexus.

Environmental considerations

When analyzing the Kootenai River Basin, it is essential to consider environmental components. This section will discuss the FEW nexus, with a specific focus on the role of wetlands and climate changes in the Kootenai River Basin. Wetlands can be seen as the nexus that links food, energy, and water (Ramsar 2013). Wetlands in the Kootenai River Basin play an important role in the environment. They allow for nutrients to flow between rivers and adjacent lands, provide storage for floodwaters, serve as habitat for wildlife, and also provide opportunities for recreation. However, the wetlands are severely impacted by dykes, and agriculture (Ramsar 2013).

Despite these stressors, the Kootenai River Basin is home to the Creston Valley Wildlife Management Area,

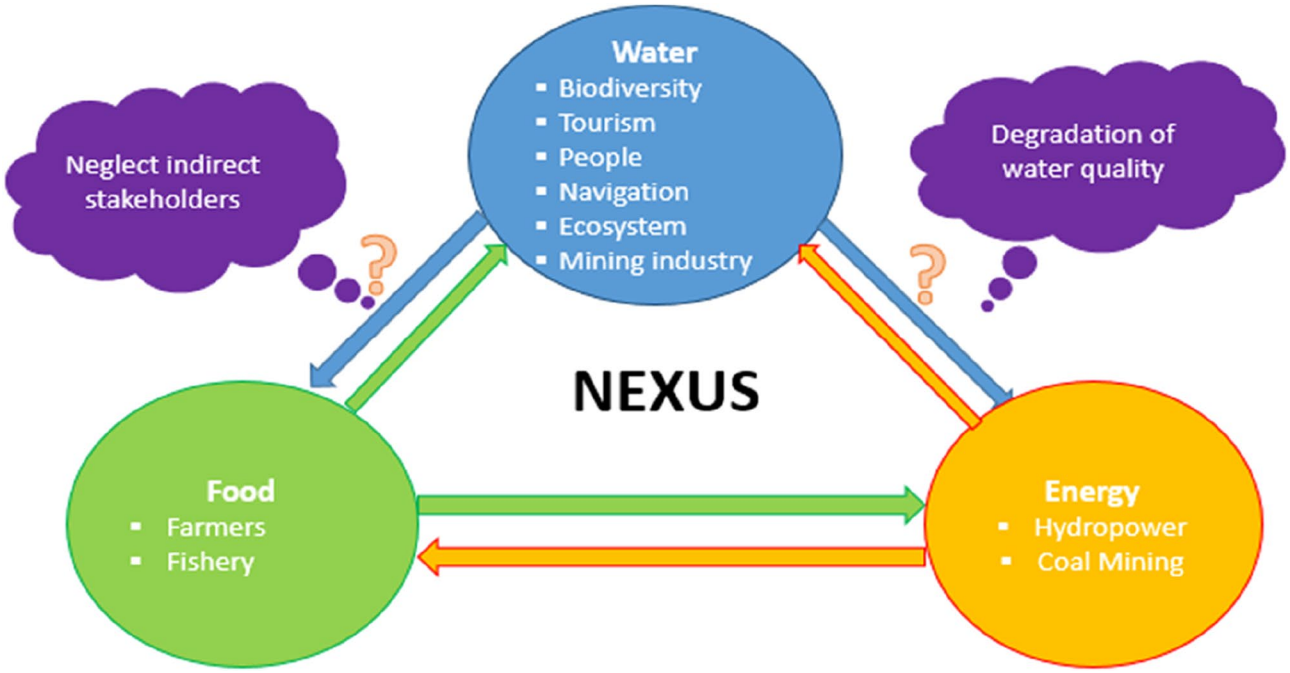

Fig. 3 Application of the WEF Nexus in the Kootenai River Basin. Source: authors' drawing. NOTE: The different colors have been used to highlight the three main components of FEW nexus

approximately 17,000 acres of wetlands that are designated as a Ramsar wetland of international significance. Wetlands are also protected and managed by the Kootenai Tribe of Idaho's Wetlands and Riparian Conservation Strategy. The updated 2011–2015 Wetland Program Development Work Plan of the Confederated Salish and Kootenai Tribes (CSKT) calls for "no net loss" of wetlands (CSK 2011).

Climate change puts a focus on the future reality of the basin and allows for consideration of the ways in which all aspects of the FEW nexus will be changed. Numerous studies (British Columbia Agriculture and Food Climate Action Initiative (BCAFCAI 2019); Pacific Climate Impacts Consortium (PCIC 2013); USA Bureau of Reclamation (USBR 2016) have assessed how climate change has already been observed in the basin and begun to establish a trajectory for probable future changes. Private and public entities on both sides of the international border are studying various aspects of the issue. Some of the most comprehensive studies include those of the Pacific Climate Impacts Consortium at the University of Victoria, the Columbia Basin Trust (CBT) in Canada, the USA Bureau of Reclamation, and the British Columbia Agriculture and Food Climate Action Initiative. General themes across this body of research include increasing temperatures, decreasing precipitation falling as snow, melting of glaciers, more extreme weather events, and a greater risk of wildfires (CBT 2017; USBR 2016). As of the early 2000s, mean winter temperatures across the Upper Columbia Basin had already increased by 1 °C as compared to the 1960s baseline value, and are estimated to rise another 3 °C by 2100 (CBT 2017). In the higher elevation areas of the basin, the percentage of precipitation that falls as snow has already decreased 5–10% and is expected to continue decreasing dramatically throughout this century (CBT 2017). Altogether, these changes are predicted to lead to lesser snowpack and drier summers, and to cause alterations in hydrologic regimes that could significantly impact late summer flows and increase the potential for wildfires in the region (BCAFCAI 2019; CBT 2017; USBR 2016). Such dramatic changes are bound to impact the FEW Nexus in multiple and entangling ways. A critical analysis of the food-energy-water nexus, with an eye toward wetlands and climate change, reveals interesting shortcomings of the nexus concept.

Food

The food component of the FEW nexus observed in the Kootenai River Basin is agriculture and fisheries. This section discusses these aspects of the food component and how they are interrelated with the issues of wetlands and climate change. The description demonstrates that it is impossible to speak of one component, for example agriculture, without giving attention to the others. Agriculture practiced in the basin is intricately connected to the surrounding environment and the hydrological regime of the watershed. Crops

and farm size vary across the basin: ranching dominates the landscape, along with smaller vegetable, barley, and oat fields and an emerging fruit tree sector (BCAFCAI 2019).

Approximately 22,000 acres of wetlands in the KRB have been converted to agriculture since the 1800s. Despite the limited overall percentage of basin land area devoted to agriculture, it does provide an economic base in the basin. Water for irrigation is sourced from precipitation and groundwater. Wetlands benefit agriculture by replenishing groundwater and surface water, which is an important consideration for the long-term sustainability of the agricultural sector. Since 1990, the USA Department of Agriculture has negatively reinforced wetland value by revoking benefits from landowners that convert wetland areas to farming (Kootenai Tribe of Idaho (KTI) 2004). The Kootenai Tribe of Idaho, together with the Kootenai Valley Resource Initiative, developed the Kootenai River Valley Wetlands and Riparian Conservation Strategy in 2004, an effort funded by the USA Environmental Protection Agency to bring attention to the ecological, economic and social benefits of wetlands (KTI 2004). This Strategy acknowledges that, although wetlands have been converted to agriculture, it would be detrimental to the community to restore the converted wetlands. Instead, the recommendation is to conserve existing wetland areas to prevent their further destruction.

From a climate change perspective, agriculture in the basin is predicted to both win and lose. A longer growing season and changes in temperature and precipitation could benefit some existing crops and allow for a new set of crops to be cultivated in the area, but the results of a changing climate are mostly foreseen to be detrimental to agricultural production (BCAFCAI 2019; PCIC 2013). Warmer and drier summers could also increase crop water demand, necessitate cooling facilities for livestock, and increase the risk of wildfires and pest infestations (BCAFCAI 2019). Increasing variability in precipitation and extreme precipitation events are predicted to lead to waterlogged soil, floods that damage crops and equipment, and disruption in supply chains that bring goods to market (BCAFCAI 2019; PCIC 2013). Those bearing the brunt of such changes are the farmers who will need to change grazing patterns, accept lower yields, and invest in water storage or flood protection infrastructure. In order to adapt to future agricultural impacts, the British Columbia Agriculture and Food Climate Action Initiative has published a "Regional Adaptation Series" in which it suggests actions for farmers and researchers to take. This campaign is limited to the Canadian portion of the basin and largely stresses knowledge-sharing, infrastructure enhancement, and preparedness planning (BCAFCAI 2019). On the other side of the border, the Confederated Kootenai and Salish Tribes have released a Climate Change Strategic Plan which includes goals such as evaluating and shifting towards alternative crops (CSKT 2016).

Fisheries in the basin are mostly for recreation—fly-fishing is a popular activity in the area. The Kootenai River is also home to the threatened bull trout, whose migration pattern is blocked by the Libby Dam (US Fish and Wildlife Services (USFWS) 2002). Fisheries in the Kootenai River Basin are negatively impacted by natural and man-made barriers and pollutants, which in turn are linked to wetlands systems. While some fish migration patterns are limited by natural barriers such as waterfalls, dams and culverts also obstruct fish migration (Walters 2004). Impacts to fisheries from the Libby Dam include change in water flow, fluctuation in nutrient levels, and change in water temperature (KTI 2004). Furthermore, fisheries are degraded by the release of toxic pollutants from open-pit coal mining. Waters such as Lake Koocanusa are listed as impaired due to the selenium in the water, released from mining, which bio-accumulates in fish (Mebane and Schmidt 2019). Wetlands mitigate these impacts by creating fish habitat, increasing the exchange of nutrients between rivers and riparian areas, and regulating water quality.

Climate impacts on fisheries are mediated by water temperature and water quality concerns. The Bureau of Reclamation has monitored several sites across the whole of the Columbia Basin and observed the negative effects of rising stream temperatures on salmonids (USBR 2016).

Energy

The energy sector is inextricably linked to food and water, as well as to wetlands and climate change. The Kootenai River Basin hosts twelve hydroelectric dams, the largest of which is the Libby Dam. Operation of Libby Dam is influenced by demands for power production, flood control, recovery of threatened fisheries, and recreational activities (Kootenai River Network (KRN) 2020). Dam operation complicates efforts to conserve wetlands by removing the natural seasonal variation of water flow. While wetlands do not threaten energy supply, the energy sector poses a huge threat to wetlands and efforts to restore them (USBR 2016).

The largest impact of climate change on the energy sector in the Kootenai River Basin will be the changing hydrological patterns and their repercussive effects on dam operation and hydropower generation. In their most recent assessment, the Bureau of Reclamation identifies that larger spring flows that could lead to more power generation than previously occurred during that time of year, but it could come at the cost of more water having to be spilled over once storage capacity is reached (USBR 2016). Conversely, a decrease in summer flows would lead to a decrease in power generation at an increasingly crucial time of the year (USBR 2016). The Bureau predicts a larger summer energy demand due to higher temperature in the region, increase in groundwater

pumping, and a growing population (USBR 2016). Many of the reservoirs in the region were built with the assumption that snowpack would act as a primary source of storage, but as snowpack decreases and more precipitation falls in the form of rain, reservoir and dam operations will need to adapt (CBT 2017; Jost and Weber, 2013; USBR 2016). Both government-run power companies like the Bonneville Power Authority and British Columbia Hydro will be impacted, as well as private entities (Jost and Weber, 2013; USBR 2016).

In addition to dams, mining operations in the Kootenai River Basin also strongly impact water resources, by posing a significant threat to water quality. Milling and the mining of metals and coal releases cadmium, copper, lead, zinc, and selenium into surrounding waters (KTI 2004). While many of the mining operations have been shut down, their legacy of polluted runoff and acid mine drainage remain as impaired water quality in tributaries of the Kootenai River. While not currently being considered as a remediation effort within the Basin, wetlands have been found to improve water quality through the uptake of toxics, such as selenium, by wetland plants (Baldwin and Hodaly 2003).

Water

The water component of the nexus encapsulates many other activities occurring in the basin, from recreation to flood control. Water demands from all sectors in the basin are poised to continue, or even grow as agriculture and populations expand (BCAFCAI 2019). The Bureau of Reclamation identifies potential challenges during the twenty-first century for all eight identified resource categories (Hydropower Generation, Reservoir Conditions and Water Delivery, Flood Control, Water Quality, Fish and Wildlife Habitat, ESA Listed Species, Ecological Resilience, and Recreation) (USBR 2016). Liu et al. (2015) emphasizes on the inclusion of ecological aspects of water, carbon and "planetary boundaries" into the FEW nexus. Additionally, Climate change and wetlands play important roles in exacerbating and mitigating these resource demands.

It is clear from the most recent assessments performed by the Bureau of Reclamation and the Columbia Basin Trust (CBT) that hydrological regimes in the Columbia Basin, including the Kootenai River Basin, are on the verge of significant changes. The greater ratio of rain to snow in the basin will cause spring runoff to spike while leaving the river largely depleted in the late summer (CBT 2017; USBR 2016). Most of the predicted impacts, including floods, water quality issues, and reservoir operation changes, will stem from this change in timing (CBT 2017; USBR 2016). The effects of climate change on groundwater in the basin require further study (CBT 2017), but it is likely that lower reservoir levels will cause greater reliance on groundwater in the region (USBR 2016). As mentioned in previous sections, wetlands have mitigating impacts in areas such as flood control and water quality, and their future role in the basin should be examined closely.

Conclusion

The FEW nexus concept was applied in the Kootenai River Basin through a series of explorations of institutions, stakeholders, and environmental aspects of the basin. This exercise allowed for an examination of the applicability of the nexus concept in this particular region, which is characterized by a number of competing water use sectors. It was found that the nexus concept was widely applicable, but several limitations also became apparent in the context of Kootenai River Basin.

The first limitation that became clear was the inability of the nexus concept to capture relevant human dimensions of activities in the basin, such as emotions. Management decisions and treaty negotiations that are relevant to the sectors of the nexus hinge on the relationships between key actors and the emotions of different groups. The FEW nexus stems from fields which largely consider individuals to be rational actors, and therefore the framework is ill-equipped to represent the nuances of human behavior.

The analysis of stakeholders revealed that the FEW nexus explicitly acknowledges the interdependence of actors within the system. However, it fails to explain possible consequences when it comes to the environment, which does not always have a human actor to speak for it. For example, the open-pit coal mining industry induces water quality degradation. The river and the fish themselves, as well as the tribal communities which use water for drinking, felt negative implications of mining operations.

In addition, although the FEW nexus is a broad concept which unites a wide range of actors under the same framework, those stakeholders who have no direct linkage with one of framework's elements can be easily disregarded. For instance, wetland ecosystems can be seen as the epitome of the nexus between water, energy, and food, yet they do not fit neatly into any one sector and therefore can be overlooked. Although the nexus concept encourages widening the environmental management lens beyond a unilateral hydrological approach to incorporate food and energy, there are important ecological areas and functions that are difficult to fit into the framework.

After analyzing the applicability of the FEW nexus concept in the basin, we suggest several adjustments to make the nexus framework more suitable for research and management of the Kootenai River Basin. It was clear that, although many economic and environmental sectors were encompassed by the framework, the actors and activities that

did not fall clearly within food, energy or water were missed. We would argue for widening the nexus even further, careful attention should be paid in the future to stakeholders such as the biodiversity of the river, which has no clear spokesperson. Finally, we recognize that there are distinct cultural and human dimensions underlying each of the food, water, and energy sectors which can easily be missed since they are undercurrents to the nexus rather than a distinct sector. To round out the current nexus concept, we suggest adding a layer for human dimensions, such as emotion and cultural values that span the interlocking sectors. This additional layer would allow for a more complete representation of the basin and encourage a holistic view for upcoming management and treaty decisions of Columbia River Basin.

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Declarations

Conflict of interest The authors declare no conflict of interest for publishing the paper.

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