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Research

Managing beyond water: utilizing community well-being interviews in the Upper Yakima River Basin, USA, for climate change adaptation

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ABSTRACT. In contemporary, natural resources dependent and specialized communities, community well-being is connected to the environment. Understanding the local connections between community well-being and the environment can provide a more complete understanding of how to manage social-ecological systems and promote community resilience. Herein, we combine semi-structured community well-being interviews with hydrologic modeling using the variable infiltration capacity (VIC) model to suggest climate adaptation pathways for a diverse set of community interests. We found that community well-being across the Yakima River Basin was connected to water, snow, and the environment through recreation opportunities, aesthetics, livelihoods, and having clean water and air. Additionally, many community members noticed changes in snowpack conditions and were aware that snow conditions affect water resources and local agriculture. We identified that community concerns, resilience, and innovation centered around preserving the Yakima Valley's historic and future potential as a regional and global agricultural and recreational hub. We discussed two case studies that highlight how climate adaptation plans can be expanded to include other groups, resources, and governance foci. The first case is about the social aspect of sustained days of high heat and the second is about an expressed false sense of security with snowmelt. We do this by incorporating modeled future projections of consecutive high heat days and snowmelt timing. By integrating well-being interviews with hydrologic modeling, we show how we can create more climate-adapted and resilient social-ecological systems that can preserve and maximize well-being in the context of changing environmental conditions. Other natural resources dependent communities also have connections between community well-being and the environment, thus a similar approach can be used in future research to explore the location-specific context.

Key Words: *climate change; community well-being; hydrologic modeling; management; resilience; water resources*

INTRODUCTION

Explicitly accounting for community well-being in climate impact assessments and plans can be a pathway for developing adaptive capacity and resilience in natural resources-based communities. Broadly, community well-being is anything that constitutes a good life but is also the interaction of individual, social, and ecological elements (Larson et al. 2015, Bache and Reardon 2016, Flint 2016, Ruggeri et al. 2020). In rural, natural resources dependent or natural resources specialized communities—contemporary communities that are economically or otherwise dependent on natural resources extraction, natural resources based economies, or outdoor recreation—community well-being is often coupled tightly to the environment and can be affected by natural resources management (Stedman et al. 2004, Bache and Reardon 2016, Mueller 2021). Community well-being in these communities varies by natural resource industry (i.e., forestry, agriculture, fisheries, etc.) and region; it can also be influenced by local climate and policies (Stedman et al. 2004). Defined by resource managers and social scientists differently, well-being can include social, cultural, psychological, physical, economic, political, and governance aspects of natural resources (Biedenweg et al. 2017, Hoque et al. 2017). It can also be a framework that informs managers about the trade-offs of different decisions related to allocating or managing the land, environment, or natural resources (Summers et al. 2014).

Resilience assessments span spatial scales, communities, and types of resiliencies. Where more physical assessments of resilience focus on assets or competencies, social assessments of resilience focus on process and action (Adger et al. 2021). For example, ecologists often define resilience in relation to ecosystem changes, such as resilience to droughts or storms, whereas a more social understanding focuses on humans and communities' ability to cope with external stressors or disturbances, environmental or otherwise (Adger 2000). A more recent development and broader understanding of resilience situates humans inside natural systems, recognizing their dynamic coupling in social-ecological systems (SESs; Cote and Nightingale 2012, Janssen 2007). Recognizing this coupling in SESs better captures the cyclical interactions humans have with the environment and how that shapes community and environmental well-being (Davidson-Hunt and Berkes 2002, Cooke et al. 2016, Folke et al. 2016). In SESs, defining resilience is inherently political and based on community power structures (Dewulf et al. 2019).

Natural resources management focusing only on ecological outcomes in SESs ignores essential components of community and catchment resilience (Adger et al. 2021). Defining resilience for a community gives meaning and values to certain human and environmental resources that are assigned to be resilient. The definition of resilience shapes the narrative about priorities and values by reflecting certain perspectives and interests of social actors but this may not be a wholly complete depiction (Lejano et al. 2013). Although the resilience framework is gaining popularity in the management of global change in SESs, there has been a lack of consideration of power dynamics that may reinforce disparities (Ingalls and Stedman 2016). Asking the questions of resilience for whom, of what, to what, and where is

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to be resilient, and what brings about resilience builds an understanding of the local systems and dynamics at play that shape natural resources management (Elmqvist 2016, Dewulf et al. 2019, Flint et al. 2024). Including diverse groups and perspectives in defining resilience can allow for a more power conscious perspective on resilience (Dewulf et al. 2019). In SESs that are heavily dependent on natural resources, well-being and resilience concepts often overlap, therefore defining resilience in terms of well-being is one power-conscious approach to resilience studies (Armitage et al. 2012, McCrea et al. 2014). Combining both ecological and social interests through a combined community well-being and resilience framework has potential for increasing adaptive capacity and resilience to climate or environmental change while considering multiple interests (McCrea et al. 2014, 2016).

Researchers, scientists, and natural resources managers often use physically based computer models to better understand future changes in environmental conditions and resource availability to inform decision making and potential climate adaptation pathways (Barnett et al. 2005, Adam et al. 2009, Malek et al. 2020). With computer models, researchers can project changes in droughts, crop yields, temperature, and many others at different temporal and spatial scales (Cooper et al. 2016, Malek et al. 2018, IPCC 2023). For example, the state of Washington commissions the Columbia River Basin Long-term Water Supply and Demand Forecast every five years to better understand the coming changes in water resources and agriculture (Hall et al. 2021). Following, quantifying how community well-being is connected to and affected by their environment gives insight on how human well-beings may be affected by future changes in the environment. With this relationship established, communities can prepare and adapt to future environmental change.

Although it is dynamic, there is a good understanding of current and future impacts from climate change on society (IPCC 2023). However, climate change adaptation plans do not always explicitly consider human health and well-being (McKinley and Sandison 2012, Wheeler and Watts 2018, Fox et al. 2019). Pure hydrologic research is concentrated on water and ecological systems, but discusses the potential impacts on humans, society, and implications for management (Hall et al. 2024). Further, water and natural resources managers frequently focus on just the management of natural resources, such as how to increase water storage, as opposed to the management of social and ecological components of natural resources and environmental change (Viviroli et al. 2011). However, there is ample opportunity to consider the role of community well-being in enhancing community resilience and adaptive capacity to climate change.

The overarching question addressed herein is what are the climate adaptation pathways that meet the needs of diverse local community perspectives? To address this question, we ask the following set of interrelated questions: (1) How do people in different communities across the Upper Yakima River Basin (YRB) talk about their connections to water?; (2) How is community well-being directly and indirectly connected to water, snow, and environmental conditions?; (3) What concerns do community members have about water and snow in the future?; and (4) What is perceived as making communities unique or resilient to future changes related to the environment? Our objective with this work is to better understand how we can manage social-ecological systems to represent a wider range of well-being indicators in climate adaptation planning. Currently, water in the Yakima Basin is managed for multiple ends but is facing many different challenges from climate change. We apply a novel approach by mixing qualitative interviews with community residents and hydrologic modeling to use participant identified concerns and indicators of well-being and resilience to propose scenarios for adaptation and improved management that could be explored further as examples of managing for multiple ends. To our knowledge, few studies have combined these two methods or conducted interviews as extensively or at the same scale across a watershed. If we can manage social-ecological systems for objectives that go beyond solely water resources availability, we can create more climate-adapted and resilient social-ecological systems that can preserve and maximize well-being in the context of changing environmental conditions.

METHODS

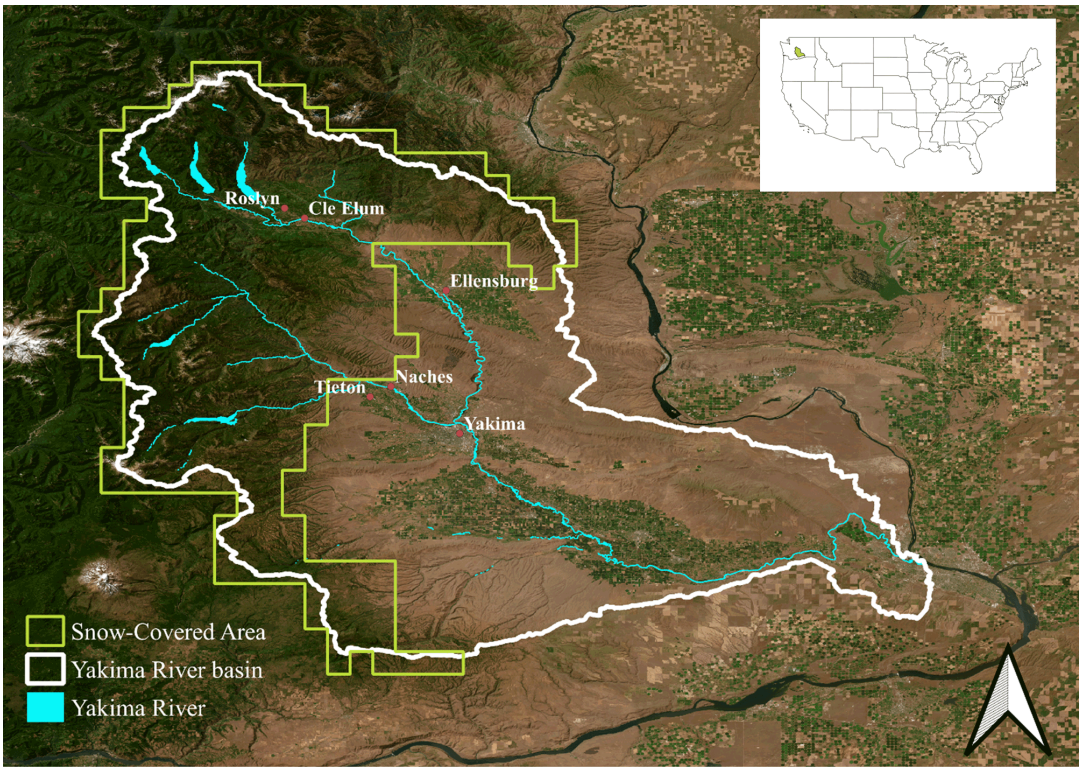
Site description

The YRB is a 15,941 km^2 watershed located in central Washington and a subbasin of the greater Columbia River Basin. The watershed has a range of landscape types, with the headwaters of the watershed being in the Cascade Mountain Range of Washington and the eastern region being in the lowland area of the Columbia Basin. The basin is composed of evergreen forest on the western edge, cultivated crops, shrub/scrub, grassland/herbaceous, and pastures/hay in the eastern part of the watershed (Dewitz and U.S. Geological Survey 2021). See Figure 1 for a map of the basin and its location within the United States. The basin has a Mediterranean climate, with warm, dry summers and wet, cold winters. The headwaters region of the basin gets an average of 550 mm of snow during the winter (December, January, and February), whereas the lowland, arid parts of the basin get an average of 152 mm of precipitation per year (USGS and USBOR 1998); the majority of the precipitation (79%) falls during the winter in the headwaters area as snow.

The YRB provides water for a myriad of uses including agriculture, domestic, and in stream ecosystems, but climate change has affected the patterns of seasonal water supply and quality. The arid lowland part of the basin is prone to droughts, having had one on average every four years over the last 20 years, which are expected to continue into the future and negatively affect crop yields and market volatility in the region (OCR and USBOR 2011, Malek et al. 2020). Climate change is exacerbating the regional drought cycles and affecting the timing of water supply and demand by humans, crops, and ecosystems (Vano et al. 2010), which requires innovative management to appease all users while adhering to water rights regulations. The basin has five major reservoirs that provide water storage for irrigation water along the river including the Keechelus, Kachess, Cle Elum, Bumping, and Rimrock.

The YRB is susceptible to major economic losses from drought because the watershed is heavily dependent on agriculture for revenue. It is estimated that between 60% and 97% of the water in the Yakima River is allocated for irrigation (Solley et al. 1998, Otak, Inc 2007, Hillman et al. 2012). The watershed is also heavily dependent on the availability and timing of spring runoff from snowmelt (Hall et al. 2024). Additionally, the basin is a major producer for the state, providing about $3.4 billion USD of the state's income derived from crop, livestock, and food production

Fig. 1. Map showing the location of the communities within the Yakima River Basin (YRB), the location of the Yakima River and other water bodies, and the area that we considered to be snow covered during the winter. The area that is within the YRB (white) but not within the snow-covered area (green) is designated as the lowland area. We used the snow-covered area for our case study about changes in snow and the lowland area for our case study about temperature.



but this is reduced in dry years (OCR and USBOR 2011). Therefore, water supply and management in the basin is a difficult balance and becoming increasingly more contentious because of climate change. The YRB water is fully appropriated and subjected to water rights prorationing rules during dry years, which limits the crops that can be grown in dry years, reduces output, and puts perennial crops at risk. However, there are competing uses of the water for municipal growth and development and domestic uses. Because climate change will continue to affect the timing and quantity of precipitation, snow accumulation and melt, and the timing and quantity of crop water use and other consumptive uses, managing water in the YRB will be a challenging feat.

The YRB encompasses the communities where residents were interviewed in the qualitative research phase. Except for Tieton and Naches, communities are located near the main stem of the Yakima River (see Fig. 1). One of the important pieces of policy as it relates to water and communities across the YRB is the Yakima Basin Integrated Plan (YBIP). The YBIP seeks to adaptively manage the water and reservoirs to optimize water use as climate change impacts the river's water quantity and quality to continue to provide water for irrigation while protecting in-stream habitats and water quality (OCR and USBOR 2011). The plan was developed after numerous groups experienced conflicts over resource uses and shocks to water and food systems due to changes in the environment. The plan brings together federal, state, and tribal groups to increase water security and to protect fish and wildlife habitats. However, the plan does not go beyond managing water resources, aquatic and terrestrial ecosystems, and water infrastructure.

Qualitative research

We interviewed 65 key informants and 52 community members and conducted four scoping interviews across six communities in two counties in the Upper YRB in Central Washington (Krannich and Humphrey 1986). Seventeen of these interviews included members of the Latine community, a growing demographic group in the area. Key informants were categorized into three spheres: Government, Non-Government Civic, and Business. We focus on the following communities based upon demographic diversity and community willingness to participate: Ellensburg, Upper County (Cle Elum and Roslyn), Yakima, Tieton, and Naches; we also discuss perspectives of participants who had broader views from Yakima County and Kittitas County. Herein, we refer to Yakima City as just Yakima and Yakima County as Yakima County. Interviews were semi-structured to allow for the unique perspectives of different participants to emerge. We used purposeful, criterion sampling and online searches for initial key informants representing governmental, non-governmental or civic, and business arenas. Additional interview participants were identified through recommendations by other contacts with

connections to communities of interest. Community interviewees were recruited via physical and electronic flyers and word of mouth. Interviews were largely conducted over Zoom, with some conducted in person.

The purpose of the interviews was to assess variability in perceptions of well-being in communities along a rural-urban continuum and how well-being is perceived to be connected to food, energy, and water systems. We asked questions on the topics of general well-being and community life, food, changes in local environmental conditions, population and demographic change, and regional systems. Interviews were analyzed using an abductive or thematically driven approach (Timmermans and Tavory 2012). Interviews were transcribed and coded for general themes, with multiple coders comparing findings to ensure reliability; transcribing was supported by Otter.ai and coding by Atlas.ti software. Themes included participant's role(s) in the community, water and snow, population and demographic change, connections to other communities, rural-urban connections, unique or innovative things about the community, defining community, contributors to well-being, concerns and excitement about the future, food access, agriculture, environmental conditions, and other topics of importance. Herein, we discuss perspectives on environmental change, with a focus on conversations about snow and water and connections to other themes, such as agriculture, environmental conditions, and unique and innovative things about interviewees' communities. We focused on Ellensburg, Yakima, and Upper Kittitas County for this analysis because these were the communities with the richest set of full perspectives from the overall study. Human subject aspects of this project were reviewed and approved by IRB for each participating university. Participants determined whether or not they wished to be identified in project reporting, however, for consistency, we have not identified any participants in this paper.

Hydrologic modeling

We implemented the variable infiltration capacity (VIC) hydrologic model (Liang et al. 1994, Cherkauer et al. 2003) for the whole Columbia River Basin but we only used grid cells from the YRB for this analysis. We ran the simulations from 1950 to 2095. See Hall et al. (2024) for further explanation of the model setup. VIC is a large-scale, semi-distributed hydrologic model that simulates hydrologic and biogeochemical fluxes. We used variables from 17 global climate models (GCMs) as meteorological inputs to drive VIC, including temperature, precipitation, wind speed, longwave and shortwave radiation, atmospheric pressure, and vapor pressure. Each grid cell is subdivided into the landcover type; vegetation is simulated using a clumped scheme, which scales a big leaf model vegetation scheme by vegetation area fraction to estimate plant specific leaf area index (LAI). Finally, VIC simulates snow in multiple stores including ground snowpack, snow in the canopy, and snow on top of lake ice, while also simulating partial snow coverage and blowing snow sublimation (Bowling et al. 2004). VIC has been evaluated and shown to simulate snow processes well, which makes it an appropriate model for our questions (Andreadis et al. 2009).

We used VIC to project future changes in snowpack and snowmelt timing to align with scenarios for potential adaptation pathways from the qualitative research findings. We also visualized future changes in temperature. We show these changes from 2025 to 2095. All figures show the range of results from the 17 GCMs using a representative concentration pathway (RCP) 8.5 (i.e., the most extreme climate pathway with the greatest amount of warming and greenhouse gas emissions). We show the number of times when there are consecutive days greater than 30 °C (85 degrees Fahrenheit) in the lowland area of the YRB through the end of the 21st century. We also show the maximum duration of those events and the total duration of consecutive high heat days. Finally, we show the average Julian Day of no SWE in the areas that tend to accumulate snow. Snow covered areas include areas within the YRB that are not designated as lowland; generally, it is the forested part of the watershed (see Fig. 1).

RESULTS

Community connections to water

Participants from each community discussed the topics of water, snow, and the environment, including the topics of water quality, flooding, changes in water availability and snowpack, infrastructure, groundwater, bottled water, recreation, water adjudication, and water temperature and fish. Ellensburg residents enjoyed their access to clean water and their connection to the snowpack that generates their water. One participant described their connection to snow as "in Ellensburg there are no water rights, but snow rights, because all the water we have comes from snowmelt." Some community members noticed that winters are changing, and these changes are having various impacts on the community, including flooding, water scarcity, and restrictions on wells. Community members who noted moving to Ellensburg within the last three to five years said that winters had extreme snowfall and cold temperatures; however, community members who had been in the area for much longer said that winters were becoming warmer with more precipitation falling as rain, less snow, or winters are generally "less heavy." Although many community members noted changes in winter, far fewer noticed changes in water availability and water resources. However, some did note more flooding. For instance,

> *I noticed that we've had more flooding the last couple years. And I think that's due to the rapid snowmelt when things get really hot really quickly, early in the season.*

There was a general sense that the community would be able to manage and resolve issues regarding water resources. One community member said when asked about changing water resources that "we'll figure it out."

In Yakima, there was a general sense of water abundance, a lack of concern about water conservation, and more of a focus on water quality issues than found in other communities. One community member said about the water abundance: "but in general, the valley definitely has a sense of like water abundance, no need to save anything at all." When commenting on water resources and snow, community members tended to focus on the use of water for watering lawns and concerns about conservation, saying, "but as far as kind of within the city, I think people just run water like nothing." However, very few people noted experiencing water scarcity, except for a select few people in the agriculture community or people connected to farms. One community member said, "and it's something I feel like that farmers worry about all the time, but so far I have yet to know a

farmer who has not had enough water." People were generally more focused on the effects on water quality from the dairy industry and army base nearby that put nitrates and per- and polyfluoroalkyl substances (PFAS) in the water, respectively. However, only one person said they were directly impacted by having to boil their water; others only heard stories about boil orders. Generally, people did not connect changes in snow with changes in water resources in the same way as those in Ellensburg and key informants speaking about Kittitas County.

In Upper Kittitas County (Cle Elum/Roslyn), there was more discussion about the environment and connections between water and forests, fish, outdoor recreation, natural beauty, and environmental change relative to other communities. However, because of these strong connections to the environment, there was clear discontent from a number of participants about the management of water rights and consequent restrictions on development and recreation. One community member said,

> *Have you looked at water rights at all in all of this? They're extremely complicated and very contentious. There's a lot of places where developers would love to go and put something in there but the water rights aren't available or the place in question may be extremely susceptible to fire or it may be in the middle of an identified wildlife habitat or corridor. So, there's this constant, I think, push-pull between development and the understanding that we need to provide for the growing population and everything that we know about resource scarcity right now.*

A number of community members expressed the sentiment that there are perhaps too many water-related regulations in this community, with many mentions of water meters, water banks, and infrastructure for fish limiting access to recreation. One community member discussed differences in feelings about these restrictions between newer residents and longer-term residents saying,

> *So it's become very strict as far as development, the old guard has bitterly complained about those new protections. But those moving into the community from outside are supportive. And so I think that we're seeing that the water ways and the water needs to be protected, environmentally, from development.*

There was a similarly strong sense of connection to and identity with water and agriculture in Kittitas County, best captured by someone saying "regardless, we're tied by water and we're tied by agriculture." Key informants speaking about Kittitas County had a lot to say about water resources and noticed more nuanced changes in the snowpack. There was a false sense of security with snow as people have noticed changes in the timing and rapidness of snowmelt. There was also more discussion about dams, water banks, and water rights than other communities. These key informants saw many connections to environmental conditions and how conditions impact their lives and access to resources.

Participants speaking about Yakima County were very focused on the future of water and water solutions and tightly coupled the environment and the community. Many of the Yakima County key informants were in local government, agriculture, or a profession related to the environment and consequently, had much to say about these topics. Interviewees discussed broader perspectives, including water solutions in agriculture and at the domestic level, connections to the dairy industry and its impact on groundwater, and water rights. There was less of a contentious feel to the discussion about water rights compared to those from other communities. However, Yakima County key informants expressed water scarcity more acutely and demonstrated a more nuanced understanding of the hydrological system. When speaking about people in the county and how they tied their lives to water, one person said,

> *And it's, a nice juxtaposition of … nature meandering and then the organization of agriculture. But they definitely flow together and are linked and connected in a very vital way, and of course that's by water.*

Although many of the participants noticed changes in water and snow, communities higher up in the watershed (i.e., Cle Elum/Roslyn) and those speaking at the county level were more likely to discuss noticing changes compared to those downstream in Ellensburg and Yakima City where many participants reported not having noticed any changes in water or snow. Participants speaking at the county level in both Yakima and Kittitas spoke more about changes in water, changes in snow and winter conditions, and water infrastructure; water infrastructure was rarely spoken about in the other communities. There was a much wider range of water-related topics that were discussed in Ellensburg and Yakima City (i.e., downstream communities).

Water, snow, and well-being

Contributors to well-being were directly and indirectly connected to water, snow, and the environment across all communities. People stated that their well-being came from recreation opportunities and easy access to forests, rivers, and mountains; having clean water and air for their health; plentiful job opportunities, namely agriculture-based jobs; and through local food production that makes its way into farmers markets. People who recently moved to the community often stated that they moved to the Upper YRB because of these abundant natural amenities. When asked about contributors to well-being, an interviewee speaking about Kittitas County said,

> *We generally have really good air quality here and our water is really excellent. You know either, we aren't dependent on having to filter our water to drink and those sorts of things. So, I think those things are all really excellent reasons why I think it's a good place to live.*

Similarly, community members in Ellensburg cited clean water as being a contributor to their well-being.

These contributors to well-being are implicitly dependent on environmental conditions and the climate. Because these communities are located within a snowmelt dominant watershed, much of the surface and groundwater is derived from snowmelt. Therefore, produce from local farms, livelihoods based in agriculture, and access to rivers and lakes with enough water for fishing, floating, and boating are all dependent on the timing and amount of snowmelt. One person summarized the outdoor opportunities saying,

> *I guess one thing that I haven't mentioned really is I've talked about the Yakima River a little bit, but just our, our access to so many different recreation opportunities, whether that's, yeah, floating the river or hiking in the*

> *Teanaway, in the Enchantments or going to see waterfalls in Snoqualmie, or even just going out east to the gorge and going to a concert or just climbing ... I think that community is really strong here.*

The timing and amount of snowmelt is dependent on the climate, with water infrastructure being necessary to capture the runoff. When it comes to agriculture, the availability of water for irrigation, which then translates to yield and jobs, is dependent on water rights, water storage, and favorable environmental conditions for both the crops and humans working on the fields. One participant said,

> *All the water resources in the basin, it's like fully adjudicated, so all the water that can be allocated out has been allocated out. And then we have drought years and water shut down. So that really impacts that agricultural economy, but it also impacts the fish that are trying to get to the rivers to spawn.*

Consequently, the management of water resources derived from snowmelt has implications for community well-being. One community member speaking about Ellensburg summarized the many connections between community well-being and water and how the communities actively shape those connections to the environment by saying,

> *The way that we manage water, we are ... fairly heavy in agriculture. So we do have irrigation water rights, we have a nice river, we have great lakes beside us. But we also have dams, we have pollution, we have, when we build our homes along the riverfront, we ... make the change into natural conditions.*

Future changes and concerns

Because many sources of well-being and aspects of the region's identity as an agricultural and recreational hub are dependent on water and snow, community members expressed concerns about the future of snow and water. The concerns across all communities are best summarized by one person speaking about Yakima County who said,

> *I think the water, you know, finding solutions to the water is going to be huge. There's ... places in Southern California in agricultural areas where I think they're going to have to come to grips with possibly fallowing 1000s of acres because the Colorado River is just in such a state. And there's been discussion about how important the Yakima Valley and the Columbia Basin will continue to be because of the possibility of lower production coming out of California and those water strained areas. So, finding solutions to our lack of snowpack is really crucial. I would say we have ideas and we have projects we're working on. We don't have all the answers yet. We're still trying to figure it out.*

There was a strong focus on future water use and access, particularly as it related to climate change and food production.

Although many people from each of the communities expressed concerns about water in the future, particularly related to water conservation, not all communities held the same level of concern or awareness. Recall that in Yakima and Ellensburg, community members more frequently said that they did not notice any changes in snow and water and did not have any concerns about the resources. Relative to other communities located further upstream, people in Yakima and Ellensburg were more focused on water quality and groundwater than they were water availability; as stated above, there was a general sense of water abundance in these communities, which likely mitigates any concerns about water availability.

Community-Identified resilience and innovation

Resilience was defined broadly and irrespective of the environment by one Ellensburg community member as,

> *I think it goes back to that grit and savvy kind of thing. I think there's a sense of resilience that people like bounce back from stuff and they also like, generally help one another.*

Further, though not about water, an Upper County community member defined resilience related to wildfire as having social protections, saying "but when it comes to community resilience and wildfire protection and things like that, there's a tremendous amount of support and social license here for that." Across all communities, resilience was characterized in relation to environmental change and the ability for the YRB broadly to retain its identity as a major agricultural producer globally.

In the context of environmental change, innovation, and uniqueness, the Yakima and Upper County interview participants discussed water and agriculture. Agriculture was the major focus of innovation and impetus for resilience related to water and environmental change, with fruit production being something that makes this region unique. Community members discussed innovations such as lining canals, changes in irrigation technology, and other technological applications to reduce water use. The YBIP came up numerous times as an aspect of the region that was increasing resilient to climate change through water management for irrigators, environmental flows and instream use for fish, and other water demands. An Upper County community member said,

> *I think the Yakima Basin Integrated Plan is an amazing example of people who historically were just suing each other back and forth for a resource... We're going to need to collaborate and figure out how to preserve water, how to find ways to store it better, how to address the fact that it's getting hotter out here. And that's, that's not something any one of us can do in our own little silo. So, in that way, I think that's been extremely innovative.*

Additionally, farmers having relationships with nearby universities was also seen as increasing resilience. Therefore, related to the future, communities across the Yakima Valley sought to preserve their identity as an agricultural hub and generally, protect and improve water security for diverse groups. The sentiment about the future is best summarized by someone from Yakima who said,

> *Well, I do think that the ability of the Yakima Valley to produce fruit is very unique and will help the future for food supply. The Yakima Valley, well, not only for the rivers that are there and the quality of the water that we have in some of the rivers there and the trees for example. This will be a region that it appears to be very resilient also to climate change. And-and I think there's a lot of adaptation there and a lot of - there's a really good*

> *relationship between the farm producers and the university and some of the educational institutions that are in the valley like the Wenatchee Valley College or the Yakima [Valley] Community College. Now they have an ag program there. So, this is a very good relationship. And I think that that will make the community more resilient to climate change. And being able to produce fruit for maybe a longer period of time compared to other regions.*

SCENARIOS

We intend for the following case studies to exemplify how we can combine community views about their well-being, their observed changes and concerns about the environment, and future projections about environmental change from computer models to bring about community-identified resilience. They are just two examples of how current climate change adaptation planning and natural resources management can be expanded to include other groups, resources, and governance foci.

Scenario 1: Social aspects of high heat in farm operations

Farm laborers are a critical component of food production. Certain crops are too delicate to harvest using machinery and require human labor to pick. Environmental conditions can have negative impacts on crop production by affecting human well-being (de Lima et al. 2021). Therefore, adapting food and water systems to climate change is not solely about managing natural resources, we also need to adapt human systems. A key finding that emerged from our interviews is that farm laborers are affected by and concerned about climate change but may lack protections in certain location-specific aspects. Farm laborers are concerned about future changes in temperature, however, there is uncertainty about what to plan for. Because well-being in the YRB is dependent upon local food and agriculture and "because this valley really, in the last 30 years has been founded on migrant workers who immigrate one way or the other from Mexico," considering specific aspects of well-being for these groups in climate adaptation and resilience planning is necessary to protect multiple aspects of Yakima community well-being.

In Yakima, multiple people shared thoughts about future changes in temperature and warming. They knew that the future was going to be warmer but there was a lack of resources and understanding about increasing resilience to temperature. One person from Yakima who works with farm laborers said,

> *And the second one is the one we are facing now in terms of climate change. And this maybe is because I'm more informed in that area in relation to conditions of heat and the resources that are available to be more resilient. I don't think we - the communities - will prepare for that and we don't have services that can educate the community in relation to being more prepared and aware of the risk of being a hotter environment, or a cooler environment, or a wetter environment.*

But when thinking about heat, it was not enough to just generally know it was going to be hotter. Consecutive days of high heat were understood as the most impactful. One community member said "And also the, for example, the heat is not just about having hotter days, but prolonged weeks of hotter days."

Perceptions about temperature changes varied between communities. Some members of the Latine community in Ellensburg had noticed temperature changes, which they described as observations rather than concerns. Temperature change was framed more as a nuisance than a social problem. Two community members said the following:

> *Last year the heat lasted longer, it was hotter. The allergies were stronger. I feel like lately every year looks different.*

> *Well, I think like in the summer, it gets very hot, very hot. I don't even want to go out because ... It goes up to 100 degrees sometimes. It is very hot.*

Only two participants used the term "climate change" to refer to well-being threats. Specifically, they talked about the impact of higher temperatures on agriculture and the water supply. More research on perceptions of climate change amongst the Latine community is needed, especially considering the important role they play in the economic and demographic aspects of the area.

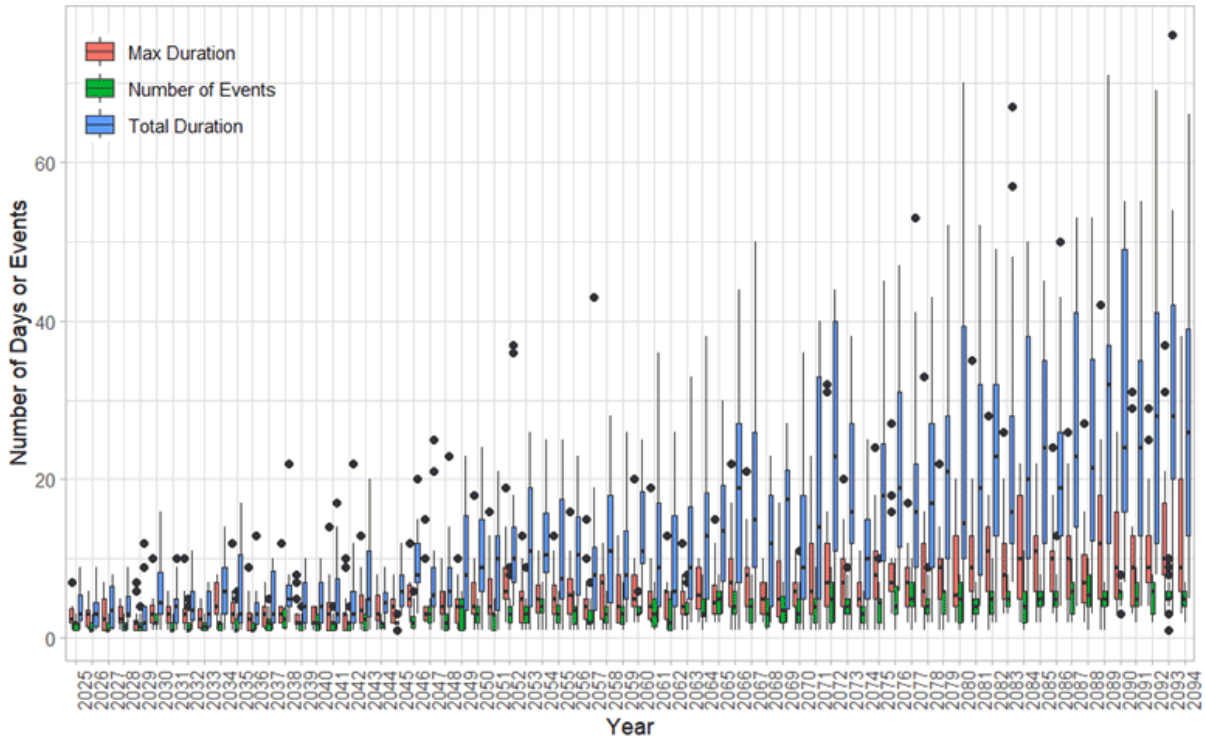
Although recent research has focused on farm labor exposure to heat at coarse spatial resolutions (i.e., state, national, and global) and use future climate change projections showing increases in temperature globally (El Khayat et al. 2022, Amoadu et al. 2023), we instead show specifically for the YRB the number of days of consecutive high heat in the future for a more targeted analysis. In Figure 2 we show the range of how many times per year through the end of the 21st century these prolonged periods of high heat could occur, their increasing duration, and the total number of consecutive days with high heat. Figure 2 does not include single days above 85 degrees, only when there are multiple days in a row. Because of the increasing duration or number of each of these aspects of high heat, it could be necessary to propose a more socially oriented climate adaptation policy related to outdoor workers and high heat. There is opportunity here to preserve and strengthen well-being related to local food security, livelihoods, and health by expanding climate adaptation planning to policies around human behaviors. Although work or farm level adaptation alone will not be sufficient in the future, it is still a critical component of adapting food systems to climate change (Tigchelaar et al. 2020).

Scenario 2: False sense of security

Climate change is affecting the timing and intensity of temperature and precipitation in mountain areas (IPCC 2023), which is affecting snowpack dynamics, such as accumulation and melt (Barnett et al. 2005). People from all communities noted seeing "erratic" or "unusual" changes in temperature, precipitation, and snow in the Cascade Mountains. Snowpack dynamics are changing in the YRB because of climate change; snow cover extent, timing of maximum snow water equivalent (SWE), duration of the snow season, and amount of SWE have all been affected (IPCC 2023). Although snow in this area is a key resource because it provides water, it also provides other aspects of people's well-being in the form of recreation and aesthetics. People pay attention to the snow because it is important for this community for myriad reasons. One community member said,

> *And I think just being in Kittitas County, you're gonna hear something about snowpack, because it's always in the paper, it's always gonna be discussed. Just because*

Fig. 2. Future changes in consecutive high temperature days from an ensemble of 17 global climate models. High temperature was designated as the average of the lowland area greater than 30 °C for more than one day in a row. Total duration is the total number of days over 30 °C from all events that year. Number of events is the number of times there were multiple days in a row with a temperature over 30 °C. Max duration is the longest event (or consecutive high temperature days in a row). Max duration, number of events, and total duration of high heat events increase through the end of the 21st century.



> *of that strong agricultural presence, I think, and that historical - I mean, it's just like, "How's the weather?" It's very common.*

Community members identified how changes in snowmelt and accumulation have affected them and their well-being. See Figure 3 for how climate change is projected to affect snowmelt timing.

There was a pervasive feeling of a false sense of security in many of the interviews. In Ellensburg, some interviewees shared a feeling that they had an abundant snowpack, which would equate to a good water year, but then there would be very erratic or abnormal melt. Interview participants noted that the snowpack was at least 100% normal but then something happened and, suddenly, there is no snow and there are concerns about prorationing water. One person said,

> *(A)nd it's interesting because in February, we had, you know, predictions of 100% snowpack or very close to. And then with warm up and, in May a lot of that water or that snowpack melted off really quickly. So, there's less water availability, and you know, the irrigators are talking about shutting off in August.*

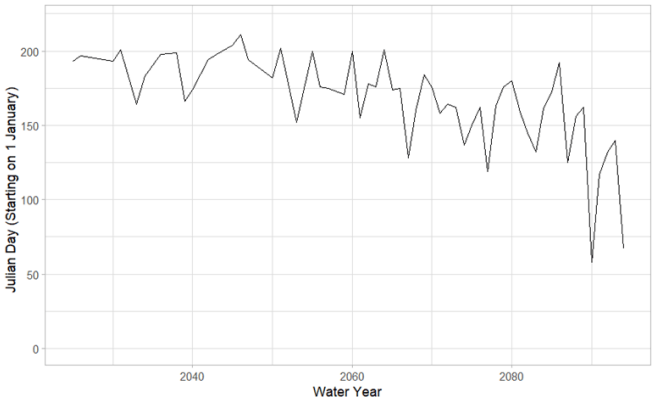
Preserving well-being in this community is preserving snow because multiple aspects of snow contribute to community well-being. Although the YBIP covers managing water storage to adapt to "a changing hydrograph," which implicitly is managing for a changing snowpack, it does not explicitly manage changing snow accumulation. To preserve community members' connections to snow through recreation and water security, there could be management directions specifically targeted at managing snow retention. We want to emphasize and recognize that it is not entirely possible to manage snow retention, and in the future, there will be a much smaller snowpack, snow extent, and snow off time in the Cascade Mountains in spite of efforts (see Fig. 3 for future snow off dates). However, in forested areas high in the mountains, there have been attempts to manage the forest structure to retain more snow and for longer. One community member even cited this work to manage the snowpack. Largely, this is a recent, open science question in the realm of management (Dickerson-Lange et al. 2021, Lewis et al. 2023). Although the objectives are similar—retain snow—it is for multiple reasons, which could inform management locations and treatments, similar to prioritizing fuel treatments for multiple objectives (Barros et al. 2019).

DISCUSSION

Increasing resilience in SES using well-being interviews

Our findings on community well-being in the Upper Yakima River Basin and Kittitas County highlight connections between SESs, well-being, resilience, and power structures in natural resources dependent communities. There is abundant literature

Fig. 3. Day of zero snow water equivalent (SWE) averaged over the headwater part of the Yakima River Basin from water year 2025 to 2094. Julian day of the time of zero SWE starts on 1 January. SWE decreases through the end of the century but has interannual variability.



about the meanings and catalysts for resilience, but there's a lack of consensus about how to bring it about (Janssen 2007). With critiques rooted in political ecology, there has been more recent pushback about long held ideas of resilience to more explicitly consider how power structures play a role in developing community resilience (Dewulf et al. 2019) and about how community well-being and resilience are complementary (Armitage et al. 2012, Hoque et al. 2017). In natural resources dependent communities, both resilience and well-being directly and indirectly depend on the environment, in the forms of community identity and shared values, livelihoods, recreation, and aesthetics (McCrea et al. 2016). However, using well-being to inform community resilience for management and governance applications is not fully explored (Ingalls and Stedman 2016).

Well-being assessments are a way to identify and increase resilience to climate shocks in SESs for a more diverse set of needs and interests (Twigger-Ross et al. 2015, Shahidullah et al. 2020). In our interviews, community members discussed what contributes to their well-being, thereby identifying what holds value or has meaning to these communities in the YRB. Additionally, interviewees implicitly and explicitly discussed and identified resilience goals of the study communities. From this work on community well-being, we identified opportunities to prioritize certain groups' resilience in climate adaptation planning. These omissions in well-being considerations could hinder basin-scale resilience and adaptation objectives. By finding what communities believe contributes to their well-being and what makes them resilient, there can be better planning to preserve those valued resources, identities, etc. Future research and/or policy development can leverage this mixed methods, social-ecological framing to further explore the feedback loop between policy, natural resources management, and community well-being and illuminate community-identified resilience.

Current natural resources management

Enduring and preparing for the impacts from climate change requires both mitigation and adaptation plans (Stehr and Storch 2005, Rosenzweig and Tubiello 2007, VijayaVenkataRaman et al. 2012). In the YRB, the main climate adaptation plan is the YBIP. The plan centers water as the key resource of concern in protecting the identity of the valley as a major contributor to regional and national economies from agriculture. A few interview participants cited the plan as a source of resilience, something unique, or something innovative happening in the Yakima Valley. One person said about the plan,

> *That's because farmers actually, I mean, they're the ones who knew things are changing, we need to plan for it. We got to figure this out. And so that's what we're doing. And I will say it is the model to be emulated across the country.*

Adapting SESs to climate change requires both the social and ecological parts of the system (Flint 2016, Givens et al. 2018, Hand et al. 2018). Adaptation to climate change in the realm of natural resources management can both be nature centric (i.e., managing forest structures) or human centric (i.e., how humans adapt to changing environmental conditions, such as temperature, increased flooding, changing water quality). One approach for incorporating human and social data into environmental data is identifying areas of resilience in communities that are highly dependent on natural resources for their well-being (McCrea et al. 2014). In areas where well-being is tightly coupled to the environment, opportunities exist to combine social data, such as well-being assessments, with environmental modeling.

Reasons for current natural resources management

We identified characteristics of those who felt water related shocks and who had not. People who generally tended not to feel water related shocks, such as water scarcity, were people in more urban settings, such as Ellensburg and Yakima, which may be because they are less directly affected by water rights. Although they are much more affected by water rights restrictions due to changes in water resources, people associated with the tree fruit industry did not express feeling too affected by changes in water resources. One person from Yakima said,

> *You will hear this from any grower in Washington - they have not suffered drought problems because of the huge amount of water availability that they still have. So, maybe a few examples where, actually I wasn't here when that happened, that they had, they faced some drought but the water availability for the tree fruit industry is not an issue. And so, there's a lot of resistance to implement better water practices, because they don't see the need; yet.*

The YRB is known as a critically important agricultural region in the U.S. and globally, producing billions of dollars' worth of crops and products yearly. In 2017, Yakima County ranked ninth in the country for overall crop production, and was ranked eighth for fruits, tree nuts, and berries (USDA NASS 2023). The total value of production amounted to almost $11 billion, with apples being the most lucrative crop at about $2 billion (USDA NASS 2023). The plans and strategies that community members identified related to future environmental change were centered around water and agricultural production. It is beyond the scope of this project to do a full-scale analysis of the power structures at play in the YRB; however, it is evident that agriculture as a whole, and tree fruit production in particular, play a large role in decision making for this area.

Climate change resilience in the YRB was defined by the communities as preserving and protecting the agricultural

industry. The YBIP appeals to a diverse set of needs, but only as it relates to water. The plan outlines a number of projects related to increasing water storage, restoring fish runs, and improving conservation of water. Community members even noted some of these as great innovations, such as lining canals to improve water conservation. However, it lacks a broader range of needs and interests related to environmental change. Our well-being study identified groups who were feeling impacts from climate change but lacked certain protections or policies to help them adapt and thrive in place. Current climate change and water resources adaptation plans could be supplemented with more localized assessments that appeal to critical groups or populations (i.e., farm laborers) through more targeted outreach or community engagement.

CONCLUSION

In contemporary natural resources dependent and natural resources specialized communities, community well-being is connected to the environment, albeit in different ways for different types of natural resources dependencies (see Mueller 2021). In the context of global environmental change and climate change resilience, community well-being assessments can be used to identify pathways for climate change adaptation to increase community resilience. Herein, we found that (1) there are myriad ways that water is discussed, including the topics of water quality, water scarcity, bottled water, groundwater, flooding, wells, water rights restrictions, and others; (2) community well-being in the YRB is directly and indirectly connected to water, snow, and the environment through recreation opportunities and easy access to forests, rivers, and mountains; having clean water and air for community members' health; plentiful job opportunities in the agriculture sector; and access to locally grown produce; (3) communities expressed concerns about water scarcity and increasing temperature in the future; and (4) identified aspects of the YRB that they thought were unique or innovative related to these concerns, including relationships with local universities that have strong agriculture programs and policies, such as the YBIP. We used these insights about resilience and innovation, along with hydrologic modeling, to highlight climate adaptation scenarios for a more diverse set of interests and community well-being indicators, including narratives around social aspects of high heat and a false sense of security about snowmelt timing and volumes to exemplify examples of managing the whole social-ecological system by using tools for each component of the "social" and "ecological." Our findings in some of the communities were limited by our interviewed population coming largely from the same industry (i.e., participants from Yakima County were heavily specialized in agriculture and local government) and demographic representation (i.e. fewer Latine community members participated in Yakima). We showed how climate adaptation planning can utilize well-being assessments to expand social and natural resources management policies and governance for a more resilient social-ecological system.

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Data Availability:

Well-being interview data are available in HydroShare at: http://www.hydroshare.org/resource/e5a4fefc9bfa428cb6f32fcf57d3554f. Other data/code that support the findings of this study are available on request from the first author, RG.

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