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Social influence shapes adaptive water governance: empirical evidence from northwestern Pakistan

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ABSTRACT. Social-ecological change has placed unprecedented stress on water resources throughout the world. This has driven water users to employ a diverse range of adaptation strategies and necessitates new governance structures, such as adaptive water governance (AWG), which have the capacity to manage resources in the midst of uncertainty and complexity. As such, AWG has the potential to support household adaptation strategies; however, little empirical work has been done to identify the factors that facilitate the emergence of AWG. To address this gap, we conducted a household survey of 448 households in northwestern Pakistan, a post-conflict, water-scarce area where adaptive governance is needed to support rural livelihoods in the midst of numerous socioeconomic and environmental transformations. Indeed, we found that households in our study area perceived a range of changes to the water system, including but not limited to declines of fish populations, decreased quality and amount of river water, and an increase of local tourism. Respondents reported a range of adaptation strategies including increasing agricultural inputs, planting new crop varieties, and changing their domestic water supply system. In some cases, households employed these adaptation strategies despite economic barriers, and although many were willing to go against friends' and community leaders' opinions to adapt, and they were less likely to counter the opinions of family members. This reveals that households negotiate multiple factors in their decisions to adapt to social-ecological change; as such, there is a great need for flexible and collaborative governance systems such as AWG to support this complexity in household adaptation decision making. Further, we argue that the varying roles of social influence should be considered to align governance structures with household decision-making processes. Thus, we suggest that AWG will be more likely to emerge when decision makers involved in water management draw on existing informal institutions and cross-sectoral collaboration to reflect the complex ways water users adapt to social-ecological change.

Key Words: *adaptive governance; climate change adaptation; household decision making; Pakistan; social influence*

INTRODUCTION

Rural livelihoods and the water systems on which they depend are under increasing stress and uncertainty from compounding social-ecological change (Foley et al. 2005, Vörösmarty et al. 2010, Mekonnen and Hoekstra 2016). This necessitates flexible and resilient governance systems that support adaptation to these changes. Adaptive water governance (AWG) has been presented as a governance system that creates the conditions to respond to uncertainty and address interactions between biophysical resources and social institutions (Huitema et al. 2009, Rijke et al. 2012). Thus, AWG is increasingly prescribed to support resilient water systems in the midst of increasing uncertainty and demand (Pahl-Wostl et al. 2012, Cosens et al. 2014, Baird et al. 2016). Adaptive water governance draws on the principals of adaptive governance broadly, which is defined as a flexible, learning-based approach to ecosystem management based on multi-scalar collaboration between diverse networks of institutions (Akamani 2016). Thus, collaboration, public participation, and social learning have been identified as important components of AWG (Folke et al. 2005, Bodin and Crona 2009, Stein et al. 2011, Chaffin et al. 2016).

Household adaptive capacity is shaped in part by the governance structures found in the multi-scalar landscape in which adaptation occurs (Ivey et al. 2004, Elrick-Barr et al. 2014, Lockwood et al. 2015, Burnham and Ma 2018). In terms of AWG, previous studies have frequently shown that AWG provides opportunities to

integrate water users' diverse values in management decisions (Bark et al. 2012, Huitema et al. 2009). It has also been posited that water users' adaptation is shaped in part by their trust in other water users, their trust in the water management institutions, and access to public participation in water governance, which are all key components of AWG (McCord et al. 2018). As such, this literature indicates that AWG can support water users' adaptive capacity in the midst of complex social-ecological change (Bayard et al. 2007, Karanja Ng'ang'a 2016, Li et al. 2017).

Adaptation was traditionally defined as an adjustment to existing practices to reduce impacts of current or future climate changes (IPCC 2001, Smit and Pilifosova 2003). Over the last two decades, there has been increasing recognition that non-climatic factors are significant drivers of climate change adaptation decisions and that water users rarely only adapt to climate change; rather, they are constantly making adjustments and changes that allow them to address a multitude of changes in their livelihood simultaneously (e.g., Carr 2008, Forsyth and Evans 2013, Manuel-Navarrete and Pelling 2015, Bennett et al. 2016a, Burnham and Ma 2016, Fedele et al. 2020). As such, instead of focusing on climate change adaptation, recent scholarship has shifted to talk about adaptation to social-ecological change more broadly, which is widely understood to be direct and indirect responses to multiple compounding social-ecological changes including climate change (e.g., Bennett et al. 2016b, Hoque et al. 2018, Lenaiyasa et al. 2020, Galappaththi et al. 2020, Erwin et al. 2021).

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Specifically, recent research has examined climatic and non-climatic factors that drive adaptation actions including political-economic constraints (Eakin 2000, Mertz et al. 2010), war and violent conflict (Galappaththi et al. 2020), urbanization (Jaramillo et al. 2013), population growth (Kaplan-Hallam 2017), and policy change and reform (Hageback et al. 2005). Building upon this literature, we define adaptation to social-ecological change as “a process, action or outcome in a system (household, community, group, sector, region, country) in order for the system to better cope with, manage or adjust to some changing condition, stress, hazard, risk or opportunity” (Smit and Wandel 2006:282).

Within the context of adaptation to social-ecological change, centralized, top-down governance systems often do not fit the social, cultural, political, economic, and institutional conditions of rural communities (Smidt et al. 2016, Pahl-Wostl 2019) and therefore, tend to overlook significant factors that influence efficacy and equity of resource governance and its role in facilitating adaptation to social-ecological change (Pahl-Wostl and Knieper 2014). In contrast, existing research shows that AWG has evolved to address complex interactions and feedbacks between the social and ecological processes associated with water governance (Huitema et al. 2009, Rijke et al. 2012) and that AWG is more responsive to the unique social-ecological contexts within which adaptation occurs (Pahl-Wostl and Knieper 2014).

In terms of household adaptation, socioeconomic demographic variables such as education level and age of household head, household size, income, and land ownership have each been identified as determinants of adaptation in many studies that focus on the relationships between access to social, political, financial, and natural capital and the decision to adapt (Croppenstedt et al. 2003, Deressa et al. 2009, Below et al. 2012, Asfaw et al. 2019). At a household level, income, labor, and access to capital remain salient in adaptation decisions (Deressa et al. 2009, Fosu-Mensah et al. 2012, Esham and Garforth 2013, Tessema et al. 2013, Antwi-Agyei et al. 2014). In addition to socioeconomic demographics, a growing body of adaptation literature has focused on how the informal institutions of social influence shape what adaptations are seen as acceptable (Curry et al. 2015, Cleaver and Whaley 2018, Porrás et al. 2020). Social influence, or the ways in which behavior is shaped by descriptive and subjective norms in the local context, has been shown to affect household decision making in a variety of contexts such as natural resource management, adoption of conservation behaviors, changing livelihood strategies, and managing environmental risks and threats (e.g., Fielding 2008, Abrahamse and Steg 2013, Dang et al. 2014, van Valkengoed and Steg 2019). In some cases, social influence can be “more powerful than cost or considerations such as convenience or effectiveness” (Wolske et al. 2020:202) and is thus, another important factor that influences the learning and collaboration that is central to AWG. In fact, scholars have argued that a better understanding of social influence will support the emergence of AWG by responding to local needs and concerns (Kerner and Thomas 2014, Porrás et al. 2020). Thus, considering the role of social-economic demographics and social influence in adaptation decision making will allow governance structures to align with the informal institutions and social-economic context on the governance area (Cleaver and Whaley 2018, Porrás et al. 2020).

We build upon this complex literature on AWG and adaptation to social-ecological change to examine the specific contexts and conditions that may foster or inhibit adaptation to social-ecological change and the emergence of AWG among water users. Specifically, our study is situated in Pakistan, one of the most water-stressed countries in the world (Hofste 2019) where adaptive governance is needed to support rural livelihoods in the midst of numerous socioeconomic and environmental transformations. Specifically, in the northwestern province of Khyber Pakhtunkhwa (KP), the Swat and Kabul rivers supply water for irrigation, wild catch fishing and aquaculture, domestic use, hydropower, and domestic tourism. However, urbanization, industrialization, and agricultural intensification have increased pollutants in the water system (Ullah et al. 2013), and it is projected that climate change will increasingly stress Pakistan’s water supply due to changes in precipitation and glacier behavior, causing increasing frequency of extreme events such as floods and droughts (Hussain and Mumtaz 2014). Finally, armed conflict displaced an estimated 2 million people around our research area in 2008, and in 2010, a massive flood further resulted in widespread destruction of infrastructure in the KP province (DDMU 2015). More recently, however, the area has seen development and rehabilitation, including the revitalization of the tourism industry (Hye and Khan 2013) as evidenced by an estimated 4.45 million tourists visiting sites around the Swat Valley in 2018 (World Bank 2019).

Nationally, water governance in Pakistan is guided by the 2018 National Water Policy as well as the 2005 National Environmental Policy, and the 2012 National Climate Change Policy (Government of Pakistan 2018). Water governance has largely been decentralized and a number of institutions are involved in the provision of domestic and irrigation water. Provincial irrigation and drainage authorities (PIDAs) and area water boards (AWBs) manage irrigation water, whereas farmers’ organizations (FOs) and water user associations (WUAs) are responsible for rehabilitating irrigation canals and collecting water fees from users who receive water on a rotating schedule (FAO 2011). In terms of domestic water governance, public health engineering departments (PHEDs) are responsible for installing infrastructure and managing operation and maintenance in rural areas. Tehsil municipal authorities (TMAs) manage water supply operation and maintenance in urban areas although in some cities this responsibility has been delegated to Water and Sanitation Agencies (WASAs). It is important to note that government-operated infrastructure does not reach all residents in KP; thus, self-provisioning of water is common. NGOs also play a role in the installation of water systems in KP and often create or facilitate local governance structures to accompany the water infrastructure installed (Cooper 2018, Government of Pakistan 2018).

At the same time, there has been concern that the current water governance system hinders communities’ ability to adapt to complex changes in the area. This is due in part to conflict across spatial scales (i.e., provincial, regional, and international) and sectors (i.e., industry and agriculture) in addition to the inability of current structures to respond to changes in water availability (Yang et al. 2014). Thus, there is a need for flexible and collaborative AWG structures to support resilience to water stress and household adaptive capacity in KP.

As McCord et al. (2018) pointed out, although there is much research on water governance and household adaptation separately, little work has been done to link these topics. As such, our research sits at the intersection of examinations of AWG and household adaptation to social-ecological change and aims to: (1) better understand the role of socioeconomic and demographic characteristics and social influence in water users' adaptation strategies; and (2) inform the incorporation of social influence considerations in AWG to support household adaptation. As mentioned earlier, we understand adaptation actions to be employed in response to various social-ecological changes and stressors (Carr 2008, Forsyth and Evans 2013, Manuel-Navarrete and Pelling 2015, Burnham and Ma 2016), thus we do not isolate adaptation to water stress from adaptation to other forms of social-ecological change in our study. Rather, we acknowledge both the centrality of water in river-based communities alongside the complexity of adaptation decision making. This leads us to examine multiple adaptation actions and livelihood strategies rather than focusing solely on those that are directly reliant on the water system.

METHODS

Research area

We conducted an in-person survey in three communities in the KP province in northwestern Pakistan: Madyan, Jehangira, and Landakay (see Fig. 1 and Table 1). Madyan and Landakay are located in the Swat District and Jehangira is located in Nowshera District. These communities were chosen to represent the livelihood strategies associated with the Swat and Kabul river ecosystems, including irrigated agriculture, wild catch and aquaculture fisheries, and tourism. Table 1 presents data at the district (i.e., Swat and Nowshera) level due to limited data availability at the community level. In summary, Jehangira (Nowshera District) is located on the Kabul River. It is closer to the urban center of Peshawar, and households in that area are less reliant on agriculture as a livelihood strategy compared to Swat District. Madyan and Landakay (Swat District) are located on the Swat River and are relatively farther away from urban centers than Nowshera, and households there are more reliant on agriculture than those in Nowshera.

Fig. 1. Map of research area

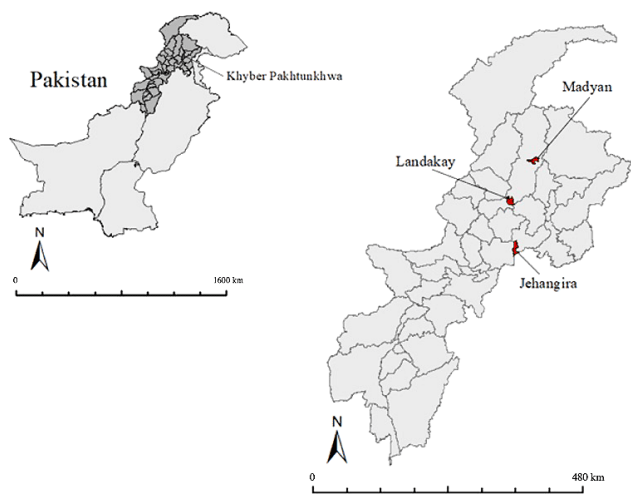


Table 1. Background information of the two districts in our research area. Note PKR = Pakistani Rupee; KP = northwestern province of Khyber Pakhtunkhwa.

Communities sampled	Swat	Nowshera
	Madyan Landakay	Jehangira
Number of household surveys	300	148
River in research area	Swat	Kabul
Demographics		
Population	2,309,570	1,518,540
Number of households	274,620	198,808
Average household size	8.8	7.7
% employed in agriculture	50.1%	25.1%
Average household income (PKR, KP region)	35,391	
Average farm size (ha, KP region)	1.5	

Sources: Pakistan Bureau of Statistics: Provisional Summary Results of 6th Population and Housing Census; Pakistan Social and Living Standards Measurement Survey; Agricultural Census.

Data collection

We surveyed 448 self-identified household heads in the 3 communities in the spring and summer of 2019. The survey collected data on household demographics, livelihood strategies, water management, perceived social-ecological changes, adaptation strategies, and perceived barriers to these adaptation strategies. The survey was designed based on findings from qualitative interviews conducted by a team of interviewers, including the first author, in the research area in 2018 and on a review of literature on key components of water governance (i.e., public participation, social networks, perception of management, etc.) and household adaptation (i.e., perceptions of social-ecological change, commonly adopted adaptation strategies, barriers to adaptation, etc.).

Specifically, we asked respondents to indicate if their household adopted one of the 17 adaptation strategies listed in the survey in the past 10 years. The adaptation strategies included were based both on the aforementioned interviews as well as on existing literature documenting types of adaptation strategies (Agrawal and Perrin 2009, Burnham and Ma 2016). This time period was chosen to include changes associated with the flood of 2010 and to allow respondents to use that significant event as a reference point. Because AWG functions in the context of complex social-ecological changes (Huitema et al. 2009, Rijke et al. 2012) and we define adaptation to social-ecological changes in the context of multiple stressors, it is important for us to consider a wide range of adaptation strategies that households may adopt in our research area. Therefore, in addition to commonly documented adaptation strategies such as changing agricultural inputs and water supply, we also included decreased time fishing as an adaptation strategy. In fact, it was one of the most commonly reported strategies from our qualitative interviews when we asked local community members about how they had responded to social-ecological change. Specifically, decreased time fishing was described by some as a step toward seeking other livelihood strategies and diversifying their livelihoods, a strategy that has

long been studied as adaptation to social-ecological change (e.g., Smit and Skinner 2002, Osbahr et al 2008, Agrawal and Perrin 2009, Nielsen and Reenberg 2010). That is, decreasing temporal investment in one livelihood strategy is an integral component of a households' construction and maintenance of a diverse portfolio of activities (Alobo Loison 2015). Decreasing time fishing was also described in terms of environmental management, another established type of adaptation (Burnham and Ma 2016). That is, local community members decreased the time they spent fishing to reduce overfishing, which they perceived to be contributing to the diminishing fish population. We also included migration as one of the possible adaptation strategies that respondents could check. Again, this emerged from our qualitative interviews as an important adaptation strategy. It has also been discussed in the adaptation literature. Both Agrawal and Perrin (2009) and Burnham and Ma (2016) developed typologies to group commonly used adaptation strategies among smallholder farmers and pastoralists. Within both typologies, migration (agropastoral, wage labor, or involuntary) is considered a type of adaptation. Previous research has also shown that people migrate for multiple and compounding reasons, including economic stress and environmental change (McLeman and Smit 2006, Wrathall and Suckall 2016, Fedele et al. 2020). Therefore, given how we define adaptation to social-ecological change, we included migration as one of the adaptation options. Additionally, in our survey, we only asked about livelihood-specific adaptation strategies (i.e., increase agricultural inputs) to respondents who indicated engagement with the that livelihood (i.e., crop production). We asked all respondents about adaptation strategies (migrate, change domestic water supply) that are not specific to a particular livelihood.

The survey was piloted in similar communities in the neighboring Islamabad Capital Territory and questions were revised based on this process. In-person survey administration has been found to be most appropriate for rural areas such as our study communities and is conducive to longer or more complex survey designs (Neuman 2010). Therefore, the survey was conducted in-person by five enumerators who were graduate students or postdoctoral researchers from the University of Peshawar using a random walking sampling strategy. In this strategy, enumerators choose a random starting location, a direction to walk, and a number of houses to skip (e.g., sample every fifth house on the street) before they selected a house to conduct an in-person survey (Himelein et al. 2016). Although selection bias is a concern for using this method (Himelein et al. 2016), it is still considered an effective collection method in places like our research area where household records are limited, and internet and phone services vary, making other sampling strategies infeasible (Himelein et al. 2016). All survey data were collected using the Survey Solutions platform with handheld tablets. This study was approved by both Pakistani research authority at the University of Peshawar and the Purdue University Institutional Review Board. We also obtained local leaders' permission for data collection in each community.

Data analysis

Responses to questions about perceived social-ecological changes were analyzed using polychoric principal component analysis (PCA), which allowed us to reduce a large number of correlated variables into uncorrelated composite variables, called principal

components (PCs), with a minimal loss of information (Field 2009, Pallant 2013). Standard PCA is designed for continuous variables. For our categorical variables, we calculated the polychoric correlation matrix and then conducted a PCA using the polychoric correlations (Kolenikov and Angeles 2009). To test the suitability of our data for PCA, we conducted both the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test of sphericity. The KMO test measures the sampling adequacy for each variable in the model and shows the proportion of variance among variables that might be common variance. The closer the value is to one, the greater sampling adequacy; however, values above 0.5 are commonly considered acceptable (Hair et al. 2010). Bartlett's test of sphericity is used to test the null hypothesis that the correlation matrix is an identity matrix, which would indicate that the variables are unrelated and not appropriate for a PCA (Bartlett 1951). In our study, the KMO value was 0.64 and the Bartlett's test of sphericity was significant ($p < 0.05$). Hair et al. (2010) suggested that KMO values between 0.5 and 0.7 are mediocre but acceptable. Therefore, both tests indicate that PCA is an appropriate data reduction strategy for our data (Field 2009).

Generally, principal components with an eigenvalue of one or greater should be retained in a PCA (Kaiser 1958, Yong and Pearce 2013). Principal component loadings of 0.50 or greater indicate a strong association among the survey items used to generate a particular PC (Cronbach 1951). This value of 0.5 has been used in several studies on adaptation decision making (e.g., Marshall and Marshall 2007, Burnham and Ma 2017). In this study, polychoric PCA was performed on 448 complete observations and 15 survey items measuring perceived social-ecological changes. The results are shown in Table 2. Five PCs had an eigenvalue greater than one and allowed for practical interpretation of the meaning of the PCs. Based on the associated survey items, the five PCs were labeled as tourism changes, agricultural changes, groundwater changes, solid waste changes, and fish changes (Table 2). The scree plot of eigenvalues confirms our decision to retain these five PCs (Fig. 2). As a measure of scale reliability, Cronbach's alpha was calculated for each PC; 0.61 or higher is often considered moderately acceptable (Taber 2018), thus, these five PCs were retained. Because perceiving decreases in river water quality did not load significantly on derived PCs, it was left to be included as an individual variable in subsequent analyses.

Fig. 2. Scree plot of eigenvalues.

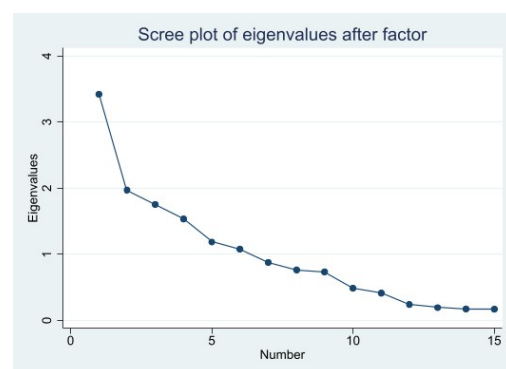


Table 2. Principal component loadings of perceived social-ecological changes

Survey items: perceived change in respondents' community in the past 10 years	Description	% of respondents perceiving a change	Rotated principal component loading				
			Tourism changes	Agricultural changes	Groundwater changes	Solid waste changes	Fish changes
Decrease in domestic water quantity	Binary-1, if change is perceived; 0, if otherwise	37			0.75		
Decrease in domestic water quality	Binary-1, if change is perceived; 0, if otherwise	46			0.72		
Decrease in groundwater quality	Binary-1, if change is perceived; 0, if otherwise	31			0.79		
Decrease in groundwater quantity	Binary-1, if change is perceived; 0, if otherwise	37			0.72		
Decrease in irrigation water quality	Binary-1, if change is perceived; 0, if otherwise	19		0.88			
Decrease in irrigation water quantity	Binary-1, if change is perceived; 0, if otherwise	16		0.90			
Decrease in yield	Binary-1, if change is perceived; 0, if otherwise	36		0.55			
Increase in waste on surface of river	Binary-1, if change is perceived; 0, if otherwise	90				0.75	
Increase in waste on shore of river	Binary-1, if change is perceived; 0, if otherwise	93				0.83	
Increase in tourist numbers	Binary-1, if change is perceived; 0, if otherwise	47	0.66				
Increase in hotels	Binary-1, if change is perceived; 0, if otherwise	48	0.89				
Increase in restaurants	Binary-1, if change is perceived; 0, if otherwise	50	0.89				
Decrease in fish numbers	Binary-1, if change is perceived; 0, if otherwise	89					0.83
Decrease in fish size	Binary-1, if change is perceived; 0, if otherwise	78					0.82
Decrease in river water quality	Binary-1, if change is perceived; 0, if otherwise	95					
Cronbach's alpha			0.76	0.71	0.76	0.83	0.61

After this PCA, we used a binomial logistic regression model to examine respondents' adoption of adaptation strategies as a dichotomous outcome (Comoé and Siegrist 2015, Mase et al. 2017). In this model the probability of the dependent variable is represented as:

$$P = \frac{\exp(\beta_0 + \beta_1 x_1 \dots \beta_i x_i)}{1 + \exp(\beta_0 + \beta_1 x_1 \dots \beta_i x_i)} \quad (1)$$

The model is represented as follows:

$$\ln\left(\frac{P}{1 - P}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots \beta_k x_k \quad (2)$$

where P is the probability of a household adopting an adaptation strategy and 1-P is the probability of a household not adopting an adaptation strategy. β_0 is the intercept, $\beta_1, \beta_2 \dots$ and β_k are regression coefficients of the explanatory variables of $X_1, X_2, X_3, \dots, X_k$. A greater-than-one odds ratio indicates a positive relationship (i.e., the odds of adopting an adaptation strategy increases as the explanatory variable increases), a less-than-one odds ratio indicates a negative relationship (i.e., the odds of adopting an adaptation strategy decreases as the explanatory

variable increases), and an odds ratio of one indicates no relationship between the adoption of an adaptation strategy and the explanatory variables (Hosmer and Lemeshow 2000).

The response variables in our models measure if a respondent's household had adopted one of the following five adaptation strategies: increase agricultural inputs, migrate, decrease time fishing, change domestic water supply, or change crop variety. The response variable takes the value 1 if a respondent's household had adopted an adaptation strategy in the past 10 years and 0 otherwise (Table 3). These 5 adaptation strategies (out of the list of 17) were reported by 10% or more of our respondents. Following other studies on adaptation actions (Bryan et al. 2009), we focus on these five to allow for a more nuanced discussion of most commonly reported adaptations in this research area.

The explanatory variables in our models measure household socio-demographic characteristics, perceived social-ecological changes, and perceived economic and non-economic barriers to each adaptation strategy (Table 4). Following previous research on barriers (Croppenstedt et al. 2003, Dang et al. 2014, De Jalón et al. 2015, Marie et al. 2020), we used binary variables to measure the presence of barriers to adaptation. We did not ask respondents to report the number of times they considered each barrier in the last 10 years, nor were we able to use a Likert scale to measure the importance of a particular barrier due to the difficulty of recalling specific frequencies over a long period of time (Bound

Table 3. Response variables used in the empirical models for estimating adaptation to social-ecological change and corresponding descriptive statistics.

Adaptation strategies adopted in the last 10 years	Description	% of respondents
Increased agricultural inputs	Binary-1, if household increased inputs; 0, if otherwise	35
Migration	Binary-1, if household member moved; 0, if otherwise	30
Decreased time fishing	Binary-1, if household decreased time fishing; 0, if otherwise	21
Changed domestic water supply	Binary-1, if household changed domestic water supply, 0, if otherwise	12
Changed crop variety	Binary-1, if household changed crop variety; 0, if otherwise	10

et al. 2001) and specific logistic challenges associated with administering surveys in our research area. To check for multicollinearity in all the models, we ran a variance inflation factor (VIF) test, represented as:

$$VIF_i = \frac{1}{1 - R_i^2} \quad (3)$$

for each regression. The VIF scores were all below four, the rule of thumb criterion for multicollinearity (Hair et al. 2010).

Following methods from Wheeler et al. (2013), we modeled each adaptation strategy separately because of the heterogeneity of the adaptation strategies (Table 5). Nagelkerke's R^2 is used to evaluate the goodness of fit of the model (Nagelkerke 1991). Acceptable values for R^2 vary by discipline and specific method used (Moksony and Heged 1990). The Nagelkerke's R^2 values for our models are similar to those reported in previous studies of adaptation decision making (Comóe and Siegrist 2015, Truelove et al. 2015, Marie et al. 2020). All data analyses were conducted using Stata 16 and 17.

RESULTS

Socio-demographic and economic characteristics of survey respondents

An overview of the explanatory variables in the models are presented in Table 4. Overall, the socio-demographic and economic characteristics of our survey respondents seemed to be comparable to the broader population in our study area (Government of Pakistan Statistics Division 2010). The average respondent was 39.4 years old with 8.4 years of formal education. The mean household size was 10 persons, and 58% of our respondents reported living in households with a joint family structure, defined as "multi-generational families with two or more married children" (Ruggles 2010). This is slightly larger than the mean household size in KP (7.3 persons), likely due in part to our rural sample in which households are often larger than in urban areas (Pakistan Bureau of Statistics 2017). Our

respondents' average farm size was 3.2 hectares (ha), which is larger than KP's average of 1.5 ha (Government of Pakistan Statistics Division 2010). However, more recent studies of agriculture in KP have reported large variation in farm size; Ullah et al. (2015) reported a mean of 2.38 ha and Khan et al. (2020) reported a mean of 7.02 ha. Our results fall within this variation of land ownership across the province. Our result could also indicate an increase in land ownership because the economy in the research area has stabilized after violent conflicts and disasters during the past decade (Hye and Khan 2013). Overall, 14.5% of our respondents reported that a household member held a leadership position in the community currently or in the past. Finally, our respondents owned an average of 2.6 head of cattle, included because it represents a source of wealth in the area (Ali and Rahut 2018).

Perceived social-ecological changes, adaptation strategies adopted, and barriers to adaptation action

We asked respondents what social-ecological changes they had observed in the past 10 years in their community. There was nearly universal agreement that river water quality had decreased (95%) and solid waste on both the shore (93%) and surface (90%) of the water had increased. Similarly, a majority of the respondents agreed that there had been a decrease in both fish numbers (89%) and size (78%). Other changes reported were related to the revitalization of the tourism industry in the area: 47% of the respondents reported an increase in tourists, 48% reported an increase in hotels, and 50% reported an increase in restaurants. Decreasing agricultural yields were reported by 36% of the respondents. Respondents also reported a decrease in ground water quality (31%) and quantity (37%), as well as changes in domestic water quantity (37%) and quality (46%).

We also asked respondents how they adapted to the aforementioned perceived social-ecological changes. Table 3 includes all adaptation strategies that were reported by at least 10% of our respondents and used in the model. Increasing agricultural inputs (35%) and having a household member migrate to another place for work (30%) were the most frequently reported strategies. Other respondents reported decreasing time spent fishing (21%), changing their domestic water supply (12%), and changing their crop variety (10%). This reflects other work from this region that reports households' using new crop varieties in response to market demand and changing water availability (Ali and Erenstein 2017, Khan et al. 2020, Nixon et al. 2022), shifting their water supplies from public to private sources and from surface to groundwater (Qureshi 2011, Nixon et al. 2022), and increasing their use of fertilizers and pesticides in response to decreasing agricultural yields (Ullah et al. 2018).

In terms of perceived barriers associated with decisions to employ each adaptation strategy, financial cost was the most frequently reported barrier by respondents (92%), followed by the time (64%) and labor (58%) needed to employ the adaptation. Going against friends' (13%) and leaders' (6%) opinions about an adaptation strategy were cited less frequently than going against family opinions (43%) as a barrier that the respondents had to overcome to employ an adaptation strategy. The least frequently reported barriers to adaptation were the need to go against cultural traditions (18%) and taking on increased uncertainty (16%) as a result of employing an adaptation strategy.

Table 4. Explanatory variables used in the empirical models for estimating adaptation to social-ecological change and corresponding descriptive statistics. Note: PCA = polychoric principal component analysis; PKR = Pakistani Rupee.

Socio-demographic characteristics	Description	Mean (range; std. dev.) or % of respondents
Age of household head	Continuous- years	39.4 (19-77; 12.9)
Education of household head	Continuous- years	8.4 (0-18; 5.5)
Household size	Continuous- persons	10.1 (2-35; 5.3)
Joint family structure	Binary-1, if multi-generational families with two or more married children; 0, if otherwise	57.6
Size of land in agricultural production	Continuous- hectares of owned and rented land in agricultural production	3.2 (0-151.8; 15.0)
Household income over 30,000 PKR	Binary-1, if household income over 30,000 PKR; 0, if otherwise	55.7
Household member in a past or current leadership position	Binary-1, if household member has held a formal or informal leadership position; 0, if otherwise	14.5
Ownership of cattle	Continuous-heads of cattle owned	2.6 (1-12; 1.9)
Perceived social-ecological changes		
PCA measuring perceiving changes in tourism	Continuous (principal component loadings, see Table 1)	0.49 (0-1; 0.47)
PCA measuring perceiving changes in the agricultural system	Continuous (principal component loadings, see Table 1)	0.18 (0-1; 0.35)
PCA measuring perceiving changes in groundwater	Continuous (principal component loadings, see Table 1)	0.21 (0-1; 0.37)
PCA measuring perceiving changes in solid waste	Continuous (principal component loadings, see Table 1)	0.89 (0-1; 0.25)
PCA measuring perceiving changes in fish populations	Continuous (principal component loadings, see Table 1)	0.77 (0-1; 0.28)
Perceiving decrease in river water quality	Binary-1, if change is perceived in past 10 years; 0, if otherwise	95
Perceived barriers to adaptation		
Financial	Binary-1, if barrier is perceived in past 10 years; 0, if otherwise	92
Time	Binary-1, if barrier is perceived in past 10 years; 0, if otherwise	64
Labor	Binary-1, if barrier is perceived in past 10 years; 0, if otherwise	58
Family members' opinion	Binary-1, if barrier is perceived in past 10 years; 0, if otherwise	43
Cultural tradition	Binary-1, if barrier is perceived in past 10 years; 0, if otherwise	18
Certainty	Binary-1, if barrier is perceived in past 10 years; 0, if otherwise	16
Friends' opinion	Binary-1, if barrier is perceived in past 10 years; 0, if otherwise	13
Leaders' opinion	Binary-1, if barrier is perceived in past 10 years; 0, if otherwise	6

Factors influencing households' decisions to employ adaptation strategies

Results of the logistic regression models are shown in Table 5. First, of all socio-demographic variables included in the model, household income and cattle ownership, were the only two significant variables that predicted the adoption of adaptation strategies. The odds ratio for household income was 3.09 ($p < 0.001$); that is, with all other variables held constant, the odds of households with an annual income of more than 30,000 PKR adopting migration as an adaptation strategy is three times the likelihood of households with lower income adapting through migration. Additionally, heads of cattle owned had a positive relationship with both increasing agricultural inputs and changing crop varieties. Specifically, an increase of one head of cattle owned was associated with a 42% increase of the odds of respondents changing their crop varieties ($p = 0.033$) and a 62% increase of the odds of respondents increasing agricultural inputs ($p = 0.007$).

Second, of the variables measuring perceived social-ecological changes, perceiving agricultural changes was the only significant variable in one model. Specifically, for every one-unit increase of a respondent's perception of agricultural changes, the odds of respondents adapting by increasing their agricultural inputs increased 14.37 times ($p < 0.001$) when all other variables were held constant.

Finally, our model results also showed how perceptions of barriers to adaptation were significant in several models that predicted respondents' adaptation decisions. Specifically, our results showed that perceiving financial barriers had a significant positive relationship with respondents' households changing their domestic water supply (odds ratio = 1.63; $p < 0.001$), increasing agricultural inputs (odds ratio = 6.02; $p < 0.001$), and engaging in migration (odds ratio = 4.58; $p = 0.015$). Perceiving increased time needed to employ the adaptation was positively associated with respondents' households changing domestic water supply (odds ratio = 10.34; $p = 0.003$) and migration (odds ratio = 2.12; $p = 0.033$). Perceiving increased labor needs as a barrier was positively associated with changing domestic water supply (odds ratio = 3.92; $p = 0.019$), migration (odds ratio = 2.19; $p = 0.016$), and increasing agricultural inputs (odds ratio = 11.86; $p = 0.013$). Perceiving increased uncertainty as a barrier was also positively associated with decreasing time fishing (odds ratio = 11.43; $p = 0.039$).

In terms of the perceiving the influence of others' opinions as a barrier to adaptation, the opinions of community leaders as a barrier of adaptation were positively associated with decreasing time spent fishing (odds ratio = 21.56; $p < 0.001$), and friends' opinions were positively associated with migration (odds ratio = 2.52; $p = 0.045$). Perceiving their family members' opinions as a barrier was positively associated with respondents' households

Table 5. Binary logistic regression results of factors influencing household decisions to employ various adaptation strategies. Note: PKR = Pakistani Rupee; PCA = polychoric principal component analysis.

	Decreased time fishing			Changed crop variety			Changed domestic water supply			Migrated			Increased agricultural inputs			
	Odds ratio	95% CI		Odds ratio	95% CI		Odds ratio	95% CI		Odds ratio	95% CI		Odds ratio	95% CI		
Age of household head	1.01	0.94	1.09	0.97	0.93	1.02	1.01	0.98	1.04	1	0.98	1.02	1.03	0.99	1.07	
Education of household head	0.92	0.79	1.08	0.95	0.85	1.06	1.04	0.96	1.13	1.01	0.95	1.07	1	0.91	1.11	
Household size	0.94	0.77	1.14	1.08	0.99	1.18	1.01	0.93	1.09	1.03	0.98	1.09	1.03	0.95	1.12	
Joint family structure	0.3	0.05	1.76	0.7	0.21	2.32	1.01	0.44	2.33	1.53	0.86	2.69	0.54	0.17	1.75	
Land size in agricultural production	1	0.96	1.05	1.01	0.98	1.03	1	0.95	1.04	0.98	0.95	1.01	1.01	0.99	1.03	
Household income over 30,000 PKR	2.16	0.42	11.06	1.09	0.36	3.32	0.82	0.37	1.8	3.09*	1.77	5.4	1.46	0.46	4.6	
Household member in leadership position	2.11	0.29	15.51	0.73	0.18	2.99	1.75	0.65	4.66	0.89	0.42	1.86	0.29	0.06	1.28	
Ownership of cattle	1.17	0.68	2.02	1.42*	1.03	1.96	0.8	0.58	1.12	0.96	0.78	1.18	1.62*	1.18	2.22	
Perceiving decrease in river water quality	3.51	0.1	22.15	2.07	0.19	22.4	0.56	0.1	3.1	0.47	0.15	1.46	0.15	0.01	1.71	
PCA measuring perceiving changes in fish populations	3.14	0.09	10.3	1.86	0.26	13.22	4.5	0.87	23.21	1.11	0.47	2.61	11.46	1.08	21.26	
PCA measuring perceiving changes in tourism	1.47	0.33	6.61	0.7	0.23	2.13	0.7	0.31	1.58	0.89	0.5	1.57	0.32	0.11	0.97	
PCA measuring perceiving changes in the agricultural system	0.68	0.06	7.99	3.69	0.86	15.84	0.92	0.31	2.75	0.62	0.27	1.41	14.37*	3.74	55.21	
PCA measuring perceiving changes in groundwater	0.27	0.02	2.97	0.32	0.07	1.44	0.77	0.31	1.9	0.67	0.33	1.37	0.8	0.22	2.83	
PCA measuring perceiving changes in solid waste	16.08	0.16	19.35	0.42	0.07	2.38	1.08	0.24	4.89	1.12	0.39	3.22	5.72	0.4	80.84	
Finances	1.63	0.06	44.43	2.81	0.73	10.87	8.48	3.85	18.72	4.58*	1.32	15.93	6.02*	3.27	11.1	
Time	10.34	0.81	31.62	0.59	0.15	2.39	6.34	1.82	22.1	2.12*	1.08	4.18	0.51	0.1	2.73	
Labor	0.87	0.15	5.2	3.19	0.73	13.97	3.92*	1.32	11.63	2.19*	1.15	4.18	11.86*	1.75	80.6	
Family members' opinion	7.17*	0.96	53.36	0.36	0.09	1.38	0.37*	0.16	0.83	0.20*	0.11	0.37	0.52	0.16	1.75	
Certainty	11.43*	1.41	92.44	1.59	0.45	5.66	0.98	0.32	2.99	1.8	0.91	3.58	2.18	0.48	9.84	
Cultural tradition	0.49	0.09	2.66	0.77	0.18	3.28	0.36	0.13	1.03	0.82	0.39	1.68	1.01	0.26	3.93	
Leaders' opinion	21.56*	4.59	30.27	2.12	0.4	11.32	1.43	0.33	6.26	1.95	0.7	5.43	1.01	0.17	5.95	
Friends' opinion	1	0.16	6.36	2.72	0.65	11.4	0.68	0.19	2.43	2.52*	1.09	5.8	0.43	0.08	2.38	
LR chi-squared (23)		66.16			34.03			90.28			108.23			174.1		
Pseudo R ²		0.5			0.19			0.28			0.2			0.55		

*p < 0.05.

decreasing time fishing (odds ratio = 7.17; $p = 0.030$). In contrast, family members' opinions had a negative relationship with respondents' households engaging in migration (odds ratio = 0.20; $p < 0.001$) and changing their domestic water supply (odds ratio = 0.37; $p = 0.018$).

DISCUSSION

Governance structures are vital in the support of household adaptation to social-ecological change; thus, this work aims to inform the emergence of AWG to respond to the complexity and nuance of household decision-making processes. Although adaptation strategies and social-ecological contexts will vary, this case study presents an example of barriers to adaptation to social-ecological change and the need for AWG among water users in an area experiencing climate change, rapid urbanization, and tourism development. In particular, we illustrate that AWG is more likely to take place when decision makers involved in water management (1) consider the complex ways water users respond to multiple social-ecological stressors, (2) implement cross-sectoral collaboration to reflect this complexity, and (3) draw on existing institutions as they relate to social influence.

Perceiving social-ecological changes does not necessarily result in adaptation

Our results extend previous research findings by demonstrating the complex relationships between perceptions of social-ecological changes and decisions to adapt. In our study, perceived changes in the agricultural system (in terms of water supply and crop yield, for example) were positively associated with increasing agricultural inputs as an adaptation strategy. Similar behaviors have been observed in other agricultural contexts as well, showing that farmers who perceive risks to their production are often more likely to adapt or want to adapt (Mase et al. 2017, Azadi et al. 2019).

It is noteworthy that perceiving other social-ecological change was not significantly associated with adoption of adaptation strategies. For example, perceiving changes in surface water and groundwater did not affect respondents' water use even though many respondents did rely on these as sources of domestic water. These results confirm what has been suggested in previous research, that is, that perceiving social-ecological changes does not necessarily lead to adopting adaptation strategies (Bryan et

al. 2009, Fosu-Mensah et al. 2012). Rather, it has been shown that even when individuals perceive climatic changes, lack of access to land, information, and finances may limit their capacity to adapt (Bryan et al. 2009, 2013). Further, perceiving climatic changes may not significantly influence adaptation because households adapt their livelihoods to multiple compounding social, economic, and environmental stressors rather than climate alone (Burnham and Ma 2018, Hoque et al. 2018, Galappaththi et al. 2020, Lenaiyasa et al. 2020, Erwin et al. 2021). Indeed, non-climatic factors such as economic, political, and social stressors are often identified as more significant drivers of adaptation decisions than climate (Mertz et al. 2010, Tucker et al. 2010, Yaro 2013). Our results echo these findings by highlighting how perceived social-ecological changes have varied influence on households' decisions to adapt as they navigate the stressors and risks associated with multiple social-ecological changes simultaneously. Therefore, although our study shows that AWG emerged in response to growing water stress (Folke et al. 2005, Boltz et al. 2019, Pahl-Wostl 2019), it also supports previous work arguing that the promotion of AWG requires not only responses to multiple social-ecological stressors encountered by water users but accounting for the complexity of decision making in these contexts (Huitema et al. 2009, Rijke et al. 2012). This means that rather than focusing solely on water supply, decision makers who want to facilitate AWG will need to consider changes across sectors (i.e., changes to crop yields or agricultural market patterns) that may drive water demand and the priorities of water users. Polycentric governance, or governance that includes multiple governing bodies, is a key aspect of AWG; however, these studies on polycentric water governance have often focused on multi-scalar collaboration (e.g., local, regional, national governance bodies; Huitema et al. 2009, Engle and Lemos 2010, Pahl-Wostl et al. 2012, Chaffin et al. 2016). We argue that collaboratively addressing multiple drivers of household adaptation through cross-sectoral institutions will further promote AWG. For our research areas, this suggests a need for the PIDAs and AWBs to work closely with the KP Agricultural Department to facilitate cross-sectoral coordination and collaboration that more accurately reflects the factors that influence adaptation decision making at the household, community, and regional scales.

Household socio-demographic characteristics shape adaptation decisions

Our research identified two socio-demographic household characteristics that shape adaptation decisions. First, respondents' household income was positively associated with using migration as an adaptation strategy. This may be explained by the fact that labor migration often requires a large initial investment to support the relocation of a household member (Mendola 2008). As such, households with higher income may be more able to employ this adaptation strategy than those with lower household income. Additionally, heads of cattle owned by a household had a positive significant relationship with both increasing agricultural inputs and changing crop varieties as adaptation strategies. Cattle represent a form of wealth and often serve as a safety net in rural areas around the world, including our research area (Ali and Rahut 2018). As such, households with more cattle may feel less risk or be more able to invest in agricultural improvements, as shown in other studies of

adaptation in agricultural settings (e.g., Wood et al. 2014, Rapsomanikis 2015). Together, our findings provide further evidence from the context of rural Pakistan that echo numerous studies showing that households' financial capital, including livestock ownership, supports their ability to adapt to social-ecological change perhaps in part due to their means to both employ adaptation action and recover from unintended outcomes (e.g., Bryan et al. 2009, Deressa et al. 2009, Below et al. 2012). In terms of the implications for governance, this nuanced understanding between socio-demographic characteristics and adaptation informs targeted support to increase households' adaptive capacity. In particular, AWG will be more likely to emerge when decision makers involved in water management consider and attend to disparities in multiple sources of capital that may be hindering adaptive capacity.

It is worth pointing out that beyond household income and cattle ownership, no other socio-demographic variables were statistically significant in our models, including age, education, and joint family structure, as suggested in other similar studies in the Global South (Deressa et al. 2009, Below et al. 2012, Asfaw et al. 2019). However, the trends are similar to other findings (i.e., household size and education of the head have a positive odds ratio with increasing agricultural inputs and migration). This may be because we analyzed adaptation types separately and these indicators have different influences on these specific adaptations. Our research context may also influence these findings; for example, the education of the household head may not be an appropriate indicator of the education of the household, especially given past conflict and instability that might have hindered education and thus limited variation in attainment (Hye and Khan 2013, DDMU 2015). Therefore, an increase in access to education or younger household members' education might make education a more accurate predictor of adaptation. The insignificance of our socio-demographic predictors may also suggest that the perceived barriers to adaptation may be a more important factor in adaptation decisions. Thus, our findings indicate that although water users' multiple sources of capital (i.e., income, livestock ownership, etc.) shape household adaptive capacity, non-economic factors should also be considered for their influence in whether household engage in adaptation.

The differentiated role of perceived economic and non-economic barriers in shaping household adaptation decisions

In addition to socio-demographic factors and perceived social-ecological changes, our results show that respondents' perceived barriers to adaptation also influence their decisions to employ some adaptation strategies. Our results show that perceiving economic barriers (finances, time, and labor) had a significant positive relationship with households changing their domestic water supply, increasing agricultural inputs, and engaging in migration as adaptation strategies. In other words, respondents reported employing these adaptation strategies even though they perceived them to be economically costly. Although time, labor, and financial factors can be significant factors that decrease the likelihood of employing adaptation actions (Silvestri et al. 2012, Tambo and Abdoulaye 2012, Tessema et al. 2013, Kuang et al. 2019), our results reveal that they do not necessarily decrease the likelihood of adaptation; rather, there may be other factors (e.g., perceived benefit of the adaptation, variation in magnitude of the cost etc.) that mitigate economic barriers and motivate adaptation

decisions. In particular, our results show that the perception of economic barriers varies across adaptation types and that in some cases, economic investments may be the expected and accepted costs of adaptation, thus having no effect on adaptation decisions.

In addition to the economic barriers to adaptation, we also examined the influence of family members', friends', and leaders' opinions on adaptation actions. In our study, respondents appeared to be largely willing to adapt in ways that go against their community leaders' opinions, for example, to decrease time spent fishing. They also seemed willing to go against their friends' opinions to migrate. They were less willing, however, to adapt in ways that went against their family members' opinions, particularly in the case of changing domestic water supply and engaging in migration. This reveals that social influence does sway adaptation decisions, but more specifically, that it can have differing influence across actions and relationship types. Indeed, in a meta-analysis on the impact of social influence on conservation behavior, Abrahamse and Steg (2013) showed that the degree to which social influence impacted behavior varied by group identification. That is, social influence has a larger impact on individuals who strongly identified with their social group in comparison to those with weaker group identification. Fielding et al. (2008) found similar trends in their study of sustainable agriculture practices: individuals with strong group identification are predominately influenced by others in their social group, while those with weaker group identification are influenced by behaviors both in and outside of their social group. Similarly, a message is known to be more persuasive if it comes from sources that are similar to and liked by the recipient of the message in both consumer behavior (Pornpitakpan 2004) and energy use (Wolske et al. 2020). Therefore, it follows that in our research, family members had a strong influence on adaptation decisions likely due in part to respondents strong group identification with family members.

More specifically, our results may be related to the specific cultural context of northwestern Pakistan where it has long been shown that familial ties are a fundamental social structure (Ahmed 1980, 2004, Lindholm 1982); therefore, opinions of family members may be more important than opinions of others when making adaptation decisions. More importantly, our results reveal that the extent to which social influence from various actors or sources affects decision making may shift based on the decision in question and the different contexts in which decisions are made. Overall, however, our work indeed confirms that social influence sways adaptation decisions, and that in our context, this influence often comes from family rather than formal leadership. In the context of AWG, this points to the need for governance regimes to address barriers to adaptations beyond providing information or financial assistance. In particular, careful consideration of the sources of information, not just information content will ensure that these individuals are trusted by the water users.

More broadly, collaborative natural resource decision making has been documented in multiple contexts through the Global South and North (e.g., Selvaraju et al. 2005, McCabe et al. 2010, Iles et al. 2020). Given this prevalence, we posit that AWG will emerge in conditions that align governance structures with the existing institutions of social influence and decision making. Our research also adds specificity to our understanding of social influence by

revealing that social influence may differ in the way it drives various adaptation strategies. That is, in our research, water users were unlikely to change their domestic water supply if their family disagreed with this adaptation, but did decrease time spent fishing even if their family disapproved. Adaptive water governance has proven to be a promising mechanism to include nuanced drivers of decision making (Bark et al. 2012, Chaffin et al. 2014), which makes it well-suited to incorporate these varied social influences in governance of adaptation.

Furthermore, our research highlights the additional work needed to understand how social influence from various groups impacts adaptation decisions. Much work has been done to show how individuals' adaptation decisions are shaped by their family members, friends, and neighbors (Dang et al. 2014, van Valkengoed and Steg 2019); however, little has been done to tease out how the influence of these groups may vary. At the same time, it is important to keep in mind that there may be other possible explanations regarding the difference in how family members' opinions shape households' decisions to employ different adaptation strategies. For example, it could be because of the weights given to different family members with different opinions about an adaptation strategy (e.g., the effect may be different if a sister disagrees rather than a father), therefore, further work is needed to examine the nuanced influence of various family members in adaptation decision making.

Nevertheless, our work does inform AWG's incorporation of existing leaders and information sources in governance structures. Leadership in AWG has been shown to be a key component of water systems' adaptive capacity (Hurlbert and Diaz 2013). In particular, Ayre and Nettle (2017) highlighted the need for multi-scalar leadership. Our work builds on this understanding by illustrating the influence of informal leaders on household adaptation decisions, and in that way, points to the need for the inclusion of informal leaders in this multi-scalar structure. For water governance in our research area, this means that entities like PIDAs, AWBs, and WUAs should consider ways to include informal leaders in both their decision making and information distribution to align their structures with the informal institutions of the area.

CONCLUSION

Our research illustrates that influences on adaptation decisions go beyond the barriers of finances, time, and labor, which have been a strong focus of many adaptation studies. In contrast, in our study context, water users were unlikely to engage in an adaptive practice if they perceived that an adaptation would go against their family members' opinions, but in many cases employed adaptation actions in spite of economic barriers. Therefore, we argue that although it is important to help rural households remove economic barriers in their adaptation decision-making processes, it is also important to recognize that social influences shape what adaptation strategies individuals and households are willing to employ. In some cases, this influence may be a more powerful driver of decisions than economic barriers. Adaptive water governance will therefore emerge when informal leaders are included in both decision making and information dissemination to align governance with existing institutions in our research area. In addition, our study reveals that multiple perceived social-ecological changes drive adaptation

actions, and thus, we posit that the AWG will be developed when polycentric governance includes coordination and collaboration across multiple sectors. These nuanced understandings of the climatic changes, economic factors, and social influences that shape adaptation to social-ecological change will allow AWG to acknowledge and align with the complex drivers of household adaptation decision making in water governance structures. Overall, our work shows that examination of social influence is one way to better understand and embed governance in specific social-ecological contexts. Household adaptive capacity is shaped in part by the governance structures found in the multi-scalar landscape in which adaptation occurs, thus AWG can support this adaptation by integrating the diversity and nuance of drivers at play in adaptation decision making to support rural livelihoods in the midst of compounding and complex social-ecological change.

Responses to this article can be read online at:
<https://www.ecologyandsociety.org/issues/responses.php/13546>

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Data Availability:

The data/code that support the findings of this study are available on request from the corresponding author, RN. Ethical approval for this research study was granted by Purdue University (IRB #1803020343).

LITERATURE CITED

Abrahamse, W., and L. Steg. 2013. Social influence approaches to encourage resource conservation: a meta-analysis. *Global Environmental Change* 23(6):1773-1785. <https://doi.org/10.1016/j.gloenvcha.2013.07.029>

Agrawal, A., and N. Perrin. 2009. Climate adaptation, local institutions and rural livelihoods. Pages 350-367 in E. N. Adger, I. Lorenzoni, and K. L. O'Brien. *Adapting to climate change: thresholds, values, governance*. Cambridge University Press, Cambridge, UK. <https://doi.org/10.1017/CBO9780511596667.023>

Ahmed, A. S. 1980. *Pukhtun economy and society: traditional structure and economic development in a tribal society*. Routledge, New York, New York, USA.

Ahmed, A. S. 2004. *Resistance and control in Pakistan*. Routledge, New York, New York, USA. <https://doi.org/10.4324/9780203337431>

Akamani, K. 2016. Adaptive water governance: integrating the human dimensions into water resource governance. *Journal of Contemporary Water Research and Education* 158(1):2-18. <https://doi.org/10.1111/j.1936-704X.2016.03215.x>

Ali, A., and O. Erenstein. 2017. Assessing farmer use of climate change adaptation practices and impacts on food security and poverty in Pakistan. *Climate Risk Management* 16:183-194. <https://doi.org/10.1016/j.crm.2016.12.001>

Ali, A., and D. B. Rahut. 2018. Forest-based livelihoods, income, and poverty: empirical evidence from the Himalayan region of rural Pakistan. *Journal of Rural Studies* 57:44-54. <https://doi.org/10.1016/j.jrurstud.2017.10.001>

Alobo Loison, S. 2015. Rural livelihood diversification in sub-Saharan Africa: a literature review. *Journal of Development Studies* 51(9):1125-1138. <https://doi.org/10.1080/00220388.2015.1046445>

Antwi-Agyei, P., L. C. Stringer, and A. J. Dougill. 2014. Livelihood adaptations to climate variability: Insights from farming households in Ghana. *Regional Environmental Change* 14:1615-1626. <https://doi.org/10.1007/s10113-014-0597-9>

Asfaw, A., B. Simane, A. Bantider, and A. Hassen. 2019. Determinants in the adoption of climate change adaptation strategies: evidence from rainfed-dependent smallholder farmers in north-central Ethiopia (Woleka sub-basin). *Environment, Development and Sustainability* 21(5):2535-2565. <https://doi.org/10.1007/s10668-018-0150-y>

Ayre, M. L., and R. A. Nettle. 2017. Enacting resilience for adaptive water governance: a case study of irrigation modernization in an Australian catchment. *Ecology and Society* 22(3):1. <https://doi.org/10.5751/ES-09256-220301>

Azadi, Y., M. Yazdanpanah, and H. Mahmoudi. 2019. Understanding smallholder farmers' adaptation behaviors through climate change beliefs, risk perception, trust, and psychological distance: evidence from wheat growers in Iran. *Journal of Environmental Management* 250:109456. <https://doi.org/10.1016/j.jenvman.2019.109456>

Baird, J., R. Plummer, R. Bullock, D. Dupont, T. Heinmiller, M. Jollineau, W. Kubik, S. Renzetti, and L. Vasseur. 2016. Contemporary water governance: navigating crisis response and institutional constraints through pragmatism. *Water* 8(6):224. <https://doi.org/10.3390/w8060224>

Bark, R. H., D. E. Garrick, C. J. Robinson, and S. Jackson. 2012. Adaptive basin governance and the prospects for meeting Indigenous water claims. *Environmental Science and Policy* 19:169-177. <https://doi.org/10.1016/j.envsci.2012.03.005>

Bartlett, M. S. 1951. The effect of standardization on a χ^2 approximation in factor analysis. *Biometrika* 38(3/4):337-344. <https://doi.org/10.1093/biomet/38.3-4.337>

- Bayard, B., C. M. Jolly, and D. A. Shannon. 2007. The economics of adoption and management of alley cropping in Haiti. *Journal of Environmental Management* 84(1):62-70. <https://doi.org/10.1016/j.jenvman.2006.05.001>
- Below, T. B., K. D. Mutabazi, D. Kirschke, C. Franke, S. Sieber, R. Siebert, and K. Tscherning. 2012. Can farmers' adaptation to climate change be explained by socio-economic household-level variables? *Global Environmental Change* 22(1):223-235. <https://doi.org/10.1016/j.gloenvcha.2011.11.012>
- Bennett, N. J., J. Blythe, S. Tyler, and N. C. Ban. 2016a. Communities and change in the anthropocene: understanding social-ecological vulnerability and planning adaptations to multiple interacting exposures. *Regional Environmental Change* 16(4):907-926. <https://doi.org/10.1007/s10113-015-0839-5>
- Bennett, N. J., A. Kadfak, and P. Dearden. 2016. Community-based scenario planning: a process for vulnerability analysis and adaptation planning to social-ecological change in coastal communities. *Environment, Development and Sustainability* 18(6):1771-1799. <https://doi.org/10.1007/s10668-015-9707-1>
- Bodin, Ö., and B. I. Crona. 2009. The role of social networks in natural resource governance: what relational patterns make a difference? *Global Environmental Change* 19(3):366-374. <https://doi.org/10.1016/j.gloenvcha.2009.05.002>
- Boltz, F., N. LeRoy Poff, C. Folke, N. Kete, C. M. Brown, S. St. George Freeman, J. H. Matthews, A. Martinez, and J. Rockström. 2019. Water is a master variable: solving for resilience in the modern era. *Water Security* 8:100048. <https://doi.org/10.1016/j.wasec.2019.100048>
- Bound, J., C. Brown, and N. Mathiowetz. 2001. Measurement error in survey data. Pages 3705-3843 in *Handbook of Econometrics*. Volume 5. Elsevier, Amsterdam, the Netherlands. [https://doi.org/10.1016/S1573-4412\(01\)05012-7](https://doi.org/10.1016/S1573-4412(01)05012-7)
- Bryan, E., T. T. Deressa, G. A. Gbetibouo, and C. Ringler. 2009. Adaptation to climate change in Ethiopia and South Africa: options and constraints. *Environmental Science and Policy* 12(4):413-426. <https://doi.org/10.1016/j.envsci.2008.11.002>
- Bryan, E., C. Ringler, B. Okoba, C. Roncoli, S. Silvestri, and M. Herrero. 2013. Adapting agriculture to climate change in Kenya: household strategies and determinants. *Journal of Environmental Management* 114: 26-35. <https://doi.org/10.1016/j.jenvman.2012.10.036>
- Burnham, M., and Z. Ma. 2016. Linking smallholder farmer climate change adaptation decisions to development. *Climate and Development* 8(4):289-311. <https://doi.org/10.1080/17565529.2015.1067180>
- Burnham, M., and Z. Ma. 2017. Climate change adaptation: factors influencing Chinese smallholder farmers' perceived self-efficacy and adaptation intent. *Regional Environmental Change* 17(1):171-186. <https://doi.org/10.1007/s10113-016-0975-6>
- Burnham, M., and Z. Ma. 2018. Multi-scalar pathways to smallholder adaptation. *World Development* 108:249-262. <https://doi.org/10.1016/j.worlddev.2017.08.005>
- Carr, E. R. 2008. Between structure and agency: livelihoods and adaptation in Ghana's Central Region. *Global Environmental Change* 18(4):689-699. <https://doi.org/10.1016/j.gloenvcha.2008.06.004>
- Chaffin, B. C., A. S. Garmestani, H. Gosnell, and R. K. Craig. 2016. Institutional networks and adaptive water governance in the Klamath River Basin, USA. *Environmental Science and Policy* 57:112-121. <https://doi.org/10.1016/j.envsci.2015.11.008>
- Chaffin, B. C., H. Gosnell, and B. A. Cosens. 2014. A decade of adaptive governance scholarship: synthesis and future directions. *Ecology and Society* 19(3):3. <https://doi.org/10.5751/ES-06824-190356>
- Cleaver, F., and L. Whaley. 2018. Understanding process, power, and meaning in adaptive governance. *Ecology and Society* 23(2):49. <https://doi.org/10.5751/es-10212-230249>
- Comoé, H., and M. Siegrist. 2015. Relevant drivers of farmers' decision behavior regarding their adaptation to climate change: a case study of two regions in Côte d'Ivoire. *Mitigation and Adaptation Strategies for Global Change* 20(2):179-199. <https://doi.org/10.1007/s11027-013-9486-7>
- Cooper, R. 2018. Water management/governance systems in Pakistan. K4D Helpdesk Report. Institute of Development Studies, Brighton, UK. https://assets.publishing.service.gov.uk/media/5c6c293140f0b647b35c4393/503_Water_Governance_Systems_Pakistan.pdf
- Cosens, B., L. Gunderson, C. Allen, and M. H. Benson. 2014. Identifying legal, ecological and governance obstacles, and opportunities for adapting to climate change. *Sustainability* 6(4):2338-2356. <https://doi.org/10.3390/su6042338>
- Cronbach, L. J. 1951. Coefficient alpha and the internal structure of tests. *Psychometrika* 16(3):297-334. <https://doi.org/10.1007/BF02310555>
- Croppenstedt, A., M. Demeke, and M. M. Meschi. 2003. Technology adoption in the presence of constraints: the case of fertilizer demand in Ethiopia. *Review of Development Economics* 7(1):58-70. <https://doi.org/10.1111/1467-9361.00175>
- Curry, G. N., G. Koczberski, J. Lummani, R. Nailina, E. Peter, G. McNally, and O. Kuaimba. 2015. A bridge too far? The influence of socio-cultural values on the adaptation responses of smallholders to a devastating pest outbreak in cocoa. *Global Environmental Change* 35:1-11. <https://doi.org/10.1016/j.gloenvcha.2015.07.012>
- Dang, H. L., E. Li, I. Nuberg, and J. Bruwer. 2014. Understanding farmers' adaptation intention to climate change: a structural equation modelling study in the Mekong Delta, Vietnam. *Environmental Science and Policy* 41:11-22. <https://doi.org/10.1016/j.envsci.2014.04.002>
- De Jalón, S. G., S. Silvestri, A. Granados, and A. Iglesias. 2015. Behavioural barriers in response to climate change in agricultural communities: an example from Kenya. *Regional Environmental Change* 15(5):851-865. <https://doi.org/10.1007/s10113-014-0676-y>
- Deressa, T. T., R. M. Hassan, C. Ringler, T. Alemu, and M. Yesuf. 2009. Determinants of farmers' choice of adaptation methods to climate change in the Nile Basin of Ethiopia. *Global Environmental Change* 19(2):248-255. <https://doi.org/10.1016/j.gloenvcha.2009.01.002>

- District Disaster Management Unit (DDMU). 2015. District Disaster Management Plan (2015-2020). Provincial Disaster Management Authority, Khyber Pakhtunkhwa, Pakistan.
- Eakin, H. 2000. Smallholder maize production and climatic risk: a case study from Mexico. *Climatic Change* 45(1):19-36. https://doi.org/10.1007/978-94-017-3010-5_3
- Elrick-Barr, C. E., B. L. Preston, D. C. Thomsen, and T. F. Smith. 2014. Toward a new conceptualization of household adaptive capacity to climate change: applying a risk governance lens. *Ecology and Society* 19(4):12. <https://doi.org/10.5751/ES-06745-190412>
- Engle, N. L., and M. C. Lemos. 2010. Unpacking governance: building adaptive capacity to climate change of river basins in Brazil. *Global Environmental Change* 20(1):4-13. <https://doi.org/10.1016/j.gloenvcha.2009.07.001>
- Erwin, A., Z. Ma, R. Popovici, E. P. S. O'Brien, L. Zanotti, E. Z. Zeballos, J. Bauchet, N. R. Calderón, and G. R. A. Larrea. 2021. Intersectionality shapes adaptation to social-ecological change. *World Development* 138:105282. <https://doi.org/10.1016/j.worlddev.2020.105282>
- Esham, M., and C. Garforth. 2013. Agricultural adaptation to climate change: insights from a farming community in Sri Lanka. *Mitigation and Adaptation Strategies for Global Change* 18(5):535-549. <https://doi.org/10.1007/s11027-012-9374-6>
- Fedele, G., C. I. Donatti, C. A. Harvey, L. Hannah, and D. G. Hole. 2020. Limited use of transformative adaptation in response to social-ecological shifts driven by climate change. *Ecology and Society* 25(1):25. <https://doi.org/10.5751/ES-11381-250125>
- Field, A. 2009. *Discovering statistics using SPSS*. Sage, Thousand Oaks, California, USA.
- Fielding, K. S., D. J. Terry, B. M. Masser, and M. A. Hogg. 2008. Integrating social identity theory and the theory of planned behaviour to explain decisions to engage in sustainable agricultural practices. *British Journal of Social Psychology* 47(1):23-48. <https://doi.org/10.1348/014466607X206792>
- Foley, J. A., R. DeFries, G. P. Asner, C. Barford, G. Bonan, S. R. Carpenter, F. S. Chapin, M. T. Coe, G. C. Daily, H. K. Gibbs, J. H. Helkowski, T. Holloway, E. A. Howard, C. J. Kucharik, C. Monfreda, J. A. Patz, I. C. Prentice, N. Ramankutty, and P. K. Snyder. 2005. Global consequences of land use. *Science* 309(5734):570-574. <https://doi.org/10.1126/science.1111772>
- Folke, C., T. Hahn, P. Olsson, and J. Norberg. 2005. Adaptive governance of social-ecological systems. *Annual Review of Environment and Resources* 30:441-473. <https://doi.org/10.1146/annurev.energy.30.050504.144511>
- Food and Agriculture Organization of the United Nations (FAO). 2011. AQUASTAT country profile - Pakistan. Food and Agriculture Organization of the United Nations, Rome, Italy. <https://www.fao.org/publications/card/en/c/CA0403EN/>
- Forsyth, T., and N. Evans. 2013. What is autonomous adaption? Resource scarcity and smallholder agency in Thailand. *World Development* 43:56-66. <https://doi.org/10.1016/j.worlddev.2012.11.010>
- Fosu-Mensah, B. Y., P. L. G. Vlek, and D. S. MacCarthy. 2012. Farmers' perception and adaptation to climate change: a case study of Sekyedumase district in Ghana. *Environment, Development and Sustainability* 14(4):495-505. <https://doi.org/10.1007/s10668-012-9339-7>
- Galappaththi, E. K., J. D. Ford, and E. M. Bennett. 2020. Climate change and adaptation to social-ecological change: the case of indigenous people and culture-based fisheries in Sri Lanka. *Climatic Change* 162:279-300. <https://doi.org/10.1007/s10584-020-02716-3>
- Government of Pakistan. 2018. National water policy. Government of Pakistan, Ministry of Water Resources, Islamabad, Pakistan. [Pakistan-National-Water-Policy-2018.pdf](https://www.water.gov.pk/Pakistan-National-Water-Policy-2018.pdf)
- Government of Pakistan Statistics Division. 2010. Pakistan Agriculture Census. Government of Pakistan Statistics Division, Islamabad, Pakistan.
- Hageback, J., J. Sundberg, M. Ostwald, D. Chen, X. Yun, and P. Knutsson. 2005. Climate variability and land-use change in Danangou watershed, China - examples of small-scale farmers' adaptation. *Climatic Change* 72(1-2):189-212. <https://doi.org/10.1007/s10584-005-5384-7>
- Hair, J. F., Jr., W. C. Black, B. J. Babin, and R. E. Anderson. 2010. *Multivariate data analysis*. Seventh edition. Pearson, London, UK.
- Himelein, K., S. Eckman, S. Murray, and J. Bauer. 2016. Second-stage sampling for conflict areas: methods and implications. World Bank, Washington, D.C., USA. <https://doi.org/10.1596/1813-9450-7617>
- Hofste, R. W., P. Reig, and L. Schleifer. 2019. 17 countries, home to one-quarter of the world's population, face extremely high water stress. World Resources Institute, Washington, D.C., USA. <https://www.wri.org/insights/17-countries-home-one-quarter-worlds-population-face-extremely-high-water-stress>
- Hoque, S. F., C. Quinn, and S. Sallu. 2018. Differential livelihood adaptation to social-ecological change in coastal Bangladesh. *Regional Environmental Change* 18(2):451-463. <https://doi.org/10.1007/s10113-017-1213-6>
- Hosmer, D., and S. Lemeshow. 2000. *Applied logistic regression*. Second edition. Wiley, New York, New York, USA.
- Huitema, D., E. Mostert, W. Egas, S. Moellenkamp, C. Pahl-Wostl, and R. Yalcin. 2009. Adaptive water governance: assessing the institutional prescriptions of adaptive (co-) management from a governance perspective and defining a research agenda. *Ecology and Society* 14(1):26. <https://doi.org/10.5751/ES-02827-140126>
- Hurlbert, M. A., and H. Diaz. 2013. Water governance in Chile and Canada: a comparison of adaptive characteristics. *Ecology and Society* 18(4):61. <https://doi.org/10.5751/es-06148-180461>
- Hussain, M., and S. Mumtaz. 2014. Climate change and managing water crisis: Pakistan's perspective. *Reviews on Environmental Health* 29(1-2):71-77. <https://doi.org/10.1515/reveh-2014-0020>
- Hye, Q. M. A., and R. E. A. Khan. 2013. Tourism-led growth hypothesis: a case study of Pakistan. *Asia Pacific Journal of Tourism Research* 18(4):303-313. <https://doi.org/10.1080/10941665.2012.658412>

- Iles, K., Z. Ma, and A. Erwin. 2020. Identifying the common ground: small-scale farmer identity and community. *Journal of Rural Studies* 78:25-35. <https://doi.org/10.1016/j.jrurstud.2020.06.018>
- Intergovernmental Panel on Climate Change (IPCC). 2001. Ecosystems and their goods and services. Pages 343-380 in J. J. McCarthy, O. F. Canziani, N. A. Leary, D. J. Dokken, and K. S. White, editors. *Climate change 2001: impacts, adaptation, and vulnerability*. Cambridge University Press, Cambridge, UK. <https://www.ipcc.ch/ipccreports/tar/wg2/pdf/wg2TARchap1.pdf>
- Ivey, J. L., J. Smithers, R. C. de Loë, and R. D. Kreuzwiser. 2004. Community capacity for adaptation to climate-induced water shortages: linking institutional complexity and local actors. *Environmental Management* 33(1):36-47. <https://doi.org/10.1007/s00267-003-0014-5>
- Jaramillo, J., M. Setamou, E. Muchugu, A. Chabi-Olaye, A. Jaramillo, J. Mukabana, J. Maina, S. Gathara, and C. Borgemeister. 2013. Climate change or urbanization? Impacts on a traditional coffee production system in East Africa over the last 80 years. *PloS One* 8(1):e51815. <https://doi.org/10.1371/journal.pone.0051815>
- Kaiser, H. F. 1958. The varimax criterion for analytic rotation in factor analysis. *Psychometrika* 23(3):187-200. <https://doi.org/10.1007/BF02289233>
- Kaplan-Hallam, M., N. J. Bennett, and T. Satterfield. 2017. Catching sea cucumber fever in coastal communities: conceptualizing the impacts of shocks versus trends on social-ecological systems. *Global Environmental Change* 45:89-98. <https://doi.org/10.1016/j.gloenvcha.2017.05.003>
- Karanja Ng'ang'a, S., M. T. Van Wijk, M. C. Rufino, and K. E. Giller. 2016. Adaptation of agriculture to climate change in semi-arid Borena, Ethiopia. *Regional Environmental Change* 16(8):2317-2330. <https://doi.org/10.1007/s10113-016-0940-4>
- Kerner, D. A., and J. S. Thomas. 2014. Resilience attributes of social-ecological systems: framing metrics for management. *Resources* 3(4):672-702. <https://doi.org/10.3390/resources3040672>
- Khan, I., H. Lei, I. A. Shah, I. Ali, I. Khan, I. Muhammad, X. Huo, and T. Javed. 2020. Farm households' risk perception, attitude and adaptation strategies in dealing with climate change: promise and perils from rural Pakistan. *Land Use Policy* 91:104395. <https://doi.org/10.1016/j.landusepol.2019.104395>
- Kolenikov, S., and G. Angeles. 2009. Socioeconomic status measurement with discrete proxy variables: is principal component analysis a reliable answer? *Review of Income and Wealth* 55(1):128-165. <https://doi.org/10.1111/j.1475-4991.2008.00309.x>
- Kuang, F., J. Jin, R. He, X. Wan, and J. Ning. 2019. Influence of livelihood capital on adaptation strategies: evidence from rural households in Wushen Banner, China. *Land Use Policy* 89 (January):104228. <https://doi.org/10.1016/j.landusepol.2019.104228>
- Lenaiyasa, M. L., B. L. Bruyere, J. Salerno, and T. Pickering. 2020. Pastoralists' use of income diversification as a strategy for adapting to social-ecological change in Samburu, Kenya. *Regional Environmental Change* 20(1):21. <https://doi.org/10.1007/s10113-020-01612-x>
- Li, S., L. Juhász-Horváth, P. A. Harrison, L. Pintér, and M. D. A. Rounsevell. 2017. Relating farmer's perceptions of climate change risk to adaptation behaviour in Hungary. *Journal of Environmental Management* 185:21-30. <https://doi.org/10.1016/j.jenvman.2016.10.051>
- Lindholm, C. 1982. *Generosity and jealousy: the Swat Pukhtun of Northern Pakistan*. Columbia University Press, New York, New York, USA.
- Lockwood, M., C. M. Raymond, E. Oczkowski, and M. Morrison. 2015. Measuring the dimensions of adaptive capacity: a psychometric approach. *Ecology and Society* 20(1):37. <https://doi.org/10.5751/ES-07203-200137>
- Manuel-Navarrete, D., and M. Pelling. 2015. Subjectivity and the politics of transformation in response to development and environmental change. *Global Environmental Change* 35:558-569. <https://doi.org/10.1016/j.gloenvcha.2015.08.012>
- Marie, M., F. Yirga, M. Haile, and F. Tquabo. 2020. Farmers' choices and factors affecting adoption of climate change adaptation strategies: evidence from northwestern Ethiopia. *Heliyon* 6(4):e03867. <https://doi.org/10.1016/j.heliyon.2020.e03867>
- Marshall, N. A., and P. A. Marshall. 2007. Conceptualizing and operationalizing social resilience within commercial fisheries in northern Australia. *Ecology and Society* 12(1):1. <https://doi.org/10.5751/ES-01940-120101>
- Mase, A. S., B. M. Gramig, and L. S. Prokopy. 2017. Climate change beliefs, risk perceptions, and adaptation behavior among Midwestern U.S. crop farmers. *Climate Risk Management* 15:8-17. <https://doi.org/10.1016/j.crm.2016.11.004>
- McCabe, J. T., P. W. Leslie, and L. DeLuca. 2010. Adopting cultivation to remain pastoralists: the diversification of Maasai livelihoods in northern Tanzania. *Human Ecology* 38(3):321-334. <https://doi.org/10.1007/s10745-010-9312-8>
- McCord, P., K. Waldman, E. Baldwin, J. Dell'Angelo, and T. Evans. 2018. Assessing multi-level drivers of adaptation to climate variability and water insecurity in smallholder irrigation systems. *World Development* 108:296-308. <https://doi.org/10.1016/j.worlddev.2018.02.009>
- McLeman, R., and B. Smit. 2006. Migration as an adaptation to climate change. *Climatic Change* 76(1):31-53. <https://doi.org/10.1007/s10584-005-9000-7>
- Mekonnen, M. M., and A. Y. Hoekstra. 2016. Four billion people facing severe water scarcity. *Science Advances* 2(2):e1500323. <https://doi.org/10.1126/sciadv.1500323>
- Mendola, M. 2008. Migration and technological change in rural households: complements or substitutes? *Journal of Development Economics* 85(1-2):150-175. <https://doi.org/10.1016/j.jdeveco.2006.07.003>
- Mertz, O., C. Mbow, J. Ø. Nielsen, A. Maiga, D. Diallo, A. Reenberg, A. Diouf, B. Barbier, I. B. Moussa, M. Zorom, I. Ouattara, and D. Dabi. 2010. Climate factors play a limited role for past adaptation strategies in West Africa. *Ecology and Society* 15(4):25. <https://doi.org/10.5751/ES-03774-150425>

- Moksony, F., and R. Heged. 1990. Small is beautiful. The use and interpretation of R² in social research. *Szociológiai Szemle* 130-138.
- Nagelkerke, N. J. D. 1991. A note on a general definition of the coefficient of determination. *Biometrika* 78(3):691-692. <https://doi.org/10.1093/biomet/78.3.691>
- Neuman, W. L. 2010. *Social research methods: qualitative and quantitative approaches*. Pearson, London, UK.
- Nielsen, J. Ø., and A. Reenberg. 2010. Cultural barriers to climate change adaptation: a case study from Northern Burkina Faso. *Global Environmental Change* 20(1):142-152. <https://doi.org/10.1016/j.gloenvcha.2009.10.002>
- Nixon, R., Z. Ma, L. Zanolli, B. Khan, T. Birkenholtz, L. Lee, and I. Mian. 2022. Adaptation to social-ecological change in Northwestern Pakistan: household strategies and decision-making processes. *Environmental Management* 69(5):887-905. <https://doi.org/10.1007/s00267-021-01583-7>
- O'Brien, K. L., and J. Wolf. 2010. A values-based approach to vulnerability and adaptation to climate change. *Wiley Interdisciplinary Reviews: Climate Change* 1(2):232-242. <https://doi.org/10.1002/wcc.30>
- Osahr, H., C. Twyman, W. N. Adger, and D. S. G. Thomas. 2008. Effective livelihood adaptation to climate change disturbance: scale dimensions of practice in Mozambique. *Geoforum* 39(6):1951-1964. <https://doi.org/10.1016/j.geoforum.2008.07.010>
- Pahl-Wostl, C. 2019. The role of governance modes and meta-governance in the transformation towards sustainable water governance. *Environmental Science and Policy* 91:6-16. <https://doi.org/10.1016/j.envsci.2018.10.008>
- Pahl-Wostl, C., and C. Knieper. 2014. The capacity of water governance to deal with the climate change adaptation challenge: using fuzzy set qualitative comparative analysis to distinguish between polycentric, fragmented and centralized regimes. *Global Environmental Change* 29:139-154. <https://doi.org/10.1016/j.gloenvcha.2014.09.003>
- Pahl-Wostl, C., L. Lebel, C. Knieper, and E. Nikitina. 2012. From applying panaceas to mastering complexity: toward adaptive water governance in river basins. *Environmental Science and Policy* 23:24-34. <https://doi.org/10.1016/j.envsci.2012.07.014>
- Pakistan Bureau of Statistics. 2017. Provisional summary results of 6th population and housing census. Government of Pakistan, Ministry of Statistics, Pakistan Bureau of Statistics, Islamabad, Pakistan. https://www.pbs.gov.pk/sites/default/files/press_releases/2017/Population_Census_2017_Results.pdf
- Pallant, J. 2013. *SPSS survival manual: a step by step guide to data analysis using IBM SPSS*. Fifth edition. Open University Press, Maidenhead, Berkshire, UK.
- Pornpitakpan, C. 2004. The persuasiveness of source credibility: a critical review of five decades' evidence. *Journal of Applied Social Psychology* 34(2):243-281. <https://doi.org/10.1111/j.1559-1816.2004.tb02547.x>
- Porras, G. L., L. C. Stringer, and C. H. Quinn. 2020. Building dryland resilience: three principles to support adaptive water governance. *Ecological Economics* 177:106770. <https://doi.org/10.1016/j.ecolecon.2020.106770>
- Qureshi, A. S. 2011. Water management in the Indus Basin in Pakistan: challenges and opportunities. *Mountain Research and Development* 31(3):252-260. <https://doi.org/10.1659/MRD-JOURNAL-D-11-00019.1>
- Rapsomanikis, G. 2015. The economic lives of smallholder farmers: an analysis based on household data from nine countries. Food and Agriculture Organization of the United Nations, Rome, Italy. <https://www.fao.org/3/i5251e/i5251e.pdf>
- Rijke, J., S. van Herk, C. Zevenbergen, and R. Ashley. 2012. Room for the river: delivering integrated river basin management in the Netherlands. *International Journal of River Basin Management* 10(4):369-382. <https://doi.org/10.1080/15715124.2012.739173>
- Ruggles, S. 2010. Stem families and joint families in comparative historical perspective. *Population and Development Review* 36(3):563-577. <https://doi.org/10.1111/j.1728-4457.2010.00346.x>
- Selvaraju, R., T. N. Balasubramanian, A. K. S. Huda, and D. A. George. 2005. Farm decision making using climate information. *Outlook on Agriculture* 34(1):23-31. <https://doi.org/10.5367/00000053295097>
- Schwartz, S. H., and A. Bardi. 1997. Influences of adaptation to communist rule on value priorities in Eastern Europe. *Political Psychology* 18(2):385-410. <https://doi.org/10.1111/0162-895X.00062>
- Silvestri, S., E. Bryan, C. Ringler, M. Herrero, and B. Okoba. 2012. Climate change perception and adaptation of agro-pastoral communities in Kenya. *Regional Environmental Change* 12(4):791-802. <https://doi.org/10.1007/s10113-012-0293-6>
- Smidt, S. J., E. M. K. Haacker, A. D. Kendall, J. M. Deines, L. Pei, K. A. Cotterman, H. Li, X. Liu, B. Basso, and D. W. Hyndman. 2016. Complex water management in modern agriculture: trends in the water-energy-food nexus over the High Plains Aquifer. *Science of the Total Environment* 566:988-1001. <https://doi.org/10.1016/j.scitotenv.2016.05.127>
- Smit, B., and O. Pilifosova. 2003. Adaptation to climate change in the context of sustainable development and equity. *Sustainable Development* 8(9).
- Smit, B., and M. W. Skinner. 2002. Adaptation options in agriculture to climate change: a typology. *Mitigation and Adaptation Strategies for Global Change* 7(1):85-114. <https://doi.org/10.1023/A:1015862228270>
- Smit, B., and J. Wandel. 2006. Adaptation, adaptive capacity and vulnerability. *Global Environmental Change* 16(3):282-292. <https://doi.org/10.1016/j.gloenvcha.2006.03.008>
- Stein, C., H. Ernstson, and J. Barron. 2011. A social network approach to analyzing water governance: the case of the Mkindo catchment, Tanzania. *Physics and Chemistry of the Earth, Parts A/B/C* 36(14-15):1085-1092. <https://doi.org/10.1016/j.pce.2011.07.083>
- Taber, K. S. 2018. The use of Cronbach's Alpha when developing and reporting research instruments in science education. *Research in Science Education* 48(6):1273-1296. <https://doi.org/10.1007/s11165-016-9602-2>

- Tambo, J. A., and T. Abdoulaye. 2012. Climate change and agricultural technology adoption: the case of drought tolerant maize in rural Nigeria. *Mitigation and Adaptation Strategies for Global Change* 17(3):277-292. <https://doi.org/10.1007/s11027-011-9325-7>
- Tessema, Y. A., C. S. Aweke, and G. S. Endris. 2013. Understanding the process of adaptation to climate change by small-holder farmers: the case of east Hararghe Zone, Ethiopia. *Agricultural and Food Economics* 1(1):13. <https://doi.org/10.1186/2193-7532-1-13>
- Truelove, H. B., A. R. Carrico, and L. Thabrew. 2015. A socio-psychological model for analyzing climate change adaptation: a case study of Sri Lankan paddy farmers. *Global Environmental Change* 31:85-97. <https://doi.org/10.1016/j.gloenvcha.2014.12.010>
- Tucker, C. M., H. Eakin, and E. J. Castellanos. 2010. Perceptions of risk and adaptation: coffee producers, market shocks, and extreme weather in Central America and Mexico. *Global Environmental Change* 20(1):23-32. <https://doi.org/10.1016/j.gloenvcha.2009.07.006>
- Ullah, Z., H. Khan, A. Waseem, Q. Mahmood, and U. Farooq. 2013. Water quality assessment of the River Kabul at Peshawar, Pakistan: industrial and urban wastewater impacts. *Journal of Water Chemistry and Technology* 35(4):170-176. <https://doi.org/10.3103/S1063455X1304005X>
- Ullah, W., T. Nihei, M. Nafees, R. Zaman, and M. Ali. 2018. Understanding climate change vulnerability, adaptation and risk perceptions at household level in Khyber Pakhtunkhwa, Pakistan. *International Journal of Climate Change Strategies and Management* 10(3). <https://doi.org/10.1108/IJCCSM-02-2017-0038>
- Ullah, R., G. P. Shivakoti, and G. Ali. 2015. Factors effecting farmers' risk attitude and risk perceptions: the case of Khyber Pakhtunkhwa, Pakistan. *International Journal of Disaster Risk Reduction* 13:151-157. <https://doi.org/10.1016/j.ijdrr.2015.05.005>
- van Valkengoed, A. M., and L. Steg. 2019. Meta-analyses of factors motivating climate change adaptation behaviour. *Nature Climate Change* 9(2):158-163. <https://doi.org/10.1038/s41558-018-0371-y>
- Vörösmarty, C. J., P. B. McIntyre, M. O. Gessner, D. Dudgeon, A. Prusevich, P. Green, S. Glidden, S. E. Bunn, C. A. Sullivan, C. Riedy Liermann, and P. M. Davies. 2010. Global threats to human water security and river biodiversity. *Nature* 467(7315):555-561. <https://doi.org/10.1038/nature09440>
- Wheeler, S., A. Zuo, and H. Bjornlund. 2013. Farmers' climate change beliefs and adaptation strategies for a water scarce future in Australia. *Global Environmental Change* 23(2):537-547. <https://doi.org/10.1016/j.gloenvcha.2012.11.008>
- Wolske, K. S., K. T. Gillingham, and P. W. Schultz. 2020. Peer influence on household energy behaviours. *Nature Energy* 5(3):202-212. <https://doi.org/10.1038/s41560-019-0541-9>
- Wood, S. A., A. S. Jina, M. Jain, P. Kristjanson, and R. S. DeFries. 2014. Smallholder farmer cropping decisions related to climate variability across multiple regions. *Global Environmental Change* 25:163-172. <https://doi.org/10.1016/j.gloenvcha.2013.12.011>
- World Bank. 2019. Khyber Pakhtunkhwa integrated tourism development project. World Bank, Washington, D.C., USA. <https://projects.worldbank.org/en/projects-operations/project-detail/P163562?lang=en>
- Wrathall, D. J., and N. Suckall. 2016. Labour migration amidst ecological change. *Migration and Development* 5(2):314-329. <https://doi.org/10.1080/21632324.2015.1022967>
- Yang, Y.-C. E., C. Brown, W. Yu, J. Wescoat, Jr., and C. Ringler. 2014. Water governance and adaptation to climate change in the Indus River Basin. *Journal of Hydrology* 519:2527-2537. <https://doi.org/10.1016/j.jhydrol.2014.08.055>
- Yaro, J. A. 2013. The perception of and adaptation to climate variability/change in Ghana by small-scale and commercial farmers. *Regional Environmental Change* 13(6):1259-1272. <https://doi.org/10.1007/s10113-013-0443-5>
- Yong, A. G., and S. Pearce. 2013. A beginner's guide to factor analysis: focusing on exploratory factor analysis. *Tutorials in Quantitative Methods for Psychology* 9(2):79-94. <https://doi.org/10.20982/tqmp.09.2.p079>