Reg Environ Change (2016) 16:801–814
DOI 10.1007/s10113-015-0789-y

ORIGINAL ARTICLE

Cognitive and institutional influences on farmers' adaptive capacity: insights into barriers and opportunities for transformative change in central Arizona

Hallie Eakin[1] · Abigail York[2] · Rimjhim Aggarwal[1] · Summer Waters[3] · Jessica Welch[1] · Cathy Rubiños[1] · Skaidra Smith-Heisters[2] · Chrissie Bausch[1] · John M. Anderies[1,2]

Received: 24 May 2014 / Accepted: 19 March 2015 / Published online: 22 April 2015

Abstract The prospect of unprecedented environmental change, combined with increasing demand on limited resources, demands adaptive responses at multiple levels. In this article, we analyze different attributes of farm-level capacity in central Arizona, USA, in relation to farmers' responses to recent dynamism in commodity and land markets, and the institutional and social contexts of farmers' water and production portfolios. Irrigated agriculture is at the heart of the history and identity of the American Southwest, although the future of agriculture is now threatened by the prospect of "mega-droughts," urbanization and associated inter-sector and inter-state competition over water in an era of climatic change. We use farm-level survey data, supplemented by in-depth interviews, to explore the cross-level dimensions of capacity in the agriculture–urban nexus of central Arizona. The surveyed farmers demonstrate an interest in learning, capacity for adaptive management and risk-taking attitudes consistent with emerging theory of capacity for land use and livelihood transformation. However, many respondents perceive their self-efficacy in the face of future climatic and hydrological change as uncertain. Our study suggests that the components of transformational capacity will necessarily need to go beyond the objective resources and cognitive capacities of individuals to incorporate "linking" capacities: the political and social attributes necessary for collective strategy formation to shape choice and opportunity in the future.

Keywords Adaptive capacity · Linking capacities · Agriculture · Peri-urban · Transformation · Water management

Introduction

Adaptation to current and anticipated climatic variability and change is a complex process involving actions at different decision-making levels, and spatial and temporal

Editor: James D. Ford.

✉ Hallie Eakin
hallie.eakin@asu.edu

Abigail York
abigail.york@asu.edu

Rimjhim Aggarwal
rimjhim.aggarwal@asu.edu

Summer Waters
swaters@sonoraninstitute.org

Jessica Welch
jessica.welch@asu.edu

Cathy Rubiños
cathy.rubinos@asu.edu

Skaidra Smith-Heisters
Skaidra.Smith-Heisters@asu.edu

Chrissie Bausch
jcbausch@asu.edu

John M. Anderies
m.anderies@asu.edu

1 School of Sustainability, Arizona State University, P.O. Box 875502, Tempe, AZ 85287, USA

2 School of Human Evolution and Social Change, Arizona State University, P.O. Box 872402, Tempe, AZ 85287, USA

3 Sonoran Institute, 11010 N. Tatum Blvd., Suite D1010, Phoenix, AZ 85028, USA

scales. Adaptation in irrigated agriculture epitomizes this challenge: farmers, the primary resource users, make decisions about crop choice, inputs, technology and finance. In aggregate, their production and livelihood decisions have implications for land and water use at a regional scale, as well as the economic viability of agriculture in particular locations. In central Arizona, the site of the research presented here, most producers employing surface water irrigation belong to formally constituted irrigation districts, where water use is managed collectively and infrastructure is provisioned in accordance with long-term resource management objectives and planning horizons. Decision-making in agriculture is further complicated by the proximity of farming to the expansive metropolitan region of Phoenix. Urban water policy and planning has co-evolved with agriculture over much of the last century, adding additional complexity to water management at all levels of analysis.

Our objective in this article is to evaluate capacities for change among irrigated field crop producers in central Arizona, recognizing that these capacities are contextualized within an institutional environment that proscribes different forms of agency to different actors. Our analysis draws from innovative work on the resilience and adaptive capacity of natural resource managers, fishers and producers in Australia, where the rate and severity of global environmental change has been particularly dramatic (Howden et al. 2007; Marshall et al. 2012; Park et al. 2012). There, conditions have become untenable for some primary industry activities, and researchers have worked with local stakeholders to identify what specific attributes of individuals and populations are most associated with a capacity to proactively embrace the scale and scope of change and fundamentally alter livelihood activities (Marshall et al. 2012). Arizona has yet to face such dramatic conditions of environmental change; nevertheless, insights from the Australian experience provide a structure from which we can assess existing capacities in anticipation of a need for potentially transformative change, at multiple scales, in the not-too-distant future.

We analyze data from a survey of irrigated growers, drawn largely from two counties (Maricopa and Pinal) in central Arizona, where the Phoenix metropolitan area has rapidly expanded over the last two decades (Fig. 1). Nearly all of these growers farm within the boundaries of state-regulated groundwater management districts, or Active Management Areas (AMAs). In these AMAs, almost all land parcels are located within specific irrigation districts. Each irrigation district has a unique water portfolio, consisting of different proportions of ground water, local surface water, imported surface water diverted from the Colorado River (called Central Arizona Project water, or CAP) and urban effluent.

In an effort to build on the work initiated in Australia (Marshall and Marshall 2007; Marshall et al. 2012), we use the survey data to identify and evaluate different cognitive dimensions of capacity—including risk perception, interest in learning, experimentation and risk-taking, perceptions of constraints on choice and perspectives on responsibility for action—in the farm population of central Arizona. We

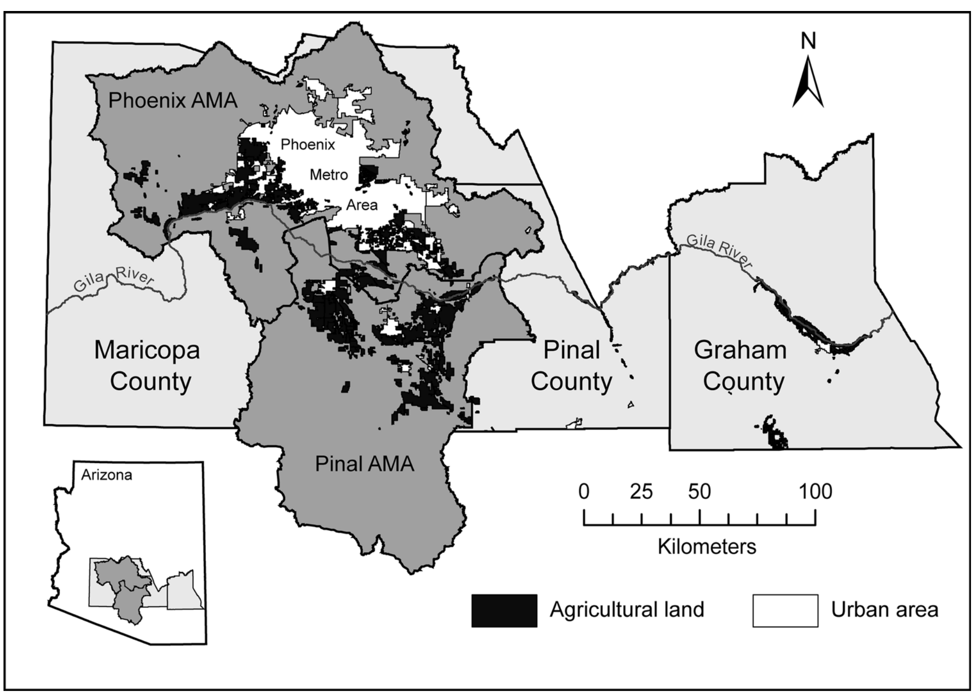

Fig. 1 Map of Arizona and Phoenix and Pinal AMAs

discuss the implications of our findings within the context of the changing institutional, demographic and biophysical environment of farming in the region in an effort to gain insight into the attributes of transformational capacity.

Assessment of adaptive capacity in primary sector industries

Typically, adaptive capacity is assessed in relation to a particular "unit of exposure," e.g., the farm enterprise, or an entire industry (Eakin and Luers 2006). Assessments of the social vulnerability of farm communities are often based on an assumption of natural resource dependence: farmers, as adapting actors, are vulnerable because the natural capital that is the foundation of their economic activities (crops and livestock, soils and water) is presumed to be highly sensitive to change and variability in climatic parameters such as rainfall and temperature (Marshall 2011). The adaptive capacity of farmers is thus a function of farmers' perceptions and experience of signals of environmental change in relation to other stressors and opportunities they face, the risks (probability of undesirable outcomes, given the sensitivity of their assets and activities) associated with those changes, and the context of decision-making.

Although much of the actor-oriented adaptation literature has focused on the external resources and entitlements of actors in the face of emerging risks (so-called "objective capacities", c.f., Grothmann and Patt 2005), a growing body of literature is highlighting the internal, cognitive dimensions of adaptation. Perception and individual cognition has long been recognized as having an important influence on risk behavior (c.f., White 1973; Burton et al. 1978; Kasperson et al. 1988; McDaniels et al. 1996). Recent scholarship has expanded theories of cognition and adaptation, focusing on how individuals perceive information sources and internalize knowledge (c.f., Cash et al. 2002; Frank et al. 2011), how they perceive their own capacities (i.e., their self-efficacy) as agents of change and how effective they believe their adaptations might be, given their particular social and institutional context of decision-making (Grothmann and Patt 2005; Burch and Robinson 2007). Critical social scientists have long understood the profound influence that social and political context—including formal institutional incentives, available information, and control over knowledge and meaning—can have on individual perceptions of oneself and one's capacities (c.f., Scott 1998; Wood 2003; Avelino and Rotmans 2009); these perceptions are now being considered as core components of individual motivations in responding to exogenous change. Literature on social–ecological and psychological resilience, for example, has emphasized individual and social characteristics such as capacities for experimentation, risk-taking and learning as determinants of abilities to respond to conditions of high uncertainty and high risk (see, e.g., Tschakert and Dietrich 2010; Brown and Westaway 2011).

The research we present here is specifically informed by research conducted by CSIRO on adaptive and transformative capacity in agricultural and ranching communities in Australia (Marshall et al. 2012). Using questionnaires to probe the attitudes, knowledge, values and perceptions of farmers, graziers, fishers and others in the primary sector, Marshall's research has empirically identified specific cognitive dimensions of individual actors' adaptive capacity in the Australian context: how risks and uncertainty are perceived and managed (*risk perception*), self-efficacy in terms of planning, learning and reorganizing in the face of change (*learning*), financial and psychological flexibility to undertake change (*flexibility*) and interest and willingness to act (*interest*) (Marshall et al. 2012). These attributes are interpreted in an anticipatory sense: they are understood as being indicative of individual capacities to respond proactively and constructively in the face of a highly dynamic and uncertain decision environment, including but not limited to climatic variability and change.

In some cases, environmental changes provoked by climate change may be so significant that existing livelihoods and economic activities become untenable, requiring a fundamental transformation (Anderies et al. 2006; Kates et al. 2012; Olsson et al. 2004; Walker et al. 2004; Westley et al. 2011). It is thought that primary sector actors (farmers, fishers, graziers) are likely to be particularly sensitive to such change, given their livelihood dependence on specific suites of natural resources and environmental conditions. Marshall et al. (2012) argue that the same capacities that they have found to be indicative of incremental adaptation (learning, flexibility, interest and risk perception) are also applicable to capacity for more profound individual transformation. However, they highlight *place attachment* and *occupational attachment* as additional variables that are likely to affect capacity in such conditions. While strong place and/or occupational attachment may provide individuals with the emotional motivation and willingness to adapt to emerging environmental change, under more extreme conditions of change, these attachments may become cognitive barriers, preventing individuals from moving locations or altering livelihoods to initiate new activities in more conducive environmental circumstances (Adger et al. 2009).

The emerging work on cognition and capacities in the Australian context does not, however, address how the institutional context of decision-making might affect both cognitive attributes as well as the objective capacities—i.e., the resources, technology, skills and knowledge—of any actor. Institutions in the social–ecological systems literature are typically defined as the formal and informal rules and norms that govern actors, resources and their interactions in any given situation. Nevertheless, understanding how institutions affect the behavior of individuals and groups also must address the attributes of a system that affect how rules are implemented, how they evolve and what implications they have on social interactions, actions and outcomes in particular contexts (Ostrom 1990). Ostrom, for example, posits that within any action situation, actors' behaviors are affected by the resources they bring to a situation, how they value different states of the world and different actions, the ways they acquire and process information and knowledge, and the processes they use to select specific alternatives of action (Ostrom 2011: 10). For complex and dynamic social–ecological systems, information circumscribes how actors may anticipate and respond to the actions of others as well as to the dynamics of a resource base. In some cases, the flow of information in a system can lead to modifications in institutions in order to manage change and uncertainty (Ostrom 2011). In many social–ecological systems, the institutional context also includes a large component of physical infrastructure (i.e., the engineered elements of an irrigation system) for which specific rules over use and maintenance are developed, and which in turn influences the dynamics of resource use and thus resource system itself (Anderies et al. 2004).

Institutions have important influences on risk perception, individual behavior and expectations about resource availability and reliability into the future (Eakin and Lemos 2010). Grothmann and Patt's MPPACC framework (2005), for example, highlights how incentive structures, social discourse, information about the behavior of other actors and about environmental change, as well as resource availability may affect different dimensions of individual cognition, including how individuals appraise their own capacity to adapt (*self-efficacy*), how individuals perceive risk (*risk appraisal*) and thus their willingness and intention to adapt. Existing empirical evidence suggests that the beliefs and attitudes of individual farmers about their future livelihood viability or obsolescence may be more strongly influenced by institutional, political and economic factors than by perceptions and experience of environmental change (Eakin et al. 2006, 2010). Expectations that formal institutions for risk management will buffer individuals from risk can also diminish the saliency of environmental risks to individuals, and undermine individual incentives to develop autonomous risk management strategies (Murtinho et al. 2013; Eakin et al. 2014).

The specific institutional arrangements that influence adaptive capacities may have long lifetimes (Stafford Smith et al. 2010), taking shape in one period but creating path dependencies and thus shaping social interactions into the future. At any moment in time, institutional change processes may be more exogenous than endogenous to adaptation decisions of any particular group of actors. Nevertheless, at broader timescales, the relationship of individuals' adaptive capacity and the institutional context in which they operate is multidirectional: farmers, individually and as organized groups, can effectively mobilize to influence the institutions that govern their choice sets (see, for example, Eakin et al. 2014). This mobilization is, in turn, dependent on capacities for collective action: having a basis of shared values, trust, and leadership—*social capital*—to organize to effect change (Adger 2003; Pelling and High 2005). Social capital and leadership, for example, help explain the successful management of water-related risk in the highlands of Colombia (Murtinho et al. 2013), and lack of social capital has been shown to be undermining adaptive capacity in Nova Scotia fisheries (Barnett and Eakin 2015). At the level of the individual, social capital and capacities for political influence, reinforced by the institutional arrangements that govern resource access and choice sets, constitute *linking variables:* the dimensions of adaptive capacity that tie individual adaptive capacities to collective action and the potential for transformative institutional change (Fig. 2).

The research we present here explores these elements through an analysis of the attributes of adaptive and potentially transformative capacity of irrigated field crop (primarily alfalfa, cotton, and grains) growers in central Arizona. We use survey data to identify cognitive and objective capacity attributes in the population, and to describe the distribution of these attributes. We explore the relationship of place and occupational attachment to the cognitive dimensions of adaptive capacity, and to provide some insight into farmers' individual perceptions and their bonds to their community and place. We interpret our quantitative findings in light of the institutional and political context of agricultural decision-making in Arizona, highlighting the significance of this context in shaping individual farmers' choices and perceptions about their future.

Site description

We focused our research on central Arizona, a region containing the farm operations and urban areas in Maricopa and Pinal counties. While the Phoenix metropolitan area dominates this area (pop. 4.3 million), the area outside the city is still agricultural. In 2012, the two counties comprising this study area produced 60 and 50 % of the state's total market value in cotton and hay (including alfalfa), respectively. Regional cotton, hay and dairy production accounted for 28 % of Arizona's $3.7 billion total value of

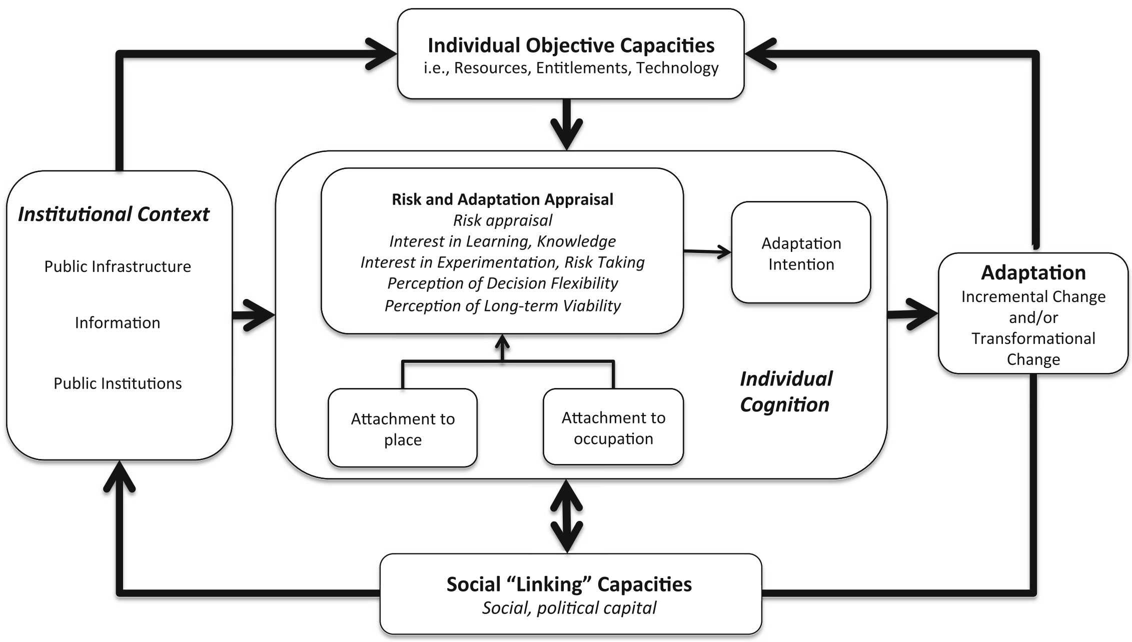

Fig. 2 Conceptual framework: Institutional context, cognitive attributes and linking variables in adaptive capacity. *Source*: Adapted by the authors from Grothmann and Patt 2005 and Marshall et al. 2012. Note: Consistent with the MPPACC framework, we consider that individual cognition is influenced by the objective capacities and the social and political capacities that enable an actor to act alone or participate in collective action. Adaptations can enhance objective capacities or represent investments in social and political capacities. In turn, social and political capacities—or *linking variables*—are those that enable individuals to help shape the institutional context of adaptation, in other words, the institutions themselves, the physical infrastructure shaping resource use, and the nature and flow of information about the social–ecological system

agricultural production in 2012 (USDA, 2012). There are over 2000 farms in Maricopa County, making it the third most significant county in terms of its farm population in Arizona (USDA 2012). Like many parts of the USA, the geographic as well as institutional interface of agriculture and urban interests is increasingly central to debates about resource access in contexts of increased climatic uncertainty (Goetz 2002).

Central Arizona roughly corresponds to the Phoenix and Pinal Active Management Areas (AMAs), the regulatory areas established under the Groundwater Management Act of 1980 (Fig. 1). Irrigated agriculture has been a feature of the region since its earliest settlers, the Hohokam people, who established over 500 miles of canal infrastructure in the area over 1500 years ago (Abbott, 2003). In the late nineteenth and early twentieth century, irrigation infrastructure along the Salt River valley enabled central Arizona to become the focal area of an industrial boom in long-staple cotton production, supplying textile and automobile industries. Much of the twentieth century was characterized by boom and bust in cotton production; farmers faced volatile markets, labor constraints and, by the 1960s, competition for water resources from growing urban areas and mining interests (Sheridan 1995).

The declining groundwater table and increased water demand eventually led to significant inter-sector conflict; in 1980, after years of negotiation, the Groundwater Management Act (GMA) was put into effect (Maguire 2007). The GMA delineated areas in the state where groundwater depletion was particularly severe, and where competition over water resources was already significant. In these AMAs, farmers were allocated annual groundwater use rights equivalent to their average water use over the 5 years prior to the GMA's implementation. No further expansion of irrigated area has been permitted. In the Phoenix AMA (roughly incorporating Maricopa County), agriculture was expected to gradually retire from the region, and agricultural water rights would become available for urban and municipal use. In the interim, state water authorities worked with municipalities to incentivize the agricultural sector to rely more heavily on surface water resources, conserving ground water for future urban growth.

Over the period 1985–2000, agricultural water use did decline by 42 % in the Phoenix AMA, primarily through the conversion of agricultural land to urban use. Groundwater resources improved as a result, aided as well by the increased reliance of farmers on surface water sources (ADWR 2011). In the Pinal AMA (roughly incorporating Pinal County), agriculture and rural land uses prevail, and agriculture has continued to rely primarily on groundwater resources (Arizona Department of Water Resources 2010a). In Maricopa County census data report a decline in numbers of farm operations as cropland has been converted, while Pinal County has seen relatively stable numbers of farm operators (National Agricultural Statistics Service 2007).

By the time the GMA was approved in the 1980s, there was relatively widespread acceptance of the idea of eventual agricultural obsolescence around the Phoenix metropolitan area, with the exception of the Native American reservation lands where agricultural land use is expected to continue (Bausch et al. 2015). The assumption of agricultural decline is also reflected in most scenarios of water demand and supply into the future (Arizona Department of Water Resources 2010b, 2011; Gober et al. 2010).

In the coming decades, water resources will become increasingly stressed as a result of increased population pressure in the Colorado River Basin and decreased surface water flows as a result of climatic changes (Morrison Institute 2011; Seager 2007; U.S. Department of the Interior Bureau of Reclamation 2012). Climate change is expected to reduce Colorado River stream flow by approximately 20 % (U.S. Department of the Interior Bureau of Reclamation 2012; Vano et al. 2013). Droughts may increase in severity, frequency and length, possibly lasting for decades (Institute of the Environment 2013). Such mega-droughts will further reduce the quantity of water available (Overpeck and Udall 2010; Seager 2007). These climatic impacts on water will have a significant effect on agriculture, as agriculture accounts for 79 % of water withdrawals in the Southwest (Institute of the Environment 2013).

While some assessments have concluded that central Arizona will have sufficient water to maintain quality of life, choices will need to be made about the allocation of resources among different uses. Agriculture still represents a significant demand on water in both Maricopa (with annual demand of 37 % in 2009) and Pinal (with an annual demand of 94 % in 2009) AMAs (Arizona Department of Water Resources 2010b, 2011). Recent volatility in commodity prices and changing urban growth patterns in the region introduce new uncertainties into the future of agriculture. It is in this context that we explore the attitudes and perceptions of local producers in relation to their capacity to adapt to potentially significant changes in water availability for farming.

Methods

Our analysis is based on a mail and online survey of farm operators, implemented in 2012, with complementary data from a series of expert interviews (33 water managers, public officials, agricultural service providers, farmers and academics) (see also Bausch et al. 2015). The survey respondents were contacted first through a postcard advising them of the survey opportunity, and inviting them to respond online. A paper copy of the survey was subsequently mailed to those who did not respond to the initial invitation. In the absence of a registry of all farm operators accessible for public use, we relied on two sources for our sampling universe: the names and addresses of individuals or enterprises listed as users of irrigation water in the Phoenix and Pinal AMAs (a random selection of 400 addresses) and the membership list of the Arizona Cotton Growers Association (a random selection of 233 association members with addresses in Maricopa, Pinal and Graham counties). The former list proved unreliable; nearly a third of the addresses proved to be obsolete or non-agricultural. The Arizona Cotton Growers Association list was far more reliable, but nonetheless, the response rate was low. Our efforts resulted in a sample of 52 growers. While under these conditions it is difficult to accurately assess the statistical representativeness of our sample, the profile of our respondents reasonably reflects the profile of operators in available secondary data (Table 1).

The survey collected information on the structure of the farm operation (crops grown, acreage, irrigation use and source of water) and of the farm's principal operator (education level, age, gender). To understand the behavior and attitudes of farmers, given the institutional and infrastructural context of the region, respondents reported on their personal experience with water scarcity, their irrigation technology, their use of climatic and hydrological information, and their participation in farm assistance programs. We hypothesized that the hydrological and climatic information available to and used by farmers, the physical infrastructure of the irrigation districts, and the availability of information and support via public programs influence their adaptive capacities and ultimately their behavior in the face of change.

To measure the different cognitive dimensions of adaptive capacity, we employed a series of Likert scale items, designed to assess the respondents' attitudes about risk, change in water availability, entrepreneurship and experimentation, interest in learning, and attitudes about the location and community in which they were farming. These Likert items were closely based on the survey instruments that Marshall et al. (2012) had developed and tested, with some modification for language and social–cultural context. Given our interest in the linkages between cognitive elements in adaptive capacity and the institutional context of decision-making, the survey also included questions to elicit the extent to which irrigation infrastructure and water policy, markets and price volatility, and farmers' access to and perceptions of public support for their activities, were affecting their experiences of risk and their attitudes about their future viability. Respondents were asked the extent to which they agreed with each

Table 1 Agricultural operations (County and State) and survey respondents

	Maricopa	Pinal	Arizona (state)	Survey Respondents
Number of farms	2479	938	20,005	52*
% Principal operators with 10 years or more at current location	78.4	72.3	80.8	81.1**
Average value of products sold	$404,790	$989,058	$186,559	–
% Of farms with sales below $10,000	67.8	50.3	79.7	–
% Principal operators working off-farm	65.3	45.0	54.1	42.0***
% Principal operators 65 years or older	38.4	25.5	40.3	36.5
Average age of grower	60.4	56.0	61.1	57.4
% Land in farms	8.1	34.2	36.0	–

Source: 2012 National Agricultural Statistics Service Data and authors' survey (2014)

* 52 refers to the number of respondents in the survey, many with multiple parcels farmed

** 81.1 % of respondents reported having farmed 10 years or more in Arizona

*** 42.0 % of respondents reported receiving some income from non-farm professional wages; 26 % derived half or more of their total income from this non-farm source

statement, on a 1–5 scale, with 5 being "strongly agree" and 1 being "strongly disagree."

We selected those items from the Likert scale that corresponded to specific capacity dimensions, as explored and refined by Marshall and colleagues. For each subset of items hypothesized to represent a specific component of capacity (e.g., attitudes about risk, entrepreneurship and experimentation), we tested for construct validity using Cronbach's Alpha. This process resulted in the elimination of some items from the scales measuring particular components. We then used factor analysis to create a single index representing the weighted mean of the Likert scale items associated with each capacity component (following Marshall and Marshall 2007). To assess attitudes in the respondents regarding their place and occupational attachment, we selected seven items from the survey that were not included in the capacity measurement. We pursued the same procedure as reported above on these items to create indices of place and vocational attachment.

We interpreted the results of this analysis in light of the remaining data from the survey, and the qualitative contextual information we have gleaned through stakeholder interviews and an assessment of the secondary literature. We used the capacity indicators to test for any correlations between specific capacity attributes and farm operator characteristics, as well as between capacity attributes and our measures of community ties and attachment. Below we report the results of our analysis.

Results

The surveyed farm population

The 52 respondents to our survey were, on average, highly educated, with 69 % reporting having obtained a higher education degree. Similar to the general agricultural population in the USA, the respondents' age averaged 57 years, and they were predominantly male. Just over half (53.8 %) reported that agricultural activities constituted more than 50 % of their total income. As was anticipated from the sampling frame, the majority of the respondents were cotton (50 %) and alfalfa (62 %) growers; other crops grown were grains (barley, wheat, corn, sorghum) and to a lesser extent, horticultural products. Respondents farmed on average 1000 acres, in parcels of 500 acres, primarily within the Phoenix and Pinal Active Management Areas. Nearly half of these parcels—47 % —were leased rather than owned.

Risk exposure and perception

With respect to the longer-term viability of their enterprise, the top two concerns reported by respondents were water availability and commodity prices. A majority of respondents (63.5 %) reported having experienced problems of water scarcity at least once over the prior decade. A third of these reported having had experienced such scarcity for 4 or more years. High water demand and limited supply was the most frequently cited cause of scarcity (55 % of respondents), followed by drought (42 %), water table decline (27 %) and problems in infrastructure capacity. Recent increases in water prices were also reported by a majority (77 %) of respondents.

This experience with water scarcity and variability in supply and price likely affected farmers' perceptions about the future of water resources. Only 23 % of respondents agreed with the statement "I do not believe that future water resource availability will be any different from my past experience," and 42.3 % concurred with the statement "Immediate action is needed to prepare for the impact of changing climate conditions on agriculture." Over half

(57.7 %) disagreed—and 25 % strongly—that "Problems in water availability are unlikely to manifest in this region for some time." A full 75 % agreed with the statement "I can't plan more than a few years ahead, things are too uncertain."

In addition to water scarcity, the respondents also confirmed significant volatility in income. Respondents estimated that in a "good year," their income from agricultural sales can increase by an average of 20 %; similarly, in a "bad year," their income might decline by an average of 27 %. This self-reported income volatility reflects the significant variability in cotton (coefficient of variation of 44 % for 2001–2011, based on yearly data from National Cotton Council of America) and alfalfa prices (coefficient of variation of 23 % for 2001–2011, based on yearly data from USDA National Agricultural Statistics Service) over the last decade. At the time of our interviews, both cotton and alfalfa prices were unusually high, driving up demand for both land and water as producers moved to take advantage of the economic opportunity in the face of limited land availability.

Capacity indicators

Our capacity indicators, while similar to Marshall et al. (2012), differ somewhat in structure, reflecting in part our particular interest in including items related to decision-making constraints and opportunities in relation to the institutional context of farming. Some of the items that proved robust in the Australian context did not prove to be salient in the Arizona case. For example, items used for measuring financial *flexibility* were ultimately dropped from our analysis after failing tests of construct validity. Nevertheless, additional statements included in our study allowed for the creation of two new indicators particular to the Phoenix context. These indicators incorporated aspects of flexibility, particularly the role of infrastructure and perceptions of personal responsibility in management choices. The resulting components of capacity were labeled *learning and knowledge seeking; risk-taking and experimentation; decision constraints;* and *adaptive management* (Table 2).

Learning and knowledge seeking

The mean and mode of the statements in this component indicate that the majority of respondents desired more information and knowledge about regional hydrology and climate (Table 2), and many respondents expressed uncertainty about their own skills in the face of change. Only half (54 %) of respondents agreed or strongly agreed with the statement "I have the skills or knowledge to protect my land from drought"; 27 % were unsure. This uncertainty was also reflected in other statements: 21 %

Table 2 Components of capacity

Component	Statement	Mean	Std dev.	Mode	Range	Factor weight
Learning and knowledge seeking	I am interested in learning about hydrological changes and their potential impacts on agriculture	3.71	0.776	4	3	0.715
	I am interested in learning about climatic changes and their potential impacts on agriculture	3.63	0.864	4	3	0.689
	I have the skills or knowledge to protect my land from drought	3.63	1.189	4	5	0.615
	I have sufficient information to make plans concerning my water use into the future	3.40	1.053	4	5	0.592
	My current approach for dealing with water challenges will be sufficient for dealing with future water challenges	3.17	0.834	3	4	0.424
	I like to discuss challenges facing the farm sector with researchers	3.56	1.056	4	5	0.488
	I seek the advice of other farmers in the region	4.02	0.896	4	5	0.556
Risk-taking and experimentation	I like to experiment with new approaches to managing my farm enterprise	3.58	1.177	4	4	0.913
	I like to experiment with new ways to irrigate	3.40	1.142	4	5	0.906
	I believe that opportunity comes from taking calculated risks	3.71	0.915	4	4	0.509
Decision constraints	My ability to manage change on my farm is constrained by state and local regulations on water use and distribution.	3.17	1.133	4	4	0.883
	My water management is impacted by inadequate irrigation infrastructure	3.00	1.237	4	4	0.883
Adaptive management	I continually monitor the condition of my land so that I can recognize important changes	4.23	0.877	4	5	0.938
	I like to think of myself as responsible for the future productivity of my land	4.44	0.698	5	3	0.938

disagreed with, and 30.8 % were unsure about, the statement "I have sufficient information to make plans concerning my water use into the future" and 52 % were unsure whether their "current approach for dealing with water challenges will be sufficient for dealing with future water challenges."

The respondents were already accessing information on irrigation improvements and water conservation: only 23 % of respondents reported they did not seek such guidance. Neighbors and the state Cooperative Extension were the primary sources of information on this issue. Most farmers also reported seeking weather and climate information (83 %), primarily from local television news networks (44 %), the Extension service and the Arizona Meteorological Network. National sector-specific climate data sources (such as the US Drought Monitor, or USDA Weather and Crop Bulletin) were seldom used.

Risk-taking and experimentation

The second component captures the entrepreneurial nature of producers' outlooks: 73.1 % agree that "Opportunity comes from taking calculated risks," although just half (51.9 %) agree with the statement "I like to experiment with new ways to irrigate." The statement "I like to experiment with new approaches to managing my farm enterprise" found 63.5 % agreement.

Despite the self-described experimental and entrepreneurial nature of the respondents, relatively few reported using irrigation technology different from the standard flood irrigation systems widely used in the area: only 7.69 % reported employing drip, sprinkler or subsurface drip systems. Some analyses find that flood irrigation has an efficiency of 40–65 %, compared to 75–85 % for sprinkler irrigation (Colby and Frisvold 2011: p. 197); nevertheless, regardless of a farmer's willingness to experiment, soil and water salinity, crop characteristics and tenure arrangements all affect whether or not a farmer can adopt more water conserving systems.

Similarly, there was little evidence that farmers were experimenting with non-conventional crops—only 27 % reported planting crops other than the standard cotton, alfalfa and grains. Again, beyond a farmer's willingness to experiment with alternative production systems, interviewed farmers reported that crop choice is also constrained by market conditions and infrastructure as well as soil and water quality.

Decision constraints

The third component focuses explicitly on perceptions of exogenous constraints on decision-making. It encapsulates two statements, reflecting growers' concerns with infrastructure and government regulation. The responses were ambivalent. Forty-two percent of respondents agreed that water regulations restricted their ability to manage change effectively, while 28.8 % were unsure. Similarly, 44.2 % agreed that their decisions were negatively affected by inadequate irrigation infrastructure.

The irrigation district water managers are often responsible for maintenance of well and canal infrastructure. Our interviews with water managers did confirm that the increased water demand in response to higher commodity prices had put considerable stress on existing infrastructure capacity, leading to conditions of scarcity for some farmers.

The implication of water regulation on farm decisions was less clear. Water regulation focuses largely on total water use, restricting farmers to the consumption associated with their allocated water rights. Yet, while farmers reported experiencing water scarcity, there was little indication that scarcity was triggered directly by water regulations. Farmers are able to accrue credits for water rights they do not consume in any given year and then use those credits to augment their demand in future years; yet, only 25.8 % reported having used these credits in the prior decade and only 6.5 % had engaged in purchasing credits from other farmers.

Adaptive management

The final component incorporated two statements reflecting stewardship and close monitoring of the resource base. Despite the uncertainty about their skills and capacities to address future water scarcity (see above), the respondents characterized themselves as concerned and committed, and responsive to signals of change. A large majority of respondents agreed with both associated statements: "I like to think of myself as responsible for the future productivity of my land" (96.1 %) and "I continually monitor the condition of my land so that I can recognize important changes" (88.4 %).

Occupational and place attachment

We ran a separate factor analysis on the seven items representing aspects of occupation and place attachment in order to evaluate the extent to which these attributes were associated with adaptive capacity indicators. The analysis resulted in three distinct components, which we interpreted as: *value of agriculture, individual-community interdependence*, and *community commitment* (Table 3).

The characterization of farming as a vocation, rather than an occupation, business or profession, is a feature of farming around the world. It is no different in our sample. The vast majority—84.7 %—considered farming as a

Table 3 Place and occupational attachment

Component	Statement	Mean	Std dev.	Mode	Range	Factor weight
Value of agriculture	Being a farmer is a lifestyle, it is not just my job	4.15	1.092	5	4	0.725
	Agriculture in Arizona provides benefits to the community beyond just the value of farm products	4.60	0.664	5	3	0.639
	Agriculture [no longer] has a central role to play in Arizona's future (REVERSED)	3.79	1.177	4	4	0.689
Individual–community interdependence	My success in farming depends on farmers in my community also being successful	3.77	0.899	4	4	0.680
	I have *many* [few] options available to me other than being a farmer (REVERSED)	2.62	1.087	2	4	0.832
Community commitment	I plan to do all I can to continue farming in this region	4.17	0.834	4	3	0.643
	Helping other farmers in my community is important, even when it means making small sacrifices	4.08	0.555	4	2	0.767

Source: Authors' survey 2012

lifestyle choice; 94.2 % agreed that there are benefits of agriculture beyond the value of farm products. Two-thirds disagree with the statement that agriculture no longer has a central role to play in the state's future. These three statements together represent a belief in agriculture as a valuable, multidimensional vocation.

While farmers can be characterized as independent and self-reliant in the West, the second identified component conveyed interdependence with community: 69.3 % of respondents agreed that their success was dependent on the success of others in the community. This statement was associated with relative uncertainty about alternatives to agriculture as a livelihood strategy: while 50 % expressed some confidence that they have options aside from farming as occupations, 32.7 % were unsure.

Finally, the last component of attachment was indicative of a commitment to place and community: 88.4 % concurred that helping others in the community was important "even when it means making small sacrifices" and 80.8 % agreed that they "plan to do all I can to continue farming in this region."

Elsewhere in the survey, when asked "what would be your most likely strategy" in the face of decreased water availability for farming, only 13.5 % indicated they would consider moving from the region; and only 2 farmers—3.8 %—indicated they would consider changing occupations. While 39 % reported that they had sold land in the previous 10 years, almost as many (29 %) reported having purchased land. The majority of these transactions took place within the Pinal and Phoenix Active Management Areas.

Of the dimensions of occupation and place attachment, only *community commitment* was associated with the identified capacity attributes. This attribute was positively associated with both the *learning and knowledge seeking* and *adaptive management* dimensions of capacity (Table 4), suggesting that both social ties and attachment are potentially motivating factors for farmers as they seek to maintain their viability as farmers through additional knowledge and close management of the resource base.

Discussion and conclusion

Our initial hypothesis was that producers in this region would be relatively immune to climatic shocks and water stress given the historical availability and reliability of irrigation in the AMAs, and the suitability of arid climate conditions for cotton production. We were less certain, however, about what attributes of capacity (as defined in previous studies) would be present in this population. Other research in the state has shown, for example, that there is some disparity among farmers and ranchers in terms of access to resources and information, and participation in social networks that are instrumental in managing risk (Coles and Scott 2009; Eakin and Conley 2002; Vasquez-Leon et al. 2003). And while irrigation buffers farmers from dealing with climatic and hydrological variability, its availability may also contribute to a sense of security that undermines the more cognitive dimensions of capacity, such as astute risk perception, self-efficacy, experimentation and learning (Brugger and Crimmins 2013).

In contrast to the farm populations featured in the research summarized above, the respondents in our study were also farmers with considerable objective capacity: they have considerable material assets; they generally have choices in terms of income sources and land use. These are educated farmers who have chosen to forego the economic opportunity the housing bubble afforded. They weathered the variability in commodity prices, land prices and water

Table 4 Association of Capacity Indicators with Place and Vocational Attachment

Correlations	Factor scores for learning and knowledge	Factor scores for risk-taking and experimentation	Factor scores for decision constraints	Factor scores for adaptive management
Factor scores for value of agriculture	−0.102	0.057	0.129	0.125
Factor scores for individual–community interdependence	0.157	−0.017	0.03	0.231
Factor scores for community commitment	0.334*	0.109	0.047	0.424**

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

availability over the last decade. Many are farming on different combinations of leased and owned land—and, opportunistically, leasing additional land as land and commodity prices permit. So far, they have proven themselves to be adaptive to dynamic political and economic circumstances. It is thus hard to describe the farmers we surveyed as vulnerable.

Nevertheless, in terms of risk perception, we found that farmers in our sample were already exposed to and concerned about water scarcity and uncertainty, despite being "buffered" from risk by irrigation infrastructure and institutions. While climate change research in the region tends to describe water scarcity as threat that will increase in the future (Gober et al. 2010; Morrison Institute 2011), farmers are already experiencing and anticipating deteriorating conditions for farming—most importantly, from a host of other policy and demographic changes, and infrastructural limitations. A majority of respondents believed that the past was no longer a good predictor of the future, and articulated a belief that conditions would only become more difficult over time. Uncertainty and volatility in economic and social factors, such as commodity, water, land and energy prices, were significant contributors to perceived risk. The state of the irrigation infrastructure itself—without which farming would be impossible in the desert—was contributing to perceptions of water resource scarcity and decision inflexibility, as demand for water exceeded the water delivery capacity in the irrigation districts.

While there was little evidence that farmers were accessing the full range of climatic and hydrological information or technical knowledge available to them, they showed a strong interest in knowledge and learning, generally expressed caution and responsibility toward the resource base, and considered themselves to be risk-takers and experimenters in the face of changing opportunities.

Their capacity for making incremental adjustments to recent political and economic changes may be at least partially explained by their strong place, occupational and community attachment. Two of the indicators of capacity (adaptive management and learning/knowledge-seeking) are associated with farmers' perceptions of and commitment to the farm community: growers seek information from each other and also are motivated to monitor their resources to maintain their viability in part because of their commitment to community. This association is consistent with the findings of Marshall et al. (2012), who determined place and occupation attachment to be potentially supportive of capacities for more incremental forms of adaptation. Central Arizona growers are committed to their community and place, and consider themselves responsible and careful resource managers. Nevertheless, some also express limits to which aspects of their resource base—finance, water availability, water quality, soil quality—they can confidently control. The respondents are thus primed for incremental adaptation to increased water risk and scarcity, although it is still unclear what real options they will have to adapt to more substantive future change.

There is little evidence in our data, for example, that farmers are actively experimenting with alternative irrigation technologies or cropping systems. Irrigation efficiency improved significantly in the years leading to and following the implementation of the Groundwater Management Act: canals were lined and fields leveled. In part, the lack of further effort in water conservation may be a result of lack of sufficient information about pending hydrological change to motivate farmers to alter their strategies. Perhaps more important, however, are the very real institutional constraints and incentive structures farmers face: water, until recently, has been relatively inexpensive, the high frequency of leased land likely dampens motivation to invest in new irrigation technology, and there are issues of water quality and salinity as well as markets that affect technological decisions. Farmers we interviewed expressed considerable doubt that the urban public and the state's policy makers understood the role of agriculture in the region or valued its contribution to the economy (Bausch et al. 2015), a perspective confirmed in other analyses of rural outlooks in relation to climate risk (Brugger and Crimmins 2013). In short, many respondents perceive their future to be determined more by policy than by their own decision-making. This perception provides little incentive to alter their strategies and make long-term investments in water conservation.

In this context, it is difficult to know whether the capacities of the farmers observed in the survey results will be sufficient to allow them to face more significant environmental and policy changes in the future. Here, our research may be demonstrating the limits to a "living with climate" approach to adaption, in which farmers make incremental adjustments to evolving circumstances (Brugger and Crimmins 2013). Despite their education and experience, growers express doubts about their own self-efficacy. They are unsure whether their knowledge and prior experience will be sufficient for the future, and many feel their command of information is insufficient. Thus, when competition over resources becomes more acute, rather than innovation in technologies or farm strategies, the growers may be more likely to choose place over occupation and retire locally into their existing complementary non-farm economic activities.

In the Australian cases, a significant change in livelihood or a retirement from agriculture might be defined as *transformative:* a strategy that requires substantive shifts in a farmer's livelihood orientation, location and ultimately identity as producers (Park et al., 2012). In other words, transformation entails significant economic, social and personal costs. However, moving locations and changing livelihoods (via retirement from farming) may not represent a transformative change for central Arizona farmers in the same way it does for Australian producers. Farmers around Phoenix have faced the idea of their eventual obsolescence for several decades—ever since the 1980 Groundwater Management Act institutionalized the notion that water would eventually be transferred from agriculture to urban use, irrespective of climatic or hydrological changes (Bausch et al. 2015). During the most recent bubble in housing prices (2002–2006), many landowners sold out to developers, and land in agriculture within the city of Phoenix declined by 45 % (Kane et al. 2014). None of our evidence to date suggests that the farmers who remained in production during and following the housing boom were disadvantaged or less capable of selling their land. Indeed, some farmers *did* sell their land but remained in the area as growers on land leased back from developers. All of our research suggests that those who remained in farming had options: they consciously chose to remain in farming despite the opportunity to sell out.

Transformation in the central Arizona case may be more about the significant changes in strategy that will be necessary to enable *persistence,* rather than about capacities associated with adapting to forced farm abandonment. In light of the more severe hydro-climatic scenarios for the regions, in the coming decades, growers may need to make significant innovations in their water management and use, land use and commercial market orientation. This will require new sources of information and knowledge, and new models of business management. Close monitoring of local conditions and incremental adjustments in response to changes as they occur may simply not be enough. As one farmer puts it, if his children are going to be successful farmers in the region in the future, "they are going to need to think outside the box": business as usual will not suffice.

Thinking outside the box will also require enhancing farmers' *linking capacities*—their ability to collectively shape the evolution of the water and land institutions that currently influence their cognitive and objective capacities. They will need to reach out to state and city authorities and urban residents to negotiate the inevitable increase in competition over the allocation of water resources in the coming decades. Urban interests are only likely to become more dominant in policy processes. Growers will likely need to better articulate the value and relevance of farm livelihoods and production to local urban policy makers and water resource managers *today* in order to ensure they have continued access to the vital components of production in the future. Essentially, if farmers are going to be active in shaping regional development policy and not just reacting to it, they will need to expand their community ties to incorporate municipal and city actors, and even representatives of environmental interests.

In short, in the complex institutional contexts in which adaptation decisions are made, it is the linking capacities that may matter most in understanding transformative potential in central Arizona agriculture. As individuals, farmers may have the cognitive attributes that have enabled them to make incremental adjustments to changing conditions, and they have the strong attachments to place and community to motivate these actions. Their fate, however, is not only a matter of their own cognition and choice: it is also a function of critical choices regarding public expenditures, water resource allocation and infrastructure improvements, in which urban interests are dominant. Farmers will thus need capacities that not only enhance their ability to perceive change and make and implement resource management decisions, but also to shape the choices they have today and in the future via political mobilization, inter-sectoral collaboration and collective action, and ultimately institutional reform.

Acknowledgments The research presented here was funded by the National Oceanic and Atmospheric Administration, Sectoral Applications Research Program, CSI Award #NA110AR4310123, H. Eakin, PI, with additional support through the National Science Foundation under Grant SES-0951366, Decision Center for a Desert City II: Urban Climate Adaptation. All findings presented are the responsibility of the authors, not the funding agencies. We greatly appreciate the support and participation of the Arizona Cotton Growers Association and Ayman Mostafa of the University of Arizona Maricopa County Extension Service in the design and implementation of this project, and Dr. Nadine Marshall, CSIRO, for generously sharing her research instruments with our team. We also appreciate the time and collaboration of the growers, water managers and other experts who have contributed to this project. Sally Wittlinger prepared the map for this manuscript. The authors appreciate the comments of two anonymous reviewers whose insights improved the manuscript considerably.

References

Abbott DR (2003) Centuries of decline during the Hohokam classic period at Pueblo Grande. University of Arizona Press, Tucson

Adger WN (2003) Social capital, collective action, and adaptation to climate change. Econ Geogr 79(4):387–404

Adger WN, Dessai S, Goulden M, Hulme M, Lorenzoni I, Nelson DR, Naess LO, Wolf J, Wreford A (2009) Are there social limits to adaptation to climate change? Clim Change 93:335–354

Anderies JM, Janssen MA, Ostrom E (2004) A framework to analyze the robustness of social-ecological systems from an institutional perspective. Ecol Soc 9(1), art. 18

Anderies JM, Walker BH, Kinzig AP (2006) Fifteen weddings and a funeral: Case studies and resilience-based management. Ecol Soc 11(1):21. http://www.ecologyandsociety.org/vol11/iss1/art21/

Arizona Department of Water Resources (2010a) Arizona water atlas, volume 8: active management area planning area. State of Arizona, Phoenix

Arizona Department of Water Resources (2010b) Pinal AMA Summary Budget. State of Arizona, Phoenix

Arizona Department of Water Resources (2011) Phoenix AMA Summary Budget. State of Arizona, Phoenix

Avelino F, Rotmans I (2009) Power in transition: an interdisciplinary framework to study power in relation to structural change. Eur J Soc Theory 12(4):543–569

Barnett A, Eakin H (2015) We and us, not I and me: Justice, social capital, and household vulnerability in a Nova Scotia fishery. Appl Geogr 59:107–116. doi:10.1016/j.apgeog.2014.11.005

Bausch J, Eakin H, Smith-Heisters S, Rubinos C, York A, White D, Aggarwal R (2015) Development pathways at the agriculture-urban interface: the case of Central Arizona. Agric Hum Values. doi:10.1007/s10460-015-9589-8

Brown K, Westaway E (2011) Agency, capacity, and resilience to environmental change: Lessons from human development, well-being and disasters. Ann Rev Environ Resour 36:14.11–14.22

Brugger J, Crimmins M (2013) The art of adaptation: living with climate change in the rural American Southwest. Glob Environ Change Hum Policy Dimens 23:1830–1840

Burch S, Robinson J (2007) A framework for explaining the links between capacity and action in response to global climate change. Clim Policy 7(4):304–316

Burton I, White G, Kates R (1978) Environment as hazard. Oxford University Press, New York

Cash D, Clark W, Alcock F, Dickson N, Eckley N, Jager J (2002). Salience, credibility, legitimacy and boundaries: Linking research, assessment, and decision-making. John F. Kennedy School of Government Faculty Research Working Paper Series (RWP02/046). Cambridge

Colby BG, Frisvold GB (eds) (2011) Adaptation and resilience: the economics of climate, water, and energy challenges in the American Southwest. Earthscan, Washington, DC

Coles AR, Scott CA (2009) Vulnerability and adaptation to climate change and variability in semi-arid rural southeastern Arizona, USA. Nat Resour Forum 33:297–309

Eakin H, Conley J (2002) Climate variability and the vulnerability of ranching in southeastern Arizona: a pilot study. Clim Res 21:271–281

Eakin H, Lemos MC (2010) Institutions and change: the challenge of building adaptive capacity in Latin America. Glob Environ Change Hum Policy Dimens 20(1):1–3. doi:10.1016/j.gloenvcha.2009.08.002

Eakin H, Luers A (2006) Assessing the vulnerability of social-environmental systems. Annu Rev Environ Resour 31:365–394

Eakin H, Tucker C, Castellanos E (2006) Responding to the coffee crisis: a pilot study of farmers' adaptations in Mexico, Guatemala and Honduras. Geogr J 172:156–171

Eakin H, Lerner A, Murtinho F (2010) Adaptive capacity in evolving peri-urban spaces: responses to flood risk in the Upper Lerma River Valley, Mexico. Glob Environ Change 20:14–22

Eakin H, Lemos MC, Nelson DR (2014) Differentiating capacities as a means to sustainable climate change adaptation. Glob Environ Change 27:1–8. doi:10.1016/j.gloenvcha.2014.04.013

Frank E, Eakin H, Carr D (2011) Social identity, perception and motivation in adaptation to climate risk in the coffee sector of chiapas, Mexico. Glob Environ Change 21:66–76

Gober P, Kirkwood CW, Balling RC, Ellis AW, Deitrick S (2010) Water planning under climatic uncertainty in Phoenix: Why we need a new paradigm. Ann Assoc Am Geogr 100:356–372

Goetz S (2002) Land use problems and conflicts in the U.S.: Northeast Regional Center for Rural Development

Grothmann T, Patt A (2005) Adaptive capacity and human cognition: the process of individual adaptation to climate change. Glob Environ Change 15:199–213

Howden M, Soussana JF, Tubiello F, Chhetri N, Dunlop M, Meinke H (2007) Adapting agriculture to climate change. PNAS 104:19691–19696

Institute Morrison (2011) Watering the sun corridor: managing choices in Arizona's megapolitan area. Morrison Institute for Public Policy Arizona State University, Phoenix

Institute of the Environment (2013) Assessment of climate change in the Southwest United States: a report prepared for the national climate assessment. In: Garfin G, Jardine A, Merideth R, Black M, LeRoy S (eds) National climate assessment regional technical input report series. Institute of the Environment, Washington, DC

Kane K, York A, Tuccillo J, Gentile L, Ouyang Y (2014) Residental development during the great recession: a shifting focus in Phoenix, Arizona. Urban Geogr 35(4):486–507

Kasperson RE, Renn O, Slovic P, Brown HS, Emel J, Goble R, Ratick S (1988) The social amplification of risk—a conceptual-framework. Risk Anal 8(2):177–187

Kates RW, Travis WR, Wilbanks TJ (2012) Transformational adaptation when incremental adaptations to climate change are insufficient. Proc Natl Acad Sci USA 109:7156–7161

Maguire RP (2007) Patching the holes in the bucket: safe yield and the future of water management in Arizona. Arizona Legal Rev 49:361

Marshall NA (2011) Assessing resource dependency on the rangelands as a measure of climate sensitivity. Soc Nat Resour 24:1105–1115

Marshall NA, Marshall PA (2007) Conceptualizing and operationalizing social resilience within commercial fisheries in Northern Australia. Ecol Soc 12, art.1

Marshall NA, Park SE, Adger WN, Brown K, Howden SM (2012) Transformational capacity and the influence of place and identity. Environ Res Lett 7:034022

McDaniels T, Axelrod LJ, Slovic P (1996) Perceived ecological risks of global change—a psychometric comparison of causes and consequences. Glob Environ Change Hum Policy Dimens 6(2):159–171. doi:10.1016/0959-3780(96)00006-4

Murtinho F, Eakin H, Lopez-Carr D, Hayes TM (2013) Does external funding help adaptation? Evidence from community-based water management in the colombian Andes. Environ Manage 52(5):1103–1114. doi:10.1007/s00267-013-0156-z

National Agricultural Statistics Service (2007) Census Volume 1. Chapter 2: County Level Data. Table 10. Irrigation 2007 and 2002. United States Department of Agriculture, Washington, DC

Olsson P, Folke C, Hahn T (2004) Social-ecological transformation for ecosystem management: the development of adaptive co-management of a wetland landscape in southern Sweden. Ecol Soc 9(4):2. http://www.ecologyandsociety.org/vol9/iss4/art2/

Ostrom E (1990) Governing the commons: the evolution of institutions for collective action. Cambridge University Press, Cambridge

Ostrom E (2011) Background on the institutional analysis development framework. Policy Stud J 39(1):190–292

Overpeck J, Udall B (2010) Dry times ahead. Science 328:1642–1643

Park SE, Marshall NA, Jakku E, Dowd AM, Howden SM, Mendham E, Fleming A (2012) Informing adaptation responses to climate change through theories of transformation. Glob Environ Change 22:115–126

Pelling M, High C (2005) Understanding adaptation: What can social capital offer assessments of adaptive capacity? Glob Environ Change Part A 15(4):308–319

Scott J (1998) Seeing like a state: How certain schemes to improve the human condition have failed. Yale University Press, New Haven

Seager R (2007) The turn of the century North American drought: Global context, dynamics, and past analogs. J Clim 20:5527–5552

Sheridan T (1995) Arizona: a History. University of Arizona Press, Tucson

Stafford Smith M, Horrocks L, Harvey A, Hamilton C (2010) Rethinking adaptaton for a 4 world. Philos Trans R Soc Lond Ser A 369:196–216

Tschakert P, Dietrich KA (2010) Anticipatory learning for climate change adaptation and resilience. Ecol Soc 15(2). Art: 11

U.S. Department of the Interior Bureau of Reclamation (2012) Reclamation: managing water in the West. Colorado river basin water supply and demand study. Executive summary. US Department of the Interior, Washington

Vano JA, Udall B, Cayan DR, Overpeck JT, Brekke LD, Das T, Hartmann HC, Hidalgo HG, Hoerling M, McCabe GJ (2013) Understanding uncertainties in future Colorado River streamflow. Bull Am Meteorol Soc 95(1):59–78

Vasquez-Leon M, West CT, Finan TJ (2003) A comparative assessment of climate vulnerability: agriculture and ranching on both sides of the US-Mexico border. Glob Environ Change 13:159–173

Walker B, Holling CS, Carpenter SR, Kinzig A (2004) Resilience, adaptability and transformability in social-ecological systems. Ecol Soc 9: 5. http://www.ecologyandsociety.org/vol19/iss12/art15

Westley F, Olsson P, Folke C, Homer-Dixon T, Vredenburg H, Loorbach D, Thompson J, Nilsson M, Lambin E, Sendzimir J, Banerjee B, Galaz V, van der Leeuw S (2011) Tipping toward sustainability: emerging pathways of transformation. Ambio 40:762–780

White G (1973) Natural hazards research. In: Chorley RJ (ed) Directions in geography. Methuen, London, pp 193–216

Wood G (2003) Staying secure, staying poor: the “Faustian Bargain”. World Dev 31(3):455–471