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Research, part of a Special Feature on Small-Scale Societies and Environmental Transformations: Co-evolutionary Dynamics

Resilience of small-scale societies: a view from drylands

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ABSTRACT. To gain insights on long-term social-ecological resilience, we examined adaptive responses of small-scale societies to dryland-related hazards in different regions and chronological periods, spanning from the mid-Holocene to the present. Based on evidence from Africa (Sahara and Sahel), Asia (south margin of the Thar desert), and Europe (South Spain), we discuss key traits and coping practices of small-scale societies that are potentially relevant for building resilience. The selected case studies illustrate four main coping mechanisms: mobility and migration, storage, commoning, and collective action driven by religious beliefs. Ultimately, the study of resilience in the context of drylands emphasizes the importance of adaptive traits and practices that are distinctive of small-scale societies: a strong social-ecological coupling, a solid body of traditional ecological knowledge, and a high degree of internal cohesion and self-organization.

Key Words: *adaptation; climate change; coping mechanisms; drylands; resilience; social-ecological systems; sustainability; traditional ecological knowledge*

INTRODUCTION

A growing body of literature suggests that the possibility of a major irreversible state shift in the Earth's biosphere, partially driven by human pressure on the environment, can no longer be excluded (Rockström et al. 2009, Barnosky et al. 2012). With increased frequency and intensity of disturbances brought about with climate change, our exposure to risks from climate-related hazards seems to have become unavoidable, and so is the need for responses to mitigate its likely negative impacts (Barnett and O'Neill 2010). Climatic models that predict temperature extremes and drought intensification in the current century suggest that these considerations are paramount in drylands (IPCC 2012). In addition, drylands contain human populations with the highest growth rates (35% of global population to date) despite having the lowest biological productivity on Earth (Stafford Smith et al. 2009), thus offering the perfect settings for extreme vulnerability to climate-related hazards (Adger et al. 2012).

In spite of the challenges for human settlement in drylands, archaeological and historical research has revealed long-term trajectories of human-environment interaction in these regions. This long-term coevolution has generated social-ecological systems where people have developed specific coping strategies and institutions that are adapted to recurrent environmental stress (Berkes et al. 2000, Folke et al. 2002, Gómez-Baggethun et al. 2012). As a result, climatic events that are considered extreme elsewhere may be perceived as a systemic element of environmental variability in regions that have traditionally been exposed to them (Colding et al. 2002, Hoffman and Oliver-Smith 2002, Gómez-Baggethun et al. 2013*a*). On this line of thought, a number of researchers have highlighted that hazards are socially mediated. That is, people and communities can be considered as constituent parts of hazards, and hazards can be considered as constituent parts of social-ecological systems (Torry et al. 1979, Oliver-Smith 1999, Colding et al. 2002, Haque and Etkin 2007). As a consequence, the study of the long-term ability of social-ecological systems to mitigate, adapt to, or aggravate the effects of environmental hazards has crucial implications for the management of present-day resources and climate-related issues worldwide (McIntosh et al. 2000).

Climate-related hazards are often described in terms of frequency and intensity (IPCC 2012). In drylands, perhaps more than elsewhere, the frequency and intensity of climate-related hazards strongly contribute to determine the vulnerability of local social-ecological systems. Climatic and environmental change in drylands is characterized by high variability over the short-term, implying high diurnal and seasonal variations, as well as climatic unpredictability over annual and decadal periods (Balbo et al. 2014). Any annual deviation in precipitation from the mean in drylands may potentially lead to droughts, fires, floods, or frosts, affecting land productivity (e.g. soil salinization and crusting, loss of vegetation cover and biomass, runoff and erosion), habitability, and consequently food, energy, and water security. The high variability characterizing dry climates implies higher probabilities of occurrence of extreme conditions and increased uncertainty in the evaluation of available resources (McGlade 2014).

In this paper we examine case studies from different dryland regions and chronological periods to discuss the potential contribution of small-scale society studies for evaluation and building of resilience. Small-scale societies have been defined as past or present societies living at low population densities in small groups ranging from a few dozen to a few thousand people, subsisting by hunting-gathering or by farming or herding (Diamond 2012). For the purpose of this work, we further characterized small-scale societies as those human groups integrated in social-ecological systems characterized by feedback mechanisms of low complexity, where the effects of a given strategy are predominantly local and last for short periods of time, i.e., days to years. This definition intentionally excludes the

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potential cumulative effects of actions by aggregates of small-scale societies. Adapting the frameworks proposed by Agrawal et al. (2008) and Thornton and Manasfi (2010), we discuss (1) mobility and migration, (2) commoning, (3) storage, and (4) collective action driven by shared religious beliefs as coping mechanisms that play a central role in ensuring the viability of small-scale social-ecological systems in arid environments. Our reference case studies are drawn from archaeological, historical, and anthropological research, and include Sahelian and Sahara pastoralists, irrigated fields of Andalusi origin (Iberian Peninsula), hunter-gatherers and agro-pastoral groups of Gujarat, India, and traditional farmers of Doñana, Southwest Spain. Although some of the adaptive strategies discussed are found in more than one case study, in the following sections we pair each social-ecological system with a coping mechanism that illustrates a significant aspect of its resilience capability in the face of particular climate-related disturbances. Our final aim is to assess the added value of integrating social and environmental information from small-scale societies in a long-term perspective to inform action aimed at mitigating the impact of climate-related hazards and preventing disaster.

CASE STUDIES

Migration and mobility: the case of Saharan and Sahelian pastoralists

Mobility and migration are core adaptive strategies within dryland pastoral systems in response to unpredictable and irregularly distributed resource availability, as well as to cope with frequent social, political, and economic change over broad and sparsely settled regions (Kavoori 1996, Salpeteur et al., *in press*). The viability of mobility and migration strategies over the long term is in turn related to the existence of (1) organizations and institutions internally regulating the mobile way of life, such as the distribution of functions among members of coexisting migration groups (Agrawal 2003); (2) formal and informal mechanisms or institutions to manage interactions with external resource users and owners, enabling negotiation and conflict resolution (Nori et al. 2008, Hussein 1998); and (3) higher institutional settings that frame land tenure and movement patterns across large areas (Galvin 2009, Nori and Davies 2007, Robinson and Berkes 2010, Oteros-Rozas et al. 2013).

Sahelian droughts have been described as some of the largest ongoing climate changes (Bates et al. 2008). Here, mobility has been the most common strategy to cope with climatic variability by spreading risk across space and time, with migration and pastoralism being widely adopted for centuries (McCarthy et al. 2000, FAO 2001, Galvin 2009, Dong et al. 2011). In the Central Sahara, animal husbandry has been the most important strategy for food security since the emergence of domesticated animals in the region circa 9 ka BP (thousands of years before present; Marshall 2000, Gifford-Gonzalez and Hanotte 2011). Here, pastoralism was never fully replaced by agriculture, owing among other things to the gradual intensification of aridity starting locally circa 4 ka BP (Di Lernia and Merighi 2006). Even during the Garamantian kingdom (c. 700 BC to 1000 AD), the earliest attested Saharan state, and later during the Islamic period (c. 700-1600 AD), the cultivation of crops in the oases was largely integrated with pastoralism in the mountain ranges (Wilson 2012, Mattingly and Sterry 2013, Mori 2013). In the same region, the Kel Tadrart Tuaregs of the Acacus Mountains (Southwest Libya) offer a contemporary example of multiresource pastoralism (Biagetti 2014). Over the past century, increasingly affected by dry spells and political restrictions to mobility and resource access, Saharan and Sahelian pastoral groups have significantly broadened the type of labor activities in which they are involved in rural as well as urban areas.

A growing body of literature aims at understanding migration as a coping mechanism (Afifi and Jäger 2010, Piguet et al. 2011), and in an historical long-term perspective, migration appears as a response in climate adaptation (Scheffran et al. 2012*a*). When migrations take place, existing social networks appear to work as potential security nets (Scheffran et al. 2012*a*, *b*). Through such networks, family members are sent away to diversify income, gain knowledge, spread risk, reduce population pressure, insure against future shocks and stresses, and gather capabilities to sustain the community. Although outmigration has been identified elsewhere as a major driver for the loss of local ecological knowledge (Iniesta-Arandia et al. 2015), in other cases migrant social networks show potential for the increase of social resilience in vulnerable communities, by offering new opportunities to diversify household livelihoods and triggering innovations across regions through, e.g., remittance flows, transfer of knowledge, technological transfer and renewable energy, collaborative projects for water management, and education to cite but a few (Scheffran et al 2012*b*, Ngaruiya et al. 2015).

Commoning: the case of Andalusi agriculturalists

Irrigated social-ecological systems of Andalusi origin (711-1492 AD) encompass long-lasting intensive agricultural systems that have shown a high degree of resilience to different social and climatic disturbances over the centuries (Puy and Balbo 2013, Puy et al. 2016). They were implemented in the Iberian Peninsula after the arrival of Arab and Berber tribes and clans in 711 AD (Guichard 1976, Barceló 1986), and allowed to acclimatize for the first time in the western Mediterranean oriental crops such as the orange or the lemon tree, the artichoke, the cucumber, the watermelon, and the sugar cane (Watson 1983, Retamero 1998). The original Andalusi irrigated field systems extended over limited areas of 2 ha or less (Sitjes 2006). These were largely extended after the feudal conquest of al-Andalus, made in the context of the European Crusades (Torró 2007, Kirchner 2009, Guinot and Esquilache 2012). Through history, irrigated fields of Andalusi origin have shifted from subsistence-based to state-regulated and market-oriented production, and some of them are currently cultivated for the production of fruits and vegetables that are exported across Europe.

Transformations and enlargements of traditional hydraulic systems are constrained by water availability and favorable slopes, because gravity is needed to allow water flow across the channel network (Barceló 1989). In addition, the initial channel layout and the location of hydraulic devices and irrigated plots cannot be modified during later extensions without putting the whole system at risk (Barceló 1989, Glick 1990). In spite of these limits to growth, traditional hydraulic systems might involve flexible water allocation regimes, which can be changed to effectively cope with water shortages. In that sense, the long-term resilience of hydraulic systems largely depends on their governance with

institutional arrangements able to swiftly respond to dry spells and to solve conflicts between irrigators potentially arising in times of water shortages. Fines to irrigators caught stealing water may be reinforced during the dry season as a deterrent to free riding and to prevent situations potentially leading to the "tragedy of the commons" (Hardin 1968, Ostrom 1990). Water allocation rules may be temporarily modified to minimize the loss in bulk production, e.g., by giving irrigation priority to crops that are in most need of water (Maas and Anderson 1978), by promoting a temporary reduction in irrigated land (Pérez et al. 2011), or by maximizing the net income per unit of water used rather than per land unit (Fereres and Soriano 2007). Adaptive water allocation rules and conflict-solving mechanisms governed by local institutions and communities are critical in ensuring the viability of these intensive agrarian areas over the long-term. The Council of the Wise Men of Murcia or the Water Tribunal of València are examples of such institutions, dating back to al-Andalus and included in the UNESCO's list of intangible heritage since 2009.

Many authors have characterized small-scale hydraulic systems as better endowed to achieve long-term survival in the face of uncertainty (Guijt and Thompson 1994, Mabry 1996*a*, *b*, Ertsen et al. 2013). However, recent studies suggest that increased water shortage, sprawling cities, market competition, aging of cultivators, and lack of modernization could undermine in the short- to mid-term the resilience of both small- and large-scale traditional Mediterranean irrigated fields (Rodríguez Díaz et al. 2007, Martínez-Fernández et al. 2013, Iniesta-Arandia et al. 2015). New institutional challenges arise as agricultural production becomes economically less important for the local population, often employed elsewhere. Work in the field has become a weekend diversion for many, and cycling, trekking, and historical routes across the irrigated fields are becoming an increasingly relevant source of income. This new wave of lucrative and ludic activities should be coupled with institutional designs aimed at maintaining traditional hydraulic systems attractive, viable, and resilient. Awareness of potential drawbacks prompted by dependency on external inputs should contribute to promoting the sustainable use of amenities and ecosystem services in these areas.

Storage: the case of early agro-pastoral systems in Gujarat

Available evidence from Gujarat (Northwest India) suggests that Holocene hunter-gatherer populations settled the region circa 9 ka BP. In contrast with more common situations where hunter-gatherers were rapidly replaced by agro-pastoral groups (e.g., Neolithic Europe; see Fort et al. 2012), hunter-gatherers in Gujarat interacted with agro-pastoral populations for millennia (c. 7.5-4 ka BP) before disappearing circa 4 ka BP. Agent-based models developed for Gujarat suggest, on one hand, that hunter-gatherer resource procurement strategies were highly adapted to the local climate, at least until drought frequency intensified around circa 4 ka BP (Clift and Plumb 2008, Anderson et al. 2010, Balbo et al. 2015). On the other hand, the same agent-based models suggest that the viability of the earliest agro-pastoral populations of Gujarat depended largely on consistent storage of foodstuff and on livestock, jointly covering at least 40% of their caloric intake. Absent from hunter-gatherer archaeological contexts, evidence of substantial storage features and cattle domestication becomes ubiquitous in agro-pastoral contexts from the late phases of the Holocene (Patel 2009, Balbo et al 2015). Storage, livestock being a variance of it (O'Brien and Bentley 2015), was interpreted as the key strategy that allowed agro-pastoral groups in Gujarat to overcome the period of intensified drought responsible for the disappearance of hunter-gatherer populations in the region circa 4 ka BP.

The case of Gujarat indicates that short-term climatic variation (standard deviation) is more relevant than long-term change (mean) in shaping population dynamics in drought-prone regions (Balbo et al. 2014). In such areas, unlike regions characterized by a steady climate ensuring year-round yields, delayed food consumption becomes fundamental to lower vulnerability and increase resilience. In the context of small-scale societies and early agricultural systems, the boundary between subsistence storage and surplus storage has been assessed to be the amount of foodstuff needed to cover three consecutive years with scarce harvests (Angourakis et al. 2015). Past those limits, storage can no longer be considered as a mere risk-reduction strategy, but rather a wealth-accumulation strategy, as emerging from the study of the evolution of Neolithic food storage in the Near East and in Europe (Kuijt 2015, O'Brien and Bentley 2015, Winterhalder et al. 2015). In such contexts, the production of surplus is in most cases directly related to the existence of effective storage structures and capabilities (Balbo et al. 2015).

Beyond the context of Gujarat, storage has emerged as a key buffering strategy to face fluctuating crop production from the very early stages of agriculture development in other regions of the world, because it allows the delayed consumption of foodstuff in sedentary agricultural societies (Balbo 2015). This adaptive strategy was intertwined with domestication in drylands in Southwest Asia (Near East) in the early Holocene, where storage of wild cereal grains is attested in Dhra' as early as 11 ka BP (Kuijt and Finlayson 2009, Kuijt 2015). In fact, agent-based models suggest that the agricultural lifestyle all together would hardly have been viable without the development of consistent and systematic storage practices and technologies (Angourakis et al. 2015). Finally, as production and storage capabilities increased above subsistence needs, the accumulation of surplus may have contributed in some measure to some of the major challenges inherited by contemporary societies, predominantly characterized by market-oriented farming: (1) the exponential spread of agricultural systems and related environmental transformations; (2) the transition to less cohesive societies, prompted in part by the accumulation of surplus (De Saulieu and Testart 2015); and (3) the progressive decoupling, in terms of perceived dependency between agricultural production and climate variability.

Shared belief systems: the case of farmers in Doñana, Southwest Spain

Doñana, a system of wetlands and sand dunes located in Southwest Spain, provides an example of climate-related collective action based on shared belief systems (López-Taillefert 1998). The area's climate has been described as semiarid (Romero Macías et al. 1996), and high precipitation irregularity leading to significant aridification phases has characterized the area in given historical periods (Sousa and García-Murillo 2003, García-Barrón et al. 2011). Consistently settled since the Phoenician and Roman periods, the marshlands of Doñana have been characterized by a subsistence-oriented economy, where in the absence of modern mechanization in agriculture until the mid

20th century livelihood relied heavily on traditional knowledge and practices (Gómez-Baggethun et al. 2010). Livestock raising and slash and burn shifting agriculture (to deal with lack of nutrients) were the main subsistence practices in use. Large parts of Doñana territory were managed as commons until land privatization in the mid 19th century (Ojeda 1987), and conservation enclosures in the mid 20th century brought about major restrictions for locals in access to land and resources (Gómez-Baggethun et al. 2013*a*). Farmers of Doñana gradually developed a rich diversity of coping strategies to spread climate-related risk across space, i.e., mobility; time, i.e., storage and rationing; assets, i.e., diversification; and households or communities, i.e., sharing and pooling (Giansante et al. 2003, Sauri et al. 2003, Gómez-Baggethun and Reyes-García 2013). In case of extreme events such as prolonged droughts, such coping strategies were complemented with collective action practices and rituals based on a shared system of beliefs around the local religious icon Virgen del Rocío (Our Lady of the Dew; Christian 1982, Barriendos 2005). The Virgin has been venerated by the locals since 1280 AD for her believed power to protect from environmental calamities (Flores Cala 2005), and at least since the 16th century locals have organized religious ceremonies, known as *Venidas de la Virgen*, to pray for her assistance in response to climate extremes (Flores Cala 2005).

The preservation of local historical archives informs on the occurrence of prolonged droughts that brought about crop failure and the dying of people and cattle (Flores Cala 2005). In Doñana, the occurrence of exceptional climate-related events matches with the celebration of ceremonies starring the statue of the Virgen del Rocío for the period 1582-1930 AD (Gómez-Baggethun et al. 2012). Most ceremonies were performed in spring to "prevent" the occurrence of a dry year. Requests to celebrate the ceremony were made by the guilds to the village council and then commanded to religious authorities, which had the final word on the possibility to perform them. By maintaining and strengthening a common identification within the framework of a shared belief system, such rituals contributed to keeping cohesion in the community during periods of shortages, arguably limiting the emergence of conflicting behavior such as robberies. The shared system of local beliefs played a critical role in maintaining long-term social-ecological resilience by facilitating collective responses and by preventing social unrest.

In addition to providing an expectation of relief, religious processions had associated effects that may also have contributed to building resilience. For example, during processions, local authorities provided food to the porters of the statue, recruited among the poorest members of the community, thus contributing to alleviating food shortage among the most exposed. Furthermore, generous public expenditure for the ceremonial processions, including the repair of local tracks, could serve as stimulus to the local economy (Flores Cala 2005). Belief-based behavior prompts changes in other behavioral spheres, e.g., affecting social structure by promoting cooperation and collective action. In spite of their potentially conservative and inhibitory nature, belief systems and religious entities can thus, in specific cases, act as a sort of mitigation technology enhancing social cohesion (Gómez-Baggethun et al. 2012). From a more general viewpoint, belief-based behavior is part of a broader framework made of traditional ecological knowledge (TEK).

PILLARS OF RESILIENCE IN SMALL-SCALE SOCIETIES

Population thresholds, mostly ranging from a few hundred to a few thousand, have often been used to define small-scale societies (Smith and Wishnie 2000, Diamond 2012). In this paper, rather than considering size as a set parameter critical to conceptualize small-scale societies, we see it as an emerging feature defined by the social-ecological contexts in which small-scale societies develop through time their resilience strategies and climate-related coping mechanisms. This approach highlights the dynamic nature of small-scale societies and stresses the need to focus on their adaptive traits and practices, which ultimately depend on their environmental awareness and institutional flexibility. Environmental awareness relies on the maintenance of strong social-ecological coupling and on the continuation of a solid body of TEK. Institutional flexibility, with the capacity for collective responses, depends on the preservation of internal cohesion and on the conservation of a high degree of self-organization (Agrawal et al. 2008, Reyes-Garcia et al. 2013). These adaptive traits are found across the case studies presented above and have been fundamental to enhance the resilience of small-scale societies in the face of climatic change, in drylands and beyond.

Regarding environmental awareness, people tend to pay attention to issues that are spatially, temporally, and socially close to their daily experiences, thus being within their own window of attention (Scheffran 2011). Small-scale societies, including those found in drylands, are often located in rural contexts with frequent exposure to, and high dependency on, local food-production processes and related activities. As a result, members of small-scale societies have often developed robust social-ecological bonds and have a more marked temporal, spatial, and social proximity with issues related to climate change (IPCC 2012), which define the perception of and response to external stressors (Pyhälä et al. 2016). Specifically, being consistently exposed to climate variability and extremes, small-scale societies in drylands have maintained a strong sense of environmental awareness that enables them to make an informed evaluation of the potential effects of local temperature rise, related hazards, and possible responses, e.g., concerning food production systems (Wildcat 2013). Although having significantly different group sizes, all social-ecological systems (foraging, pastoral, agricultural, and mixed) reviewed in this paper showed a high degree of investment in coping mechanisms aimed at the management of local food resources, the availability of which has been historically strongly coupled with climate variability, at least until the introduction of mechanization and modern technologies. Migration, storage, regulated sharing of common pool resources, and shared belief systems have all played important roles as buffering strategies aiming at dealing with shortages and preventing social conflict in times of scarcity, thus ensuring the continuity of the basic structure and function of the social-ecological system in which they are implemented, that is, their resilience.

The effectiveness of such coping strategies relies largely on a solid body of TEK. TEK refers to a cumulative assemblage of knowledge, practice, and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relation of living beings, including humans, with one another and with their environment (Berkes et al. 2000). Within small-scale societies, TEK forms an ensemble of intangible

customary devices that include multiple practices to cope with disturbance and change (Gómez-Baggethun et al. 2013*b*). As such, TEK includes adaptive strategies in response to environmental hazards that are based on long-term trajectories of human-environment interaction. The ways in which TEK is acquired, shared, and maintained within a given group, as well as between groups, depend largely on the social-ecological context in which the group is embedded, and may as such involve communities of different sizes or distinctive sectors within a given community. For example, knowledge about migration routes and related resources among pastoral groups are often shared within migration clusters based on kinship, as is the case for present-day Rabari pastoral groups in Gujarat (Salpeteur et al. 2015). Likewise, storage facilities in early farming communities may have been implemented differently at the individual, household, subgroup, and group level, depending on the group social structure and on the TEK held by those implementing them (Balbo et al. 2014). Irrigators from different hydraulic systems may share basic knowledge regarding irrigation, but their water allocation regimes and adaptive solutions to uncertainty will be specifically adapted to local social-ecological conditions. Likewise, as seen in the case of farming populations in Doñana, a specific aspect of TEK, i.e., that concerning belief-based behavior, tends to be shared among larger portions of a given community or larger communities altogether (Gómez-Baggethun et al. 2012).

The constitution, implementation, and maintenance of TEK-based actions are largely based on group cohesion. Anthropological and historical studies have widely documented the existence of group-size thresholds, within a given decision-making process and the involved community, beyond which collaboration, agreement, and flow of information are seriously impaired (overview in Alberti 2014). This matter had previously been described as the "scalar stress" issue (Johnson 1982), in which the increase in population is correlated with an increase in in-group disputes. Rising communication flows caused by booming populations tend to reach a threshold beyond which the workload required to process the information exceeds the intellectual capacity of the group members or the amount of resources they want to spend in coordination, leading to disappointment, stress, and conflict (Meier 1972). Different thresholds ranging from 6 to 200 individuals have been proposed for the onset of unmanageable disputes leading to group division, development of hierarchical structures, and/or collapse (Johnson 1982, review in Alberti 2014). Although critical thresholds may vary depending on pre-existing social and ecological factors, an early example being that of storage among Neolithic agriculturalists, the very existence of a negative correlation between cooperation, agreements, and group size suggests that (1) the emergence and maintenance of swift collective and coordinated action may have been easier in relatively small populations, contributing, e.g., to the long-term viable management of such commons as water, pasture, or foodstuff (Ostrom 1990); and (2) the existence of a strong internal cohesion in small-scale societies has contributed to improving their capacity to adapt and rearrange their strategies in the face of climatic disturbances, providing they were able to maintain a high-degree of self-organization (Adger 2003, Pelling and High 2005).

Together with internal cohesion, autonomy and self-organization are critical attributes endowing small-scale societies with the capacity to develop dynamic coping mechanisms in a timely way. Self-organization is observed across small-scale societies of different types and sizes. Highly mobile pastoral and foraging groups are topic examples of self-organized communities, living across established administrative and political borders (Agrawal 2003). Autonomous communities have implemented irrigated agricultural systems of Andalusi origin mostly as self-organized systems. Although these social-ecological systems are now embedded in broader political and economical frameworks, such as the hydrographical confederations defining the management and distribution of water proceeding from major Iberian river systems, local communities retain a relatively large degree of autonomy for regulating water allocation among local users (Ostrom 1990). The capacity for self-organization may therefore enable small-scale societies to persist in spite of external political changes or economical shifts and to respond faster than larger-scale governance bodies to local climatic challenges because of their accurate social-ecological knowledge and greater operational proximity.

Two questions remain. First, how can semiautarchic systems, characterized by strong internal cohesion and self-organization, be integrated in the contemporary context of global interconnectedness? Second, to what the degree can their traditional knowledge and coping practices be applied today? Accelerated global change may rapidly push slowly built coping competence in different directions, thus affecting the capacity of small-scale societies, in drylands as elsewhere, to respond to climate-related stress. Some features identified as historically nurturing community resilience to cope with environmental change, such as social-ecological coupling and living bodies of TEK, are likely to be eroded as small-scale societies become increasingly integrated in the market economy (Gómez-Baggethun et al. 2010, Reyes-Garcia et al. 2013). The recent acceleration in urbanization and technification is also likely to foster social-ecological decoupling, promoted by the fast deterioration of generalized ecological knowledge and the physical and cognitive detachment of humans from the environment. On the other hand, contemporary hyperconnectivity, with increased and generalized access to long-range transportation and communication, promotes migratory activity and the intensification of exchanges. With migration routes and communication networks, goods, information, and knowledge travel faster over larger areas (see Sow et al. 2015, for the case of Morocco). These new dynamics, coupled with sensible regulations, have the potential to increase the flexibility, diversity, and creativity of communities in addressing environmental stress, fostering the development of innovative coping practices (Scheffran et al. 2012*b*) and the integration of TEK with new technologies for resilience and sustainability solutions (Berkes et al. 2000, Kristofferson and Berkes 2005, Berkes and Turner 2006, Armitage et al. 2009).

CONCLUSIONS

Small-scale societies in drylands are characterized by their exceptional exposure to climate-related hazards. For that reason, the long-term study of foraging, pastoral, and farming social-ecological systems in drylands provides a vantage viewpoint into the challenges and opportunities for resilience under current global climatic trends.

A long-term perspective on climatic adaptive capacity among small-scale societies in drylands highlights key adaptive traits that have been relevant for the maintenance of environmental awareness and institutional flexibility, with potential for fostering resilience strategies in regions exposed to climate-related hazards: maintenance of strong social-ecological coupling, living bodies of TEK, preservation of internal cohesion, and conservation of a high-degree of self-organization.

However, coping mechanisms to build resilience that have been implemented and successfully used over the long term are now facing new challenges as small-scale societies become globally integrated. As social complexity increases, supported by technological and institutional innovation, biophysical constraints on small-scale societies are released, leading to a gradual decoupling of social-ecological systems (Mumford 1934, Hill et al. 2015). The progressive assimilation of small-scale societies within the global work market poses significant challenges for the integration of TEK systems in the spheres of formal education and new technologies (Kramer 2005). Culturally and geographically consistent in traditional small-scale societies, identity and group cohesion are increasingly layered and distributed concepts in present hyperconnected societies. Finally, adaptive flexibility arising from self-organization in small-scale societies may be hampered when they become embedded within broader institutions and organizations that oversee or fail to involve local and informal organizations and institutions (Holling and Meffe 1996, Gómez-Baggethun et al. 2013*a*).

Responses to this article can be read online at:
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