BUILDING DRYLAND RESILIENCE: THREE PRINCIPLES TO SUPPORT ADAPTIVE WATER GOVERNANCE

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ABSTRACT

Increasing dryland degradation and expansion shows that attempts to strengthen dryland resilience in the face of land degradation and climate change have not been successful. If current development pathways do not change, future prospects for the drylands are worrisome: potential large-scale migration, increasing water scarcity and land degradation, growing poverty, along with significant losses of key ecosystem services that support dryland social-ecological functioning. Based on our empirical research and the wider literature, we identify an important barrier to achieving resilience: poor integration of institutional and other human factors in shaping adaptive capacity, into ecosystem management. By exposing the need for a better understanding of the institutional setting, system stressors, and the human potential to face uncertainty, this paper integrates resilience and vulnerability approaches with adaptive governance, elucidating three principles that must be considered

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when moving towards more adaptive water governance. Use of these principles could represent a way forward to mitigate dryland degradation and the problems related to conflicts, marginalisation, and migration, increasing dryland resilience through water governance. The next steps should be the implementation of these principles in drylands or any ecosystem with undesirable states of water governance, to better integrate societal factors in efforts to strengthen dryland resilience.

Keywords Social-ecological resilience · Vulnerability · Dryland expansion · Societal stressors · Institutions

1. Introduction

Drylands are water-scarce regions that cover around 46.2% (±0.8%) of the Earth's surface (Mirzabaev et al., 2019). Approximately 72% of drylands are located in developing countries, and based on the aridity index, they are classified into hyper-arid (6.9%) arid (12.4%) semi-arid (17.5%) and dry sub-humid (10%) (FAO, 2016; Safriel et al., 2005). Hyper-arid and arid areas are mostly composed of desert, while semi-arid areas are mainly composed of grasslands and dry sub-humid areas by forest (FAO, 2016). Dryland livelihoods mainly depends on agriculture; therefore, dryland populations decrease with increasing aridity (since more arid means less rain and more heatwaves and so more marginal conditions for people to live in) moving from 71 persons per km^2 in dry sub-humid areas to 10 persons per km^2 in hyper-arid areas (Safriel et al., 2005). Nevertheless, estimates indicate that dryland populations have reached 3 billion, and it is projected that this number will increase to 4 billion by 2050 (Mirzabaev et al., 2019). Dryland inhabitants are the poorest, least healthy, hungriest, and most marginalized people in the world, living in highly conflict-prone areas (Middleton et al., 2011), where water limitations make it difficult to secure water ecosystem services (WES) and human welfare (Prăvălie, 2016). Water regulation is the overarching dryland ecosystem service which has a cascading effect on all dryland livelihoods (Safriel et al., 2005). Accordingly, water governance plays a major role in dryland development pathways. However, traditional water governance has failed to address uncertainty and changing social-ecological system (SES) conditions, leading to a decline of WES, limiting dryland development and endangering its livelihoods (Davies et al., 2016; DeCaro et al., 2017b; Smidt et al., 2016).

Dryland resilience consists of the ability to cope with a diverse range of stressors and shocks, and to adapt or transform in the face of uncertainty; in order to achieve development, human well-being, and secure the WES on which livelihoods directly rely (Barrett and Constas, 2014; Mortimore et al., 2009; Reed and Stringer, 2015). Dryland resilience can be strengthened by increasing human capacity to cope with stressors (of a social and/or climate nature) and to adapt or transform in the face of uncertainty, so that people can continue to exist in the system (Engle, 2011; Folke, 2016). Accordingly, adaptive water governance (AWG) has been proposed as a governance regime to increase adaptive capacity by operating through the elements of connectivity, learning, flexibility, collaboration, iteration and subsidiarity, adjusting access to WES according to SES conditions (Hill Clarvis et al., 2014; Lopez Porras et al., 2019). AWG has the potential to enhance WES conservation and allow ecological functioning to recover (Akamani, 2016), which is important for reducing dryland degradation and better supporting natural resource-based livelihoods (Mortimore et al., 2009).

Nonetheless, there still a lack of critical institutionalism that unravels the societal structures, power relations, and social norms shaping adaptation. A better appreciation of the meaning and values underlying social arrangements is needed for enabling AWG (Cleaver and Whaley, 2018).

To address dryland development challenges, SES assessments need to “unpack relationships and interactions in social-ecological systems, livelihood portfolios and value chains” (p. 1956), by setting boundaries and identifying relevant stakeholders (Stringer et al., 2017). Considering the above, more information is needed regarding the social influences on dryland resilience, in order to improve understanding of the attributes and properties that increase dryland adaptive capacity. This paper emphasises the societal aspects of SES and their potential to address the challenging context of drylands by increasing their adaptive capacity through AWG, by presenting three principles for moving towards AWG. In doing so, we focus our considerations on the main dryland challenges when strengthening resilience: the institutional setting, and the societal and climate stressors to which drylands may be exposed.

2. Dryland challenges

The current increase in hydro-climatic intensity, characterised by less precipitation and more dry spells, is overall, leading to dryland expansion in many parts of the world (Huang et al., 2015). This climatic aridity, mixed with intensive land degradation and water overexploitation, can lead to desertification, exacerbating social crises associated with poverty, famine, conflicts, marginalisation, migration, and political instability (Huang et al., 2017; Prăvălie, 2016). Estimates suggest that 143 million people would be forced to migrate by 2050 if the current problems of desertification and climate change are not addressed, and the consequences of this are unpredictable (Mirzabaev et al., 2019). One important strategy to mitigate and even reduce dryland expansion is to increase SES resilience. Resilience literature provides various concepts that can be used to facilitate our understanding of dryland resilience. For instance, 'Panarchy' (Cosens et al., 2018) can be used to illustrate how the interaction of slow (e.g. soil fertility) and more fluctuating (e.g. precipitation) variables can undermine dryland resilience and lead to a regime shift. However, the relationship between resilience and vulnerability is complex. As an illustration, it is common practice for dryland farmers to try and strengthen specified resilience of crop production to droughts, by increasing groundwater use for irrigation (Garrick, 2018; Lopez Porras et al., 2019). However, maintaining agricultural coping strategies for certain persistent social or economic conditions, can increase vulnerability to climate change and reinforce poverty, by hindering innovation and social learning (Miller et al., 2010; Osbahr et al., 2008). Moreover, when strategies are adopted at a farm or rural household level they can negatively impact general resilience at a wider scale, which may generate other conflicts at local, regional, national or even international scale (Garrick, 2018). As such, adaptive strategies must be complemented with a vulnerability approach, that properly identifies who is vulnerable to what, when and why, so we can properly capture and address SES threats and stressors (Downing et al., 2006).

Drylands are particularly sensitive to environmental change, and even small changes, like irregular precipitation, can have large impacts at SES scale (Huang et al., 2017). Keeping SES away from the thresholds that will change their structure (e.g. from a grass-dominated to a shrub-dominated regime) is more challenging in a dryland context, but is key to avoid dryland degradation and sustain natural resource-based livelihoods. Furthermore, drylands are also prone to the occurrence of violent conflicts (IPBES, 2018) and exposed to other stressors with a social origin that undermine human well-being and adaptive capacity (Lopez Porras et al., 2018). Learning, iteration, and collaboration are important principles of AWG for increasing adaptive capacity and mitigating SES sensitivity (Hill Clarvis et al., 2014). Nonetheless moving towards AWG requires a deep understanding of the societal and ecological stressors, as they define SES exposure and the threats that must be addressed (Lopez Porras et al., 2019). Accordingly, the lack of recognition of the societal stressors undermines the coping or adaptive strategies needed to face them, increasing SES vulnerability (Miller et al., 2010). While this paper uses examples from drylands, the necessity for enhancing WES conservation and allowing ecological functioning to recover, for which AWG has been proposed, is not exclusive to dryland systems. Enabling AWG in other SES is also paramount if they are valuable, and yet, damaged and degraded natural systems, vulnerable to multiple stressors (Capon et al., 2015; Zhang et al., 2018). AWG fits for any SES where water governance has failed to effectively manage WES, given exposure and sensitivity to societal and environmental stressors.

3. Adapting to societal and environmental stressors

Dryland stressors are not exclusively climatic or environmental (IPCC, 2014). The social dimensions of SES have only been discussed in terms of livelihoods or economic vulnerability, with focus often being placed on poverty (Downing et al., 2006). Accordingly, exposure to harm has not been captured in terms of security, good social relations, peace of mind and spiritual experience, – all of which are basic elements of human well-being (Díaz et al., 2015). Research has shown that adapting legal frameworks to focus only on economic development generates societal stressors that increase vulnerability to the loss of ethnicity, culture, and lifestyle, and may lead to violent conflicts and rebellions (Alfie Cohen, 2015; Pichler and Brad, 2016; Stoltenborg and Boelens, 2016).

Among societal stressors, we find corruption, illegal practices, unequal distributions of costs and benefits, and systematic human rights violations. These can be as dangerous as natural hazards, since they may lead to social clashes, as well as crop and dam destruction (Lopez Porras et al., 2018; Pichler and Brad, 2016). They fragment and limit water governance (Chaffin et al., 2016; Lopez Porras et al., 2019) increasing water crises in drylands since water-related problems are connected to or influenced by governance failures (Loë and Patterson, 2017; Pahl-Wostl, 2017). The greater the integration of these elements when conducting a SES assessment, the greater the potential understanding of the relationship between resilience and vulnerability, and how climate and/or societal stressors can exacerbate each other (IPCC, 2014).

4. Principles for moving towards adaptive water governance

Enabling AWG requires an adjustment of the institutional setting, according to, and by understanding, stakeholder perceptions, SES attributes, and the properties that maintain the system's functioning (De Vente et al., 2016; Huitema et al., 2009; Pahl-Wostl and Knieper, 2014; Schlüter et al., 2017). Given the need for better integration of society's role in increasing dryland adaptation to climate change and uncertainty, along with its influence over resilience, we developed three principles (Table 1) that aim to increase the practical value of resilience theory and AWG literature in drylands.

Table 1 Principles for moving towards adaptive water governance.

Principle 1	Water governance must consider informal institutions when aiming to support adaptation
Principle 2	Compliance with and enforcement of rules are the means through which a system's functioning can continue
Principle 3	Context shapes the guidelines for a transition towards adaptation

4.1 Water governance must consider informal institutions when aiming to support adaptation

It is currently understood that informal authorities and institutions play a major role in water governance, for which increasing public-private coordination and participation has been sought for the benefit of all stakeholders (Rogers et al., 2003). Informal institutions refer to norms of behaviour that are ruled by culture, such as traditions, religious beliefs, perceptions, and moral values (Pejovich, 1999). Accordingly, informal institutions guide decision-making processes (Kaufmann et al., 2018; North, 1990). They affect the way societies interact with their environment (e.g. in obtaining benefits from nature), and the experience resulting from this shapes their perspectives on the relationship between nature and good quality of life (Díaz et al., 2015).

WES are valuable in terms of how they are perceived, which in turn, shapes how they are accessed. But when stakeholders with opposing perceptions share common pool resources like water, and formal institutions do not foresee this situation, water access can give rise to overexploitation and social conflicts (Lopez Porras et al., 2018). Putting this in a dryland context, where extreme drought is associated with an increase of 45 percent in violent conflicts (IPBES, 2018), the challenge is not only how to deal with water shortages, but also the rivalries and behaviours underlying this conflictive context. WES management objectives set by formal institutions will not succeed if they do not consider the complexities around informal institutions (Pahl-Wostl and Knieper, 2014).

Another example of an informal institution is corruption (Kaufmann et al., 2018), consisting of the abuse or misuse of power (Søreide and Truex, 2013). Corruption undermines SES resilience and can worsen institutional deficiencies caused by conflicting perspectives by boosting system exposure to other stressors (Leitao, 2016). Even though addressing corruption is complex as it is shaped by economic, historical, social, political, and cultural factors (Iza and Stein, 2009; Leitao, 2016), it must be reduced at least to a point where it does not increase SES vulnerability (e.g. via water depletion or social clashes). For instance, enabling local water management embedded with transparency, legitimacy, and accountability can mitigate corruption (Iza and Stein, 2009; Søreide and Truex, 2013).

Huitema et al., (2009) say that informal institutions comprise “the power relations and practices that have developed and the rules that are followed in practice” (p. 2), influenced by social, environmental and political factors that increase institutional complexity when aiming for adaptation (Cortez Lara, 2010; Huitema et al., 2009). Public participation and actions of local stakeholders are fundamental for driving institutional change and dealing with societal complexities, even in large-scale SES (Cortez Lara, 2010). Although this raises a concern about the assignment of governance responsibilities, the AWG principle of subsidiarity emerges as a suitable solution by allowing institutional design and implementation at the lowest or most suitable scale for addressing local needs (Garrick, 2018; Hill Clarvis et al., 2014).

Water governance systems whose formal institutions are centralised and alien to SES dynamics or local context, are weakly enforced and have a poor and undermined rule of law, which facilitates corruption (Leitao, 2016; Rogers et al., 2003). Conversely, multi-scale governance systems with sufficient independence and autonomy to create their own rules embedded with local knowledge and customs, have better monitoring, collaboration and rule compliance (Ostrom, 2010). Strong and suitable institutions mean strong rule of law supported by civil society, with clear rules of conduct; where values and norms of behaviour play a major role in the compliance with and enforcement of rules (Leitao, 2016; Pejovich, 1999; Rogers et al., 2003).

4.2 Compliance with and enforcement of rules are the means through which a system's functioning can continue

Rules facilitate SES goals: they give structure and order, avoiding the chaos that could emerge from crossing system thresholds (Peterson, 2018); rules must shape human behaviour so SES functioning can continue. If rules consider informal institutions, they should aim for mutual betterment, and therefore, stakeholders should be willing to meet their obligations; nonetheless, when someone fails to comply, enforcement is necessary to provide security for other stakeholders (Iza and Stein, 2009). Rules, to be effective, not only must adequately punish corruption, overexploitation, or breach of law, but also need to contemplate incentives for WES conservation, for instance, by establishing a compensation system for compliance with water conservation standards. This is based on the assumption that to influence human behaviour, rules must 1) foresee positive (rewards) and negative (penalties) consequences (Doménech Pascual, 2015), 2) be developed in relation to people's needs, and 3) be designed in context with the SES reality (DeCaro et al., 2017a).

Rules need to match the appropriate scale, fostering local creativity and innovation because problems are scale-dependent, and rules can be better enforced if they are designed using local knowledge, which also increases their legitimacy and acceptance (Cosens et al., 2017; Garmestani and Benson, 2013). High costs and complexities in law enforcement make for a failed rule of law (Rogers et al., 2003), negatively impacting the SES. Rules should be limited to those strictly necessary, as this will require fewer resources for law enforcement, besides, bad and unnecessary rules diminish respect for good rules (Peterson, 2018).

As *water governance must consider informal institutions when aiming to support adaptation* (principle 1), rules must be developed with similar levels of awareness about SES conditions. Inequalities in awareness (e.g. the benefits of WES conservation) lead to breaches of law as there are few disincentives to reduce overexploitation (Lopez Porras et al., 2019). Unequal awareness brings a lack of understanding of why the regulations are established, and of uncertainty about the achievement of the objectives (e.g. increasing adaptive capacity or WES conservation). It is common for societies threatened by uncertainty to feel conflict over rule adherence, ("strict rules and laws are a good thing if others, not myself, follow them"(p.399)) when they are not conscious of the consequences of not fulfilling their obligations (Kaufmann et al. 2018). Uncertainty and unequal awareness of the negative outcomes of our actions, lead to decreased pro-social behaviour and promote selfishness (Kappes et al., 2018).

If, for instance, dryland farmers are uncertain about whether their agricultural practices are causing water depletion or not, they are more likely to keep overexploiting water resources.

However, perceptions of social norms establish that if comparable levels of awareness and values are developed and uncertainty is reduced, negative outcomes can be identified, agreed, and so avoided (Kappes et al., 2018). In the case of dryland farmers, more certainty about the negative effects of agriculture on WES conservation will clarify the rules' functional aims, and so, the importance of respecting them. Suitable rules require common goals so as to establish priorities and thus a hierarchy of values. This then has the potential to reconcile opposing perceptions, create a shared value system, and create a cultural alignment that stabilises interactions between stakeholders, enhancing their collaboration (Peterson, 2018).

4.3 Context shapes the guidelines for a transition towards adaptation

The transition towards adaptation refers to the trajectory of a governance regime designed to increase adaptive capacity. Increasing adaptation through governance regimes requires a deep understanding of the social influence over SES, in order to adjust rules according to system identity and create sustainable resource management (Kerner et al., 2014). Ways to enable AWG vary according to each context (De Vente et al., 2016). In a dryland context, this means managing resource scarcities and addressing the weaknesses that undermine adaptive capacity (Balbo et al., 2016). For instance, in Mexico (where approximately 60% of the country is dryland (Mirzabaev et al., 2019)) water overexploitation and conflicts over access are increasing (Athie, 2016; Lopez Porras et al., 2019). Accordingly, adaptive strategies need to also consider the conflictive context that can undermine adaptive capacity. Even though adaptation has a nuanced association with climate change (Folke, 2016; Garrick, 2018), it should not be limited to the capacity to respond (by adjusting or transforming) to climate, but also to societal impacts on the SES. Movement towards AWG can only be achieved under that premise.

This takes on greater relevance given the increasingly conflictive context in drylands, where increasing poverty, lack of food, migration, land degradation, water scarcity and its "weaponization"[2] generate an enormous social toll and negatively impact SES; and effects transcend national borders (IPBES, 2018; Werrell and Femia, 2017). Equal consideration of dryland exposure to climate and societal stressors appreciates that adaptation is not a blueprint, while failed adaptation means failed understanding of SES stressors.

Context shapes the guidelines for a transition towards adaptation, means that besides the options for adapting to climate change, for instance, those that were presented by the IPCC (2014), the inherent complexity of SES requires consideration of non-environmental factors that influence vulnerability, and to which it also has to be adaptive. As found in Australia (where approximately 8% of global drylands are located (Mirzabaev et al., 2019)) increasing water scarcity, bureaucratic obstacles, and inability to overcome conflicting interests have undermined water governance and transitions to AWG in the Murray Darling Basin (Alexandra, 2018). Knowing what to do and how to do it when aiming to increase adaptation, requires unpacking the co-adapting SES processes, components, and dynamics that are shaping its development pathway, looking across multiple sectors and scales (Rammel et al., 2007; Stringer et al., 2017).

Successful transitions and transformations are based on accurate interpretations of the roles of societal factors in shaping SES resilience, including all the voices and values that will allow and reinforce AWG (Chaffin et al., 2014). To define suitable AWG for a system context that

[2] When in water-scarce contexts, water access is used to exercise and impose power (King, 2015).

will potentially increase SES resilience, we need to understand the system dynamics, resilience attributes, and vulnerabilities (Downing et al., 2005; Engle, 2011). That is, unravelling context-specific components shaping SES pathways facilitates a transition to AWG (Engle, 2011), by identifying how governance regimes should match local geographic and social conditions (e.g., location, physical assets, and procedures) for increasing adaptation (Garrick, 2018).

5. Conclusion

Strengthening dryland resilience is paramount given its water-scarce context and the challenging conditions in which its inhabitants live. However, traditional water governance has failed to achieve resilience, and worse still, has led to a decline in WES, increasing conflicts over water access, and driving migration to find better opportunities for human development. AWG has the potential to increase dryland adaptation by adjusting water access according to SES context, allowing the conservation of WES on which many dryland livelihoods rely.

Enabling AWG for increasing adaptation requires a better recognition of the exposure and sensitivity to societal as well as climate stressors, the formal and informal institutions that hinder or boost adaptation, and the ecological and social context (e.g., dryland and conflictive). The principles for moving towards adaptive water governance aim to integrate those complexities, so dryland expansion and degradation can be better addressed, by increasing adaptation and strengthening resilience. The next steps should be the implementation of these principles in drylands, and in other SES with undesirable states of water governance.

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References

Akamani, K., 2016. Adaptive Water Governance: Integrating the Human Dimensions into Water Resource Governance. J. Contemp. Water Res. Educ. 158, 2–18. https://doi.org/10.1111/j.1936-704X.2016.03215.x

Alexandra, J., 2018. Evolving Governance and Contested Water Reforms in Australia's Murray Darling Basin. Water 10, 113. https://doi.org/10.3390/w10020113

Alfie Cohen, M., 2015. Conflictos socio-ambientales: la minería en Wirikuta y Cananea. El Cotid. 97–108.

Athie, K., 2016. El Agua, ayer y hoy. Camara de Diputados LXIII Legislatura, Mexico City.

Balbo, A.L., Gómez-Baggethun, E., Salpeteur, M., Puy, A., Biagetti, S., Scheffran, J., 2016. Resilience of small-scale societies: a view from drylands. Ecol. Soc. 21, art53. https://doi.org/10.5751/ES-08327-210253

Barrett, C.B., Constas, M.A., 2014. Toward a theory of resilience for international development applications. Proc. Natl. Acad. Sci. U. S. A. 111, 14625–30. https://doi.org/10.1073/pnas.1320880111

Capon, S.J., Lynch, A.J.J., Bond, N., Chessman, B.C., Davis, J., Davidson, N., Finlayson, M., Gell, P.A., Hohnberg, D., Humphrey, C., Kingsford, R.T., Nielsen, D., Thomson, J.R., Ward, K., Nally, R. Mac, 2015. Regime shifts, thresholds and multiple stable states in freshwater ecosystems; a critical appraisal of the evidence. Sci. Total Environ. 534, 122–130. https://doi.org/10.1016/J.SCITOTENV.2015.02.045

Chaffin, B.C., Garmestani, A.S., Gosnell, H., Craig, R.K., 2016. Institutional networks and adaptive water governance in the Klamath River Basin, USA. Environ. Sci. Policy 57, 112–121. https://doi.org/10.1016/j.envsci.2015.11.008

Chaffin, B.C., Gosnell, H., Cosens, B.A., 2014. A decade of adaptive governance scholarship: Synthesis and future directions. Ecol. Soc. 19, 56. https://doi.org/10.5751/ES-06824-190356

Cleaver, F., Whaley, L., 2018. Understanding process, power, and meaning in adaptive governance: A critical institutional reading. Ecol. Soc. 23, 49. https://doi.org/10.5751/ES-10212-230249

Cortez Lara, A., 2010. Reflexiones teórico-metodológicas sobre la cultura de sustentabilidad en el manejo de aguas transfronterizas del bajo río Colorado. Culturales 6, 34.

Cosens, B.A., Craig, R.K., Hirsch, S.L., Arnold, C.A. (Tony), Benson, M.H., DeCaro, D.A., Garmestani, A.S., Gosnell, H., Ruhl, J.B., Schlager, E., 2017. The role of law in adaptive governance. Ecol. Soc. 22, 30. https://doi.org/10.5751/ES-08731-220130

Cosens, B.A., Gunderson, L., Chaffin, B.C., 2018. Introduction to the Special Feature Practicing Panarchy: Assessing legal flexibility, ecological resilience, and adaptive governance in regional water systems experiencing rapid environmental change. Ecol. Soc. 23, 4. https://doi.org/10.5751/ES-09524-230104

Davies, J., Barchiesi, S., Ogali, C.J., Welling, R., Dalton, J., Laban, P., 2016. Water in drylands: Adapting to scarcity through integrated management. IUCN, Gland, Switzerland. https://doi.org/http://dx.doi.org/10.2305/IUCN.CH.2016.06.en

De Vente, J., Reed, M.S., Stringer, L., Valente, S., Newig, J., 2016. How does the context and design of participatory decision making processes affect their outcomes? Evidence from sustainable land management in global drylands. Ecol. Soc. 21, 24. https://doi.org/10.5751/ES-08053-210224

DeCaro, D.A., Arnold, C.A. (Tony), Frimpong Boamah, E., Garmestani, A.S., 2017a. Understanding and applying principles of social cognition and decision making in adaptive environmental governance. Ecol. Soc. 22, 33. https://doi.org/10.5751/ES-09154-220133

DeCaro, D.A., Chaffin, B.C., Schlager, E., Garmestani, A.S., Ruhl, J.B., 2017b. Legal and institutional foundations of adaptive environmental governance. Ecol. Soc. 22, 32. https://doi.org/10.5751/ES-09036-220132

Díaz, S., Demissew, S., Carabias, J., Joly, C., Lonsdale, M., Ash, N., Larigauderie, A., Adhikari, J.R., Arico, S., Báldi, A., Bartuska, A., Baste, I.A., Bilgin, A., Chan, K.M., Figueroa, V.E., Duraiappah, A., Fischer, M., Hill, R., Koetz, T., Leadley, P., Lyver, P., Mace, G.M., Martin-Lopez, B., Okumura, M., Pacheco, D., Pascual, U., Pérez, E.S., Reyers, B., Roth, E., Saito, O., Scholes, R.J., Sharma, N., Tallis, H., Thaman, R., Watson, R., Yahara, T., Hamid, Z.A., Akosim, C., Al-Hafedh, Y., Allahverdiyev, R., Amankwah, E., Asah, S.T., Asfaw, Z., Bartus, G., Brooks, L.A., Caillaux, J., Dalle, G., Darnaedi, D., Driver, A., Erpul, G., Escobar-Eyzaguirre, P., Failler, P., Fouda, A.M.M., Fu, B., Gundimeda, H., Hashimoto, S., Homer, F., Lavorel, S., Lichtenstein, G., Mala, W.A., Mandivenyi, W., Matczak, P., Mbizvo, C., Mehrdadi, M., Metzger, J.P., Mikissa, J.B., Moller, H., Mooney, H.A., Mumby, P., Nagendra, H., Nesshover, C., Oteng-Yeboah, A.A., Pataki, G., Roué, M., Rubis, J., Schultz, M., Smith, P., Sumaila, R., Takeuchi, K., Thomas, S., Verma, M., Yeo-Chang, Y., Zlatanova, D., 2015. The IPBES Conceptual Framework — connecting nature and people. Curr. Opin. Environ. Sustain. 14, 1–16. https://doi.org/10.1016/j.cosust.2014.11.002

Doménech Pascual, G., 2015. Por qué y cómo hacer análisis económico del Derecho. Rev. Adm. Pública 0, 99–133.

Downing, T.E., Aerts, J., Soussan, J., Barthelemy, O., Bharwani, S., Hinkel, J., Ionescu, C., Klein, R.J.T., Mata, L., Matin, N., Moss, S., Purkey, D., Ziervogel, G., 2006. Integrating social vulnerability into water management. NeWater Working Paper No. 5.

Downing, T.E., Patwardhan, A., Authors, C., Klein, R.J.T., Mukhala, E., Stephen, L., Winograd, M., Ziervogel, G., 2005. Assessing Vulnerability for Climate Adaptation.

Engle, N.L., 2011. Adaptive capacity and its assessment. Glob. Environ. Chang. 21, 647–656. https://doi.org/10.1016/J.GLOENVCHA.2011.01.019

FAO, 2016. Trees, forests and land use in drylands: The first global assessment Preliminary Findings. Rome, Italy.

Folke, C., 2016. Resilience (Republished). Ecol. Soc. 21, 44. https://doi.org/10.5751/ES-09088-210444

Garmestani, A., Benson, M., 2013. A Framework for Resilience-based Governance of Social-Ecological Systems. Ecol. Soc. 18, 9. https://doi.org/10.5751/ES-05180-180109

Garrick, D., 2018. Decentralisation and drought adaptation: Applying the subsidiarity principle in transboundary river basins. Int. J. Commons 12, 301. https://doi.org/10.18352/ijc.816

Hill Clarvis, M., Allan, A., Hannah, D.M., 2014. Water, resilience and the law: From general concepts and governance design principles to actionable mechanisms. Environ. Sci. Policy 43, 98–110. https://doi.org/10.1016/j.envsci.2013.10.005

Huang, J., Li, Y., Fu, C., Chen, F., Fu, Q., Dai, A., Shinoda, M., Ma, Z., Guo, W., Li, Z., Zhang, L., Liu, Y., Yu, H., He, Y., Xie, Y., Guan, X., Ji, M., Lin, L., Wang, S., Yan, H., Wang, G., 2017. Dryland climate change: Recent progress and challenges. Rev. Geophys. 55, 719–778. https://doi.org/10.1002/2016RG000550

Huang, J., Yu, H., Guan, X., Wang, G., Guo, R., 2015. Accelerated dryland expansion under climate change. Nat. Clim. Chang. 6, 1–22. https://doi.org/10.1038/nclimate2837

Huitema, D., Mostert, E., Pahl-wostl, C., 2009. Adaptive Water Governance : Assessing the Institutional Prescriptions of Adaptive (Co-) Management from a Governance Perspective and Defining a Research Agenda 14, 26. https://doi.org/10.1111/j.1541-1338.2009.00421_2.x

IPBES, 2018. Summary for policymakers of the assessment report on land degradation and restoration of the Intergovernmental SciencePolicy Platform on Biodiversity and Ecosystem Services. R. Scholes, L. Montanarella, A. Brainich, N. Barger, B. ten Brink, M. Cantele, B. IPBES secretariat, Bonn, Germany.

IPCC, 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)], Kristin Seyboth (USA). IPCC, Geneva, Switzerland.

Iza, A., Stein, R., 2009. Rule - Reforming water governance. International Union for Conservation of Nature and Natural Resources, Gland, Switzerland.

Kappes, A., Nussberger, A.-M., Faber, N.S., Kahane, G., Savulescu, J., Crockett, M.J., 2018. Uncertainty about the impact of social decisions increases prosocial behaviour. Nat. Hum. Behav. 2, 573–580. https://doi.org/10.1038/s41562-018-0372-x

Kaufmann, W., Hooghiemstra, R., Feeney, M.K., 2018. Formal institutions, informal institutions, and red tape: A comparative study. Public Adm. 96, 386–403. https://doi.org/10.1111/padm.12397

Kerner, D.A., Thomas, J.S., Kerner, D.A., Thomas, J.S., 2014. Resilience Attributes of Social-Ecological Systems: Framing Metrics for Management. Resources 3, 672–702. https://doi.org/10.3390/resources3040672

King, M.D., 2015. The Weaponization of Water in Syria and Iraq. Wash. Q. 38, 153–169. https://doi.org/10.1080/0163660X.2015.1125835

Leitao, A., 2016. Corruption and the Environment. J. Soc. 5, 5. https://doi.org/10.41 72/2167-0358.1000173

Loë, R.C. de, Patterson, J.J., 2017. RETHINKING WATER GOVERNANCE: MOVING BEYOND WATER-CENTRIC PERSPECTIVES IN A CONNECTED AND CHANGING WORLD. Nat. Resour. J. https://doi.org/10.2307/26202188

Lopez Porras, G., Stringer, L.C., Quinn, C.H., 2019. Corruption and conflicts as barriers to adaptive governance: Water governance in dryland systems in the Rio del Carmen watershed. Sci. Total Environ. 660, 519–530.

https://doi.org/10.1016/J.SCITOTENV.2019.01.030

Lopez Porras, G., Stringer, L.C., Quinn, C.H., 2018. Unravelling Stakeholder Perceptions to Enable Adaptive Water Governance in Dryland Systems. Water Resour. Manag. 32, 1–17. https://doi.org/10.1007/s11269-018-1991-8

Middleton, N., Stringer, L., Goudie, A., Thomas, D., 2011. The Forgotten Billion MDG Achievement in the Drylands. New York.

Miller, F., Osbahr, H., Boyd, E., Thomalla, F., Bharwani, S., Ziervogel, G., Walker, B., Leeuw, S. Van Der, Hinkel, J., Downing, T., Folke, C., Nelson, D., 2010. Resilience and Vulnerability: Complementary or Conflicting Concepts? 15, 11.

Mirzabaev, A., Jianguo, W., Evans, J., Garcia-Oliva, F., Hussein, I., Iqbal, M., Kimutai, J., Knowles, T., Meza, F., Nedjraoui, D., Tena, F., Türkeş, M., Vázquez, R., Weltz, M., 2019. Desertification, in: Shukla, J.S.E.C.B.V.M.-D.H.-O.P., D.C. Roberts, P.Z.R.S.S.C.R. van D.M.F.E.H.S.L.S.N.M.P.J.P., J. Portugal Pereira, P.V.E.H.K.K.M.B.J.M. (Eds.), Climate Change and Land: An IPCC Special Report on Climate Change, Desertification, Land Degradation, Sustainable Land Management, Food Security, and Greenhouse Gas Fluxes in Terrestrial Ecosystems. In press.

Mortimore, M., Anderson, S., Cotula, L., Davies, J., Faccer, K., Hesse, C., Mortin, J., Nyangena, W., Skinner, J., Wolfangel, C., 2009. Dryland opportunities: a new paradigm for people, ecosystems and development. IUCN, IUCN, Gland, Switzerland; IIED, London, UK and UNDP/DDC, Nairobi, Kenya.

North, D.C., 1990. Institutions, institutional change, and economic performance. Cambridge University Press, Cambridge.

Osbahr, H., Twyman, C., Neil Adger, W., Thomas, D.S.G., 2008. Effective livelihood adaptation to climate change disturbance: Scale dimensions of practice in Mozambique. Geoforum 39, 1951–1964. https://doi.org/10.1016/J.GEOFORUM.2008.07.010

Ostrom, E., 2010. Polycentric systems for coping with collective action and global environmental change. Glob. Environ. Chang. 20, 550–557. https://doi.org/10.1016/j.gloenvcha.2010.07.004

Pahl-Wostl, C., 2017. An Evolutionary Perspective on Water Governance: From Understanding to Transformation. Water Resour. Manag. 31, 2917–2932. https://doi.org/10.1007/s11269-017-1727-1

Pahl-Wostl, C., Knieper, C., 2014. The capacity of water governance to deal with the climate change adaptation challenge: Using fuzzy set Qualitative Comparative Analysis to distinguish between polycentric, fragmented and centralized regimes. Glob. Environ. Chang. 29, 139–154. https://doi.org/10.1016/J.GLOENVCHA.2014.09.003

Pejovich, S., 1999. The effects of the interaction of formal and informal institutions on social stability and economic development, Journal of Markets and Morality. Published by the Center for Economic Personalism.

Peterson, J.B., 2018. 12 rules for life: An antidote to chaos. Random House Canada, Toronto, Canada.

Pichler, M., Brad, A., 2016. Political ecology and socio-ecological conflicts in Southeast Asia. ASEAS-Österreichische Zeitschrift für Südostasienwissenschaften 9, 1–10. https://doi.org/10.14764/10.ASEAS-2016.1-1

Prăvălie, R., 2016. Drylands extent and environmental issues. A global approach. Earth-Science Rev. 161, 259–278. https://doi.org/10.1016/J.EARSCIREV.2016.08.003

Rammel, C., Stagl, S., Wilfing, H., 2007. Managing complex adaptive systems — A co-evolutionary perspective on natural resource management. Ecol. Econ. 63, 9–21. https://doi.org/10.1016/j.ecolecon.2006.12.014

Reed, M.S., Stringer, L.C., 2015. Climate change and desertification: anticipating, assessing & adapting to future change in drylands. 3rd UNCCD Scientific Conference, Cancun, Mexico.

Rogers, P., Hall, A.W., Van de Meene, S.J., Brown, R.R., Farrelly, M. a., 2003. Effective Water Governance Global Water Partnership Technical Committee (TEC), Global Environmental Change. https://doi.org/10.1016/j.gloenvcha.2011.04.003

Safriel, U., Adeel, Z., Niemeijer, D., Puigdefabregas, J., White, R., Lal, R., Winslow, M., Ziedler, J., Prince, S., Archer, E., King, C., Shapiro, B., Wessels, K., Nielsen, T., Portnov, B., Reshef, I., Thonell, J., Lachman, E., Mcnab, D., 2005. Chapter 22 Dryland Systems. Ecosystems and Human Well-being: Current State and Trends. Volume 1, findings of the Responses Working Group of the Millennium Ecosystem Assessment., Ecosystems and Human Well-being: Current State and Trends. Island Press, Washington, D.C., USA.

Schlüter, M., Baeza, A., Dressler, G., Frank, K., Groeneveld, J., Jager, W., Janssen, M.A., McAllister, R.R.J., Müller, B., Orach, K., Schwarz, N., Wijermans, N., 2017. A framework for mapping and comparing behavioural theories in models of social-ecological systems. Ecol. Econ. 131, 21–35. https://doi.org/10.1016/j.ecolecon.2016.08.008

Smidt, S.J., Haacker, E.M.K., Kendall, A.D., Deines, J.M., Pei, L., Cotterman, K.A., Li, H., Liu, X., Basso, B., Hyndman, D.W., 2016. Complex water management in modern agriculture: Trends in the water-energy-food nexus over the High Plains Aquifer. Sci. Total Environ. 566–567, 988–1001. https://doi.org/10.1016/J.SCITOTENV.2016.05.127

Søreide, T., Truex, R., 2013. Multi-stakeholder Groups for Better Sector Performance: A Key to Fighting Corruption in Natural-Resource Governance? Dev. Policy Rev. 31, 203–217. https://doi.org/10.1111/dpr.12003

Stoltenborg, D., Boelens, R., 2016. Disputes over land and water rights in gold mining : the case of Cerro de San Pedro , Mexico. Water Int. 41, 447–467. https://doi.org/10.1080/02508060.2016.1143202

Stringer, L.C., Reed, M.S., Fleskens, L., Thomas, R.J., Le, Q.B., Lala-Pritchard, T., 2017. A New Dryland Development Paradigm Grounded in Empirical Analysis of Dryland Systems Science. L. Degrad. Dev. 28, 1952–1961. https://doi.org/10.1002/ldr.2716

Werrell, C., Femia, F., 2017. EPICENTERS OF CLIMATE AND SECURITY: THE NEW GEOSTRATEGIC LANDSCAPE OF THE ANTHROPOCENE.

Zhang, K., Yang, X., Kattel, G., Lin, Q., Shen, J., 2018. Freshwater lake ecosystem shift caused by social-economic transitions in Yangtze River Basin over the past century. Sci. Rep. 8, 17146. https://doi.org/10.1038/s41598-018-35482-5