Chapter 1
Introduction: International Network for the Sustainability of Drylands—Transdisciplinary and Participatory Research for Dryland Stewardship and Sustainable Development

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Abstract Drylands are the largest biome complex on Planet Earth and home to over 40% of the human population. Their extraordinary high biotic and cultural richness is endangered by global climate change, land use pressures including coastal/marine systems, and environmental degradation. Understanding and maintaining the functional integrity of dryland socio-ecological systems (DSES) is fundamental for sustainable development. It requires resilience-based dryland stewardship, where land users, managers and decision-makers incorporate change, as understood from the multiple actors' perspective of a SES, into their planning and governance. The linkage of America's drylands with west Africa and Southern Europe is often overseen, however increasing economic activities in these DSES have enormous impacts on their functional integrity. In response to this daunting

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task, academic and government institutions founded the Agadir Platform as a coordinating instrument for cooperation in the Global South. As focal node of this platform, Mexico established the first international network to co-generate knowledge through transdisciplinary research partnerships. We present the conceptual framework of this network highlighting 1) the socio-ecological system's approach, 2) the transdisciplinary scope of participatory research, 3) the intercultural action scheme, and 4) the repercussions of this integrated approach on polycentric governance. This book includes diverse examples of the application of this framework in DSES ranging from co-designing socio-ecological development projects, to adaptive management, and policy development.

Keywords RISZA · Transdisciplinary networks · Co-designed projects · Arid lands · Participative research · South-South and triangular cooperation

Drylands are the largest biome complex on Planet Earth and home to over 40% of the human population. Their extraordinary high biotic and cultural richness is endangered by global climate change, land use pressures including coastal/marine systems, and environmental degradation. Understanding and maintaining the functional integrity of dryland socio-ecological systems (DSES) is fundamental for sustainable development. It requires resilience-based dryland stewardship, where land users, managers and decision-makers incorporate change, as understood from the multiple actors' perspective of a SES, into their planning and governance. The linkage of America's drylands with west Africa and Southern Europe is often overseen, however increasing economic activities in these DSES have enormous impacts on their functional integrity. In response to this daunting task, academic and government institutions founded the Agadir Platform as a coordinating instrument for cooperation in the Global South. As focal node of this platform, Mexico established the first international network to co-generate knowledge through transdisciplinary research partnerships. We present the conceptual framework of this network highlighting 1) the socio-ecological system's approach, 2) the transdisciplinary scope of participatory research, 3) the intercultural action scheme, and 4) the repercussions of this integrated approach on polycentric governance. This book includes diverse examples of the application of this framework in DSES ranging from co-designing socio-ecological development projects, to adaptive management, and policy development.

Aridity is often characterized by an aridity index (AI) (Thomas and Middleton 1992), calculated as annual precipitation divided by annual potential evapotranspiration, and ranges from a minimum of 0.05 to a maximum of 0.65 (Hulme 1996; Safriel et al. 2005). Based on the AI drylands can be classified as hyperarid, arid, semi-arid, and dry sub-humid (UNCCD 1994). In comparison to other biomes, life in the drylands has evolved under highly variable precipitation, extreme water scarcity, pronounced fluctuations in diurnal temperatures, and extended exposure to high levels of solar radiation (Noy-Meir 1973). These factors continuously exert strong selection pressures on specialized life forms (Whitford 2002). However, there is an exceptionally high species diversity across all categories of biota that contributes to varied ecosystems that span from coastal drylands to intracontinental basins and highland plateaus.

Dryland ecosystems offer a wealth of ecosystem goods and services for human well-being (Safriel et al. 2005; Stafford Smith et al. 2009). Large populations of agriculturalists, pastoralists, and coastal fishermen have enormous cultural wealth and ecological knowledge. Over millennia, humans have adapted to the scarcity and abundance cycles of natural resources, shaping their livelihoods accordingly (Stafford Smith and Cribb 2009; Davis 2016a). The long history of fine-tuning socio-economic and political life among drylands peoples reflects some of the oldest legacies of socio-ecological system (SES) development, and today are characterized by both their ecological significance in sustaining the supply of ecosystem services and their capacity to support millions of people (Safriel et al. 2005; Cherlet et al. 2018). Variability is an inherent structural property of drylands (Stafford Smith et al. 2009) to which local communities have adapted and evolved under, thereby lowering their vulnerability to unpredictable environmental changes (Krätli 2015; Davis 2016b). These adaptive social–ecological interdependencies of human activities and ecosystem services require collective knowledge-based actions supporting dryland stewardship (Chapin III et al. 2009a, b, c).

However, over recent decades, drylands have suffered substantial losses of productivity and biodiversity, increasing the severity and frequency of droughts, food insecurity, poverty, violence, emigration, and social disintegration (Reed and Stringer 2016; Cherlet et al. 2018; Middleton 2018). In addition, some areas have been converted to irrigated lands to expand high-input agriculture and to pastures for intensive livestock production (Jia et al. 2004; Squires 2010) triggering irreversible systemic changes. The processes underlying all these changes are often termed desertification (UNCCD 1994; Reynolds et al. 2007) undermining the sustainable regional development and threatening the global dryland SES (UNCCD 1994; Cherlet et al. 2018), which are mainly situated in the Global South. According to the sustainable development goals, the objectives include thriving lives and livelihoods, sustainable food security, sustainable water security, universal clean energy, healthy and productive ecosystems, and governance for sustainable societies (Griggs et al. 2013).

The scope of this chapter is to elucidate the challenges of understanding current human and environmental conditions in the drylands and identify emerging research needs that can help forge pathways towards improved stewardship and sustainable development in future drylands in a world that will also be buffeted by climate change. Many issues related to transforming and governing drylands have been developed theoretically at the global scale [e.g., sustainable development goals and land degradation neutrality (Orr et al. 2017; Cowie et al. 2018)]. Some plans have been implemented at a national scale (INEGI 2019; UNCCD 2019), but scaling down sustainable development to dryland local communities is still lacking. Furthermore, suitable SES research methods that fully respond to such theoretical developments are required and need to be better defined and promoted.

Therefore, we present the International Network for Dryland Sustainability ("Red Internacional para la Sostenibilidad de Zonas Áridas, RISZA") that tackles the current dryland challenges at the local and regional scale, and supports several activities and goals. These include: (1) Creation of multisectoral partnerships associated with local SESs; (2) facilitation of intercultural exchange and dialogue; (3) weaving of different knowledge systems (Johnson et al. 2016; Tengö et al. 2017); (4) encouragement of transdisciplinary and participatory research (Schuttenberg and Guth 2015; Hickey 2018, Hickey et al. 2018; Willyard et al. 2018) for the co-production of relevant knowledge for action research (Clark et al. 2016; Durose et al. 2018); (5) generation of place-based learning communities (Davidson-Hunt and O'Flaherty 2007); (6) stimulation of the co-design of novel management, assessment, and governance schemes (Whitfield and Reed 2012; Schoon et al. 2015; Bautista et al. 2017; Bodin 2017; de Vente et al. 2017, (7) providing information for sustainable policy and socio-economic development standards in accordance with the United Nations Sustainable Development Goals (Agenda 2030). This network is the first national/international node of a recently founded international platform (see Chap. 13) to coordinate novel research, management, and assessment models in the drylands of Latin America, North Africa, and Europe in response to global environmental change in the Anthropocene.

The RISZA initiative also contributes to the wide range of activities related to the so-called *Global South* to foster the global scientific and research-development agenda on drylands. As a matter of context, the concept "Global South" refers broadly to the regions of Latin America, Asia, Africa, and Oceania. It is a term that has emerged as an alternative to the misconceived and former colonial ideas of "The Third World" and "Periphery" adopted in Europe and North America pointing to low-income and often politically or culturally marginalized countries of the planet (Dados and Conell 2012). The use of the "Global South" idea marks a shift from a central focus on underdevelopment or cultural differences in world countries, towards an emphasis on geopolitical relations of power among more equal nations. This is possible through the economic, political, cultural, and environmental changes that many developing nations in different continents have undergone over the past three decades. The Global South is rather an international political and economic concept that focuses on how world cultures, particularly those from Latin America Africa and Asia, respond to globalization and global processes linked to the environment, poverty, immigration, gender, etc., together with transformation, colonialism and post-colonialism, and modernity.

In the specific case of this book, we address the vision of drylands stewardship through the lens of a group of countries in Latin America (mostly Mexico) and Africa, through the nexus with the Agadir Platform, a transdisciplinary initiative, where countries from the two regions and Southern Europe collaborate on a common scientific agenda on sustainable development in drylands in the light of climate change.

Drylands Vulnerability in the Twenty-First Century

Over millennia the drylands have undergone innumerable transformations in climate, biotic interactions, and human conditions. Pressing current challenges in global drylands include a broad spectrum of issues as shown in Table 1.1.

Hence, these challenges explain why drylands currently cover over 35% of the global biodiversity hotspot area (Davies et al. 2012) and 28% of the total area of World Heritage Sites (Gudka et al. 2014). Past climate warming has been most

Table 1.1 Pressing current challenges in global drylands

Challenges	Some references
Human population growth	Wang et al. (2012), Reid et al. 2014), Cherlet et al. 2018)
Conversion of key rangeland resources to agricultural uses and groundwater exploitation	Chapter 3; Peters et al. (2015)
Sedentarization of pastoralists and other changes in traditional livelihoods	Chapter 2; Marlowe (2005), Reid et al. (2014)
Migration	Coppock et al. (2017)
Privatization of communal land	Reid et al. (2014)
Expanding urbanization	Reid et al. (2014), Peters et al. (2015)
Expansion of infrastructure for renewable energy generation and intensive agriculture	Chapter 5; Matson (2012), Reid et al. (2014), Cherlet et al. (2018)
Extraction of fossil fuels	Reid et al. (2014)
Expansion of mining	Reid et al. (2014)
Overgrazing by domestic livestock	Peters et al. (2015), Cherlet et al. (2018), Middleton (2018)
Invasive species	Reid et al. (2014)
Proliferation of water development	Chapter 3; Wilcox et al. (2011)
Aquifer overexploitation	Chapter 3; Aeschbach and Gleeson (2012)
Imposed or inadequate conservation management plans	Dudley (2008), Dressler et al. (2010) but see Gudka et al. (2014)
Inappropriate restoration and/or afforestation projects to enhance carbon capture	Wilcox et al. (2011), Veldman et al. (2015), Nolan et al. (2018)
Loss of local and indigenous knowledge	Figueroa (2011), Johnson et al. (2016) but see Gómez-Baggethun and Reyes-García (2013) for interpretation
Increased frequency of droughts	Chapter 15; Huang et al. (2017b)

pronounced in drylands, with an average increase of 1.7 °C between the years 1948 and 2008 (Huang et al. 2012); this warming trend is about 2.1 and 1.5 times greater than any increase observed in humid regions and globally, respectively (Huang et al. 2015, 2017a, b). Over a sixty-year period (1948–2008), drylands have expanded to their current extension (Feng and Fu 2013). Drylands are one of the most vulnerable biomes to climate warming, likely unable to tolerate the 2 °C warming threshold of the 2015 Paris agreement (Huang et al. 2017a). When considering high CO_2 emission scenarios (RCP 8.5), global drylands are predicted to expand at an even faster rate in that they will cover up to 56% of the terrestrial surface by 2071–2100 (Huang et al. 2015, 2017b). When considering only the CO_2 fertilization effect, drylands are predicted to increase their productivity. It has been shown that within 28 years (1982–2010) leaf cover has increased by 11% likely attributable to a 14% increase in atmospheric CO_2 concentration (Donohue et al. 2013). Finally, recent simulation models suggest that temperate drylands will shrink by a third and convert to subtropical drylands, and that drought may reduce water availability primarily at deep soil layers during the growing season with obvious implications on vegetation shifts, declines in ecosystem services supply and livelihood options (Schlaepfer et al. 2017).

Such accelerated changes in dryland use can introduce new dynamics in SES and in the transitions between stable and unstable SES states (Huber-Sannwald et al. 2012; Bestelmeyer et al. 2015). A state is characterized by certain vegetation and soil types and ecosystem processes (Bestelmeyer et al. 2015), which supplies a set of ecosystem goods and services in accordance to human demand (Yahdjian et al. 2015). Inherent and new sources of disturbances may cause changes of SES states; these changes can be abrupt, gradual, reversible, or persistent. Hence, unpredictable trends of change will be accompanied by new challenges related to understanding the combined and interacting effects of historic land use change, climate variability, alterations in the functioning of dryland SES, and their resilience and ability to deliver future ecosystem services (Folke et al. 2009, 2010). While extended droughts and increased variability in precipitation directly exacerbate socio-environmental degradation in drylands (Puigdefábregas 1998; Stott 2016), indirect policy-induced desertification also occurs (Geist and Lambin 2004; Adams 2009; Davis 2016b; Huaico Malhue et al. 2018).

Scholars have long debated on how to better manage the inherent variability of drylands to improve human living conditions. Such engineering approaches are grounded on the premise that one can reduce the inherent variability of drylands by adopting agricultural practices that have been successful where water availability is more predictable. A prominent example is crop irrigation, for instance, in the Yaqui valley in Mexico; this desert area has been the cradle of the Green revolution and the worldwide leader in wheat producer (Matson 2012). Environmental uniformity and stability, and the removal of redundancy may guarantee short-term high crop yields and temporarily increase food security, yet at the cost of irreversible loss of biotic and cultural diversity (Holling and Meffe 1996; Safriel et al. 2005; Walker and Salt 2006) along with trade-offs on sustaining ecosystem services (Papanastasis et al. 2017).

Human interventions intended to achieve sustainable development, as defined in the UN Sustainable Development Goals (https://www.un.org/sustainabledevelopment/sustainable-development-goals/), no longer require investment in maximizing commodity production, but rather in diversifying protections afforded to the biota, cultures, and knowledge systems in order to increase the response and adaptation spectra to regional or global socio-environmental change (Chapin III et al. 2009a). This increases the system buffering capacity against unpredictable change (Huber-Sannwald et al. 2012). The role of traditional ecological knowledge in understanding SES is crucial to understand how some local communities have sustained resilient landscapes, but also for the successful stewardship of diverse SES where the division between nature and society is bridged and true ethical multisectoral collaborations are accomplished (Johnson et al. 2016).

Desertification and Land Degradation Versus Drylands Resilience

According to the United Nations Convention to Combat Desertification (UNCCD 1994) desertification refers to land degradation in drylands due to various factors, including climatic variations and/or human activities (Article 1 of the UNCCD). The

Millennium Ecosystem Assessment (2005) defines land degradation as a process that leads to a long-term failure to balance the demand for and the supply of ecosystem goods and services. While there are estimates that about 10–20% of global drylands suffer from desertification (Reynolds et al. 2007; D'Odorico et al. 2013), due to the complexity of the causes of desertification and the impacts of land degradation, we have little understanding of both local expressions and the global extent of this problem (Cherlet et al. 2018). What is the origin of desertification? Where does its legacy originate, in the (false) sense that deserts are the result of deforestation, overgrazing, and excessive burning by indigenous nomadic pastoralist populations (Davis 2016a, b)? How can one explain major investments globally and regionally in strategic projects of "re"forestation and greening that promise to convert deserts into "productive land" (Davis 2016a, b; Stafford Smith 2016; 8000 km of Great Green Wall in the Sahel https://www.greatgreenwall.org/about-great-green-wall)?

The Earth's largest drylands are about 65 million years old, but like other biomes drylands have undergone dramatic changes over time (Goudie 1986). As noted above, in the drylands the scarcity, variability, and unpredictability of water over space and time are unique characteristics that have challenged traditional linear approaches to understanding ecosystem dynamics (Whitfield and Reed 2012). Seminal works by Westoby et al. (1989), Walker (1993), and Holling (1988) have stated that after a disturbance event, ecosystems return to a stable state of "equilibrium" or "climax," with a new "non-equilibrium" paradigm (Westoby et al. 1989). However, in most dryland SES most likely we will find both equilibrium and non-equilibrium features due to an extremely high spatiotemporal heterogeneity in structure, function, and overall system resilience (Coppock and Briske personal comment). What is currently labeled redundant or "noise" may be the source of system stability and resilience in the future under changing and interacting environmental conditions (Folke et al. 2010).

This concept of "non-equilibrium" is not only reflected in multiple stable biophysical states, but necessarily applies also to alternative socio-economic states (Reynolds and Stafford Smith 2002; Huber-Sannwald et al. 2012). While innate natural disturbance regimes have been acknowledged in contributing to the natural dynamics of SES (Pickett and White 1985), these aspects have not been considered in environmental policy formulation, concepts of dryland development, and anti-desertification policies (Behnke and Mortimore 2016; Davis 2016b) with potentially detrimental implications as they do not foresee the unpredictable non-linear nature of SES change (Reynolds et al. 2007; von Wehrden et al. 2012).

Desertification was recognized as one of the first major global change problems (UNCCD 1994; Thomas and Middleton 1992) and since then, it has been on the global UN agenda (Stafford Smith 2016). In 1977, the first United Nations Conference on Desertification (UNCOD) was organized. In parallel, in the second half of the twentieth century global dryland policy was targeted towards dryland restoration to enhance productivity in ways aligned with capitalist development goals (Davis 2016a). Ironically, however, some of the regions, most severely affected by desertification seem to have been related to those inappropriate policies that arose from misperceptions on the origin and (falsely promoted lack of) value of drylands and the supposedly inappropriate traditional uses by local populations (Davis 2016a). While scholars continue to debate how to best distinguish land degradation from desertification and to identify their underlying causes (Reynolds and Stafford Smith 2002; Reed and Stringer 2016; Reed et al. 2011; Behnke and Mortimore 2016; Davis 2016a, b), or measuring how much land loss has occurred (Huaico Malhue et al. 2018), the UN is targeting a land degradation neutral world by 2030 as one of the sustainable development goals (Chasek et al. 2015; Safriel 2017; Cowie et al. 2018), highlighting new challenges and opportunities (Stavi and Lal 2015; Akhtar-Schuster et al. 2017) and ignoring potential pitfalls (Easdale 2016; Okpara et al. 2018). Undoubtedly however, climate change may have contrasting impacts at the regional scale and thereby interact with human effects on land degradation, either by causing mega-droughts reducing vegetation cover and thereby exacerbate land degradation or by enhanced precipitation leading to some re-greening of drylands (for example, in the Sahel, Herrmann and Sop 2016; Behnke and Mortimore 2016).

Despite global awareness of and attention to desertification, success stories about its combating and/or developing the world's drylands are surprisingly scarce (for exception, see Reid et al. 2014). Thus, leading us to question why re- and afforestation projects have failed and have, at times, negatively affected biodiversity, as well as the hydrological and biogeochemical cycles of drylands (Amdan et al. 2013). Both irrigated and rain-fed agricultural schemes in drylands have overall rendered low crop yields and increased soil salinization and land degradation (Southgate 1990; Lambin et al. 2001), while rangeland management programs appear to have had little or no effects on improving land degradation (Dregne and Chou 1992). Conversely, regions formerly claimed to be notoriously and presumably irreversibly degraded by overgrazing have recovered after the end of long drought periods (Donohue et al. 2013; Dardel et al. 2014). In the wake of an accelerated rate of global socio-environmental change (Steffen et al. 2015), it is useful to question whether drylands are doomed to be physically degraded and desertified by humans (Reynolds and Stafford Smith 2002), or whether they instead present an opportunity for sustainable development (Reynolds et al. 2007; Mortimore et al. 2009; Krätli 2015; Behnke and Mortimore 2016).

Dryland Socio-Ecological Systems Are Complex Systems

Socio-ecological systems are complex adaptive systems where the relationships between humans and nature are based on interconnections among system components, whose interlinkages and dynamics create emerging properties with synergistic effects (Berkes et al. 2008; Koontz et al. 2015; Biesbroek et al. 2017; Tàbara et al. 2018). All complex systems have their inherent quantitative measures such as structure, dynamics, evolution, development, and complexity (Bar-Yam 1997; García 2006). Physical, biological, social, cultural, economic, and political components interact and provide feedback at different rates and intensities across different spatial and temporal scales, thus, they undergo non-linear, unpredictable changes and self-organize after disturbance events (Liu et al. 2007).

Understanding the connectedness between humans and nature necessarily requires inter- and transdisciplinary efforts and frameworks, including scholarly expertise from the natural and social sciences, and platforms of communication, negotiation, and decision-making that facilitate the formation of learning communities (similarly to Davidson-Hunt and O'Flaherty 2007; Bautista et al. 2017). The purpose of such learning communities is the sharing of scientific, local, indigenous, and technical knowledge, and ethics, wisdom, and worldviews, to ensure equal dialogue among all involved stakeholders. Utilizing and simultaneously protecting the wealth of natural resources and ecosystem goods and services upon which humanity depends calls for novel, holistic, transboundary designs, analysis, and knowledge co-production (Daily 1997; MEA 2005; Chapin III et al. 2009b). This integrated approach is fundamental for co-management, collaborative governance, and adaptive policy development (Bautista et al. 2017).

With this perspective, in 2002, a global multidisciplinary think tank of dryland specialists developed the Drylands Development Paradigm (DDP) (Stafford Smith and Reynolds 2002; Reynolds et al. 2007). The DDP is an integrative framework for the analysis, restoration, mitigation, and/or prevention of dryland SES as affected by degradation and/or desertification (Reynolds et al. 2007) and for policy development. The DDP is based on complex adaptive systems theory (CAS) (Ashby 1962; von Bertalanffy 1968), in that systems consist of interconnected elements conferring a particular structure following the underlying rules of the specific purpose or function of a system (Meadows 2008). Elements and processes may change at different rates, either "slow" or "fast," and at and across different spatial and/or temporal scales. The CAS has three key properties: (1) order is emergent not pre-determined, where the system adjusts and self-organizes after disturbance events; (2) historic impacts are irreversible in that current dynamics are linked to and influenced by past events (legacy effects); (3) based on (1) and (2) the future of CAS is unpredictable and the past lays the foundation for future changes (Chapin III et al. 2009a; Curtin 2015).

When studying SES, we need to ask the questions what causes overall system dynamics, internal connectedness, SES contexts and feedbacks of system components in response to internal and external long-term drivers (e.g., climate change, human population growth), stressors (e.g., mega-drought, emigration, fluctuations in markets or commodity prices, policy change), or pulsed trigger events (e.g., extreme weather or natural hazards, sudden access to electricity, communication technology), and how do system elements (resources, species, social actors) disperse, migrate, or interact across socio-ecological systems (Biggs et al. 2012). Do the variables and processes change slowly or rapidly and are they connected to the dynamics of events occurring at other times or places (Folke et al. 2009)?

For relevant research questions, clear understanding is required of the spatial and temporal dimensions of connectivity in SES. This implies understanding the connections between landscape units, habitats, species, social groupings, generations, knowledge types, institutions, and policies, among others (Biggs et al. 2015). Comprehending the functional integrity of SES as CAS is daunting yet crucially important, as the younger generations' tolerance to and perception of environmental degradation is changing such that the threshold of acceptance of environmental condition is declining, a psychological and sociological phenomenon laconically coined shifting baseline syndrome (SBS) (Pauli 1985). Hence, understanding SES dynamics and the degree of land degradation and potential human's preventive, reactive, proactive, mitigating, and/or adaptive responses requires a multi-criteria assessment in different contexts (Ocampo-Melgar et al. 2017).

When SES are managed, restored, or protected, necessarily through the lens of CAS theory, they will not remain or can be maintained at a mature or desirable state, respectively, but rather undergo adaptive cycles (Gunderson and Holling 2002). Complex systems may organize around one of several stable states within a desirable (from a stakeholder perspective) regime of the system. Thus, rather than focusing on detailed characteristics of one stable state, one may want to understand the internal and external drivers that cause the transition to alternative states and how systems elements reorganize without losing the underlying interconnectedness, structure, function, and feedback responses of the system, thus maintaining its resilience (Westoby et al. 1989; Scheffer and Carpenter 2003).

In Holling's adaptive cycle, the systems once fully developed are commonly held in the so-called conservation phase (Walker and Salt 2006). Humans tend to interfere in the adaptive cycle and frequently prolong this phase. For instance, by maximizing the production of a single ecosystem service, for example, forage production, water extraction, and so on, thereby eliminating unnecessary system variability and redundancy. However, this comes at the cost of eradicating high levels of diversity including biotic (species and functional groups, ecosystem service bundles), cultural (flexibility to adapt and adopt new livelihoods, high adaptive capacity related to local knowledge), and social diversity (institutional organizations, social networks, social memory, adaptive local governance systems). This diversity is needed as it confers insurance and buffer against unpredictable future changes (e.g., prolonged drought, fire, diseases, pests, drop in prices of commodities, new legislation). Similarly, we may want to ask do high levels of response diversity also provide systems with a potentially broad adaptive capacity to reorganize once a system has collapsed and shifted from the conservation to the release phase. How do SES reorganize, after they have lost the internal connectedness and release all resources, energy, and/or information itself?

Acknowledging and eventually managing the cyclic behavior of SES requires the incorporation of different sources of knowledge. The trajectory of system development follows both the system's memory and the current social–ecological context and conditions, thus conferring new ecological and/or social opportunities characterizing a certain system state within the desired regime (Huber-Sannwald et al. 2012). Lack of ability to respond to or recover after a system has collapsed may trigger the crossing of a threshold (biophysical or socio-economic) or tipping point (social, ecological, or socio-ecological (Milkoreit et al. 2017), and the shift into a new (albeit less desirable) regime. A system's capacity to build and maintain resilience and to re(self)-organize after a shock or severe disturbance event is critical, whether external, internal, or interacting drivers induce system change. Since the 1950s, in the time of Great Acceleration (Steffen et al. 2007), this may occur more rapidly, unpredictably, or irreversibly (global population growth, local and regional migration, land use change, soil erosion), directionally (loss of vegetation cover, change in species composition, climate warming, exploitation of aquifers, fisheries) (Steffen et al. 2015), or as an emerging phenomenon (loss of system resilience, landscape dysfunction, impoverishment of local traditional knowledge by introduction of information technology, migration, land degradation, desertification). Therefore, due to the complexity of SES, monitoring, tracing, and evaluating socio-ecological system change require multiple disciplines, expertise, knowledge systems, concepts, methodologies, frameworks, novel platforms, newly emerging sciences, thus fundamental approaches to do dryland system science achieve the stewardship of future drylands and the sustainable development goals (see Table 1.1).

RISZA and the Conceptual/Operational Model

In March 2017, the *International Network for Drylands Sustainability/Red Internacional para la Sostenibilidad de las Zonas Áridas (RISZA)* (www.risza.com.mx) was launched by the Instituto Potosino de Investigación Científica y Tecnológica (IPICYT) in San Luis Potosi, Mexico, with financial support from the National Council of Science and Technology (CONACYT by its Spanish acronym). The aim of RISZA is to generate and foster research, development, and innovation in partnership at the national level linked to the tripartite alliance between Latin America, Africa, and Europe (see Chap. 13/Agadir Platform), with a strong regional, inter-sectoral emphasis.

RISZA aims to guide and facilitate transdisciplinary and participatory research including academics, governmental and non-governmental organizations, civil societies, local stakeholders, and policy-makers, to foster collective knowledge production, iterative system monitoring and (re) evaluation, and capacity building in dryland stewardship at all levels. The principal research goal is to contribute to accomplish the SDGs in Mexican drylands in synergistic ways, drawing on expertise from other countries of the Platform of Agadir. As a ratifying country, Mexico needs to comply with each of the SDGs and their associated targets. Pre-established global indicators and country-specific indicators serve to monitor each SDG. The role of Mexico's and global drylands in meeting the SDGs both as a national and a global biome is poorly understood (for an exception, see FAO 2018). RISZA as part of the Agadir Platform will contribute with knowledge, technology, and innovation to meet these goals, in particular to the SDGs 13, 14, 15, and 17.

As a product of the inaugural RISZA participatory planning meeting in May 2017, a transdisciplinary group consisting of 80 people co-designed a comprehensive framework consisting of four dimensions: philosophies, study objects, actions, and long-term goals (Fig. 1.1). The framework is also a network, with the four dimensions representing nodes and the participatory or collective nature of the network representing the links, the blue line meaning water (a crucial determinant of drylands) as a transversal main focal point. This framework is flexible and open for feedback and adjustment; its emphasis lies on establishing the basis for inter- and transdisciplinary collaborations in national and international drylands with a current emphasis on Latin America, North Africa, and Southern Europe. It is also necessary to motivate the dialogue and co-production of knowledge by different actors (i.e., academia, government, private sector, civil societies, local communities, indigenous groups).

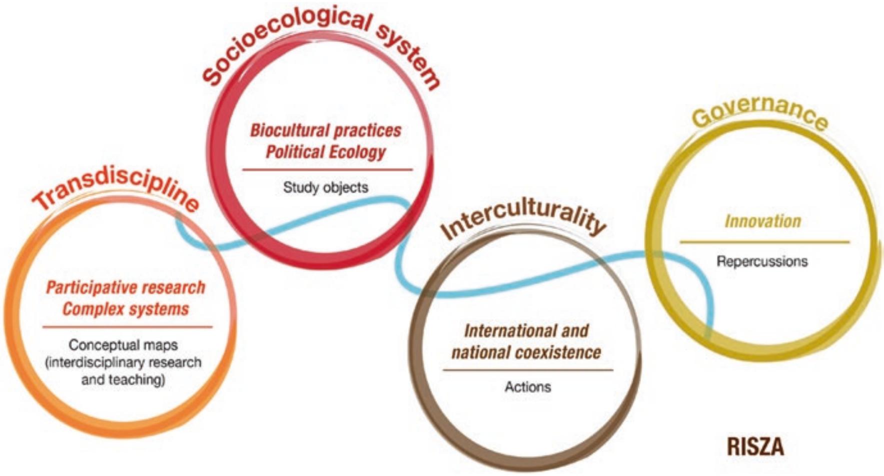

Fig. 1.1 Conceptual and operational framework of the International Network for the Sustainability of Drylands (RISZA—the Spanish acronym)

Part I: Drylands and Socio-Ecological Systems

Places, territories, landscapes, and/or ecosystems where people live and depend on natural resources and regulating forces have been described as social–ecological systems (SES). For this reason, the central study units for RISZA are SES, as people associate important values to these services, many represented by the 17 sustainable development goals (SDGs). When land conditions change caused by external or internal drivers, the quality and quantity of these services change as well.

For example, dryland degradation is advancing rapidly (Safriel et al. 2005; Safriel 2017) affecting the productivity and the functioning of inland and coastal ecosystems. Loss of biotic and cultural diversity, and climate change and socio-economic changes related to globalization enhance the effect of land degradation, thereby eliminating the inherent buffer characteristics that allow SES to resist, mitigate, or adapt to these adverse effects. Biodiversity and cultural diversity are directly related; cultural diversity includes genetic, linguistic, and cognitive diversity and thus has tangible and intangible assets. Cultural diversity often originates from the biotic diversity regularly in places inhabited by indigenous or rural communities (Toledo and Barrera-Bassols 2008). Furthermore, beyond a direct relationship the concept of biocultural eliminates the dichotomy and describes objects like animals, plants, rivers, or mountains as having a corresponding linguistic expression, charged with identity and individual or collective memory, sacred meaning, or ritual importance (Boege 2008).

Therefore, the interactions between humans and the environment are highly complex resulting from various interrelated factors. Research has demonstrated a broad transcultural variability in the environmental consequences of human behavior (Oviedo et al. 2000). In addition to the employment of SES as a study object and framework, political ecology research has analyzed the different actions and perceptions that social actors have and their relations of dependence and influence with their environment, together with the understanding of what causes such interrelationships (Robbins 2012). Thus, the emphasis is placed on the relationship of environmental, ideological, social, economic, and political aspects on each particular spatiotemporal context while articulating their local, regional, and global components (Greenberg and Park 1994). In both approaches, for research to have real repercussions in the objectives of sustainable development, an emphasis is placed on the importance of the role of institutions and social organizations in environmental contexts, where the individual and social diversity must be considered and the power relationships understood through governance studies.

Dryland socio-ecological, biocultural systems, and sustainable land management practices are affected by global socio-environmental change (i.e., land use change, climate change, diversity loss, livestock grazing, mining, migration, among others). Understanding specific historical, socio-cultural, socio-economic, and socio-political contexts will allow interregional, intercultural, and inter-policy comparisons among similar dryland SES and their divergent responses to global environmental change drivers. For RISZA we adopt the drylands development paradigm (Reynolds et al. 2007), as it considers the complexity, diversity, and uncertainty as inherent properties of dryland SES, as well as different system components, slow variables, cross-scale linkages, and diverse knowledge systems both as scientific and operational framework (Reynolds et al. 2007; Stringer et al. 2017).

Part II: Transdisciplinarity in Drylands

Participatory research originated in the 1970s in Latin America as part of social movements and processes of policy transformations related to social and education planning (Freire 1970). New research approaches with active democratic participation of the population via participatory mechanisms were proposed to plan and execute new education and development projects (Durston and Miranda 2002), as well as research efforts for conservation aims (Newing et al. 2011). Participatory research requires the fulfillment of a series of operational procedures to acquire useful knowledge and to eventually induce change in a situation or system. Many different methods have been efficiently used, the most common being action research (Whyte 1989), participatory rural appraisal (Chambers 1983), participatory mapping (Chapin et al. 2005), and participatory workshops and monitoring (Knapp et al. 2011). Due to its participatory nature, dialogue development among participating actors leads to the co-production of knowledge, allows the systematization of experiences, collective wisdom, and local knowledge (Ander-Egg 1990), and generates confidence among participants. All of these components are essential in positive governance (Schuttenberg and Guth 2015).

Problem solving inherently is multi, inter, or transdisciplinarity, requiring necessarily participatory research, because it involves collaboration among different stakeholders and is based on the generation of knowledge that emerges and extends beyond the limits of single scientific disciplines. It starts from the premise that knowledge is constantly developing by weaving scientific knowledge with empirical observations, technical know-how, contemporary scientific facts, local and traditional knowledge, and ancestral wisdom. Bridging and connecting knowledge systems helps understand socio-ecological system dynamics, opens dialogue between different cultures, mental models, institutions, actors, and their practices and influences, and/or informs governance schemes and policies (Tengö et al. 2017; Challenger et al. 2018). Co-production of knowledge opens new learning and teaching opportunities (Gutiérrez Serrano 2016) and contributes to an ever-growing horizontal learning community. The concept of transdisciplinarity originally stems from the idea that thinking is a complex process including biological, cerebral, spiritual, logical, linguistic, cultural, social, and historical processes, with emphasis on the connections and communication between knowledge systems (Morin 1977; García 2006; Castañares Maddox 2009; Díaz et al. 2015, 2018). Furthermore, it emerges with the intention to not only systematically solve a problem, but to make research and thus education more relevant to society (Kockelmans 1979).

Part III: Interculturality in Drylands

The development of transdisciplinary and participatory research is based on continuous knowledge development and dialogue as the basis to develop sustainable development projects with direct participation of local actors. Multiple stakeholder collaborations are fundamental for the co-production of useful knowledge production as different wisdoms, disciplines, foci, and positions can be shared (Gutiérrez Serrano 2016). This transdisciplinary academic context has strongly helped remove unequal power relations, which is the basis for interculturality (Alsina 2003), and thus generates friendly intimate relations built on confidence and trust to their legitimacy (Coppock 2016). Interculturality refers to the process of establishing equitable communication and interaction forms between people and groups with specific cultural identities, which stimulates dialogue and integration between different cultures, knowledge, and worldviews (Alsina 2003; Clark et al. 2016). The process of action through interculturality requires not only a different type of knowledge, but also a novel process of knowledge creation. It requires the creation of collective and participatory wisdom based on equal cognitive and emotional exchanges, providing an emancipatory knowledge that goes beyond colonialism to accomplish solidarity (Santos 2002).

While intercultural dialogues are not always exempt of conflict, strong emphasis is given on mutual respect, horizontality in communication channels, equitable access to information, and joint search for synergies (Alsina 2003). Thus, when looking for engagement by a diverse group of stakeholders, emphasis needs to be given on a diverse spectrum of values with potentially conflicting worldviews, and on different knowledge systems, rules, and norms (Gorddard et al. 2016). This then will guide management practices, power relations, skills, and preferences, which in turn may dramatically influence the perception, definition, and stewardship of socio-ecological systems (Davies et al. 2015). Therefore the diverse values, knowledge, and rules of multiple social actors influence the decision-making context and together with the inherent complexity and interrelatedness of dryland SES components, their feedbacks and non-linear responses to management and climate change across different spatial and temporal scales may trigger uncertainty related to both the vulnerability to increasing risks associated with climate change and the resilience to the long-term provisioning of ecosystem services and human well-being.

These so-called wicked problems (a type III problem according to Rittel and Webber 1973 cited in DeFries and Nagendra 2017) that RISZA will be tackling have no clearly defined solutions, yet require continuous collective learning, integrated collaborative institutional designs, and adaptive, iterative pathways, towards finding solutions both at the management, policy, and governance level (Curtin 2015; DeFries and Nagendra 2017). Ultimately, to guarantee respectful exchange among knowledge types and diverse cultures, RISZA commits to follow the established ethical codes to protect human rights (see United Nations Rights of Indigenous Peoples and the regulations of the WIPO "World Intellectual Property Organization") and to adopt the scheme of basic agreements on human studies established by the Institutional Review Boards (IRBs) in the USA. It is important to note that transdisciplinary and intercultural endeavors must require a commitment to true ethical academic procedures where the individual becomes part of a research team and considers the participation of all actors involved throughout all the project's stages: from the establishment of objectives to the final co-authorship of research results.

Part IV: The Governance of Drylands

Drylands are the home for a large amalgamation of geological, biological, and cultural diversity (Stafford Smith et al. 2009). For local populations, they consist of meaningful places representing history, memory, and identity, where accumulated experiences and knowledge are weaved into objects, songs, rituals, stories, and other social practices (Martínez-Tagüeña and Torres Cubillas 2018). The creation of stable institutions with high institutional capacity implying clearly defined equitable rules, and openness for shared learning as a basis for collective action related to sustainable resource use is essential for the conservation of the biotic and cultural diversity (Ostrom 2000). Hence, the study of governance is fundamental in order to understand the processes of interaction between social actors involved in public affairs that require decision-making and the formulation of public policies. Governance is considered an emerging pattern of interaction among social actors, their objectives, and the instruments used to direct socio-ecological processes within a particular policy area (Kofinas 2009). The governance of complex systems is produced at various scales from local to global and by different sectors including civil, public, and private (Rhodes 1997).

For fisheries, governance proposals have been suggested through the implementation of SES in order to evaluate their sustainability (Leslie et al. 2015). In defined SES, like national protected areas or in specific environmental themes, governance systems have been analyzed to assess their performance and relevance (Martínez and Espejel 2015; Martínez et al. 2015, 2016). In the context of SES in order to maintain certain favorable stable states, it is important to form participatory inter- and transdisciplinary partnerships, who do not only integrate the natural and social sciences, but incorporate knowledge, needs, and interests of all stakeholders, which then allows the co-production of knowledge, diagnostics, monitoring and evaluation systems, and the development of public policies (Ostrom 2009). In Mexico, inventories on biodiversity operated by CONABIO have generated novel forms of knowledge generation through participatory monitoring (www.biodiversidad.gob.mx/sistema_monitoreo), while at the Latin American level citizen observatories have contributed to novel forms of knowledge production (www.desertificación.gob.ar/). In both examples, citizen involvement in knowledge production has transformed attitudes and conferred good governance schemes related to nature, life quality, and the implementation of good practices.

Governance schemes should be flexible and support innovation and risk-taking in research. For instance, the creation of a cross-sectional innovation unit can bridge the gap between public research and private sector initiatives directly engaged in sustainable management and development of the drylands. Thus, RISZA considers that alongside good governance, social innovation is crucial to achieve the sustainable development goals in drylands. Social innovation refers to novel solutions created to solve social problems in a more efficient, effective, sustainable, and fair manner than previous solutions, where the resulting aggregated value corresponds to society at large rather than to a few individuals (Philis et al. 2008). Beyond ample creativity, successful ideas for social innovation have originated from people's needs and dislocations, dissatisfactions, and blockages. And furthermore, from the generation of new knowledge that opens the door to problem solving in innovative ways (Mulgan 2006).

While certain governments have been reticent to invest in social innovation because it entails risk of failure, innovation has a better chance of success when users have choices and contracts for services reward outcomes achieved rather than outputs or activities, or when there is some competition rather than a state monopoly (Díaz Foncea et al. 2012). Other challenges for social innovation come from the typical insights obtained from business innovation. Contrary to following typical market structures these endeavors align with social organizations that have different motives going further than material incentives to include political recognition and support, voluntary labor, compassion, identity, autonomy, and care. According to the authors' experiences, social organizations tend to grow slower than private businesses, but they also tend to be more resilient. However, clearer metrics are needed to understand social innovation since it is complicated to judge their success. Scale or market share may matter little for a social innovation concerned with a very intense but contained need. In some cases, participants' lives are dramatically improved by the act of collaboration (Mulgan 2006, also for an example, see http://www.in-control.org.uk).

In drylands, it is important to document multiple innovation examples that have been implemented to better manage natural resources like water, minerals, new technology for pastoralism and ranching and agricultural practices, among others.

Social technologies are looking to develop novel tools for diagnostic, monitoring, evaluation, and transfer needed in order to have successful social innovation projects that provide potentially better management schemes and in particular deal with water scarcity. It is important to mention the efforts made in the area of technology for social businesses that promote rural development and in social entrepreneurship that join a socio-ecological scope with an economic benefit based on local communities' self-management (Navarro and Climent 2010).

In this book, a series of chapters retake the key concepts and pillars of the RISZA conceptual framework explained throughout this introduction chapter. Examples of innovative dryland policies and case studies in response to climate change and other global change drivers, and collective thinking gave place to this compendium of highly diverse experiences representing transdisciplinary efforts coauthored by a total of over 80 co-authors from different sectors and organizations. It presents novel ideas to solve the continuously evolving and challenging dryland problems of the Global South.

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