Chapter 9
Interactions Between Changing Climates and Land Uses: The Case of Urmia Lake, Iran

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Abstract Iran is experiencing rapid population growth coupled with the negative impacts of global warming and land-use change. These impacts pose significant challenges for water managers and planners trying to match supply and demand. The twin challenges of land-use management and planning for climate change are exemplified in the case of Lake Urmia—situated in a closed basin in northwestern Iran. The basin supports agriculture from water stored in several reservoirs. Lake Urmia was once the largest saltwater lake in the Middle East and North Africa. It has recently become an environmental concern due to shrinking by 80% within the last 30 years. The dropping water level is exacerbated by a combination of declining precipitation and land conversion practices. Water loss provokes severe socio-environmental consequences (including chronic health impacts, child mortality risks, and agricultural threats) that are similar in magnitude to those seen in the Kazakhstan–Uzbekistan Aral Sea disaster. This chapter explores the interactions

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between climate and land use, and reveals the difficulties faced by short-term land-use policies that favor urban expansion and agricultural productivity over long-term protection of ecosystems. Lessons from indigenous water management practices in Iran are drawn upon to assess the long-term social sustainability of common pool resource management in the region.

Keywords Climate change · Land-use change · Iran · Lake Urmia Basin · Water management · Wicked problems

9.1 Introduction

Environmental degradation of arid and semi-arid ecosystems is exacerbated by global warming and land-use change, both of which alter the provision of water and natural resource, resulting in thirst and hunger challenges that undermine progress toward Sustainable Development Goals (Ghanian et al., 2022; Winslow et al., 2004). This interconnected set of environmental challenges constitutes a *super-wicked* problem, based upon compounding positive feedbacks that reinforce changes in environmental systems from human activities (Ghanian et al., 2020; Eskandari-Damaneh et al., 2020). Urgent action is required to avoid a tipping point of non-reversible environmental harm, yet the people generating the changes are the same people seeking a solution. Land-use governance practices commonly discount long-range futures in a way that fails to address the core environmental challenges of water, climate, and food productivity within an ever-narrowing window of opportunity (Levin et al., 2012). In this chapter, we consider the intersection of two environmental policy domains—one concerning climate change adaptation and the other concerning land-use change and economic productivity. The reinforcing interactions of an ongoing global land grab for agriculture, increasing pressure on water resources in arid and semi-arid regions, global population increase, and economic growth, create a deepening vortex of environmental degradation in certain regions. This chapter explores the interactions between global heating-induced changes, land-use decision-making, and the role of indigenous knowledge at an environmentally sensitive site experiencing decline—the Lake Urmia Basin (LUB) in Iran, among the threatened saltwater lakes of the Middle East and North African (MENA) region. This assessment provides insight into the management of threatened lake ecosystems globally.

9.1.1 The Global Hunger Challenge

Global population is expected to grow from approximately seven to nine billion people by 2050 and will be a key challenge for sustainable development (Bene et al., 2015). Almost one billion people suffer malnourishment, primarily in Asia (578 million) and Sub-Saharan Africa (239 million). Alleviating chronic hunger is one of the biggest sustainable-development challenges (Dahimavy et al., 2015; Ghoochani et al., 2017a; Wheeler & Von Braun, 2013). Agricultural productivity and food distribution must outpace population growth to resolve hunger and malnutrition (Azadi et al., 2015). An additional 200 million extra tons of livestock products and 1 billion tons of cereals per annum are needed and the growing wealth of people in middle-income countries necessitates a 60–70% increase in annual agricultural output is required; such growth would be unprecedented in human history (Ghoochani et al., 2017b). The growth of agricultural capacity is vital for the improvement of standards of living and for the avoidance of the Malthusian trap of using food abundance to further population growth (Kögel & Prskawetz, 2001). The imperative for such agricultural growth and modernization is strongest in developing countries, where the challenge is not just to provide food but to make sure that distribution networks ensure food access and encourage food security (Abbasi et al., 2016) in line with Sustainable Development Goal #2—to end hunger, achieve food security, improve nutrition, and promote sustainable agriculture (Behera et al., 2019).

One person in 20 continues to be in danger of undernourishment in developing countries, irrespective of whether agricultural production doubles by 2050. This is equivalent to 370 million hungry people. Most of these people live in Sub-Saharan Africa and Central and Southern Asia (Dubois, 2011). The agricultural sector is the engine of social development and economic growth, particularly within the poorest regions, though sustainable agriculture is vital to ensure the long-term provision of ecosystem services like water quality, biodiversity, and carbon management (Powlson et al., 2011). The demand for food commonly prompts a shift toward the intensification of food systems (Garnett et al., 2013; Godfray & Garnett, 2014). However, expansion of agricultural land use is often a central cause of environmental degradation—commonly through deforestation (Barbier, 2004; Fuller et al., 2019). Economic globalization shrinks cropland availability and sometimes triggers land-cover conversion and deforestation under conditions of land scarcity, and few developing countries have managed a transition that simultaneously increases agricultural production and forest cover (Lambin & Meyfroidt, 2011; Zambrano-Monserrate et al., 2018). To maintain ecosystem services produced by forests and simultaneously remedy food scarcity, improvements to agriculture must be made through *sustainable* forms of intensification involving integrated assessments of natural resources and the drivers of food demand.

The twentieth century achieved agricultural intensification through high-yield crop varieties, new fertilization technologies, irrigation, genetic modification, and pesticide use. Collectively, these have contributed to enormous gains in food production, though they also altered ecologies and the patterns of resource availability with serious adverse consequences for local, regional, and global environmental quality and socio-economic impacts on vulnerable communities (Rasmussen et al., 2018). Cropping patterns and land management practices have an enormous effect on freshwater availability, biogeochemical cycles, and soil quality (Palatnik & Roson, 2009). Land use plays a very important role in methane generation, carbon cycling, and carbon storage (Azadi & Barati, 2013), strongly impacting atmospheric composition (World Bank, 2008). Land-cover and land-use change is a serious driver of global environmental change (See et al., 2015). The pursuit of food security is both subject to and the cause of environmental pressures and is a key challenge this century (Ghoochani et al., 2017b). Accelerated global warming confounds the prediction of climate change trends and coupled with the direct destruction of natural habitats threatens terrestrial biodiversity (Anderson et al., 2016) and agricultural productivity (Gornall et al., 2010). These will be acute challenges for sustainable development under the climates of the MENA region (Kaniewski et al., 2012; Sowers et al., 2011; Hameed et al., 2020), and in Iran in particular (Amiri & Eslamian, 2010; Mahdavi Damghani et al., 2019).

9.1.2 Anthropogenic Climate Change

Greenhouse gases are increasing in atmospheric concentration. Carbon dioxide (CO_2) levels have now exceeded the 400-ppm benchmark (the concentration is over 418 ppm in early 2022), and the global mean temperature has risen by 0.8 °C since the 1850s. The warming has been evidenced by three independent terrestrial and maritime temperature records (Pachauri et al., 2014). The globally averaged combined land and ocean surface temperature data as calculated by a linear trend reveal a warming of 0.85 °C [0.65–1.06 °C] between 1880 and 2012 (Wheeler & Von Braun, 2013). The interactive effects of carbon-based fuel use and land-use changes upon anthropogenic warming are described as a *super-wicked problem* (Levin et al., 2012) that has complex and interrelated impacts on both human and natural systems (Foley et al., 2005). Changing climates driven by anthropogenic warming of the atmosphere are bringing myriad socio-environmental impacts: including changes in rainfall patterns, reduced global snow and ice coverage (including glacial retreat), increased frequency and severity of weather events, rising sea levels, and ocean acidification (Wheeler & Von Braun, 2013). There will be disproportionately greater changes to spatial and temporal patterns of precipitation and temperature on land than over oceans, toward the poles than near the equator, and in arid regions more than humid regions (Rogelj et al., 2012).

Food productivity is consequently dependent upon agricultural resilience in the face of changing climates, both in the short and long terms (Ghoochani et al., 2018). Though some regions may benefit in the immediate future from longer growing seasons or a shift to more temperate climates, the influence that global warming will have on feed, fodder, or food production, on livestock health, and on the patterns of trade of food and food products will be profoundly negative (Wheeler & Reynolds, 2013). Impacts will vary with the degree of change in regional climates (i.e., the associated changes in precipitation and thermal patterns compounded by local and/or regional drivers of micro-climates). But changing climates disrupt both food production and food demands locally, where communities rely on local farmers' markets and their own food production (Wheeler & Von Braun, 2013). The net effect of global warming is probably going to weigh down or reverse any progress we have made toward a world without hunger.

9.1.3 Land Use Change

'Land-grab' concerns have been raised about acquisitions of large agricultural properties and resulting in the destruction of natural ecosystems and displacement of local communities (Teklemariam et al., 2015). Others have conceptualized transnational land acquisitions within the widely evolving global capitalist development framework, and the relationships among political economies working toward confronting the converging global crises in food, energy, financial capital, and global warming. Large portions of developing countries are cultivated by smallholders, often families based within indigenous communities. The International Fund for Agricultural Development—IFAD (2013) estimates that about two billion people in developing countries are small landholders and they produce about 70% of the developing world's food. This is, however, an increasingly precarious livelihood strategy (Murshed-e-Jahan & Pemsl, 2011) that returns low yields (Chamberlin et al., 2014). Under conditions of rapid population growth and urbanization, agricultural policymakers frequently seek external investment and trade agreements to meet domestic national and regional food demands (Kalamkar, 2009; Hallam, 2009; Lavers, 2012), and Iran is particularly harassed by external economic sanctions. Many smallholder farmers also suffer from uncertain legal rights and face the prospects of dispossession (Palmer et al., 2009). Unmitigated land-use instability is pushing the global agricultural sector to a tipping point for subsistence and smallholder farming societies (Anseeuw et al., 2012). Interrelated processes of economics and land conversion are also driving toward this tipping point (Azadi et al., 2011). Although land-use practices vary greatly internationally, their outcome is usually susceptible to land-grabbing. This universal problem—the acquisition of natural resources for immediate human needs—frequently occurs at the expense of the environment and this is often viewed to be a global tragedy of the commons (Dell'Angelo et al., 2017).

The magnitude, pace, and spatial reach of alterations of Earth's surface are unprecedented (Nunes & Rezende, 2016). Key aspects of the functions of environmental systems are severely impacted globally by changes of land covers and land uses (Lambin et al., 2001). We are seeing: declines in biodiversity globally; changing climates that are impacting locally, regionally, and globally; and degradation and desiccation of soils. These changes affect the capacities of biological systems to support human needs by altering and disabling ecosystem services (Chhabra et al., 2006), with knock-on impacts to livelihoods and economic development opportunities. Since 1850, about 6 million km^2 of forests and woodlands and 4.7 million km^2 of savannas, grasslands, and steppes have been converted due to the expansion of croplands around the world. Approximately 1.5 million km^2 of cropland have since been abandoned in formerly wooded areas and 0.6 million km^2 have since been abandoned in grassland environments (Lambin et al., 2001). Land-cover changes to short-term transitional conditions (such as forest succession under slash-and-burn cultivation) also are widespread (Agrawal et al., 2014) as are the most severe conversions of expanding cropland and pastoral land into pristine natural ecosystems (Power, 2010). From 1980 to 2000, concerns grew about environmental services and global biodiversity because approximately half of new agricultural lands of the tropics derived from intact forests, and another 28% came from disturbed forests (Gibbs et al., 2010). Rapid deforestation throughout the tropics, in turn, has global implications for sustainable development, global warming, and biodiversity conservation (Lasco, 2008) because of the alteration of precipitation and regional temperature patterns by land conversion and changes to transpiration rates.

9.1.4 The Interaction Between Land Use and Climate Change

Land-use and land-cover change is profoundly disturbing to terrestrial ecosystems, interacting with anthropogenic heating of the atmosphere which drive climates to change (Azadi & Barati, 2013; Lambin & Meyfroidt, 2011). This is specifically relevant to uncontrolled land conversion for agriculture (Backlund et al., 2008). This is principally driven by economic growth, increasing population density, and urbanization (Azadi et al., 2011) which make it almost certain to happen to many parts of the developing world (Putro et al., 2017). The trends, intensities, and drivers of agricultural land conversion vary by country, however. Land conversion has multiple driving factors operating over a variety of temporal and spatial scales, each with differentiated impacts on the human environment (Verburg et al., 2013; Bryan et al., 2016): these include the use and demands of natural resources; cultural, political, aesthetic and moral values; and economic and technological processes and policies. Managing the complexity of land conversion for agriculture requires the mixing of diverse stakeholder values through sustained engagement and policy construction to form appropriate strategies that will preserve and prevent conversion of agricultural lands to other uses (Löhr, 2010). Authorities throughout the developing world have used such measures to prevent conversion of agricultural land to other uses with varied success (Azadi et al., 2011).

The interaction between land-use decision-making and global-warming mitigation efforts is key. Rapid anthropogenic warming is driven by activities that produce greenhouse gases (principally carbon dioxide and methane) and from changes in the conditions of land covers that can also augment greenhouse gas emissions such as the drying of wetlands and peatlands (Vitousek et al., 1997) and the drying out of forests that increases their susceptibility to wildfires. Land-cover changes also affect local climates by changing surface energy and water balance. Humans have simultaneously transformed the hydrological cycle to produce freshwater for irrigation, industry, and domestic consumption (Cunha et al., 2015) which can alter the characteristics of wetlands and their capacities as carbon sinks. Furthermore, anthropogenic nutrient inputs to the biosphere from airborne and waterborne pollution and fertilizers exceed the natural capacities to absorb them and have widespread impacts on maritime, estuarine, and freshwater ecosystems (David & Lal, 2013). Land conversion also drives declining biodiversity through the destruction, modification, and fragmentation of habitats, the degradation of soil and water, and the overexploitation of native species (De Las Heras, 2014). Each type of land-cover change is tied to other secondary environmental impacts. Wetland drainage, for example, can affect biodiversity, trace gas emissions, soil, and hydrological balance. But the secondary impacts of land-cover changes are difficult to differentiate from natural variation. Climatic change and water flows are a case in point (Meyer & Turner, 1992). Environmental changes of either kind become global changes in either of two ways: either through top-down impacts as the global effect of net GHG emissions causes warming that influences local conditions, precipitation patterns, sea-level rise, salinity intrusion, or bottom-up impacts wherein drying due to warming interacts with micro-climatic conditions, and land types are altered by broader macro-trends in environmental change. The latter generates an accumulation of localized land-use changes that sum to global significance (Pachauri et al., 2014). Land-use change contributes to both kinds of global environmental change. It can cause global systemic changes through trace-gas accumulation and generates local cumulative impacts like soil degradation, biodiversity loss, and hydrological change that have broader regional-national-international scale interactions with global climate systems. It is the interaction between the macro-and micro-scale effects that yield global environmental impacts with negative outcomes for humans and natural systems.

9.1.5 Climate and Land Use Change in Iran

Like many other developing countries, Iran's climates and land uses are both changing rapidly. These changes pose significant challenges for water managers and planners working to match supply and demand (Barati et al., 2018). Iran is 29.2% arid, 20.1% semi-arid, 35.5% hyper-arid, 5% Mediterranean, and 10% wet. Water and environmental management are among the foremost challenges for policy-makers (Jowkar et al., 2016). The population of Iran has increased rapidly since 1950, reaching approximately 75 million by 2011. It is projected to exceed 100 million by 2050. This growth has increased resource scarcity within the semi-arid regions of Iran. Water is particularly scarce due to the high levels of consumption in petrochemical industries, for agriculture, and domestic use. Drought frequency has increased and has been exacerbated by changing climates.

Changing climates and land uses are the principal environmental challenges Iran faces (Tahbaz, 2016). Their impacts on hydrological and bio-geological functions impact the behavior of the terrestrial components, and rapid growth increases the severity of impacts from anthropogenic global warming (Stephenson et al., 2010; Mahdavi Damghani et al., 2019; Karimi et al., 2018). The primary impacts are decreased snowpack, earlier snowmelt, altered patterns of precipitation including watershed desiccation, increased winter precipitation that causes flooding, drought, and higher summer and lower winter temperatures. When these exogenous factors are augmented by rising water demand, it becomes increasingly difficult for authorities to plan for and meet future water needs. Historically, annual rainfall in Iran has been approximately 250 mm, less than one-third of the global average (860 mm). Sparse precipitation combines with erratic rainfall patterns (Abbasi et al., 2016) that significantly increase flood risk in populated areas (Taherei Ghazvinei et al., 2016). Despite low average annual rainfall, peak-flood intensity continues to increase (Panahi et al., 2010). Analysis of daily rainfall confirms that extreme events occur across the country, and areas with impermeable surfaces are very likely to flood in the wake of extreme rainfall (Darabi et al., 2020).

While changing climates impact the stability and productivity of farmland, the acreage of farmland in Iran has expanded by more than 900% (from 2.6 to 24.5 million ha) and natural forests, rangelands, and bare lands have decreased. Forests have shrunk by about 6.6 million ha between the 1950s and the 1990s (Bahrami et al., 2010) and more is predicted to occur in the 2020s and 2030s as forests are consumed for residential areas, agricultural lands, and grassland for animal production (Joorabian Shooshtari et al., 2020). The projection for 2030 indicates that agricultural land will be converted to urban uses, will be lost to salinization of soils, and will be fragmented to support infrastructure. Flooding has increased substantially in Iran while freshwater reserves have diminished (Abbaspour et al., 2009; Darabi et al., 2020). Natural resource stocks, ecosystem services, and resource demands are increasingly imbalanced. Iran is therefore exemplifying the super-wicked interaction between natural resource management decision-making, agricultural land productivity, food security, water quality and supply, forest cover, and wetland biodiversity under conditions of increasing aridity, more frequent and more widespread droughts, and increasing flood risk.

9.2 The Case of the LUB

The LUB is an example of how changing land uses and global warming interact in an environmentally threatened ecosystem. Lake Urmia is located between the Iranian provinces of East Azerbaijan and West Azerbaijan and has a catchment area of 51,876 km^2 (Hassanzadeh et al., 2012b). The LUB contains fertile land that is used for agriculture supported by several reservoirs. Seventy-six million people live within a radius of 500 km of the LUB. The LUB has 12 seasonal rivers and 39 streams, and 11 sub-basins with 17 main rivers (Hasemi, 2011). Its continental climate has temperatures that range between -20 and 0 °C during the winter months and can rise to 40 °C in summer (Eimanifar & Mohebbi, 2007). These are predicted to increase by the end of the twenty-first century (Doulabian et al., 2021). Lake Urmia was once the biggest saltwater lake within the MENA region. However, its water level has been declining continuously since the 1990s, having shrunk by some 80% (Faramarzi, 2012; Shadkam et al., 2016; Balkanlou et al., 2020). The depth of

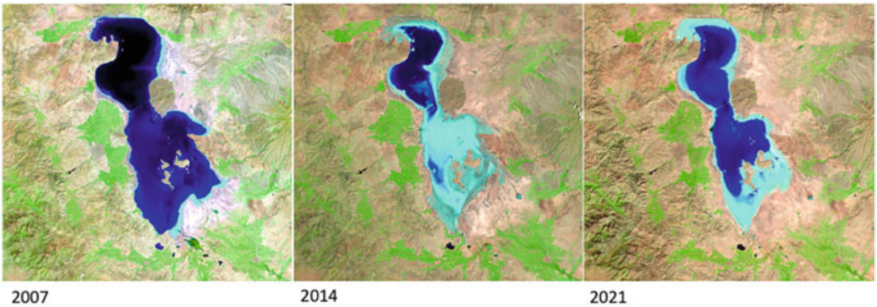

Fig. 9.1 The changing water levels of Lake Urmia from 2007 to 2021. Source: USDA Foreign Agricultural Service (2021)

the lake had declined to 1271.58 m in 2008 from its most recent record of depth at 1277.80 m in 1994. Salinity has also increased (Hassanzadeh et al., 2012a). Since 2017 there has been an observable increase in water level and a relative improvement in Lake Urmia's condition, but controversy remains over whether this has been due to active restoration or due to temporary increases in rainfall in the basin (Nikraftar et al., 2021). Longer-term observable conditions like increased salinity from 205 to 338 g/l due to evaporation and reduced inflow indicate degradation (Faramarzi, 2012; Mohammadi et al., 2019). Ghale et al. (2017) showed that salts and salination of soils have increased dramatically from 1995 to 2014, and over 5000 km^2 of Lake Urmia's water area was converted to salt pans and/or highly saline soils significantly impacting the lake's biodiversity, ecosystem services, and usefulness for irrigation. Desertification and salinization are not limited to the increasingly exposed lake bottom. Though hectares of irrigated lands have more than doubled during the studied period, soil salinity has also increased within the vicinity of Lake Urmia (Fig. 9.1).

The lake's decline is driven by multiple factors. Most significant are the destruction of Zagros forests and Iranian government water policies that have consistently diverted water from the LUB to politically-connected agricultural land users. As Henareh Khalyani et al. (2014) show, this process of water system governance exacerbates existing social inequity, particularly to indigenous peoples, and prompts further deforestation, creating a vicious circle of land and water degradation. Responsibility rests partially with the commercial agricultural sector and resource over-exploitation by farmers (Pouladi et al., 2019, 2020; Abadi et al., 2018; Sadeghi et al., 2020; Shojaei-Miandoragh et al., 2020). It is notable that unlike in other regions of Iran, where indigenous knowledge practices of water management provide adaptive capacity in the face of drought, farmers in the LUB have little historical experience or memory of water scarcity (Azizzadeh & Javan, 2018; Amirataee et al., 2018). Unlike community-based water sharing practice inherent to indigenous communities in Iran (Ghorbani et al., 2021), historically, the farmers in the LUB region used the techniques of water supply and distribution based on the continuous availability of sufficient water resources. Only by refashioning water governance through organized indigenous collaboration can water resources be equitably and sustainably shared (Azarnivand & Banihabib, 2015).

Studies of farmers' perception of the LUB water crisis have found changing cultivation patterns, the expansion of profitable cultivation, overproduction at the expense of subsistence-indigenous needs, and disregard for land and water resources potential, leading to water depletion (Abbaszadeh et al., 2020). Cultivation patterns are perceived as a supra-regional process: national economic goals shape crop cultivation practices. Whereas independent indigenous farmers would cultivate diverse crops according to the needs and local market for produce, contemporary farming practices are driven by national agricultural policy of the Iranian Government. The changing scale of agricultural management from indigenous knowledge and local governance to national policy is a core aspect of this crisis. Farmers in the LUB have taken collective action to adapt to climate change in recent years; such as 'the increased desire for cultivation of cash crops'; 'using more fertilizers and pesticides'; 'cultivating multi-crops'; 'renting their lands to others'; 'replacement of agriculture and horticulture by animal husbandry'; and 'sale of land and migration to urban areas' (Ghanian & Mohaamdzadeh, 2019). However, analysis of the structure of social relations of local farmers showed their low desire to reduce their water consumption through individual actions. In fact, farmers' ambiguity and distrust of the usefulness and effectiveness of their action to protect water resources is the result of three factors. First, the wide radius of the population involved and affecting the catchment area of Lake Urmia and the lack of a collective consensus based on public respect at the expense of personal interests. Second, the wide radius of the population involved and affecting the catchment area of Lake Urmia and the lack of a collective consensus based on public respect at the expense of personal interests. Third, is distrust of the major water resources management institutions of the basin and their lack of seriousness and support, and consequently failures of individual impact. The reality of the region shows that the shrinkage of the lake has led to acute water scarcity for surrounding settlements (Fathian et al., 2014). Ghale et al. (2017) revealed that drought, environmental degradation, and increases of agricultural activities were the most significant drivers of the shrinking of the lake and have caused severe socio-environmental consequences including infant mortality, chronic malnutrition, and diminishing profits for farmers. This is very similar in scale and scope to the disaster connected to the depletion of the Aral Sea (Shadkam et al., 2016)—a similar endorheic basin located between Uzbekistan and Kazakhstan.

The impacts of land use and climate change in the Urmia basin are of interest to scholars who are examining a diverse array of environmental drivers (Ghale et al., 2017, 2018; Shadkam et al., 2016; Balkanlou et al., 2020; Hassanzadeh et al., 2012b). The average temperature and mean maximum temperature in the southern basin of Lake Urmia increased by 1.8 °C and 3.5 °C, respectively, over the last three decades (Ghanian & Mohaamdzadeh, 2019). Mean minimum temperature, mean precipitation, and humidity have decreased by 1.3 °C, 10.3 mm, and 5% over the same period. Ghodousi et al. (2014) showed that the volume of Lake Urmia has decreased by 51% and the actual evapotranspiration rate increased by 13%, with the rate of water loss accelerating in recent years. They predicted increasing frequency droughts that will intensify the shrinking volume despite recent signs of rising levels (Mirgol et al., 2021). These trends will change the ecological matrix of the lake region. Areas of dense grass, sparse grass, and woodlands have declined sharply in the southern part of the basin. Forests have diminished to only 5% of the region. Growing pasturelands and diminishing soil cover are similarly problematic. By the year 2027, the intensification of irrigated agriculture is expected to grow by nearly 9000 ha and rain-fed agriculture is expected to grow by 1000 ha, further threatening the region's biodiversity. Shakeri (2021) reports that the land-use change and water-resource challenges emerging in the basin are exacerbated by increased residential land use (increasing 40% over 20 years), creating multiple and compound threats to ecological stability.

The considerable expansion of salt pans to the south and west of Lake Urmia may have further consequences like intrusion of salts into aquifers and salt storms that will yield social consequences like those experienced around the Aral Sea. Within the last decade, most of the land around Lake Urmia Lake has been rendered unusable; causing serious problems for northwestern Iran's agriculture and industrial productivity (Ghale et al., 2017). The increasing stress from droughts, dams, environmental degradation, and rapid growth of agriculture in the basin have created a state of perpetual environmental crisis and the socio-ecological system is rapidly losing resilience (Fathian et al. (2014). Yet agricultural and water plans don't seem to be sufficiently robust to counter the negative impacts of the interaction between climate and land-use change on residential development, ecosystem services, or biodiversity (Shadkam et al., 2016). Managing these complex interactive effects requires an integrated sustainable land-use management approach that draws upon indigenous and other forms of community knowledge, beyond the agricultural productivity gains asserted through national-scale land-use policy.

Within land-use policy networks in Iran, the controversy has centered upon the urban fringes (the spaces where agricultural land meets urban and residential development). This is also referred to as the urban hinterland. Policy debate around settlements within the LUB focuses on whether agricultural land in the fringe should be maintained, expanded, or converted to other uses. This debate may be regarded as either pro-rural or pro-urban policy perspectives. The pro-rural viewpoint sees conversion of land to urban uses as having negative impacts: reducing agricultural jobs, destroying prime agricultural land, displacing indigenous peoples and livelihoods, and wasting investments that have been made on irrigation infrastructure. This change could affect agricultural production and threaten national/regional food security. Pro-ruralists conclude that agriculture should be protected and expanded to increase food production. Pro-urbanists, however, argue that land conversion could be a logical consequence of urban growth. Reduced food production, they argue, could be solved by agricultural intensification and improved technologies for food production. Land conversion, in their view, is not a threat, but an opportunity for agricultural innovation. The result of this debate is that the solution to the super-wicked problem for sustainable ecology and water management is stymied by a framing conflict created by the competing visions for social development, land productivity, and technology. In both cases, land-use policy ignores the long-term risks that land conversion will have on the ecological system in favor of the immediate goals of fulfilling acute human needs. Without agreement on the core goals of a sustainable management strategy, there will be no consensus upon an answer and environmental degradation will accelerate to the detriment of all in the region.

9.3 Discussion

The gradual drying of Lake Urmia and interactions between climate change and land-use change have created significant regional socio-environmental challenges that include the destruction of agricultural lands and pastures, inadequate potable water, deteriorating air quality, and increased migration away from communities near the lake. Land-use change and climate change generate substantial negative impacts on biodiversity and rural livelihoods within the LUB though there is little research into the interaction of these two drivers. Their combined effects compound one another and make current adaptive solutions and conservation management strategies insufficient to sustainably manage the ecosystem services of the basin.

This chapter finds that the evidence of droughts, decreasing precipitation, and increasing temperature collectively demonstrates that the climates of the LUB are changing (Balkanlou et al., 2020). Its interaction with land-use change presents significant challenges for local and provincial planning authorities and national natural resource managers. Focusing only on environmental matters like greenhouse gas emissions reduction is not enough. The poor levels of environmental monitoring and regulation, the failures of agricultural and land management stakeholders to follow scientifically based rules, the inappropriate enforcement of protections for biological resources, and the weak coordination within the Iranian state together promote adverse socio-environmental outcomes. From the farmers' point of view, with the collapse of traditional irrigation systems and the disappearance of local sovereignty, both water resource reserves have been destroyed, and social capital and the most fundamental ethics have been infiltrated. A practice that seeks to maximize individual profit and gain regardless of the possibility of future resource availability and severely undermines local governance, and ultimately the outcome of all these were water crisis conditions over the past few decades. Although farmers use their strategies in the absence of a legitimate governance system to manage the status quo and try to establish individual or collective order on a micro-kinship-neighborhood scale, the results are counterproductive in two ways. Consequences that will intensify the crisis in the form of conflict and divergence will lead to the withdrawal and transfer of agricultural lands, and or as a group that will try to overcome the current crisis with resistance and hope. Stronger focus on policies that build community resilience includes changing to knowledge and attitudinal perspectives amongst farmer-stakeholders to longer-term views that support pro-environmental agricultural practices and that minimize their vulnerabilities through education and awareness. They can improve adaptation and overall climate literacy in the face of these threats (Mileř & Sládek, 2011). However, following the Islamic revolution in 1987, Iran has been deeply affected by multilateral (UN) and unilateral (USA) international economic sanctions, reducing the socio-economic and political capacities of national and regional authorities to plan for a sustainable future. They are forced to simply strive to extract food and water and to manage land in the LUB to meet short-term needs at the cost of longer-term ecosystem stability.

International best practices for land-use planning and climate-change response in the USA and China involve operational and integrative approaches premised on extensive financial and research support. In the USA, this includes integration of satellite-based remote sensing with ground-based observational networks, and multi-agency coordination (between the Department of Energy, Environmental Protection Agency, and Department of Agriculture, among others) using integrative analysis of comprehensive scientific and ecological information to form coherent policy (Wang et al., 2016). In China, the Organization of Environmental Protection (in coordination with 30 other government agencies) provides extensive financial and research support to prevent the degradation of pastures and other productive lands, as well as for climate dynamics and land-use modeling efforts from which global socio-economic development planning is based. Though these exemplars provide a basis from which to understand best practices, the smaller pool of resources for environmental monitoring in Iran, the lack of integration across government departments, and the lack of political will toward sustainable planning remain key barriers to the sustainable management of the LUB.

9.4 Conclusions

Land-use change is intertwined with changing climates as both are consequences of and promoters of increasing global warming (Dale, 1997). Building dams for electricity, water storage, or irrigation water is land-use change that affects hydrologic processes and spawns other direct impacts upon regional and global atmospheric conditions (Taherei Ghazvinei et al., 2016). Other land-cover changes like deforestation, road construction, and agricultural cultivation on steep slopes produce similar local-to-global impacts (Santika et al., 2017). Yet a changing climate is often considered to be a factor driving land-use and land-cover changes (Marshall et al., 2018). As many have demonstrated, climate change has prompted land-use changes; there is a positive feedback for both of these facets of environmental change (Peters et al., 2019; Hohmann et al., 2018). The importance of this interaction and the role of the aquatic ecosystems (wetlands, mudflats, natural and artificial basins, lagoons, ponds, and swamps) become increasingly significant over time as we collectively undermine the ecosystem services that support human development. These challenges are most acute in lake systems and other wetland habitats as these delicate socio-ecological systems rapidly lose their resilience to multiple interacting changes

(Faramarzi, 2012). Modern land-use practices and policies in Iran and beyond focus too strongly upon increasing the short-term supply of material goods to meet acute (often local) human needs and undermine the fundamental ecosystem services that support regional to global needs over the longer term. Land-use policies that emphasize either urban (construction) or rural (agricultural) land allocation have an enormous impact on ecosystem sustainability and this is a global issue that reaches far beyond local decision-makers and indigenous communities (Delattre et al., 2015). Confronting the worldwide environmental challenges of land use would require assessing and managing inherent trade-offs between meeting and maintaining the capacity of ecosystems and the immediate human needs for goods and services well into the future.

The LUB is an important and valuable ecosystem; one that is deeply significant to local, national, and international environmental protection communities. We need a new *integrative* management approach (e.g., Esmaeilnezhad et al., 2021) to address the challenges of the basin to reach sustainable water use and ensure conservation of the lake ecosystem. A new strategy must be *holistic* in its approach to understanding the interaction of climate and land-use change: it must have the capacity to mediate competing land--use perspectives against long-term ecosystem-service provision, changes in agricultural capacity, and changes resulting from long-term climate change, and should aim to directly halt and reverse ongoing processes of degradation. Consequently, policymakers must improve their understanding of the water resources system and its different components within the basin by striving to understand the socio-hydrological elements of the lake system (Pouladi et al., 2021). Lessons from indigenous knowledge practices elsewhere in Iran provide particular insight. Water sharing and long-term management practices within indigenous Iranian communities have shown long-term sustainability across multi-generational timeframes (Ghorbani et al., 2021), primarily because water resources are managed within socially prescribed limits to meet local agricultural needs without exceeding the carrying capacity of the local common pool resource (Hosseini et al., 2011). Learning from such cases can assist in the development of new water management plans. The most recent plan to rescue the lake involves rapidly decreasing irrigation water use by 40% (Shadkam et al., 2016). This will create, however, social and economic pressure for the residents that depend on water access for sustainable livelihoods. The LUB is gaining increased public scrutiny, with civilian dialogue on the potential environmental threat and the unwanted economic, social, and cultural consequences of new management plans on the area's inhabitants. An integrated approach to land-water use planning and climate change adaptation that learns from indigenous knowledge elsewhere in Iran would improve agricultural development in the region and reduce the desiccation of this hyper-saline lake. But the approach must be one that all stakeholder groups, including agricultural water users, can agree with.

Finding a balance between what is needed for both settlements and regional or national food systems and for longer-term ecosystem stability is critical for the long-run sustainability of water resources. Prediction of water-balance components could be a valuable component of water supply analysis and watershed management, and it could help to prevent land degradation, to estimate water availability for irrigation, to enhance food security, or to calculate the amount of groundwater withdrawal that would be sustainable. While international assistance remains an important aspect of future environmental management policy and practice, Iranians, as those who live with developing economies, must lead regional restoration of Lake Urmia and provide their insights into the management of other major fresh and saltwater bodies. In fact, without a pragmatic action plan, the country faces severe water stress that is increasing the already considerable problem of hunger within the country. Land use, climate change, water management, and human development policy cannot be separated into discrete problems for policy formation or planning. Any sustainable long-term management plan must be based on a strong assessment of the interactions of land-use change and climate change and their effects on natural resource availability and resilience, and on the stability of ecosystem services. The allocation of agricultural and urban land uses must be accomplished in ways that reduce long-term risks by placing basin restoration at the heart of future planning in a way that indigenous approaches to water management have done for centuries, if there is to be a concerted effort to maintain and increase the recent gains in water availability in the LUB.

References

Abadi, B., Jalali, M., & Mousavi, S. B. (2018). The path analysis of water conservation behavior in agricultural sector and revivification of Lake Urmia: The case of farmers in Southern Basin of Lake Urmia. *Iranian Agricultural Extension and Education Journal, 13*, 251–268.

Abbasi, N., Ghoochani, O., Ghanian, M., & Kitterlin, M. (2016). Assessment of households' food insecurity through use of a USDA questionnaire. *Advances in Plants and Agriculture Research, 4*, 00155.

Abbaspour, K. C., Faramarzi, M., Ghasemi, S. S., & Hong, Y. (2009). Assessing the impact of climate change on water resources in Iran. *Water Resources Research, 45*. https://doi.org/10.1029/2008WR007615

Abbaszadeh, M., Banifatemeh, H., & Nikdel, N. (2020). A study of farmers' perception of Urmia Lake (UL) crisis with grounded theory approach. *Journal of Applied Sociology, 31*, 1–22.

Agrawal, A., Wollenberg, E., & Persha, L. (2014). Governing agriculture-forest landscapes to achieve climate change mitigation. *Global Environmental Change, 29*, 270–280.

Amirataee, B., Montaseri, M., & Rezaie, H. (2018). Regional analysis and derivation of copula-based drought Severity-Area-Frequency curve in Lake Urmia basin, Iran. *Journal of Environmental Management, 206*, 134–144.

Amiri, M., & Eslamian, S. (2010). Investigation of climate change in Iran. *Journal of Environmental Science and Technology, 3*, 208–216.

Anderson, T. R., Hawkins, E., & Jones, P. D. (2016). CO2, the greenhouse effect and global warming: From the pioneering work of Arrhenius and Callendar to today's Earth System Models. *Endeavour, 40*, 178–187.

Anseeuw, W., Wily, L. A., Cotula, L., & Taylor, M. (2012). *Land rights and the rush for land: Findings of the global commercial*. ILC.

Azadi, H., & Barati, A. A. (2013). *Agricultural land conversion drivers in Northeast Iran LDPI working papers*. The Land Deal Politics Initiative. Working Paper 36.

Azadi, H., Ghanian, M., Ghoochani, O. M., Rafiaani, P., Taning, C. N., Hajivand, R. Y., & Dogot, T. (2015). Genetically modified crops: Towards agricultural growth, agricultural development, or agricultural sustainability? *Food Reviews International, 31*, 195–221.

Azadi, H., Ho, P., & Hasfiati, L. (2011). Agricultural land conversion drivers: A comparison between less developed, developing and developed countries. *Land Degradation and Development, 22*, 596–604.

Azarnivand, A., & Banihabib, M. E. (2015). Two stage multi attributes decision making to evaluate the sustainability of Lake Urmia restoration alternatives. *Journal of Range and Watershed Managment, 68*, 197–212.

Azizzadeh, M., & Javan, K. (2018). Temporal and spatial distribution of extreme precipitation indices over the lake Urmia Basin, Iran. *Environmental Resources Research, 6*, 25–40.

Backlund, P., Janetos, A., & Schimel, D. (2008). *The effects of climate change on agriculture, land resources, water resources, and biodiversity in the United States.*

Bahrami, A., Emadodin, I., Atashi, M. R., & Bork, H. R. (2010). Land-use change and soil degradation: A case study, North of Iran. *Agriculture and Biology Journal of North America, 1*, 600–605. (In Persian).

Balkanlou, K. R., Muller, B., Cord, A. F., Panahi, F., Malekian, A., Jafari, M., & Egli, L. (2020). Spatiotemporal dynamics of ecosystem services provision in a degraded ecosystem: A systematic assessment in the Lake Urmia basin, Iran. *Science of the Total Environment, 716*, 137100.

Barati, A. A., Asadi, A., & Kalantari, K. (2018). *Provision of a system for managing the causes and effects of land use change and land cover with emphasis on agricultural lands*. Education for Sustainable Development.

Barbier, E. B. (2004). Explaining agricultural land expansion and deforestation in developing countries. *American Journal of Agricultural Economics, 86*, 1347–1353.

Behera, B. K., Rout, P. K., & Behera, S. (2019). *Move towards zero hunger*. Springer.

Bene, C., Barange, M., Subasinghe, R., Pinstrup-Andersen, P., Merino, G., Hemre, G.-I., & Williams, M. (2015). Feeding 9 billion by 2050–Putting fish back on the menu. *Food Security, 7*, 261–274.

Bryan, B. A., Nolan, M., Mckellar, L., Connor, J. D., Newth, D., Harwood, T., King, D., Navarro, J., Cai, Y., & Gao, L. (2016). Land-use and sustainability under intersecting global change and domestic policy scenarios: Trajectories for Australia to 2050. *Global Environmental Change, 38*, 130–152.

Chamberlin, J., Jayne, T., & Headey, D. (2014). Scarcity amidst abundance? Reassessing the potential for cropland expansion in Africa. *Food Policy, 48*, 51–65.

Chhabra, A., Geist, H., Houghton, R. A., Haberl, H., Braimoh, A. K., Vlek, P. L., Patz, J., Xu, J., Ramankutty, N., & Coomes, O. (2006). Multiple impacts of land-use/cover change. In *Land-use and land-cover change.* Springer.

Cunha, A. P., Alvalá, R., Kubota, P. Y., & Vieira, R. (2015). Impacts of land use and land cover changes on the climate over Northeast Brazil. *Atmospheric Science Letters, 16*, 219–227.

Dahimavy, A., Ghanian, M., Ghoochani, O. M., & Zareyi, H. (2015). Process of application of multi criteria decision making models in prioritizing of water development projects of rural areas in the Khuzestan province. *Journal of Water and Sustainable Development, 1*(3), 9–16.

Dale, V. H. (1997). The relationship between land-use change and climate change. *Ecological Applications, 7*, 753–769.

Darabi, H., Haghighi, A. T., Mohamadi, M. A., Rashidpour, M., Ziegler, A. D., Hekmatzadeh, A. A., & Kløve, B. (2020). Urban flood risk mapping using data-driven geospatial techniques for a flood-prone case area in Iran. *Hydrology Research, 51*, 127–142.

David, U., & Lal, R. (2013). *Soil emission of nitrous oxide and its mitigation*. Springer. BN.

De Las Heras, A. (2014). *Sustainability science and technology: An Introduction*. CRC Press.

Delattre, L., Chanel, O., Livenais, C., & Napoleone, C. (2015). Combining discourse analyses to enrich theory: The case of local land-use policies in South Eastern France. *Ecological Economics, 113*, 60–75.

Dell'Angelo, J., D'Odorico, P., Rulli, M. C., & Marchand, P. (2017). The tragedy of the grabbed commons: Coercion and dispossession in the global land rush. *World Development, 92*, 1–12.

Doulabian, S., Golian, S., Toosi, A. S., & Murphy, C. (2021). Evaluating the effects of climate change on precipitation and temperature for Iran using RCP scenarios. *Journal of Water and Climate Change, 12*, 166–184.

Dubois, O. (2011). *The state of the world's land and water resources for food and agriculture: Managing systems at risk*, Earthscan.

Eimanifar, A., & Mohebbi, F. (2007). Urmia Lake (northwest Iran): A brief review. *Saline Systems, 3*, 5.

Eskandari-Damaneh, H., Noroozi, H., Ghoochani, O. M., Taheri-Reykandeh, E., & Cotton, M. (2020). Evaluating rural participation in wetland management: A contingent valuation analysis of the set-aside policy in Iran. *Science of The Total Environment, 747*, 141127.

Esmaeilnezhad, R., Zeinalzadeh, K., Nazarnejad, H., & Mohammadpour, M. (2021). Assessment of agricultural development preventive policies for restoration of Urmia Lake in Barandoz Basin, Iran. *The Egyptian Journal of Remote Sensing and Space Science, 24*, 1103–1110.

Faramarzi, N. (2012). *Agricultural water use in Lake Urmia basin, Iran: An approach to adaptive policies and transition to sustainable irrigation water use*.

Fathian, F., Dehghan, Z., & Eslamian, S. (2014). Analysis of water level changes in Lake Urmia based on data characteristics and non-parametric test. *International Journal of Hydrology Science and Technology, 4*, 18–38.

Foley, J. A., Defries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., Chapin, F. S., Coe, M. T., Daily, G. C., & Gibbs, H. K. (2005). Global consequences of land use. *Science, 309*, 570–574.

Fuller, C., Ondei, S., Brook, B. W., & Buettel, J. C. (2019). First, do no harm: A systematic review of deforestation spillovers from protected areas. *Global Ecology and Conservation, 18*, e00591.

Garnett, T., Appleby, M. C., Balmford, A., Bateman, I. J., Benton, T. G., Bloomer, P., Burlingame, B., Dawkins, M., Dolan, L., & Fraser, D. (2013). Sustainable intensification in agriculture: Premises and policies. *Science, 341*, 33–34.

Ghale, Y. A. G., Altunkaynak, A., & Unal, A. (2018). Investigation anthropogenic impacts and climate factors on drying up of Urmia Lake using water budget and drought analysis. *Water Resources Management, 32*, 325–337.

Ghale, Y. A. G., Baykara, M., & Unal, A. (2017). Analysis of decadal land cover changes and salinization in Urmia Lake Basin using remote sensing techniques. *Natural Hazards and Earth System Sciences*. https://doi.org/10.5194/nhess-2017-212

Ghanian, M., Ghoochani, O. M., Dehghanpour, M., Taqipour, M., Taheri, F., & Cotton, M. (2020). Understanding farmers' climate adaptation intention in Iran: A protection-motivation extended model. *Land Use Policy, 94*, 104553.

Ghanian, M., Ghoochani, O. M., Noroozi, H., & Cotton, M. (2022). Valuing wetland conservation: A contingent valuation analysis among Iranian beneficiaries. *Journal for Nature Conservation, 66*, 126140.

Ghanian, M., & Mohaamdzadeh, L. (2019). Analyzing the farmers' professional competencies needed against climate change; the case study of Southern Basin of Urmia Lake. *Geography and Environmental Planning, 30*(3), 115–136.

Ghodousi, M., Delavar, M., & Morid, S. (2014). Impact of land use changes on hydrology of Ajichai Basin and its input to Urmia Lak. *Iranian Journal of Soil and Water Research, 45*(2), 123–133.

Ghoochani, O. M., Ghanian, M., Baradaran, M., Alimirzaei, E., & Azadi, H. (2018). Behavioral intentions toward genetically modified crops in Southwest Iran: A multi-stakeholder analysis. *Environment, Development and Sustainability, 20*, 233–253.

Ghoochani, O. M., Dorani, M., Ghanian, M., & Cotton, M. (2017a). Analyzing stakeholder water source preference based upon social capital: A case study of the Fajr Jam Gas Refinery in Iran. *Water Conservation Science and Engineering, 2*(4), 109–120.

Ghoochani, O. M., Ghanian, M., Baradaran, M., & Azadi, H. (2017b). Multi Stakeholders' attitudes toward Bt rice in Southwest, Iran: Application of TPB and multi attribute models. *Integrative Psychological and Behavioral Science, 51*, 141–163.

Ghorbani, M., Eskandari-Damaneh, H., Cotton, M., Ghoochani, O. M., & Borji, M. (2021). Harnessing indigenous knowledge for climate change-resilient water management–lessons from an ethnographic case study in Iran. *Climate and Development, 13*, 766–779.

Gibbs, H. K., Ruesch, A. S., Achard, F., Clayton, M. K., Holmgren, P., Ramankutty, N., & Foley, J. A. (2010). Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s. *Proceedings of the National Academy of Sciences, 107*, 16732–16737.

Godfray, H. C. J., & Garnett, T. (2014). Food security and sustainable intensification. *Philosophical Transactions of the Royal Society B: Biological Sciences, 369*, 20120273.

Gornall, J., Betts, R., Burke, E., Clark, R., Camp, J., Willett, K., & Wiltshire, A. (2010). Implications of climate change for agricultural productivity in the early twenty-first century. *Philosophical Transactions of the Royal Society B: Biological Sciences, 365*, 2973–2989.

Hallam, D. (2009, December 7–8). *Foreign investment in developing country agriculture: Issues, policy implications and international response. Beyond the crisis: International investment for a stronger, cleaner, fairer global economy*. OECD 8th Global forum on international investment. OECD Conference Centre.

Hameed, M., Ahmadalipour, A., & Moradkhani, H. (2020). Drought and food security in the middle east: An analytical framework. *Agricultural and Forest Meteorology, 281*, 107816.

Hasemi, M. (2011). *A socio-technical assessment framework for integrated water resources management (IWRM) in Lake Urmia Basin*. Newcastle University.

Hassanzadeh, E., Zarghami, M., & Hassanzadeh, Y. (2012a). Determining the main factors in declining the Urmia Lake level by using system dynamics modeling. *Water Resources Management, 26*, 129–145.

Hassanzadeh, E., Zarghami, M., & Hassanzadeh, Y. (2012b). Determining the main factors in declining the Urmia Lake level by using system dynamics modeling. *Water Resource Management, 26*, 129–145.

Henareh Khalyani, A., Mayer, A. L., & Norman, E. S. (2014). Water flows toward power: Socioecological degradation of Lake Urmia, Iran. *Society and Natural Resources, 27*, 759–767.

Hohmann, C., Kirchengast, G., & Birk, S. (2018). Alpine foreland running drier? Sensitivity of a drought vulnerable catchment to changes in climate, land use, and water management. *Climatic Change, 147*, 179–193.

Hosseini, S. J. F., Azita, Z., & Arfaee, M. (2011). Determining factors influencing the adoption of indigenous knowledge in agriculture water management in dry areas of Iran. *African Journal of Agricultural Research, 6*, 3631–3635.

Ifad, U. (2013). *Smallholders, food security and the environment*. International Fund for Agricultural Development.

Joorabian Shooshtari, S., Silva, T., Raheli Namin, B., & Shayesteh, K. (2020). Land use and cover change assessment and dynamic spatial modeling in the Ghara-su Basin, Northeastern Iran. *Journal of the Indian Society of Remote Sensing, 48*, 81–95.

Jowkar, H., Ostrowski, S., Tahbaz, M., & Zahler, P. (2016). The conservation of biodiversity in Iran: Threats, challenges and hopes. *Iranian Studies, 49*, 1065–1077.

Kalamkar, S. (2009). Urbanisation and agricultural growth in India. *Indian Journal of Agricultural Economics, 64*, 442.

Kaniewski, D., Van Campo, E., & Weiss, H. (2012). Drought is a recurring challenge in the Middle East. *Proceedings of the National Academy of Sciences, 109*, 3862–3867.

Karimi, V., Karami, E., & Keshavarz, M. (2018). Climate change and agriculture: Impacts and adaptive responses in Iran. *Journal of Integrative Agriculture, 17*, 1–15.

Kögel, T., & Prskawetz, A. (2001). Agricultural productivity growth and escape from the Malthusian trap. *Journal of Economic Growth, 6*, 337–357.

Lambin, E. F., & Meyfroidt, P. (2011). Global land use change, economic globalization, and the looming land scarcity. *Proceedings of the National Academy of Sciences, 108*, 3465–3472.

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., Coomes, O. T., Dirzo, R., Fischer, G., & Folke, C. (2001). The causes of land-use and land-cover change: Moving beyond the myths. *Global Environmental Change, 11*, 261–269.

Lasco, R. D. (2008). Tropical forests and climate change mitigation: The global potential and cases from the Philippines. *Asian Journal of Agriculture and Development, 5*, 82.

Lavers, T. (2012). 'Land grab'as development strategy? The political economy of agricultural investment in Ethiopia. *Journal of Peasant Studies, 39*, 105–132.

Levin, K., Cashore, B., Bernstein, S., & Auld, G. (2012). Overcoming the tragedy of super wicked problems: Constraining our future selves to ameliorate global climate change. *Policy Sciences, 45*, 123–152.

Löhr, D. (2010). The driving forces of land conversion. Towards a financial framework for better land use policy. *Land Tenure Journal, 1*, 61–89.

Mahdavi Damghani, A., Kambouzia, J., Aghamir, F., & Mahmoudi, H. (2019). Sustainable intensification of agricultural systems in Iran for adaptation to climate change: Opportunities and challenges. *Strategic Research Journal of Agricultural Sciences and Natural Resources, 4*, 157–168.

Marshall, L., Biesmeijer, J. C., Rasmont, P., Vereecken, N. J., Dvorak, L., Fitzpatrick, U., Francis, F., Neumayer, J., Ødegaard, F., & Paukkunen, J. (2018). The interplay of climate and land use change affects the distribution of EU bumblebees. *Global Change Biology, 24*, 101–116.

Meyer, W. B., & Turner, B. L. (1992). Human population growth and global land-use/cover change. *Annual Review of Ecology and Systematics, 23*, 39–61.

Mileř, T., & Sládek, P. (2011). The climate literacy challenge. *Procedia-Social and Behavioral Sciences, 12*, 150–156.

Mirgol, B., Nazari, M., Etedali, H. R., & Zamanian, K. (2021). Past and future drought trends, duration, and frequency in the semi-arid Urmia Lake Basin under a changing climate. *Meteorological Applications, 28*, e2009.

Mohammadi, A., Darvishi, K. J., Salehi Pour, A., Kaveh, F. A., & Lak, R. (2019). Thegenesis of micro-landforms of muddy and salty plains of Urmia Lake. *Quaternery Journal of Iran, 5*, 237–262.

Murshed-e-Jahan, K., & Pemsl, D. E. (2011). The impact of integrated aquaculture–agriculture on small-scale farm sustainability and farmers' livelihoods: Experience from Bangladesh. *Agricultural Systems, 104*, 392–402.

Nikraftar, Z., Parizi, E., Hosseini, S. M., & Ataie-Ashtiani, B. (2021). Lake Urmia restoration success story: A natural trend or a planned remedy? *Journal of Great Lakes Research, 47*, 955–969.

Nunes, R. R., & Rezende, M. O. O. (2016). Influence of land use on the chemical and physical characteristics of sediments from the Brazilian Savannah. *Cogent Environmental Science, 2*, 1218994.

Pachauri, R. K., Allen, M., Barros, V., Broome, J., Cramer, W., Christ, R., Church, J., Clarke, L., Dahe, Q., & Dasgupta, P. (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.

Palatnik, R. R., & Roson, R. (2009). *Climate change assessment and agriculture in general equilibrium models: Alternative modeling strategies*.

Palmer, D., Fricska, S., & Wehrmann, B. (2009). *Towards improved land governance*. UN-HABITAT.

Panahi, A., Alijani, B., & Mohammadi, H. (2010). The effect of the land use/cover changes on the floods of the Madarsu Basin of Northeastern Iran. *Science Research, 2*. https://doi.org/10.4236/jwarp.2010.24043

Peters, M. K., Hemp, A., Appelhans, T., Becker, J. N., Behler, C., Classen, A., Detsch, F., Ensslin, A., Ferger, S. W., & Frederiksen, S. B. (2019). Climate–land-use interactions shape tropical mountain biodiversity and ecosystem functions. *Nature, 568*, 88–92.

Pouladi, P., Afshar, A., Afshar, M. H., Molajou, A., & Farahmand, H. (2019). Agent-based socio-hydrological modeling for restoration of Urmia Lake: Application of theory of planned behavior. *Journal of Hydrology, 576*, 736–748.

Pouladi, P., Afshar, A., Molajou, A., & Afshar, M. H. (2020). Socio-hydrological framework for investigating farmers' activities affecting the shrinkage of Urmia Lake; hybrid data mining and agent-based modelling. *Hydrological Sciences Journal, 65*, 1249–1261.

Pouladi, P., Badiezadeh, S., Pouladi, M., Yousefi, P., Farahmand, H., Kalantari, Z., David, J. Y., & Sivapalan, M. (2021). Interconnected governance and social barriers impeding the restoration process of Lake Urmia. *Journal of Hydrology, 598*, 126489.

Power, A. G. (2010). Ecosystem services and agriculture: Tradeoffs and synergies. *Philosophical Transactions of the Royal Society B: Biological Sciences, 365*, 2959–2971.

Powlson, D. S., Gregory, P. J., Whalley, W. R., Quinton, J. N., Hopkins, D. W., Whitmore, A. P., Hirsch, P. R., & Goulding, K. W. (2011). Soil management in relation to sustainable agriculture and ecosystem services. *Food Policy, 36*, S72–S87.

Putro, U. S., Ichikawa, M., & Siallagan, M. (2017). *Agent-based approaches in economics and social complex systems IX*. Springer.

Rasmussen, L. V., Coolsaet, B., Martin, A., Mertz, O., Pascual, U., Corbera, E., Dawson, N., Fisher, J. A., Franks, P., & Ryan, C. M. (2018). Social-ecological outcomes of agricultural intensification. *Nature Sustainability, 1*, 275–282.

Rogelj, J., Meinshausen, M., & Knutti, R. (2012). Global warming under old and new scenarios using IPCC climate sensitivity range estimates. *Nature Climate Change, 2*, 248.

Sadeghi, A., Bijani, M., & Farhadian, H. (2020). The mediating role of farmers' time perspective in water resources exploitation behaviour in the eastern area of Lake Urmia, Iran: An environmental psychological analysis. *Water and Environment Journal, 34*, 106–120.

Santika, T., Meijaard, E., Budiharta, S., Law, E. A., Kusworo, A., Hutabarat, J. A., Indrawan, T. P., Struebig, M., Raharjo, S., & Huda, I. (2017). Community forest management in Indonesia: Avoided deforestation in the context of anthropogenic and climate complexities. *Global Environmental Change, 46*, 60–71.

See, L., Fritz, S., You, L., Ramankutty, N., Herrero, M., Justice, C., Becker-Reshef, I., Thornton, P., Erb, K., & Gong, P. (2015). Improved global cropland data as an essential ingredient for food security. *Global Food Security, 4*, 37–45.

Shadkam, S., Ludwig, F., Van Oel, P., Kirmit, Ç., & Kabat, P. (2016). Impacts of climate change and water resources development on the declining inflow into Iran's Urmia Lake. *Journal of Great Lakes Research, 42*, 942–952.

Shakeri, R. E. Z. A. (2021). Quantitative analysis of changes in Urmia Lake basin from the past to the future with remote sensing and ecological change prediction model. *Journal of Environmental Science Studies, 6*(2), 3637–3643.

Shojaei-Miandoragh, M., Bijani, M., & Abbasi, E. (2020). Farmers' resilience behaviour in the face of water scarcity in the eastern part of Lake Urmia, Iran: An environmental psychological analysis. *Water and Environment Journal, 34*, 611–622.

Sowers, J., Vengosh, A., & Weinthal, E. (2011). Climate change, water resources, and the politics of adaptation in the Middle East and North Africa. *Climatic Change, 104*, 599–627.

Stephenson, J., Newman, K., & Mayhew, S. (2010). Population dynamics and climate change: What are the links? *Journal of Public Health, 32*, 150–156.

Tahbaz, M. (2016). Environmental challenges in today's Iran. *Iranian Studies, 49*, 943–961.

Taherei Ghazvinei, P., Hassanpour Darvishi, H., Hashim, R. B., Musav Jahromi, I. S. H., & Aghamohammadi, N. (2016). Assessment of climate change and land use development effects on dam reliability. *Journal Hydrology and Earth System Sciences (HESS).* https://doi.org/10.5194/hess-2015-481

Teklemariam, D., Azadi, H., Nyssen, J., Haile, M., & Witlox, F. (2015). Transnational land deals: Towards an inclusive land governance framework. *Land Use Policy, 42*, 781–789.

USDA Foreign Agricultural Service. (2021). *Eathshots, Lake Urmia Iran* [online]. Retrieved from https://eros.usgs.gov/image-gallery/earthshot/lake-urmia-iran#earthshot-stories

Verburg, P. H., Mertz, O., Erb, K.-H., Haberl, H., & Wu, W. (2013). Land system change and food security: Towards multi-scale land system solutions. *Current Opinion in Environmental Sustainability, 5*, 494–502.

Vitousek, P. M., Mooney, H. A., Lubchenco, J., & Melillo, J. M. (1997). Human domination of Earth's ecosystems. *Science, 277*, 494–499.

Wang, G., Mang, S., Cai, H., Liu, S., Zhang, Z., Wang, L., & Innes, J. L. (2016). Integrated watershed management: Evolution, development and emerging trends. *Journal of Forestry Research, 27*, 967–994.

Wheeler, T., & Reynolds, C. (2013). Predicting the risks from climate change to forage and crop production for animal feed. *Animal Frontiers, 3*, 36–41.

Wheeler, T., & Von Braun, J. (2013). Climate change impacts on global food security. *Science, 341*, 508–513.

Winslow, M., Shapiro, B., Thomas, R., & Shetty, S. (2004). *Desertification, drought, poverty and agriculture: Research lessons and opportunities*.

World Bank. (2008). *Sustainable land management sourcebook*. World Bank.

Zambrano-Monserrate, M. A., Carvajal-Lara, C., Urgiles-Sanchez, R., & Ruano, M. A. (2018). Deforestation as an indicator of environmental degradation: Analysis of five European countries. *Ecological Indicators, 90*, 1–8.

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