Chapter 11
Vulnerability Analysis of Farmers in the Roodasht Region, Iran

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11.1 Introduction

Climate change and water resource overuse have led to water scarcity in Iran over the years. This puts high pressure not only on Iran's environment but on sectors with high water consumption, like agriculture in particular. Agriculture does not only overstrain surface- and groundwater resources by excessive water withdrawal for irrigation but also by heavy pollution of the Zayandeh Rud river with agricultural inputs.

The area under investigation is located in the lower reaches of the river (see Fig. 11.1) and comprises the populated and cultivated lands served by the Roodasht irrigation network and nearby wells.[1] Roodasht borders on the Dasht-e Kavir desert in the north and east, and the Gavkhuni, a salt lake and marshland designated as UN Ramsar site, in the south-east. The population of the area is about 50,000 including more than 10,000 active farmers and their families.

After the Iranian revolution modern irrigation systems (Abshar and Roodasht network) were built to increase agricultural production, and in years with sufficient water resources the canals provide water for around 70,000 ha of cultivated area.

Climate change and resource depletion have resulted in extreme water shortage and ongoing desertification in the region. Ironically, cultivation has prevented the expansion of the desert at the same time. Drought periods, however, have brought the government to rationalize and frequently cut surface water supply to Roodasht.

[1] Although it is not its official (administrative) name of this region, for more convenient reading we will call it just "Roodasht" in the text but it is actually the "region served by the Roodasht irrigation network".

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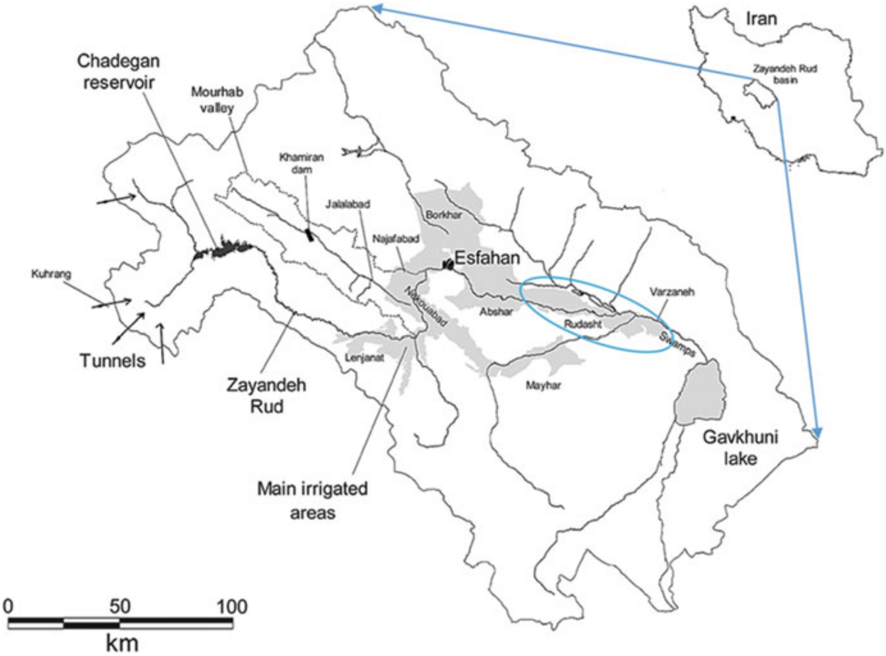

Fig. 11.1 Location of the Zayandeh-Rud basin and Roodasht region (source Molle et al. 2009)

As a result, farmers started to overuse local groundwater resources, which again led to dropping water tables and salinization.

Tensions between different water users have been increasing. Though farmers have received some financial compensation for their crop losses, all these measures are in no way sustainable or able to substitute a long-term strategy for land and water management. In order to develop a feasible and acceptable land use concept that helps stakeholders prevent or reverse land degradation and use water resources efficiently, it is necessary to depict the complex situation. A vulnerability assessment is an adequate tool to understand the sensitivity of farmers to water scarcity and possible starting point for developing adaptation measures.

11.2 Theoretical Framework and Method

Vulnerability is often conceptualized as the degree to which a system is susceptible to harm when exposed to hazards and risks (Turner et al. 2003; Adger 2006; Füssel 2007). However, in most cases, vulnerability itself is a consequence, resulting from underlying social and environmental conditions which need to be understood (Voss 2008).

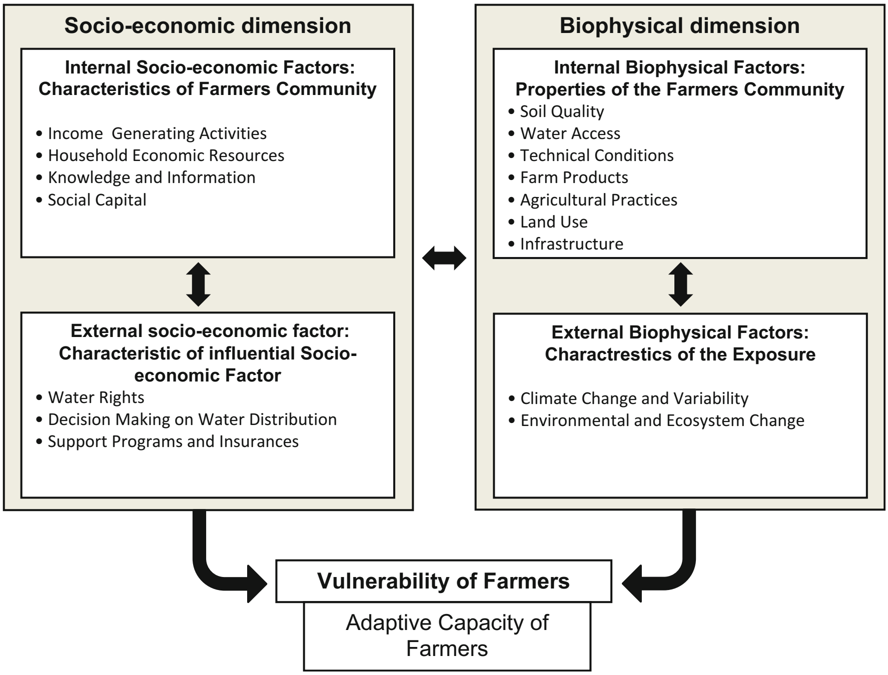

Fig. 11.2 Applied vulnerability framework (adapted from Füssel 2007)

Against this backdrop, the theoretical framework used to analyse the vulnerability of farmers to water scarcity in Roodasht is based on a comprehensive approach presented by H.M. Füssel (2007). According to Füssel, vulnerability is conceptualized by distinguishing among the internal and external spheres (or scales) and the socio-economic and biophysical knowledge domains. The internal sphere includes factors describing the properties of the vulnerable system or community itself, whereas factors from the external sphere describe aspects beyond the local community. By adapting Füssel's classification scheme, 16 factors to assess vulnerability of farmers to water scarcity in Roodasht have been classified and assorted to the overall structure of the vulnerability framework Fig. 11.2.

In view of these 16 factors, data collection and analysis was facilitated. It was based on a mixed method using both qualitative and quantitative data which include more than 20 site visits, a literature review, analysis of official data, 30 in-depth interviews with farmers, seven workshops and 30 interviews with experts from administration and civil society, and a remote sensing analysis.

Qualitative data of farmers' interviews and meetings with the experts were analysed topic by topic. Regarding selected internal and external factors, the data was subsequently examined, coded and categorized to identify relevant topics and issues. Extensive field notes collected during the site visits were used throughout the analysis and coding. Based on this, the main thematic fields of vulnerability in Roodasht were identified (see Sect. 11.3.1). Adaptive capacity as an important aspect of vulnerability (IPCC 2001; Smit and Wandel 2006) will be discussed in the conclusions only.

11.3 Vulnerability Assessment

This section presents the current state of vulnerability of farmers to water scarcity in Roodasht. The goal of this section is to characterize factors and conditions connected to water scarcity, which currently impact negatively on farmers and may ultimately lead to environmental degradation, desertification and social conflicts.

11.3.1 Thematic Fields of Vulnerability

The main cause for vulnerability of farmers in the region is their exposure to poor *water availability in Roodasht* during the last water scarce decade. Coupled with a range of connected factors, the lack of irrigation water in years gone by has led to significant cuts in local *agricultural production*, impacting negatively on *farmers' livelihoods*. Amongst others, the aspects mentioned have caused *regional entrepreneurship* to stagnate and restrict activities on *environmental conservation*. Adversely, the absence of ecologic and sustainable regional development negatively affects on-farm activities and the livelihood of farmers.

It has been found that in the past decade farmers have become increasingly vulnerable to water scarcity in Roodasht. With no structured and powerful counteractive measures, the main risks of *desertification and environmental degradation* as well as *social conflicts* are expected to lead to a crisis in the near future, while symptoms can already be observed today.

In Fig. 11.3 the thematic fields with associated conditions are found in the green boxes and characteristics in Roodasht in the blue boxes. Due to limited space in this chapter, only the main thematic fields will be discussed with selected aspects in detail.

11.3.2 Water Availability in Roodasht

In the past decade, the effects of climate change and particularly climate variability have led to variance in precipitation[2] and higher temperatures in the Zayandeh Rud basin and specifically in Roodasht; a phenomenon which is expected to continue in

[2]Natural precipitation in Roodasht is usually lower than 100 mm/a.

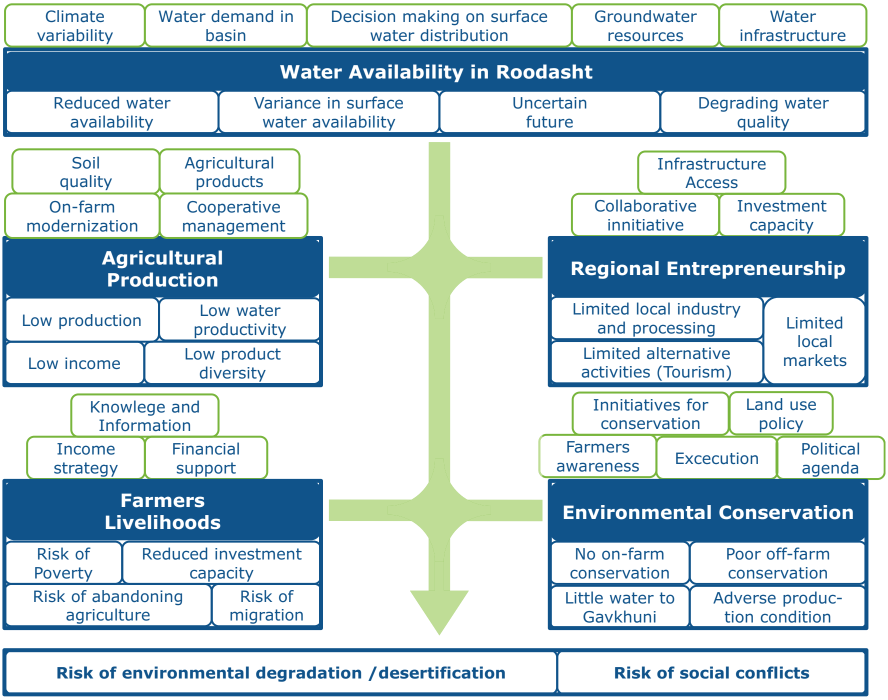

Fig. 11.3 Thematic fields of farmers' vulnerability in Roodasht

the future (Gohari et al. 2013; Eslamian et al. 2016). At the same time, the number of water users in the basin has increased due to population growth, economic development and intensified agricultural activities. The reduced water availability and increased competition for scarce water resources has led to significant cuts in water supply to the Roodasht irrigation network (see Fig. 11.4).

Decisions on water distribution in the Zayandeh Rud basin are made by a complex interaction of decision-making bodies on different levels based on available water stocked in the Zayandeh Rud dam as well as water rights and other criteria (for a detailed description see Chap. 3 in this volume). Interviews with farmers in Roodasht found that decision-making on water distribution is highly unclear to them, leading to great uncertainty regarding future water availability for agriculture. A notion of being deprived of water rights illegitimately consequently leads to a perception of exclusion and fraud.

Figure 11.5 shows the amount of available water in the Zayandeh Rud dam and water diverted to the Roodasht irrigation network between 2006 and 2015. Parallel to a downward trend of the water stock in the dam, surface water division to the

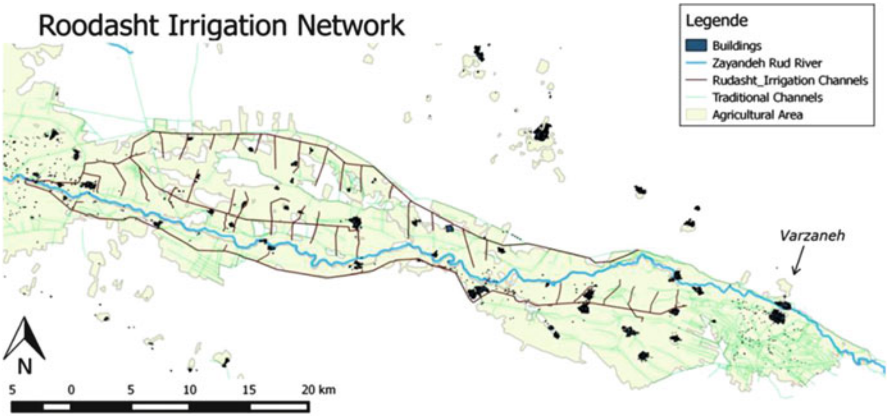

Fig. 11.4 Irrigation network Roodasht area

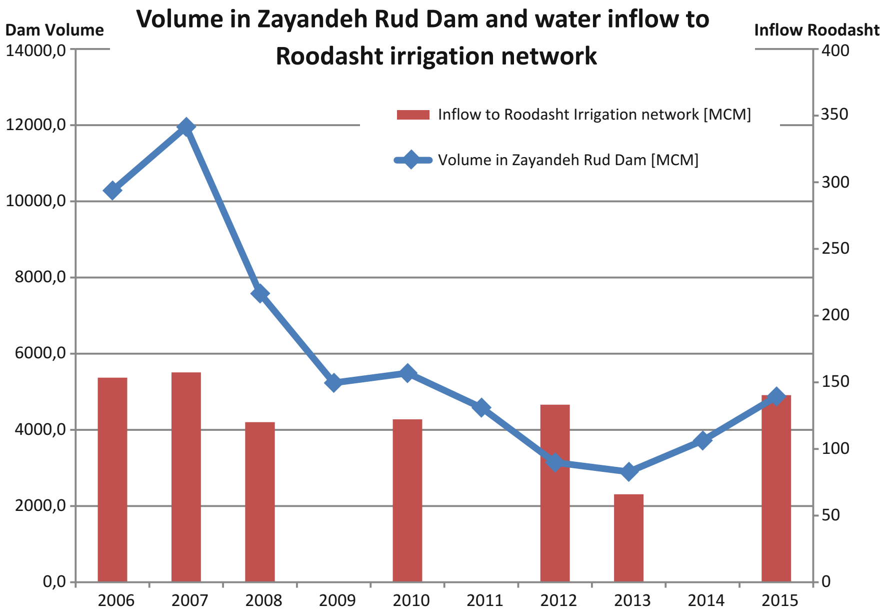

Fig. 11.5 Time series on annual water stock in the Zayandeh Rud dam and water supply to Roodasht irrigation network (data source: Isfahan Water Board Company). (A water year is presented with figures from September of the last year, until September of the given year. For example for a figure of the year 2015, data from September to December 2014 and January–September 2015 are presented)

Roodasht irrigation network is decreasing and shows strong fluctuations with several dry years with no water supply at all. In normal years water is supplied to Roodasht twice a year (in spring and autumn).

Most farmers in Roodasht use water from the irrigation network combined with other water resources which allows for farming for a period of time independently of surface water availability. Other water sources are wells, a few qanats[3] and springs. For the hydrological unit (Kouhapayeh-Segzi plain) where the Roodasht irrigation network and parts of the Abshar irrigation network are located, data from 2006/2007 suggest that almost 99% of exploited "other water resources" originate from approx. 8000 semi-deep/shallow and few deep wells.[4]

Data from the Isfahan Water Board Company also show that the yield of wells decreased by around 42% even though the number of wells increased by 11% between 2006 and 2012. The limited extraction volume may be due to declining groundwater quantity and quality in terms of salinization (with extreme EC values of up to 20 dS/m), which makes wells partly unproductive for agricultural activities. Degrading groundwater resources were also bemoaned during farmer interviews.

According to experts, increasing ground water salinity during the past decade is mainly caused by dropping groundwater tables. Limited water supply to the Roodasht irrigation network and the downstream region of the Zayandeh Rud river reduces recharge of particularly shallow aquifers and fosters overexploitation of these. Figure 11.6 shows an approx. 2 m decrease of groundwater tables of five shallow wells within 7 years between 2006 and 2013, with the most significant drops in periods of cut irrigation water in Roodasht. The figure highlights the sensitivity of shallow groundwater to surface water supply.

The complexity of problems around water availability in Roodasht is the main root cause for the thematic fields of vulnerability discussed in this chapter.

11.3.3 Agricultural Production

11.3.3.1 Soil Quality

Long-term degrading soil quality of farmland in Roodasht is a threat to high agricultural potential and fosters desertification. The main parts of agricultural soil in Roodasht have high clay content, little organic carbon and are saline/alkaline. Particularly when soils are dried out, these conditions imply a high risk of reduced productivity of soil and erosion, fostering the process of desertification.

Reduced availability of surface water forces farmers to irrigate excessively with saline groundwater to sustain their production which inevitably leads to accumulation of salts in the soil (experts report salt concentrations with EC of up to 14 dS/m). Soil degradation by salinization/alkalization has an adverse effect on agricultural yields (see Fig. 11.7) and may lead to abandoning or pausing agricultural activities

[3]Traditional underground channel with a series of vertical access shafts, used to transport water from an aquifer under a hill.

[4]Additional to these official wells, experts expect high numbers of illegal wells in Roodasht.

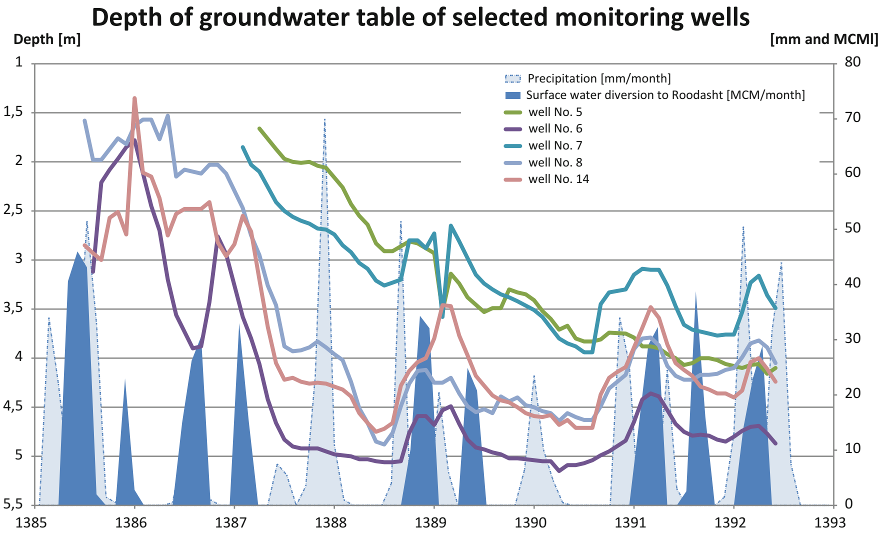

Fig. 11.6 Depth of selected monitoring wells in Roodasht with data on water supply and precipitation (data source: Isfahan Water Board Company)

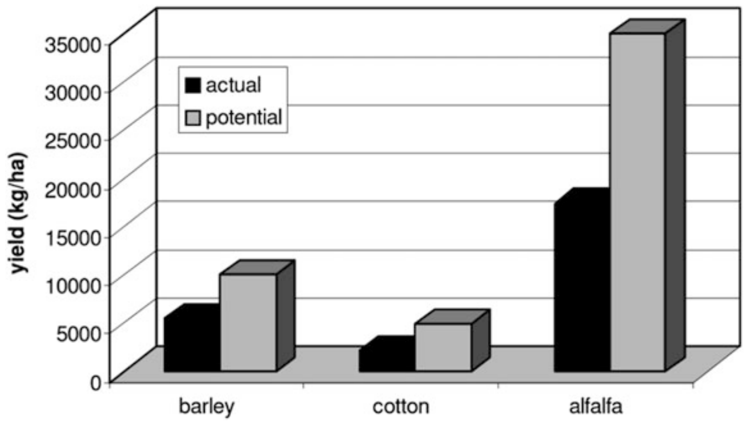

Fig. 11.7 Yield gap of selected crops due to soil and water salinization in Roodasht (source: Salemi et al. 2000)

in dry years, which increases the risk of desertification and further loss of productivity of soils.

Salinization and reduced productivity of the soil is aggravated by unfavourable agricultural practices. In general, sustainable conservation agriculture with minimal soil disturbance, permanent soil cover and crop rotations are only practiced in rare exceptions in Roodasht due to limitations in knowledge and skills as well as access to adapted farming equipment.

Regarding biomass management, the main part of the crop residuals, is removed from the field and used or sold as livestock fodder. About 1/3 of the farmers interviewed use manure as additional fertilizer but state that high costs and limited availability are practical restrictions for application, even though they are aware of the potentially positive effects on their fields.

All farmers interviewed use mineral fertilizer and pesticides/herbicides on their fields to sustain productivity. Experts note that fertilizer application is not very efficient, due to limited knowledge on soil-water-plant relationships and has the potential to further increase salinity of soils.

11.3.3.2 Cultivated Area

Next to long term effects on soil quality, cuts in surface water supply to the Roodasht irrigation network have a direct effect on the extent of cultivated areas. Figure 11.8 shows the cultivated areas in Roodasht split into areas being harvested (black column) and areas being planted but not harvested (black and white column) for the years between 2006 and 2015. The figure also shows the annual water supply (orange line) to the Roodasht irrigation network with a percentage of volume of annual water being supplied in spring time (February to July). Cultivated areas derived from remote sensing data[5] analysis are also included in the figure.

The figure shows the direct relationship of water supply and cultivated areas in Roodasht. A good proportion of cultivated areas could not be sustained and were not harvested in 2008 when surface water supply to the Roodasht irrigation network started to decrease. A reason for this may have been the decreased proportion of water being supplied during spring time (84% in 2007 and 60% in 2008) which is essential particularly for winter crops like wheat and barley (farmers have enough water to plant but not to sustain their crops over the year). This effect can also be observed in 2010 and 2012.

In the years 2009, 2011, and 2014 some cultivated areas could be sustained even without water from the irrigation network. The dataset indicates that these areas were irrigated by groundwater only and are presumably connected to (deep) wells in certain locations taping a productive aquifer resilient to limited recharge. Nevertheless a decreasing trend in water scarce years in these areas can be observed.

Interestingly in the years 2010, 2012, and 2015, the level of cultivated areas decreased by around 40% in comparison to the years 2006–2008, where similar amounts of surface water were available in Roodasht. According to experts, the reason for this phenomenon might be a strong increase in salinity and decline of (shallow) groundwater resources after dry years, which takes time to restore its capacity when surface water is available again. These restrictions for conjunctive water use leads to limitations of cultivated areas. Furthermore, agricultural areas

[5]Annual cultivated areas from the remote sensing mission (Landsat Program) have been derived by merging detected cultivated areas from the months April, May and August for each year.

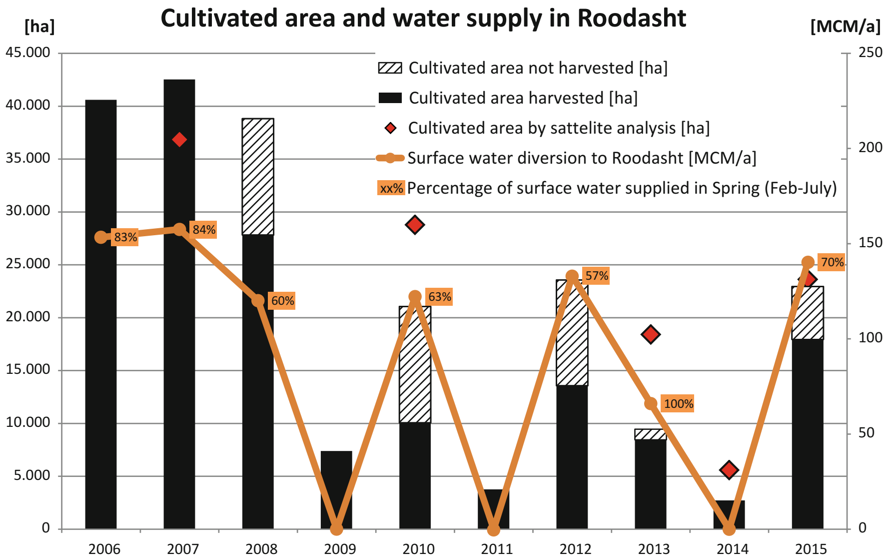

Fig. 11.8 Time series, cultivated areas merged with data on water distribution to Roodasht irrigation network and remote sensing data (data sources: AOI and Isfahan Water Board Company). (An agricultural and water year runs from approx. 20.September-20.September and is named according to the year where the calculation ends. For example: 20.9.2014–20.9.2015 is presented for the year 2015)

which are not irrigated frequently by surface water are expected to have an increase in soil salinization, making them prone to degradation and desertification particularly in desert border regions. It is assumed that these areas have been abandoned during dry years and are not easily rehabilitated to agricultural production during times when irrigation water is available. Cultivated areas in these border regions abandoned after 2007 can be observed for the downstream region of Roodasht. Figure 11.9 shows remote sensing images of cultivated areas in Roodasht for the years 2007, 2010, and 2015 are presented.

Another reason for low production in Roodasht is the common presence of small farms that are fragmented to different plots, which is typical for Iran (Ahmadpour et al. 2013). Kalantari and Abdollahzadeh (2008) and Soltani (1978) point out that the size and fragmentation of plots is an important factor for yields and production costs. Arsalanbod and Esmailpour (2000) show that for wheat production both a 1% increase in farm size or a 1% decrease in fragmentation of plots leads to a 0.4% decrease in production cost. Despite governmental subsidies, the uptake of land defragmentation measures is generally low in Roodasht since it requires cooperation between farmers, establishment of a cooperative company as well as a certain spread of know-how and investment capacity of farmers' households.

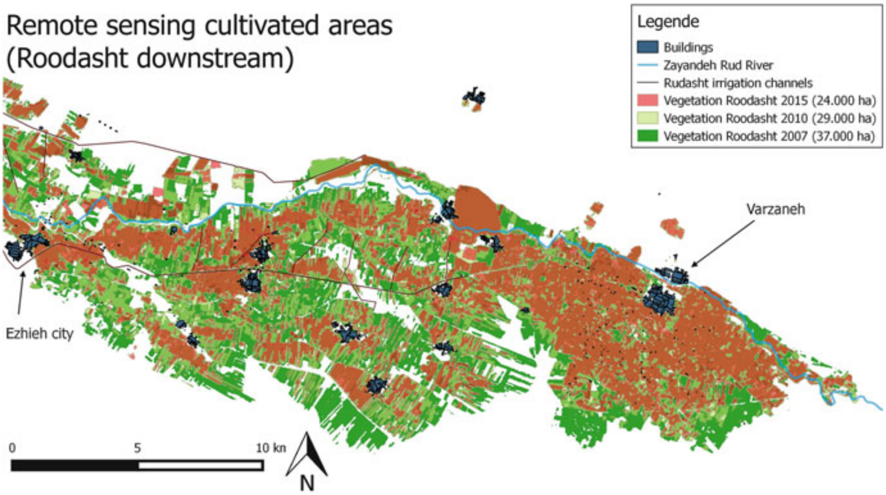

Fig. 11.9 Downstream part of Roodasht irrigation network with areas cultivated in 2007, 2010, and 2015 detected by remote sensing (data source: Technical University of Berlin, Hengsbach)

11.3.3.3 Agricultural Products

The choice of agricultural products is strongly dependent on local biophysical and infrastructure conditions, but determines income generation, options for local entrepreneurship and resilience of farmers towards water scarce conditions.

Crop choice in Roodasht is limited and dominated by (winter) wheat and barley, covering around 80% of the planted area. These grains are relatively salt tolerant, but have comparably long cultivation periods which make them dependent on irrigation water for several months, implying a high vulnerability to cuts in irrigation water particularly in spring time.

Most farmers interviewed with access to deep wells stated that they also plant other crops like alfalfa, cotton, beet, safflower, lettuce or millet and broom sorghum or were even thinking about setting up an orchard with pistachios or pomegranates.

Data on cropping patterns in Roodasht confirm the limited crop choice on fields with access to surface water and shallow wells in comparison to farms with access to deep wells or very productive aquifers (Fig. 11.10).

Figure 11.11 shows the cultivated areas for different crop types between 2006 and 2015 as well as the annual water supply to Roodasht (orange line). The proportion of wheat and barley of the total cultivated and harvested area was around 75% between 2006 and 2008. In water scarce years with low overall production this percentage decreases to 50% as more diverse production with groundwater irrigation occurs. In 2015 wheat and barley accounted for 90% of the cultivated areas. It seems these grains are the “safe option” particularly for farmers relying on surface water and shallow wells.

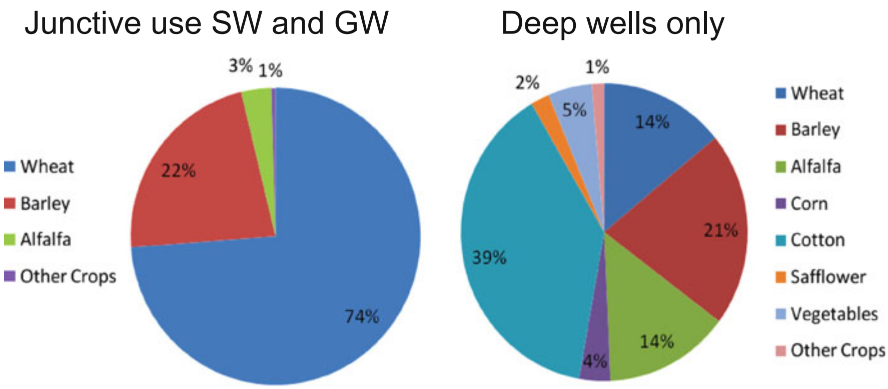

Fig. 11.10 Percentage of cultivated crop types [ha] for Bonroud district in 2015, split into areas with surface water and shallow well access only and areas with access to deep wells (source: Agricultural Organization Isfahan)

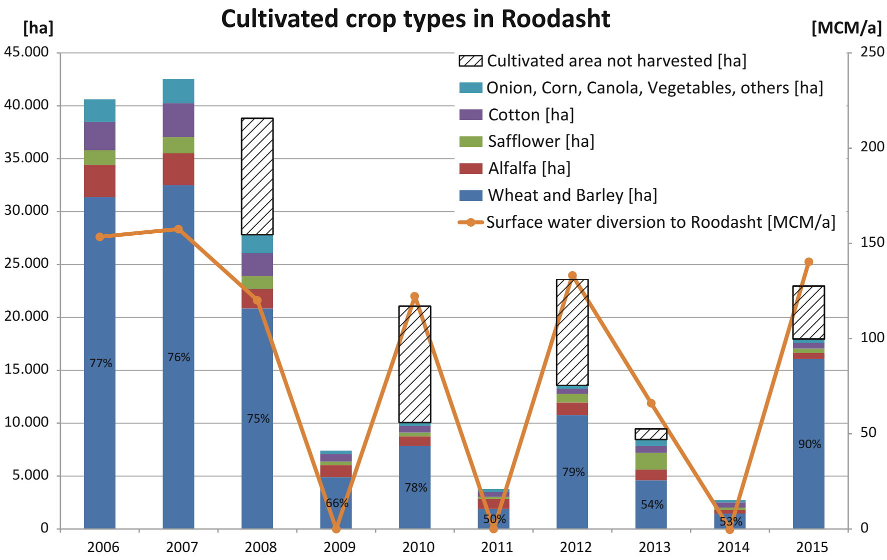

Fig. 11.11 Time series, cultivated crop types, merged with data on water distribution to Roodasht irrigation network. *Percent figures* show the proportion of wheat and barley of the correlating column (sources: AOI and Isfahan Water Board Company) (An agricultural and water year runs from approx. 20.September-20.September and is named according to the year where the calculation ends. For example: Data on water supply and cultivation between 20.9.2014–20.9.2015 are presented for the year 2015)

With regards to yields, wheat and barley are dominant in the region, followed by onion, corn and vegetables. Data show that yield per ha have not changed significantly over the years.

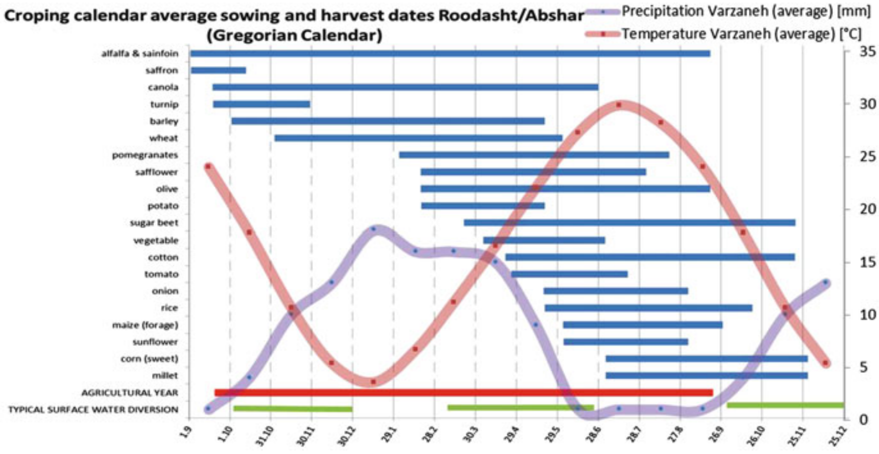

Fig. 11.12 Crop calendar for Roodasht and Abshar region, with the time period of an agricultural year and typical periods of surface water diversion to Roodasht irrigation network and average precipitation and temperatures in Varzaneh (source: Agricultural Organization Isfahan, Isfahan Water Board Company, climate-data.org)

Figure 11.12 presents an average cropping calendar for the Roodasht and Abshar regions. Time periods of an agricultural year and of typical surface water diversion to the Roodasht irrigation network are included. The figure also shows average precipitation and temperature data, related to the time scale. Comparing irrigation water availability and possible crops, it becomes obvious that timing of irrigation water does not support the cultivation of certain crops (e.g. saffron, corn, millet, etc.). It also shows that a large proportion of possible crops would be cultivated during the hottest period of the year (June to October) with almost zero precipitation, and typically no irrigation water supply to Roodasht's irrigation network. Due to an estimated irrigation water demand[6] for wheat and barley between November and May with a peak between March and May, the timing of surface water supply is optimal for these crops.

Crop choice of farmers is not very diverse in the region. During interviews, all farmers stated that the choice for wheat and barley is mainly due to low water demand and stress tolerance to drought and saline conditions, marketing at guaranteed prices with cooperative companies, production of own seeds, tradition and household consumption.

In general, there is only limited availability of improved seeds, markets for alternative products, adapted equipment but also know-how and motivation of farmers for cultivating alternative crops. Only few alternative crops like chamomile, castor seed and dill are planted on experimental farms of the Agricultural Research Centre and Agricultural Service Centres, which are used for presentation and training or by few pioneer farmers.

[6] Calculated Evapotranspiration in Varzanhe Plain with NETWAT software.

11.3.3.4 On-Farm Modernization

On-farm modernization to water-efficient agricultural production systems in Roodasht is restricted due to a range of factors. In general technical modernization is constrained due to perceived irrationality to invest in the farming sector due to high insecurity of future water availability, limited household investment capacity and little motivation to change the farming system intensively for traditional reasons and a lack in knowledge and skills, particularly among old farmers. Furthermore, experts stated that due to limited investment by farmers in past dry years, the coverage and quality of required service provision by consultancy and technical service companies has decreased. Hence, despite several governmental efforts and programs for on-farm modernization, traditional agricultural production methods with high water demand, high dependency on surface water and limited crop choice have hardly changed.

11.3.4 Farmers' Livelihoods

Knowledge of farmer households is focused on farming, deeply rooted in everyday practices, experience and skills acquired over time. Know-how is not necessarily related to formal education, as most of the interviewees have only an elementary school education. New information on farming aspects are acquired from Agricultural Service Centres and consulting companies through attending training or bilateral talks with pioneer farmers. Media, such as TV, radio or in limited cases the internet, adds to social and religious networks being used for obtaining information on farming and non-farming aspects. However, only young farmers perceive themselves as capable and willing to change and adapt their agricultural practice or start a different type of income generating activity.

But, options for income diversification through working in non-farm occupations as in local manufactories, processing facilities, industry, mines or tourism are rare in Roodasht. Farmers who pursue non-farming activities usually work as builders or drivers in the cities. Nevertheless these jobs are mainly seasonal occupations and imply low long-term income stability.

The livelihood of 75% of the farmers interviewed is entirely dependent on income generating farming.[7] For farmers with alternative sources of income, farming still accounts for more than 50% of the household income. Consequently, during water scarcity and when they could not farm, they suffered from significant cuts in their household income. There are insurances for crop loss and social security, but farmers stated that these hardly cover living costs. As one third of the interviewees own livestock, this can be an important asset during times of

[7]Farmers state to earn gross around 60–180 M IRR (1.500–4.500€) per ha a year when cultivation is possible.

low agricultural production. However, due to increased production cost and dropping prices in an unstable livestock market, many livestock keepers have sold their whole livestock below value.

The focus on traditional farming in combination with the cut in agricultural production caused significant reductions of income for farmers' livelihoods from 2009 onwards. In this situation, farmers are highly dependent on governmental financial support and loans which have piled up over successive dry years to become a huge financial burden. Continuous low agricultural incomes, financial burden of loans and debts as well as heavy inflation, make farmers prone to poverty and cause a lack of investment capacity to fund modern, adapted agricultural production systems or alternative non-farming activities. This tense situation and the risk of poverty provokes the abandoning of agriculture in order to gain income through selling land and equipment, reduce running costs for sustaining agricultural lands, or reduce the dependency on water availability. This situation makes young people in particular migrate into cities. Migration of larger numbers of farmers to cities entails the risk of segregation of this poor and poorly educated group in slums, leading to social tensions with vast impacts on cities as seen in many examples around the world.

11.3.5 Regional Entrepreneurship

Particularly in rural areas, poor access to production means like energy, water and gas infrastructure hinders local development potential for industry. This holds particularly true for processing industries (commodity chains) connected to the agricultural sector where uncertainty on future water availability makes large investments of entrepreneurs risky and irrational.

Commodity chains in the form of processing and marketing facilities for agricultural products could also be implemented collaboratively by farmers by way of cooperative companies. This type of farmers' entrepreneurship was founded in some cases particularly with livestock keepers. Establishing farmer-owned processing facilities requires know-how and a powerful collaborative initiative by farmers, which is rare in Roodasht, as in most other parts of Iran. The main reasons are mistrust amongst the members, inefficient management, a lack of experts, the lack of adequate relationships and networks between governmental organizations and rural communities, the absence of necessary equipment and facilities, and the lack of credits and vital agricultural inputs (Azkia 1992; Azkia and Ghafari 2013). Figures on the whole Zayandeh Rud basin show that with less than 6%, agricultural exploitations with cooperative companies are rather low compared to 94% individual farmers operations (Yekom 2012).

Moreover farmers' households need to dispose of a certain investment capacity to set up a business, which has diminished during dry years. To access a large share of the governmental support programs a functional cooperative structure is required. Cooperative management in terms of shared investment and joint action is a way for farmers to reduce production costs and increase agricultural productivity and income generation. In the form of NGOs and later as syndicates or cooperative companies, they could also develop alternative non-farming related activities like local (eco-) tourism. But touristic development requires an intact ecosystem, particularly in the Gavkhuni wetland as one of the regional highlights which has degraded in the last decade.

The limited regional entrepreneurship is the main reason for poor local market demand for regional (raw) products as well as little alternative employment options for farmers.

11.3.6 Environmental Conservation

Environmental degradation through desertification is an ongoing process in Roodasht. As shown in Fig. 11.13, the land cover and environment around the Roodasht irrigation network is dominated by desert and poorly vegetated range lands. Water scarcity, loss of natural ground cover, limited agricultural activities, strong winds and dust storms as well as salinization/alkalinisation of soils are drivers of an ongoing desertification process with rapid land degradation (Barzani and Salleh 2015). The Gavkhuni wetland, the mouth of the Zayandeh Rud river, is

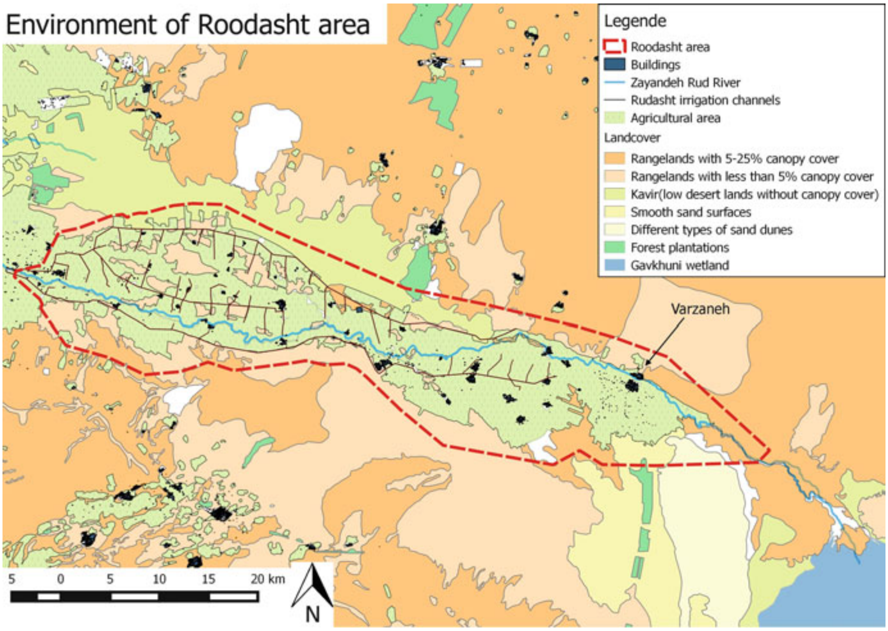

Fig. 11.13 Land cover around Roodasht irrigation network

drying out (Iranmehr et al. 2015), deteriorating the micro climate, and fostering dust storms.

The absence of conservative agricultural practices with permanent crop cover, mulching or low tillage as well as excessive application of mineral fertilizers on agricultural fields exacerbates the situation. Initiatives for environmental conservation on private land in the form of financial incentives, bids or bans, targeted information or training on conservative i.e. alternative agriculture, could not be observed. The transformation of fertile natural areas into urban or agricultural areas, free livestock grazing as well as mining activities have also degraded the quality of remnant range land patches (Bateni et al. 2012).

Little executive control of environmental offences like damaging range lands by free grazing livestock, uncontrolled mining activities or illegal water extraction from wells or from the Zayandeh Rud river, give farmers no initiative to practice environmental conservation. A reason for little execution power on the field is also that interest groups such as environmental NGOs have little, although growing, legal embedment and support.

11.4 Conclusion

With the application of an adapted conceptual framework from Füssel (2007), a range of vulnerability factors from the socio-economic and biophysical domains have been considered. Since these conditions have not yet been targeted with powerful policy measures or action plans, two main risks could be identified which are expected to grow and lead to a crisis in the near future: desertification/ land degradation and social conflict.

A high risk of desertification is founded in soil erosion and salinization, abandoned agricultural lands, little desertification control and environmental conservation, and drying out of Gavkhuni with its central function of stabilizing the local microclimate. This may have severe impacts on agricultural activities and human settlements in the whole region, risking the regional environment to degrade and making the region uninhabitable. Long term effects on the neighbouring Abshar irrigation network and even Isfahan city, with increasing sand and dust storms and changing microclimate are possible.

A high risk for social conflicts is the short and long term effect of a feeling of farmers being deprived by decision-makers and the high risk of impoverishment. The traditional form of farming is eroding and the only options seem to be to migrate to cities or remain in poverty. This setting has already caused several, also violent, protests but may escalate in the future.

Nevertheless, any kind of external stress always triggers a reaction from farmers. Adaptive capacity can be defined as the ability of farmers to adapt to external factors like water scarcity and is determined by a range of internal factors (Smit and Wandel 2006; Füssel and Klein 2006). The aspects of adaptive capacity identified, economic resources, collaborative networks, knowledge and information, infrastructure and technology, are currently low in Roodasht, but may serve as a possible entry point to develop strategies for sustainable land use and management concepts in Roodasht.

Knowledge and information dissemination are key factors for farmers for understanding the drivers of their current vulnerability and to developing adapted solutions. Informed local people can also participate in regional planning with governmental institutions.

Improved access to economic resources e.g. by targeted funding, public private partnerships or governmental incentives might empower farmers to invest in farm modernization and water-efficient agriculture or local processing facilities and other types of regional entrepreneurship. Furthermore, financial incentives to allow farmers to cover their livelihood costs with on-farm conservation measures may boost environmental conservation and reduce regional water demand.

Support and facilitation of collaborative networks e.g. by targeted training and information campaigns may enable farmers to create powerful cooperative companies. Functional cooperative companies may lead to higher uptake of land defragmentation projects, sharing farming equipment or even establishment of cooperative commodity chains, alternative income activities like eco-tourism which creates jobs and income for farmers' livelihoods, as well as a market for alternative crops.

Focused information and training campaigns could, for example, be implemented for promoting alternative farm products to more adapted species, to enable farmers to follow other jobs and develop local business, to increase farmers' awareness on environmental conservation and show opportunities for their livelihoods through these practices.

Improved access to adapted infrastructure and technology may empower farmers to adapt their farming system to modern and water efficient farming practices. Introducing environmental technologies such as decentralized energy production could support the development of local processing industry and give opportunities for local people to combine income generation with environmental conservation.

References

Adger WN (2006) Vulnerability. Glob Environ Chang 2006(16):268–228

Ahmadpour A, Feali S, Soltani S (2013) Factors affecting farmers' resistance to adoption of land consolidation case study: paddy farmers in Mazandaran province, Iran. Int J Agric Crop Sci 5(23):2871. SABI Publications

Arsalanbod M, Esmailpour A (2000) Effect of farm smallness and fragmentation of productive units on production costs: case of irrigated wheat in West Azerbaijan. Agric Econ Dev Q J 8(2): 109–116

Azkia M (1992) An evaluation of production cooperative in the Marun catchment. Zomar Consultant Engineering, Tehran, pp 81–105

Azkia M, Ghafari G (2013) Rural development, with emphasis on Iranian rural society, 4th edn. Nashreney, Tehran. (in Farsi)

Barzani MM, Salleh KO (2015) An integrated desertification hazard assessment in Iran. Int J Appl Environ Sci 10(5):1823–1834

Bateni F, Soffianian A, Fakheran S (2012) Rangeland degradation and its impacts on water quality in Zayandehroud River Basin. In: Nejadkoorki F (ed) International conference on applied life sciences. InTech, Rijeka, pp 117–121

Eslamian S, Safavi HR, Gohari A, Sajjadi M, Raghibi V, Zareian MJ (2016) Climate change impacts on some hydrological variables in Zayandeh-Rud River Basin, Iran. Isfahan University of Technology, Isfahan

Füssel H-M (2007) Vulnerability: a generally applicable conceptual framework for climate change research. Glob Environ Chang 17:155–167

Füssel H-M, Klein RJT (2006) Climate change vulnerability assessments: an evolution of conceptual thinking. Climatic Change 75(3):301–329

Gohari A, Eslamian S, Abedi-Koupaei J, Bavani AM, Wang D, Madani K (2013) Climate change impacts on crop production in Iran's Zayandeh-Rud River Basin. Sci Total Environ 442: 405–419. Elsevier

IPCC (2001) Climate change 2001: the scientific basis. In: Houghton JT, Ding Y, Griggs DJ, Noguer M, van der Linden PJ, Dai X, Maskell K, Johnson CA (eds) Contribution of working group 1 to the third assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge

Iranmehr M, Pourmanafi S, Soffianian A (2015) Ecological monitoring and assessment of spatial-temporal changes in land cover with an emphasis on agricultural water consumption in Zayandeh-Rud Region. Iran J Ecohydrol 2(1)

Kalantari K, Abdollahzadeh G (2008) Factors affecting agricultural land fragmentation in Iran: a case study of Ramjerd Sub District in Fars Province. Am J Agric Biol Sci 3(1):358–363

Molle F, Ghazi I, Murray-Rust H (2009) Buying respite: Esfahan and the Zayandeh-Rud River Basin, Iran, in river basin trajectories: societies, environments and development. International Water Management Institute, Colombo

Salemi HR, Mamanpoush A, Miranzadeh M, Akbari M, Torabi M, Toomanian N (2000) Water management for sustainable irrigated agriculture in the Zayandeh Rud Basin, Esfahan Province, Iran. International Water Management Institute, Colombo

Smit B, Wandel J (2006) Adaptation, adaptive capacity and vulnerability. Glob Environ Chang 16: 282–292

Soltani GR (1978) Small farm versus large farm development in Iran. Indian J Agric Econ 33(3): 94

Turner BL, Kasperson RE, Matson PA, McCarthy JJ, Corell RW (2003) A framework for vulnerability analysis in sustainability science. Proc Natl Acad Sci 14(100):8074–8079

Voss M (2008) The vulnerable can't speak. An integrative vulnerability approach to disaster and climate change research. J Civilis 1(3):39–56

Yekom consultants (2012) Agricultural studies report. Ministry of Energy, Deputy of Water and Wastewater, vol 9