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Drought Risk Assessment: Towards Drought Early Warning System and Sustainable Environment in Western Iran

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Abstract

Prolonged drought is considered as a creeping natural hazard, which has created a financial burden and unsustainable environment in Iran. Moreover, the effect of drought phenomenon in rural areas is more extensive, causing significant challenges to the rural economy in general and agricultural production in particular. A common strategy to manage drought is based on crisis management (ex-ante). However, for effective drought management, risk management seems to be more in line with drought early warning systems. This quantitative study used risk assessment, which is the function of two elements such as hazard (SPI and SDI indices) and vulnerability (exposure, sensitivity, and adaptive capacity). This study aims to build the foundations for drought early warning systems in limited resource areas such as Kermanshah Township in the northwestern part of Iran. The population of this study comprised of wheat farmers in which 293 farmers were selected using multistage cluster sampling method. In the next step, the drought risk map for Kermanshah Township was developed, which revealed that the majority of villages are at intense environmental risk. The result of this study has implications for drought management practitioners. For example, the results can aid policymakers in the design of an early warning system in order to reduce risk and thus empower farmers toward resilient farming.

Keywords: Drought; Early warning system; Risk management; Vulnerability; Environmental risk; Resilient farming.

1. Introduction

Iran is located in a dry and semi-arid climate (Daryabari, 2011). Consequently, dry years are more prevalent than wet ones, which lead to prolonged drought incidents in the country every few years or even in continuous years (Daryabari, 2011; Babaee Fini and Alijani, 2013). Recently, the head of the National Center for Climatology in Iran announced that over the next 40 years, the Middle East region, including Iran, will face severe drought for 30 years (Jamshidi, 2016). This growing threat has extended throughout the country, more specifically in the western part of Iran, including Kermanshah province.

Moreover, the effect of drought phenomenon in rural areas is more extensive as it can lead to significant challenges to the rural economy in general and agricultural production in particular. In fact, reducing rainfall and its impact on surface and underground water flows, along with inappropriate water management, have caused farmers to experience the worst drought conditions and thus become more vulnerable to them (Zarafshani et al., 2012). Studies show that the vulnerability of rural communities is in fact related to crisis management in Iran (Karami, 2009). Many researchers have clearly indicated that crisis management is significantly non-productive, untimely, and not economically viable (Knutson et al., 2001; Thurow and Taylor, 1999; Wilhite, 2017; Gerber and Mirzabaev, 2017; Zhao et al., 2017). However, for effective hazard management such as drought control, some scholars believe that planning should be based on environmental risk management. Although researchers have contended that for risk management strategy, it is imperative to launch an early warning system (Wilhite et al., 2014), this strategy is not well-appreciated among disaster policy-makers in Iran (Sharafi, 2017).

The current study is novel due to implementing mutually compatible methodologies as a means of comprehensively assessing drought costs and impacts. Currently, it is difficult to compare many available estimates of drought costs. Therefore, in this study, the main step is to establish a drought early warning system to conduct a continuous risk assessment. Drought risk assessment helps in identifying drought prone areas towards enabling policy-makers to provide the necessary information and warn farmers based on the risk map of regions. Drought risk assessment provides the opportunity to reduce the high cost of crisis management, which in turn increases the resilience of farmers and leads to sustainable production.

Therefore, the main objective of this study is to assess drought risk at farm level and build the foundations for drought early warning systems in Kermanshah Township. Toward this end, the specific objectives are as follows: i) reviewing several methodologies to come up with economic drought impact assessments and describing the main obstacles and opportunities facing the transition from crisis management to risk management, ii) exploring the drivers of ex-ante and ex-post actions against drought, iii) determining the main actions linked with co-benefits beyond the management of drought risk, and iv) establishing a drought early warning system to conduct a continuous risk assessment using the function of two elements such as hazard (SPI and SDI indices) and vulnerability (exposure, sensitivity, and adaptive capacity). The risk assessment is a part of a drought early warning system, and this paper would shed light on establishing a drought early warning system.

1.1.Risk assessment

Risk assessment is a common type of risk knowledge creation. Moreover, the risk assessment process has three steps: (i) identifying the nature, location, intensity, and probability of a threat (hazard assessment); (ii) determining the existence and degree of vulnerability and exposure; and (iii) identifying the coping capacities and resources available to address or manage threats. Risk knowledge has the benefit of allowing decision-makers and the community to understand their exposure to various hazards and their social, economic, environmental, and physical vulnerabilities (Zhang, 2004; Chang Seng, 2010).

Risk is a combination of hazard, vulnerability, and coping capacity. ISDR expresses risk in the context of the probability of harmful consequences or expected losses (i.e., deaths, injuries, property, livelihoods, disrupted economic activity, or environmental damage). These consequences result from crossovers between natural or human-induced disasters and vulnerable conditions (UN/ISDR, 2004; Gao et al., 2018). In this direction, Sönmez et al. (2005) have estimated that the drought poses a significant risk to agriculture in the south-eastern region of Anatolia from a climatological perspective. In addition, Kahraman and Kaya (2009) estimated the drought risk of Istanbul dams using several processes-based indices, and Şen et al. (2012) estimated the drought risk associated with crop productivity for future projection.

1.1. Vulnerability assessment

Hazard is defined as a phenomenon that causes harm or loss to people's lives (Multihazard Mitigation Council, 2002). Hazard leads to social, economic, and environmental impacts (Aliasgar, 2012). In this research, drought is defined as a hazard, and its evaluation is based on indicators such as frequency, duration, and severity of drought. Assessing the frequency, duration, and severity of the drought is extremely important in planning future policy actions to reduce the potential damages (Rajsekhar et al., 2015). Risk assessment is not only relevant to hazard but also relevant to the vulnerability. Accordingly, the concept of vulnerability will be reviewed in the next section. The vulnerability assessment provides a framework for identifying the social, economic, and environmental causes of a disaster (Zarafshani et al., 2016) and is a central moment in adaptation activity to mitigate adverse climatic impacts such as drought (Corobov et al., 2013). In recent decades, a considerable number of studies (Füssel and Klein, 2006; Füssel, 2007; Reed et al., 2013) have focused on vulnerability to climate change. The result of such studies has led to several frameworks for vulnerability assessment. Among vulnerability assessment models, the Intergovernmental Panel on Climate Change (2001) has presented a model, which can be generalized to our context in Kermanshah Township (Fig. 1).

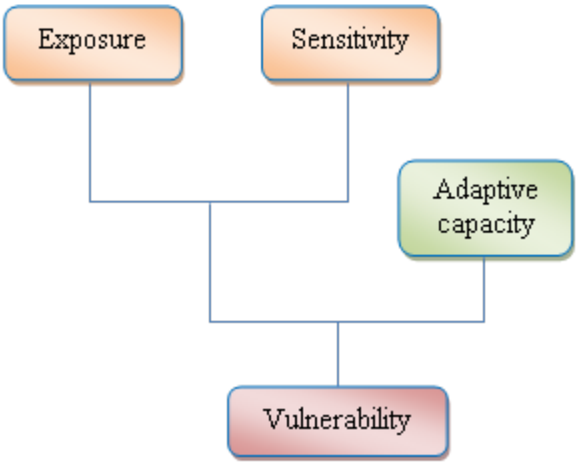

Fig. 1. Vulnerability model presented by the IPCC (2001).

According to IPCC (2001), vulnerability is defined as the extent to which a natural or social system is susceptible to damage from climate change. Furthermore, vulnerability is a function of three attributes: 1) the “exposure” of a particular system to climate change, 2) the “sensitivity” of the system to climate change, and 3) the “adaptive capacities” of the system to cope with losses when exposed to climate change. Exposure is related to the degree in which a system is exposed to environmental, political, and social stresses. Sensitivity is the degree in which a social system is susceptible to hazards such as drought (Fontaine and Steinemann, 2009). Adaptive capacity tends to reduce stressful conditions. In other words, farmers with high adaptive capacity tend to mitigate the harmful effect of drought. The IPCC model has been considered by many researchers when measuring vulnerability (Sharma and Patwardhan, 2008; Fontaine and Steinemann, 2009; Gizachew and Shimelis, 2014; Nazari et al., 2015; Zarafshani et al., 2016; Zarafshani et al., 2019).

Garcia et al. (2011) used biophysical indicators (sensitive areas and sensitive products) and socioeconomic indicators (dependency rates such as old and young members of population and income from climate sensitive sources) to estimate the sensitivity. Piya et al. (2012) identified rural households' sensitivity to climate change by assessing the income structure (income based on climatic conditions and non-agricultural income) and damage to assets (damage to farmland, loss of livestock, and crop damage).

1.2. Adaptive capacity assessment

Due to lack of a comprehensive framework for assessing adaptive capacity (Jones, 2011), a large part of studies in this field are categorized based on five capitals (natural, economic, human, social, and physical capitals) (Zarafshani et al., 2016; Nazari et al., 2015; Maleki et al., 2014; Piya et al., 2012; Guerrin, 2009; Eakin and rquez-Tapia, 2008; Deressa, 2008; Brown et al., 2010; Brooks et al., 2005). However, Jones (2011) criticized using the five capitals as they do not provide a clear picture of the adaptive capacity of a system. Farmers' ability to adapt to growing hazards and environmental risks such as drought is related to their coping strategies.

The study by Venot et al. (2010) showed that farmers mitigated drought conditions through various practices, including crop diversification, a shift in calendar, late sowing, selling their livestock, and using sprinkler irrigation. Interestingly, Campbell et al. (2011) showed Jamaican farmers' coping strategies to drought, including resistant crop varieties, crops with multiple use, scaling down production, avoiding planting during the dry season, mulching, drip irrigation, changing the timing of water application, buying water, sharing water, spraying plants with leaf fertilizer, limiting cultivation, downscale cropping, seeking off-farm employment, seeking labor work, and selling livestock. Bryan et al. (2011) showed an interesting result by arguing that meteorological information is an effective tool in enhancing the adaptive capacity of farmers to mitigate the stressful effects of drought. Given the literature discussed above, Fig. 2 is a schematic representation of the main steps in designing a risk assessment model in Kermanshah Township.

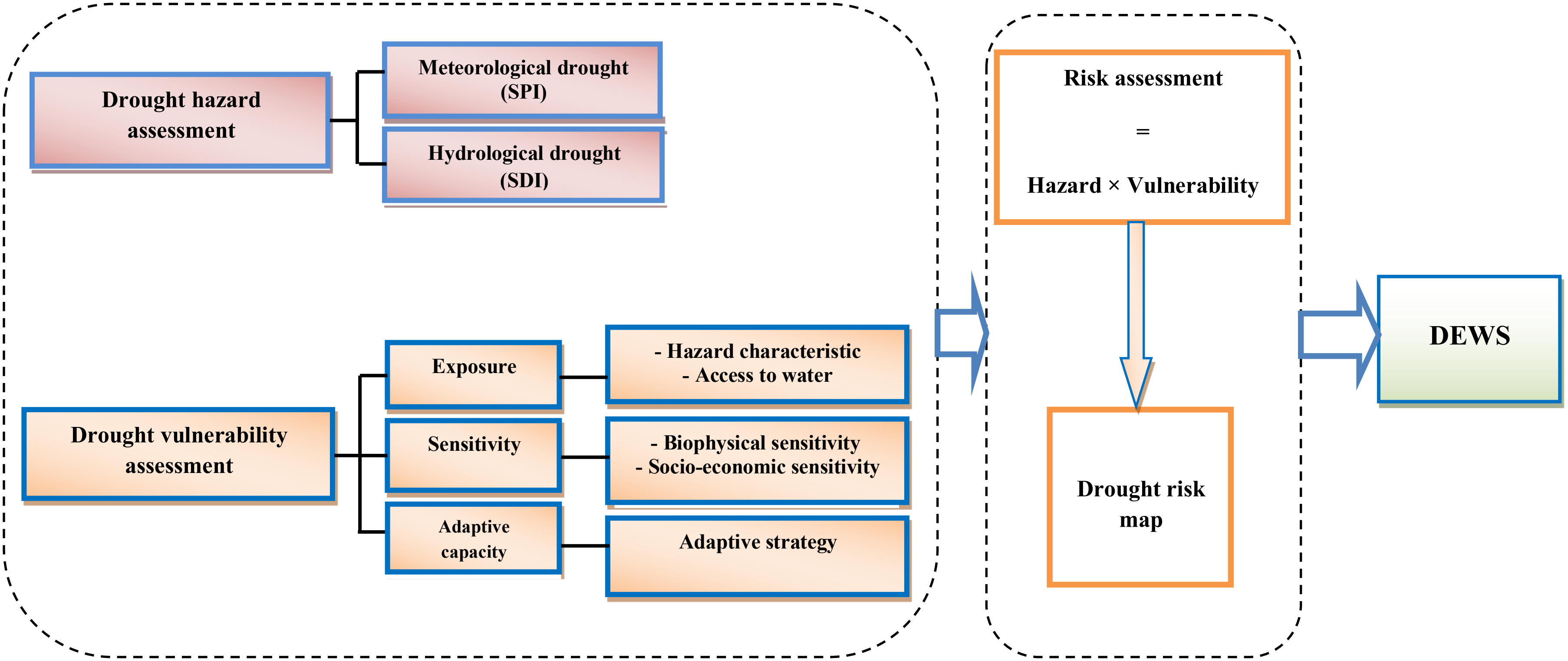

Fig. 2. Conceptual framework for risk assessment.

2. Research Method

This study utilized a survey research design in Kermanshah Township in the western part of Iran (Fig. 3). In the following section, the method of study (hazard assessment and vulnerability assessment) will be reviewed in detail.

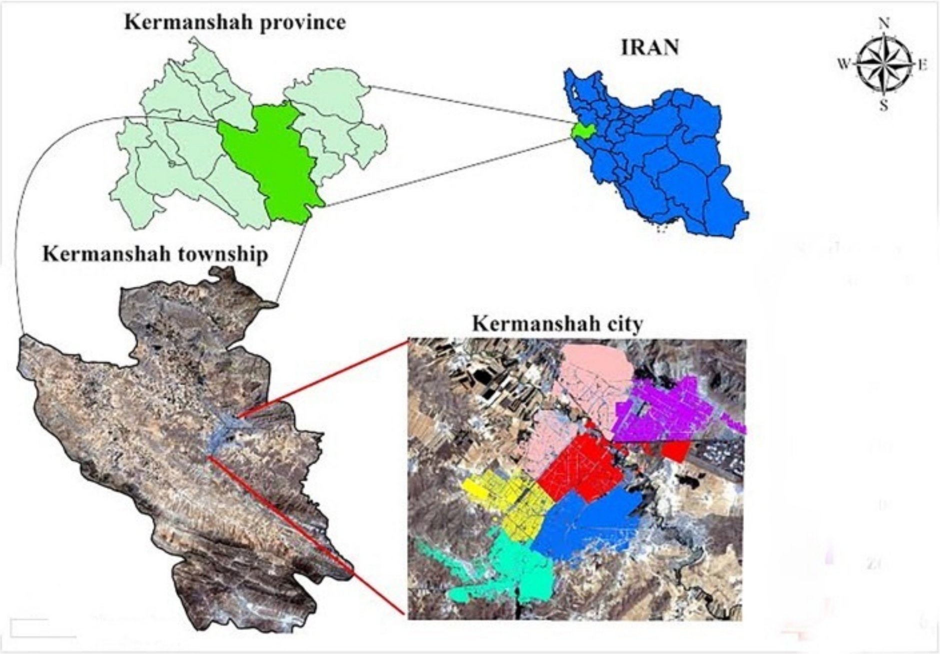

Fig. 3. Geographical position of the study area.

2.1. Hazard assessment

In this research, the hazard is defined as the meteorological drought and hydrological drought severity, which has different severity in different parts of Kermanshah. In the following, the estimation of meteorological drought indices based on SPI indices will be provided. Subsequently, the estimation of hydrological drought indices will be investigated.

2.1.1. Meteorological drought

In order to measure meteorological drought severity, the SPI index (Standardized Precipitation Index) proposed by McKee et al. (1993) was used. SPI is a climate drought index that calculates the probability of precipitation for timescales. As a matter of fact, the only needed input parameter is precipitation. The SPI is a powerful, flexible index that is simple to use. In addition, it is effective in analyzing both wet and dry periods/cycles, as well as drought warning severity. Positive SPI values are greater than median precipitation, and negative values are less than median precipitation (World Meteorological Organization, 2012).

McKee et al. (1993) used the classification system shown in the SPI value (Table 1) to define drought intensities resulting from the SPI. A drought incident occurs at any time when the SPI is continuously negative and reaches an intensity of -1.0 or less. However, the incident ends when the SPI becomes positive.

Table 1
Drought severity classification system based on SPI index.

SPI values	Drought situation
-2 and less	extremely dry
-1.5 to -1.99	severely dry
-1.0 to -1.49	moderately dry
0 to -0.99	mild drought
0 to 0.99	mildly wet
+1.0 to +1.49	moderately wet
1.5 to 1.99	very wet
2.0+	extremely wet

In order to measure SPI for 12-month timescales, 10 barometric stations, including long-term precipitation statistics, were used (from 1985-1986 to 2014-2015). Table 2 shows different rain station locations in Kermanshah Township.

Table 2
Rain station locations in Kermanshah Township.

Station	Village	Longitude	Latitude	Altitude (m)	Renovation years
Boozhan	Osmanvand	47.25	33.97	1600	11
Sarfiroozabad	Sarfiroozabad	47.28	34.06	1510	3
Sarabniloofar	Baladarband	46.87	34.40	1280	9
Mahidasht	Mahidasht Chaghanarges	46.85	34.27	1415	2
Shadman	Droodfaraman Gharahsoo	47.19	34.26	1320	7
Koozaran	SanjabiHaftashian	46.60	34.50	1380	6
Marzbani	Bilavar	47.08	34.70	1650	10
Chenar-Jalalvand	Jalalvand	47.12	33.93	1140	11
Jologireh-olya	Miandarband	46.85	34.58	1180	2

To calculate the SPI index, the following formula presented by McKee et al. (1993) was used:

$$SPI= \frac{X_i - \bar{X}}{S_X}$$

X_i: Monthly rainfall

X: The average rainfall on the time scale

S_X: Deviation of rainfall on a time scale

2.1.2. Hydrological drought

The hydrological drought was measured using SDI (Streamflow Drought Index). This indicator was presented by Nalbantis et al. (2009) to identify the hydrological drought (Table 3). Based on this classification, positive SDI values indicate a normal or wet condition, whereas negative values indicate drought status.

Table 3
Classification of hydrological drought based on SDI.

Description	Criterion
Extreme drought	$SDI < -2.0$
Severe drought	$-2.0 \leq SDI < -1.5$
Moderate drought	$-1.5 \leq SDI < -1.0$
Mild drought	$-1.0 \leq SDI < 0.0$
None drought	$SDI \geq 0.0$

Long-term Debi river statistics (30 years) that had a longer statistical period were used to calculate SDI. The hydrological drought was measured using 12-month time scales using the following formula provided by Nalbantis et al. (2009):

$$SDI_{i,k} = \frac{V_{i,k} - \overline{V_k}}{\overline{S_k}}$$

$V_{i,k}$: Monthly river flow

V_k: Mean value of cumulative streamflow for the kth period

S_k: Standard deviation of cumulative streamflow for the kth period

Table 4 shows the geographic location of the hydrometric stations in Kermanshah Township.

Table 4
Hydrometric station locations in Kermanshah Township.

Station	River	Village	Longitude	Latitude	Altitude (m)
Doabmereg	Gharahsoo	Sanjabi	47.47	34.33	1290

Khersabad	Mereg	Sarfiroozabad Haftashian Mahidasht Chaghanarges	47.44	34.30	1320
Faraman	Gharahsoo	Droodfaraman Gharahsoo Baladarband	47.15	34.14	1295
Hojatabad	Razavar	Miandarband Bilavar	46.53	34.38	1300
Gamasiab	Gamasiab	Jalalvand Osmanvand	47.54	34.53	1410

Finally, the total weight of hazard indicators (SIP value and SDI value for the 2014-15 period) was considered as a drought hazard for each village. The weight of hazard indicators is calculated using the Shannon Entropy Method (Table 5).

Table 5
Weight of hazard indicators.

Component	Index	Weight
Hazard	Meteorological drought severity in 2014-15	0.491
	Hydrological drought severity in 2014-15	0.509

2.2. *Vulnerability assessment*

The vulnerability was evaluated using the Fontaine and Steinemann (2009) formula:

$$\text{Vulnerability} = (\text{Exposure} + \text{Sensitivity}) / \text{Adaptive Capacity}$$

Using the literature review, variables for each component (exposure, sensitivity, and adaptive capacity) were extracted, and the indicators for each variable were identified through the index construction method (Table 6). Since each and every indicator held different scales, we attempted to fix and homogenize the scales (Kalantari, 2001).

Fixing scales were assessed using Indexing Method. In this method, the maximum value of each index was considered as 100; thus, other values were proportionately given certain values. This method has the advantage of keeping the proportionate values unchanged. Thus, the different coefficients obtained are equal to different coefficients of the main values (Kalantari, 2001). Finally, using Shannon Entropy Method, the weight of each indicator (exposure, sensitivity, and adaptive capacity) was determined (Table 6).

Table 6

Weight of vulnerability indicators.

Component	Variable	Index	Weight
Exposure (Negative index)	Frequency of meteorological droughts	The ratio of meteorological drought for each village during the past 10 years to total drought for each village during the past 30 years	0.236
	Frequency of hydrological drought	The ratio of hydrological drought for each village during the past 10 years to total drought for each village during the past 30 years	0.303
	Access to water (rain-fed farming)	Average water accessibility for irrigation (inches)	0.253
	Access to water (irrigated farming)	Average water accessibility for irrigation (inches)	0.208
Sensitivity (Negative index)	Rate of individuals under 5 years old in household	The ratio of under 5 years old to total household	0.069
	Rate of literacy or low literacy adults in the household	The ratio of illiterate adults to the total household	0.078
	Household unemployment rate	The ratio of unemployed to the total household	0.080
	Income dependency on climate resources	The ratio of climate resource based income to total households' income	0.116
	Rate of drought immigrant households	The ratio of drought immigrants to total households	0.054
	Rate of household individuals who left farming due to drought	The ratio of unemployed (due to drought) to total household	0.052
	Number of land fragmentation near water resources	The ratio of land fragmentation near water resources to total land holdings	0.110
	Distance from farmland to the main road	The average farm ownership from main road	0.088
	Damage to land due to drought	Percentage of damage to land due to drought	0.107
	Rate of livestock sold due to drought	The ratio of animal units sold to total livestock units	0.056
	Rate of farmland sold due to drought	The ratio of land sold to the total land	0.024
	The size of irrigated land	The size of irrigated land to the total land	0.104
	The size of rain-fed land	The size of rain-fed land to the total land	0.062
Adaptive Capacity (Positive index)	Using new and high performance varieties	The ratio of farmers who use new and high-yielding wheat cultivars to the total number of farmers	0.039
	Using drought tolerant varieties	The ratio of farmers who use drought resistance wheat cultivars to the total number of farmers	0.041
	Using early yielding wheat cultivars	The ratio of farmers who used early wheat cultivars to the total number of farmers	0.026
	Tillage operations	The ratio of farmers who practiced minimum tillage to the total number of farmers	0.044
	Crop rotation practice	The ratio of farmers who practiced crop rotation to the total number of farmers	0.042
	Changes in wheat sowing date	The ratio of farmers who changed sowing date to the total number of farmers	0.034
	Less use of chemical fertilizer	The ratio of farmers who used less chemical fertilizers during drought to the total number of farmers	0.051
	Less use of herbicides	The ratio of farmers who used less herbicides during drought to the total number of farmers	0.045
	Weed control practices	The ratio of farmers who controlled weeds during drought to the total number of farmers	0.042
	Using more animal manure	The ratio of farmers who used animal manure during drought to the total number of farmers	0.024
	Increased row distances	The ratio of farmers who increased row distances during drought to the total number of farmers	0.027
	Cultivation of spring crops	The ratio of farmers who cultivated spring crops to the total number of farmers	0.028
	Irrigated channels construction	The ratio of farmers who constructed irrigation channels during drought to the total number of farmers	0.017

	Buying water during drought	The ratio of farmers who bought water during drought to the total number of farmers	0.023
	Using less water during each irrigation period	The ratio of farmers who used less water during drought to the total number of farmers	0.035
	Using new irrigation systems	The ratio of farmers who used new irrigation systems to the total number of farmers	0.020
	Using plastic covers to conserve water	The ratio of farmers who used plastic covers to conserve water to the total number of farmers	0.028
	Selecting suitable irrigation time	The ratio of farmers who selected suitable irrigation time to the total number of farmers	0.037
	Avoid irrigation in the middle of the day	The ratio of farmers who avoided mid-day irrigation during drought to the total number of farmers	0.029
	Digging wells	The ratio of farmers who dug well during drought to the total number of farmers	0.022
	Digging new wells	The ratio of farmers who dug new wells to the total number of farmers	0.014
	Receiving a bank loan	The ratio of farmers who received bank loan to the total number of farmers	0.031
	Using crop insurance	The ratio of farmers who used crop insurance to the total number of farmers	0.036
	Practicing non-agricultural jobs	The ratio of farmers who turned to non-agricultural jobs during drought to the total number of farmers	0.038
	Using savings in drought	The ratio of farmers who used their savings during drought to the total number of farmers	0.041
	Using weather forecasting	The ratio of farmers who used meteorological forecasting to the total number of farmers	0.046
	Contact with agricultural experts	The ratio of farmers who contacted agricultural experts to the total number of farmers	0.048
	Participating in extension classes	The ratio of farmers who participated in extension classes to the total number of farmers	0.034
	Reducing unnecessary expenses like clothes and so on	The ratio of farmers who reduced unnecessary expenses during drought to the total number of farmers	0.046
	Changing agricultural land to non-agricultural activities	The ratio of farmers who changed their land-based activities to non-agricultural activities to the total number of farmers	0.012

The population of this study comprised of 31,000 wheat farmers in Kermanshah Township. Using a sample size table (which certifies a 5% margin of error) proposed by Bartlett et al. (2001), 370 farmers were selected by a multi-stage cluster sampling method (12 villages, 12 clusters). The research instrument for assessing vulnerability was a questionnaire. The vulnerability was measured through drought exposure (4 items), sensitivity (13 items), and adaptive capacity (30 items). Vulnerability questionnaire was distributed among the statistical population, and finally, 293 questionnaires were completed and found to be suitable for analysis (return rate: 79.2%). Reliability was measured using Cronbach's alpha coefficient (α=0.82). Internal validity was measured using a panel of experts (including the scientific staff of the College of Agriculture, Razi and Shiraz University).

Finally, the risk was assessed using the multiplication of hazard and vulnerability. In some studies, the relationship between vulnerability, hazard, and risk is presented in the following formula (Wolfgang and Bollin, 2001; Global Water Partnership, 2015; Aliasgar, 2012; Füssel, 2007; Kumpulainen, 2006; Brooks et al., 2005; Wisner, 2004; 2001; Wolfgang et al., 2001).

$$\text{Risk} = \text{Vulnerability} \times \text{Hazard}$$

The Arc GIS software was utilized to graph the study area in terms of drought hazard, exposure, sensitivity, adaptive capacity, vulnerability, and risk.

3. Result

3.1. Drought hazard assessment

3.1.1. *Estimation of meteorological drought indices (SPI)*

Two indicators of meteorological drought (SPI) and hydrological drought (SDI) were used for hazard assessment.

Results indicate that the Sarfiroozabad station shows the highest drought frequency (18 meteorological droughts) in a 30-year period. Other stations have also experienced droughts, including Mahidasht and Jologireholya stations (17 meteorological droughts), Chenar-Jalalvand and Sarabniloofar stations (17 meteorological droughts), Shadman station (15 meteorological droughts), and Ghoharchagha and Koozaran stations (14 meteorological droughts). It is worth mentioning that in recent years, the stations of Kermanshah Township have experienced several droughts. In addition, droughts have been observed in all stations during 2014-2015 (Table 7).

Table 7
SPI trend in a one-year period at barometric stations in Kermanshah Township.

Year	Mahidasht		Sarabniloofar		Sarfiroozabad		Chenar-Jalalvand		Boozhan		Jologireholya		Marzbani		Koozaran		Ghoharchagha		Shadman	
	Drought situation	SPI	Drought situation	SPI	Drought situation	SPI	Drought situation	SPI	Drought situation	SPI	Drought situation	SPI	Drought situation	SPI	Drought situation	SPI	Drought situation	SPI	Drought situation	SPI
1985-1986	S. d.	0.54	S. d.	-0.10	S. W.	0.56	S. W.	0.30	S. w.	0.70	V. w.	1.52	V. w.	1.50	V. w.	1.67	V. w.	1.65	S. w.	0.79
1986-1987	S. d.	-0.10	S. d.	-0.08	S. W.	0.34	S. W.	0.28	S. W.	029	S. w.	0.30	Se. d.	-1.50	S. w.	0.22	S. d.	-0.38	S. w.	0.70
1987-1988	M. w.	1.21	M. w.	1.33	S. W.	0.86	S. W.	0.99	S. W.	0.83	V. w.	1.90	S. w.	0.37	V. w.	1.72	S. w.	0.23	V. w.	1.96
1988-1989	S. d.	0.94	S. d.	1.06	S. d.	-0.36	S. d.	-0.43	S. d.	-0.55	S. d.	-0.08	S. d.	-0.55	S. w.	0.36	V. w.	1.58	S. d.	-0.05
1989-1990	S. d.	0.08	S. d.	0.09	S. d.	-0.31	S. d.	-0.34	S. d.	-0.38	S. w.	0.75	S. w.	0.22	S. d.	-0.19	S. w.	0.39	M. w.	1.06
1990-1991	S. d.	-0.79	S. d.	-0.66	S. d.	-0.76	M. d.	-1.02	M. w.	-1.10	S. d.	-0.60	S. d.	-0.47	M. d.	-1.20	M. d.	-1.03	S. d.	-0.72
1991-1992	M. w.	1.02	S. W.	0.98	S. W.	0.03	S. W.	0.38	S. W.	0.21	M. w.	1.16	S. w.	0.33	S. w.	0.41	M. w.	1.23	S. w.	0.68
1992-1993	S. d.	-0.01	S. d.	-0.04	S. W.	0.53	S. d.	-0.47	S. d.	-0.29	S. d.	-0.63	S. d.	-0.23	S. w.	0.52	V. w.	1.50	S. w.	0.67
1993-1994	S. d.	0.52	S. W.	0.22	V. w.	1.87	M. w.	1.14	S. W.	0.99	S. w.	0.50	M. w.	1.30	S. w.	0.65	S. w.	0.30	S. w.	0.02
1994-1995	E. w.	2.69	E. w.	2.18	E. w.	2.89	E. w.	2.39	E. w.	3.26	V. w.	1.55	E. w.	2.58	V. w.	1.58	M. w.	1.21	E. w.	2.20
1995-1996	S. d.	-0.02	S. W.	0.09	V. w.	1.68	E. w.	2.94	E. w.	2.48	S. d.	-0.12	S. d.	-0.58	S. d.	-0.06	S. w.	0.82	S. d.	-0.12
1991-1997	S. d.	-0.58	S. d.	-0.55	S. d.	-.47	M. w.	1.29	M. w.	1.02	S. d.	-0.10	M. d.	-1.09	M. d.	-1.03	S. d.	-0.86	M. d.	-1.13
1997-1998	V. w.	1.68	V. w.	1.87	M. w.	1.40	S. W.	0.19	S. W.	0.26	V. w.	1.61	V. w.	1.66	M. w.	1.27	M. w.	1.01	S. w.	0.82
1998-1999	S. d.	-1.65	M. d.	-1.43	M. d.	-1.08	M. d.	-1.40	M. d.	-1.28	S. d.	-0.57	S. d.	-0.57	Se. d.	-1.08	S. d.	-0.86	S. d.	-0.85
1999-2000	S. d.	-1.56	M. d.	-1.24	M. d.	-1.43	S. d.	-0.55	M. d.	-1.19	Se. d.	-1.60	M. d.	-1.01	Se. d.	-1.55	Se. d.	-1.83	M. d.	-1.37
2000-2001	S. d.	0	S. d.	-0.41	S. d.	-0.69	S. d.	0.02	S. d.	-0.65	M. d.	-1.05	S. d.	-0.70	S. d.	-0.95	S. d.	-0.94	M. d.	-1.21
2001-2002	S. d.	-0.05	S. d.	-0.34	S. d.	-0.27	S. d.	-0.19	S. d.	-0.34	S. w.	0.06	S. w.	0.31	S. w.	0.24	S. d.	-0.26	S. w.	0.51
2002-2003	S. d.	-0.10	S. d.	-0.27	S. d.	-0.30	S. d.	-0.12	S. W.	0.03	S. d.	-0.13	S. w.	0.61	S. w.	0.10	S. d.	-0.14	S. d.	-0.31
2003-2004	S. d.	-0.26	S. W.	0.32	S. d.	0.28	S. d.	0.01	S. d.	0.08	S. d.	-0.06	S. w.	0.07	S. w.	0.73	S. w.	0.60	S. w.	0.84
2004-2005	S. d.	-0.12	S. W.	0.39	S. d.	-0.48	S. d.	-0.91	S. d.	-0.24	S. w.	0.10	S. w.	0.50	S. w.	0.84	S. w.	0.84	S. d.	-0.53
2005-2006	S. W.	0.75	V. w.	1.63	S. d.	-0.56	S. W.	0.40	S. W.	0.27	S. w.	0.79	S. w.	0.78	S. w.	0.86	S. w.	0.60	S. w.	0.27
2006-2007	S. W.	0.38	S. W.	0.05	S. W.	0.36	S. W.	0.28	S. W.	0.18	S. d.	-0.12	M. w.	1.45	S. w.	0.49	S. w.	0.42	M. w.	1.08
2007-2008	E. d.	-2.35	E. d.	-2.54	Se. d.	-1.72	Se. d.	-1.85	Se. d.	-1.43	E. d.	-2.12	Se. d.	-1.69	E. d.	-2.30	E. d.	-2.30	E. d.	-2.13
2008-2009	S. d.	-0.73	S. d.	-0.93	S. d.	-0.69	S. d.	-0.65	S. d.	-0.93	M. d.	-1.15	S. d.	-0.10	S. d.	-0.08	S. d.	-0.51	S. d.	-0.39
2009-2010	S. W.	0.41	S. W.	0.70	S. w.	0.83	S. W.	0.39	S. W.	0.38	V. w.	1.62	S. w.	0.47	S. w.	0.25	S. w.	0.13	S. w.	0.44
2010-2011	S. d.	-0.51	S. d.	-0.37	S. d.	-0.11	S. d.	-0.21	S. d.	-0.50	S. w.	0.07	S. d.	-0.18	S. d.	-0.15	S. d.	-0.85	S. d.	-0.82
2011-2012	M. d.	-1.14	M. d.	-1.03	S. d.	-0.56	S. d.	-0.69	S. d.	-1.17	S. d.	-0.31	S. d.	-0.48	S. d.	-0.41	S. w.	0.24	M. d.	-1.10
2012-2013	S. d.	-0.12	S. d.	-0.24	S. d.	-0.32	S. d.	-0.94	S. d.	-0.28	S. d.	-0.86	M. d.	-1.47	S. d.	-0.97	S. d.	-0.96	S. d.	-0.67
2013-2014	S. W.	0.72	S. W.	0.33	S. d.	-0.21	S. d.	-0.22	S. d.	-0.28	S. d.	-0.46	S. d.	-0.50	S. d.	-0.13	S. d.	-0.94	S. w.	0.57
2014-2015	S. d.	-0.85	M. d.	-1.02	M. d.	-1.29	S. d.	-0.98	S. d.	-0.35	S. d.	-0.92	M. d.	-1.02	S. d.	-0.89	S. d.	-0.89	M. d.	-1.22

S. d. (Slightly dry) M. d. (Moderately dry) Se. d. (Severely dry) E. d. (Extremely dry) S. w. (Slightly wet) M. v. (Moderately wet) V. w. (Very wet) E. w. (Extremely wet)

Table 8
SDI trend in a one-year period at hydrometric stations in Kermanshah Township.

Year	Gamasiab		Faraman-Ghorbaghestan		Sarasiab		Khersabad		Doabmereg	
	Drought situation	SDI	Drought situation	SDI	Drought situation	SDI	Drought situation	SDI	Drought situation	SDI
1985-1986	None drought	0.14	None drought	0.54	None drought	1.47	None drought	0.44	None drought	0.37
1986-1987	None drought	0.32	None drought	0.75	None drought	1.47	None drought	0.36	None drought	0.65
1987-1988	None drought	1.03	None drought	2.43	None drought	1.80	None drought	1.65	None drought	2.38
1988-1989	None drought	0.33	None drought	0.78	None drought	1.47	None drought	0.89	None drought	0.60
1989-1990	None drought	0.07	None drought	0.61	None drought	1.47	None drought	0.84	None drought	0.56
1990-1991	Mild drought	-0.27	Mild drought	-0.24	None drought	1.47	Mild drought	-0.19	Mild drought	-0.18
1991-1992	None drought	1.32	None drought	1.86	None drought	1.14	None drought	1.73	None drought	1.75
1992-1993	None drought	1.12	None drought	0.14	Mild drought	-0.44	None drought	0.63	Mild drought	-0.07
1993-1994	None drought	0.32	None drought	0.58	None drought	0.12	None drought	0.61	None drought	0.54
1994-1995	None drought	1.45	None drought	1.61	None drought	1.15	None drought	3.01	None drought	2
1995-1996	None drought	0.72	None drought	0.82	None drought	0.22	None drought	1.03	None drought	0.93
1996-1997	Mild drought	-0.13	Mild drought	-0.55	Mild drought	-0.92	Mild drought	-0.09	Mild drought	-0.13
1997-1998	Mild drought	0.09	None drought	1.67	None drought	0.54	Mild drought	1.22	Mild drought	-0.13
1998-1999	Mild drought	-0.56	Mild drought	-0.83	Moderate drought	-1.10	Mild drought	-0.64	Moderate drought	-0.63
1999-2000	Mild drought	-0.54	Moderate drought	-1.38	Moderate drought	-1.31	Mild drought	-0.77	Moderate drought	-1.03
2000-2001	Mild drought	-0.51	Moderate drought	-1.20	Moderate drought	-1.06	Mild drought	-0.73	Moderate drought	-1.05
2001-2002	Mild drought	-0.48	Mild drought	-0.75	Mild drought	-0.60	Mild drought	-0.72	Mild drought	-0.83
2002-2003	Mild drought	-0.25	Mild drought	-0.41	Mild drought	-0.30	Mild drought	-0.78	Mild drought	-0.25
2003-2004	Mild drought	-0.18	Mild drought	-0.28	Mild drought	-0.13	Mild drought	-0.38	Mild drought	-0.33
2004-2005	Mild drought	-0.06	None drought	0.35	None drought	0.31	Mild drought	-0.42	None drought	0.17
2005-2006	None drought	0.12	None drought	0.54	None drought	0.23	None drought	0.21	Mild drought	-0.11
2006-2007	Mild drought	0.29	None drought	0.07	Mild drought	-0.09	Mild drought	-0.64	Mild drought	-0.04
2007-2008	Mild drought	-0.32	Moderate drought	-1.14	Moderate drought	-1.30	Mild drought	-0.92	Moderate drought	-1.15
2008-2009	Mild drought	-0.67	Moderate drought	-1.06	Mild drought	-0.73	Mild drought	-0.90	Moderate drought	-1.13
2009-2010	Mild drought	-0.38	Mild drought	-0.46	Mild drought	-0.44	Mild drought	-0.86	None drought	0.27
2010-2011	Mild drought	-0.70	Mild drought	-0.91	Mild drought	-0.93	Mild drought	-0.92	Mild drought	-0.94
2011-2012	Mild drought	-0.58	Mild drought	-0.89	Mild drought	-0.66	Mild drought	-0.90	Mild drought	-0.97
2012-2013	Mild drought	-0.66	Mild drought	-0.89	Mild drought	-0.92	Mild drought	-0.92	Moderate drought	-1.07
2013-2014	Mild drought	-0.30	Mild drought	-0.77	Mild drought	-0.76	Mild drought	-0.91	Mild drought	-0.95
2014-2015	Mild drought	-0.73	Moderate drought	-1.07	Moderate drought	-1.15	Mild drought	-0.92	Moderate drought	-1.21

3.1.2. Estimation of hydrological drought indices (SDI)

Results of hydrological drought show that the most intensive drought occurred in Doabmereg station with a frequency of 19 times in a 30-year period. However, Faraman experienced the least frequency (16 droughts). This result clearly indicates that drought occurrence has increased in the study area. For example, the Khersabad station had experienced 19 drought incidents within a 30-year period (1985-86 to 2014-15). This condition remains the same across Kermanshah hydrometric stations (Table 8).

Table 9
Value of drought hazard across villages in Kermanshah Township.

Villages	Meteorological drought	Hydrological drought	Hazard	Ranking
Droodfaraman	-1.22	-1.07	-2.29	1.5
Gharahsoo	-1.22	-1.07	-2.29	1.5
Sarfiroozabad	-1.29	-0.92	-2.21	3
Bilavar	-1.02	-1.15	-2.17	4
Sanjabi	-0.89	-1.21	-2.10	5
Baladarband	-1.02	-1.07	-2.09	6
Miandarband	-0.92	-1.15	-2.07	7
Haftashian	-0.89	-0.92	-1.81	8
Mahidasht	-0.85	-0.92	-1.77	9.5
Chaghanarges	-0.85	-0.92	-1.77	9.5
Jalalvand	-0.98	-0.73	-1.71	11
Osmanvand	-0.35	-0.73	-1.08	12

Total Mean: 1.95
Total Std. deviation: 0.36

The result of the drought hazard showed that Droodfaraman and Gharahsoo villages had the highest drought severity (-2.29). Moreover, Sarfiroozabad and Bilavar villages were ranked 3rd and 4th in terms of drought hazard with the values of -21.2 and -2.17 (Table 9).

The results also indicate that the crisis was more severe in 7 villages. In addition, 4 villages were in very intense condition, and finally, 1 village was in intense condition. Fig. 4 (A) shows the hazard prone areas in Kermanshah Township[1].

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[1] These maps are provided in the UTM system and in Zone 38N.

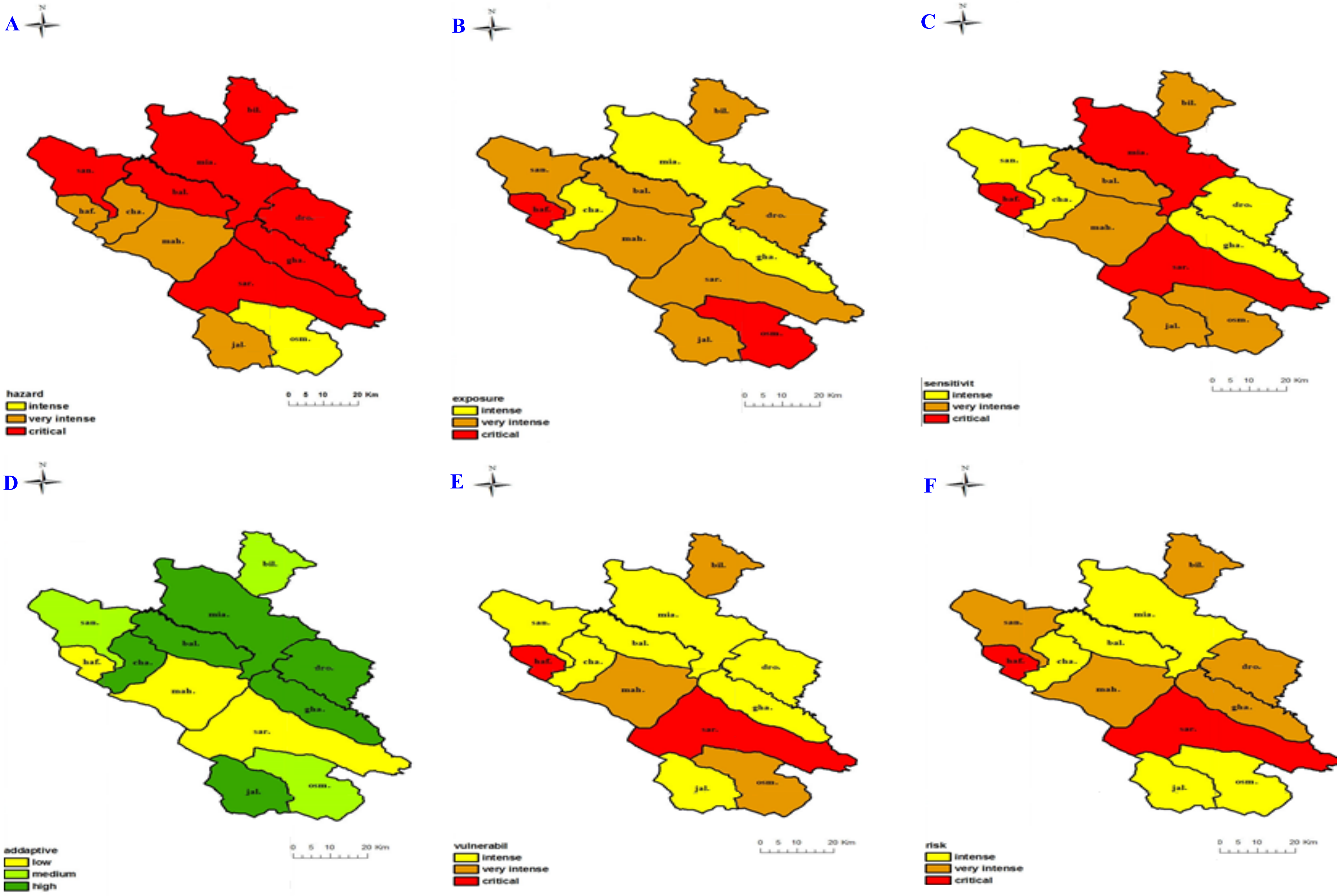

Fig. 4. Drought hazard (A), exposure (B), sensitivity (C), adaptive capacity (D), vulnerability (E), and risk (F) prone areas in the study area.

3.2. Vulnerability assessment

3.2.1. Drought exposure assessment

Exposure, sensitivity, and adaptive capacity components were evaluated using the formula proposed by Fontaine et al. (2009). This formula is derived from the IPCC model. Exposure was measured using four indicators. The total weight of the indicator was considered for each village based on the exposure value (Table 10).

Table 10

Value of drought exposure across villages in Kermanshah Township.

Villages	Exposure	Ranking
Osmanvand	93.81	1
Haftashian	93.03	2
Sarfiroozabad	87.20	3
Jalalvand	86.27	4
Sanjabi	85.43	5
Droodfaraman	84.80	6
Mahidasht	83.74	7
Bilavar	83.36	8
Baladarband	82.04	9
Gharahsoo	78.81	10
Chaghanarges	77.98	11
Miandarband	74.87	12

Total Mean: 84.28
Total Std. deviation: 5.61
Exposure range: 0-100

As shown in Table 13, Osmanwand (93.81), Haftashian (93.03), and Sarfirozabad (87.20) were ranked high in terms of drought exposure. However, Chaghanarges (77.98) and Miandarband (74.87) were ranked low in terms of drought exposure.

The classification of villages in terms of drought exposure intensity shows that 2 villages were in critical condition, whereas 7 villages were in very intense condition. Finally, 3 villages were in intense condition. Moreover, Fig. 4 (B) shows the drought exposure prone areas in Kermanshah Township.

3.2.2. Drought sensitivity assessment

The sensitivity component was evaluated using 13 indicators. The total weight of each indicator for each village reflects the sensitivity of that village.

Table 11
Value of drought sensitivity across villages in Kermanshah Township.

Villages	Sensitivity	Ranking
Miandarband	75.20	1
Haftashian	72.17	2
Sarfiroozabad	69.45	3
Bilavar	67.78	4
Jalalvand	66.88	5
Mahidasht	66.03	6
Osmanvand	63.23	7
Baladarband	61.46	8
Droodfaraman	57.73	9
Sanjabi	57.14	10
Gharahsoo	56.60	11
Chaghanarges	53.33	12

Total Mean: 63.92
Total Std. deviation: 6.81
Exposure range: 0-100

Table 11 shows the value of drought sensitivity for each village in Kermanshah Township. The villages of Miandarband (75.20), Haftashian (72.17), and Sarfiroozabad (69.45) ranked first to third in terms of sensitivity, while the lowest sensitivity belonged to Gharahsoo and Chaghanarges villages (56.60 and 53.33).

Table 14 represents the level of sensitivity in Kermanshah Township. The result showed that 3 villages were in critical condition, 5 villages were in very intense condition, and 4 villages were in intense condition. Fig. 4 (C) shows the drought sensitive prone areas in Kermanshah Township.

3.2.3. Adaptive capacity assessment

Adaptive capacity was measured with 30 indicators. The total weight of these indicators constitutes the amount of adaptive capacity of each village. Information on prioritization of villages in terms of adaptive capacity is visible in Table 12.

Table 12
Value of drought adaptive capacity across villages in Kermanshah Township.

Villages	Adaptive Capacity	Ranking
Miandarband	81.68	1
Chaghanarges	81.11	2
Jalalvand	78.10	3
Gharahsoo	74.64	4
Baladarband	74.59	5
Droodfaraman	69.94	6
Sanjabi	66.64	7
Bilavar	64.55	8
Osmanvand	60.49	9
Sarfiroozabad	52.58	10
Mahidasht	51.33	11
Haftashian	45.93	12

Total Mean: 66.80
Total Std. deviation: 12.09
Adaptive capacity range: 0-100

According to Table 12, farmers in Miandarband, Chaghanarges, and Jalalvandhad have a better adaptive capacity (81.68, 81.11, 78.10) compared to their counterparts. However, farmers in Mahidasht and Haftashian had somewhat weak adaptive capacity (51.33, 45.93) towards drought.

In terms of the level of adaptive capacity, 6 villages were considered highly adaptive, whereas 3 villages were considered moderately adaptive, and finally, 3 villages were considered low adaptive. Fig. 4 (D) shows the drought adaptive capacity prone areas in Kermanshah Township.

3.2.4. Drought vulnerability assessment

According to Table 13, the result of vulnerability assessment revealed that Haftashian (3.60), Sarfiroozabad (2.98), and Mahidasht (2.92) were most vulnerable towards drought. On the other hand, Gharahsoo and Chaghanarges were least vulnerable towards creeping hazards such as drought (1.81, 1.62).

Table 13
Value of drought vulnerability across villages in Kermanshah Township.

Villages	Vulnerability	Ranking
Haftashian	3.60	1
Sarfiroozabad	2.98	2
Mahidasht	2.92	3
Osmanvand	2.60	4
Bilavar	2.34	5

Sanjabi	2.14	6
Droodfaraman	2.04	7
Jalalvand	1.96	8
Baladarband	1.92	9
Miandarband	1.84	10
Gharahsoo	1.81	11
Chaghanarges	1.62	12

Total Mean: 2.31
Total Std. deviation: 0.59

The level of vulnerability among farmers illustrated that 2 villages were in critical condition, 3 villages were in very intense condition, and finally, 7 villages were in intense condition. Fig. 4 (E) shows the status of the villages of Kermanshah in terms of vulnerability.

3.3. Drought risk assessment

As already stated, risk is a function of two components of hazard and vulnerability, which are shown in the following table. Therefore, the drought risk was investigated using this relationship in the villages of Kermanshah Township (Table 14).

Table 14
Value of drought risk across villages in Kermanshah Township.

Villages	Hazard	Vulnerability	Risk	Ranking
Sarfiroozabad	-2.21	2.98	-6.58	1
Haftashian	-1.81	3.60	-6.52	2
Mahidasht	-1.77	2.92	-5.17	3
Bilavar	-2.17	2.34	-5.08	4
Droodfaraman	-2.29	2.04	-4.67	5
Sanjabi	-2.10	2.14	-4.49	6
Gharahsoo	-2.29	1.82	-4.17	7
Baladarband	-2.09	1.92	-4.01	8
Miandarband	-2.07	1.84	-3.81	9
Jalalvand	-1.71	1.96	-3.35	10
Chaghanarges	-1.71	1.62	-2.87	11
Osmanvand	-1.08	2.60	-2.81	12

Total Mean: -3.99
Total Std. deviation: 2.42

Results of drought risk assessment revealed that farmers in Sarfiroozabad (-6.58), Haftashin (-6.52), and Mahidasht (-5.17) were at high risk, whereas farmers in Chaghanarges (-2.87) and Osmanvand (-2.81) villages were facing minimum risk.

Based on the risk level, 2 villages in Kermanshah Township were in critical condition, whereas 5 villages were in very intense condition, and finally, 5 villages were facing intense conditions. Fig. 4 (F) shows the drought risk prone areas in Kermanshah Township.

4. Discussion

4.1. Hazard assessment

The risk assessment proposed in this study has provided a methodology for Iran. The country is unable to develop its own risk assessments due to poor resources and facilities. Disaster authorities can use this map to allocate resources across townships in Kermanshah province. The results can also be used to develop local and national adaptive capacity to control drought in Iran.

The present study also showed that Kermanshah Township has experienced drought for the past 30 years; thus, it has become a recurrent incident. This is due to the fact that the majority of farmlands in Kermanshah Township are rain-fed. Shewmake (2008), Paavola (2008), Trærup (2007), and Alcamo (2005) have revealed that rain-fed farms are more affected by climate change and thus are more vulnerable. The obtained results indeed suggest that the drought incident will be prolonged in the study area; therefore, farmers should take appropriate actions to compensate for the severe effects of drought. Jamshidi et al. (2016) confirmed that the climate in Iran is changing in a way that the country will experience prolonged drought in the next 40 years.

In addition, the results showed that the majority of villages in Kermanshah Township have experienced both hydrological and meteorological drought. This means that farmers in those regions have faced dry rivers as well as dry wells, which in turn have reduced the adaptive capacity of farmers, thus making them more vulnerable. In this regard, Koochaki et al. (2007) argued that data (from 37 meteorological stations across Iran) showed an increase in average temperature over 25-50 years. This clearly indicates that water management policy-makers in

Iran should focus their attention on measuring both meteorological and hydrological drought in order to set a reliable drought early warning system.

4.2. Exposure assessment

The findings revealed that farmers' exposure to drought across villages was high. However, the variation of exposure between villages is somewhat different. Recurring drought incidents in the region, on the one hand, and lack of water access, on the other hand, have created a critical status for farmers in arid and semi-arid areas. As mentioned earlier, low precipitation across the region has dried up rivers, wells, and qanats, which in turn has increased farmers' vulnerability. High exposure to drought forced farmers to leave their land for better opportunities, and other farmers have limited irrigation and crop production. This dilemma was even common in irrigated farming. Brant (2007) and Wilhelmi and Wilhite (2002) showed that lack of access to water supply tends to decrease farmers' resilience and thus increase their vulnerability.

4.3. Sensitivity assessment

The region's sensitivity analysis showed that farmers were highly sensitive to conditions of drought. According to the findings, "the size of irrigated land" is one of the indicators that has made farmers more sensitive to drought conditions. This can be explained by the fact that rain-fed farming is more prevalent in the studied region. In general, rain-fed farming does not take much time to work. In other words, farmers have limited adaptive capacity depending on natural precipitation. Although Iran's government has provided subsidies for rain-fed farmers to practice conservative agriculture, in reality, farmers are not motivated to practice conservative agriculture. This is due to the fact that most farmers believe that conservative agriculture plays a limited role in improving their economic conditions. Therefore, most rural development projects such as limited tillage, no-tillage, and interventions of climate smart agriculture have not been successful in recent years. In line with the results of this study, several studies, including Zarafshani et al. (2012), Shewmake (2008), and Paavola (2008), also showed that farmers who rely on rainfall are more sensitive to drought compared with those with irrigated farming.

Loss of land due to drought is another indicator of sensitivity. When farmers are forced to leave their farms unplanted, their income reduces drastically. Research shows that major sources of income for Iranian farmers are based on the size of land and yield. When drought hits rural communities, production loss is the first and direct impact. The study by Paavola (2008) confirms that income loss has a significant role in increasing farmers' vulnerability. Eakin and Tapia (2008) and Guerrin (2009) also showed that damage to land due to drought has an effect on farmers' sensitivity towards drought.

The biophysical status of the study area showed that those farmers who had access to water were somewhat in a better position compared with those without access to nearby water. The proximity to the water source leads to cheaper water prices as well as low pipes and fittings costs. In other words, water distribution in well-designed irrigation systems tends to save a large amount of money and thus build farmers' resilience to drought sensitivity. However, our study revealed that farmers are faced with high water distribution costs due to the distance from the water source. In this regard, Garcia et al. (2011) argue that some areas are more susceptible to disasters (sensitive areas); therefore, they suffer more damage during hazards. The researchers introduced this kind of sensitivity as biophysical sensitivity. Thus, during drought, lands located near water resources are less susceptible.

One of the interesting indicators of sensitivity is known as “climate change migration”. In the study area, it was concluded that climate change migration had become an epidemic among rural populations. Although researchers have concluded that rural migration is considered as an adaptive capacity towards natural disasters such as drought (Vento et al., 2010; Singstam, 2009; Shewmake, 2008), only a few researchers have shown concern towards this notion.

4.4. Adaptive capacity assessment

The results showed that the majority of farmers in this study were highly to moderately adaptive to the drought incidents. The rest of this article will discuss some of the shared adaptive capacity indicators across villages in Kermanshah Township.

Tillage operation is one of the key indicators of adaptive capacity. Extension agents have consistently emphasized minimum tillage practices among farmers in the study area. In other words, farmers are motivated to practice minimum or no-tillage operations as a means to save or conserve water resources. Numerous researchers have emphasized that soil conservation practices are among the effective adaptive strategies when dealing with drought (Gwambene and Majule, 2010; Zarei et al., 2014). Minimum tillage practices also tend to preserve crop remains in the soil that turn into usable fertilizers and prevent water evaporation from sunlight, which in turn, conserve water in the soil (Keshavarz and Karami, 2008).

The results also revealed that minimum use of chemical fertilizers and herbicides was practiced by farmers as an adaptive strategy. Studies showed that the use of chemical fertilizers and herbicides during drought not only creates more water stress for plants but also eradicates organisms that are helpful in water infiltration (Karami, 2008; Sharafi and Zarafshani, 2014). Thus, such an adaptive strategy is considered as an effective mitigation method in dealing with drought incidents.

The results of this study indicated that farmers' information has helped them use effective adaptive strategies to reduce their vulnerability towards drought. For example, contacting extension agents, using the weather forecasts, using appropriate irrigation timing, changing the wheat sowing date, and avoiding mid-day irrigation were all effective in coping with drought incidents. Several studies have shown that farmers do not operate based on a conventional agricultural calendar during climatic hazards, but their coping behavior is based on previous rainfall duration (Vento, 2010; Mengistu, 2011; Ifeanyi-obi et al., 2012). In Iran, the government-based extension system has its strengths and weaknesses. For example, when farmers are motivated to contact extension agents, it shows that the extension system is working effectively to the extent that target groups are willing to use extension advice to cope with drought. This, in turn, would lead to a situation where agents provide farmers with meteorological information to improve crop production. Pat and Guata (2002) agreed that farmers with high meteorological literacy would more likely use weather information for crop cultivation. In addition, Simlton et al. (2009) concluded that farmers who have more access to meteorological information tend to use this information in selecting suitable seeding dates, which in turn, can help them cope with drought more effectively. In other words, the advantage of contacting agents is to use weather forecast information and receive information for proper planting timing.

5. Conclusion and recommendations

Drought risk reduction measures require long term plans, and early warning should be seen as a strategy to effectively reduce the growing vulnerability of communities and assets (Grasso, 2009). In terms of drought early warning systems, it is generally recognized that it is fundamental to establish an effective drought early warning system to better identify the risk and better monitor the level of vulnerability of farmers (Grasso, 2009). The main argument of this study is that an effective and sustainable DEWS depends on multi-level governance, institutional arrangements, and frameworks that draw on attributes of risk assessment for a creeping hazard such as drought.

In this regard, Iran has a weak system of governance and would probably face tough challenges to implement and sustain an effective DEWS. However, by embarking and focusing on multi-stakeholder perspectives, the current challenges can be overcome. For example, sound data is necessary for implementing an effective drought early warning system. However, Iran is facing issues such as data poverty to develop its own risk assessments. Poor data sources are due to weak real-time sensors that are required for a disaster such as drought that usually affects a much larger, less dense, and less developed area. Moreover, although Iran has meteorological and hydrological stations throughout the country, inadequate and less coordinated network of stakeholders creates an ineffective spatial characterization of drought. In addition, these stations are only capable of presenting raw data which is not adequate and in most cases is less up-to-date.

Finally, for a drought early warning system to be used by drought policy-makers, it is necessary that the system provides valid information. A wrong forecast creates distrust among users which in turn makes any preventive measures unsuitable. Hence, drought early warning system administrators should make sure that reliable information is being communicated to decision-makers and the general public.

Potential future research directions are as follows:

- Building up case studies and evaluating the costs of action versus inaction against droughts using consistent and mutually comparable methodological approaches. This should allow a better understanding of the drought costs, impact pathways, vulnerabilities, costs and benefits of various crisis and risk management approaches against droughts, and the co-benefits of risk management approaches. These actions will ultimately lead to better informed policy and institutional actions on droughts.
- Comprehensive evaluations of the costs of action need to be performed by drought risk assessments. They require weather and drought monitoring networks with sufficient coverage as well as the adequate human capacity to analyze and transform this information into drought preparedness and mitigation actions.

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References

Adger, W. N. 2006. Vulnerability. Global Environ Chang. 16, 268-281.

Alcamo, J., Acosta-Michlik, L., Carius, A., Eierdanz, F., Klein, R., Krömker, D., Tänzler, D. 2005. A new approach to the assessment of vulnerability to drought, Presented at concluding symposium of the German climate research programme (DEKLIM), Leipzing.

Aliasgar, K. 2012. Developing a geoinformatics based early warning system for floods in the caribbean, Trinidad and Tobago, PhD thesis, Southern Cross University, Lismore, NSW.

Babaeefini, A., Alijani, B. 2013. Spatial analysis of long term drought in Iran. Natl Geogr Research, 45(3), 1-21.

Bartlett, J. E., Koterlik, J. W., Higgins, Ch. C. 2001. Organizational research: Determining appropriate sample size in survey research. ITLPJ, 19(1), 43-50.

Brant, S. 2007. Assessing the vulnerability to drought in Ceara, Northeast Brazil. Retrieved 08.02.2009 from the World Wide Web: http://hdl.handle.net/2027.42/57432.

Brooks, N., Adger, W. N., Kelly, P. M. 2005. The determination of vulnerability and adaptive capacity at the national level and the implications for adaptation, Global Environ Chang, 15, 151-163.

Brown, P. R., Nelson, R., Jacobs, B., Kokic, P., Tracey, J., Ahmed, M., DeVoil, P. 2010. Enabling natural resource managers to self-assess their adaptive capacity. AgricSyst, 103(8), 562-568.

Bryan, E., Ringler, C., Okoba, B., Roncoli, C., Silvestri, S., Herrero, M. 2011. Adapting agriculture to climate change in Kenya: Household and community strategies and determinants. In International Conference on May (Vol. 18).

Campbel, D., Barker, D., McGregor, D. 2011. Dealing with drought: Small farmers and environmental hazards in southern St. Elizabeth, Jamaica, ApplGeogr, 31, 146-158.

Chang Seng, D. 2010. The Role of risk governance, multi-institutional arrangements and polycentric frameworks for a resilient Tsunami early warning system in Indonesia, PhD dissertation.

Crichton, D. 1999. The risk triangle. In: Ingleton, J. (ed.), Natural disaster management. Tudor Rose, London.

Daryabari, J. 2011. The zoning of droughts in Iran over the last 50 years, Encyclopedia (geography), 82, 33-48.

Deressa, T., Hassan, R. M., Ringler, C. 2008. Measuring Ethiopian framers' vulnerability to climate change across regional sates, International Food policy research institute.

Eakin, H., rquez-Tapia, L. A. B. 2008. Insights into the composition of household vulnerability from multicriteria decision analysis, Global Environ Chang, 18, 112–127.

Fontaine, M. M., Steinemann, A. C. 2009. Assessing vulnerability to natural hazards: Impact-based method and application to drought in Washington State, Nat Hazards Rev, 10, 11-18.

Füssel, H. M., Klein, R.J., 2006. Climate change vulnerability assessments: an evolution of conceptual thinking. Clim. Change 75, 301–329.

Füssel, H.-M. 2007. Vulnerability: A generally applicable conceptual framework for climate change research, Global Environ Chang, 17, 155-167.

Füssel, H.-M., Klein, R. J. T. 2002. Assessing vulnerability and adaptation to climate change: an evolution of conceptual thinking, paper presented at the UNDP expert group meeting on integrating disaster reduction and adaptation to climate change, Havana, Cuba.

Gao, X., Liud, Zh., Zhaoa, X., Lingc, Q., Huoc, G., Wu, P. 2018. Extreme natural drought enhances interspecific facilitation in semiarid agroforestry systems. AgricEcosyst Environ, 265, 444–453

Garcia, J. N., Wagan, A. M., Medina, S. M. 2011. Vulnerability and adaptive capacity assessment in different a groecosystems (VAS-Agro). Agricultural Cluster, University of the Philippines Los Baños. https://www.apn gcr.org/resources/files/original/a6ea8463f54ba22a1f66ae550f6a4e8d.pdf

George, D. A., Clewett, J. F., Wright, A. H., Birch, C. J., Allen, W. R. 2007. Improving farmer knowledge and skills to better manage climate variability and climate change, JIAEE, 14 (2), 5-18.

Gerber, N., Mirzabaev, A. 2017. Benefits of action and costs of inaction: Drought mitigation and preparedness – a literature review. World Meteorological Organization (WMO) and Global Water Partnership (GWP) (2017). Benefits of action and costs of inaction: Drought mitigation and preparedness - a literature review (N. Gerber and A. Mirzabaev). Integrated Drought Management Programme (IDMP) Working Paper 1. WMO, Geneva, Switzerland and GWP, Stockholm, Sweden.

Ghambarali, R., Papzan, E., Afsharzadeh, N. 2012. Farmers' views on climate change and adaptation strategies, Rural Research, 3(3), 187-208.

Gizachew, L., Shimelis, A. 2014. Analysis and mapping of climate change risk and vulnerability in central Rift Valley of Ethiopia. African Crop Science Journal, 22(4), 807-818.

Global Water Partnership (Central and Eastern Europe). 2015. Drought risk management scheme -a decision support system, Technical note: Integrated Drought Management Programme in Central and Eastern Europe, p. 1-13.www.gwpcee.org.

Grasso, V. F. 2009. Early warning systems: State of art analysis and future directions, Draft report, United Nations Environment Programme (UNEP).

Guerrin, J. 2009. Vulnerability assessment of rural groundwater users to global changes: Gajwel watershed, Andhra Pradesh, India, Master dissertation in Water Management.

Gwambene, B., Majule, A. E. 2010. Contribution of tillage practices on adaptation to climate change and variability on agricultural productions in semi-arid areas of central Tanzania, 9th European IFSA Symposium “Climate change: Agriculture, food security and human health”, 4-7 July 2010, Vienna (Austria), 1300-1306.

Ifeanyi-obi, C. C., Etuk, U. R., Jike-wai, O. 2012. Climate change, effects and adaptation strategies; Implication for agricultural extension system in Nigeria, GJAS, 2(2), 53-60.

IPCC (International Pannel on Climate Change). (2001). Climate change 2001. Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change (R.T. Watson and the Core Writing Team, eds.). Cambridge University Press, Cambridge, United Kingdom, and New York, USA.

Jamshidi, R. 2016. Continuity of a decade of drought in stone and water Land, HamshahriNewspaper, 17 may 2016.

Jones, L. 2011. Towards a holistic conceptualization of adaptive capacity at the local level: Insights from the local adaptive capacity framework (LAC). A paper presented at the ‘Building Livelihoods Resilience in a Changing Climate’ conference, Kuala Lumpur, 3-5th March.

Kahraman, C., & Kaya, İ. (2009). Fuzzy process accuracy index to evaluate risk assessment of drought effects in Turkey. Human and Ecological Risk Assessment, 15(4), 789-810.

Kalantari, Kh. 2001. Regional planning and development (theories and techniques), Tehran: Khoshbin.

Kapoor, S. and Ojha, R. K. 2006. Vulnerability in rural areas: potential demand for micro insurance. Int. Rural. Manag, 2(1), 64-83.

Karami, E. 2009. Drought management and the role of knowledge and information. In Proceedings of the National Conference on Challenges and Strategies of Drought, Shiraz, Iran, 23–24 May 2009; pp. 40–65.

Knutson, G. L., Blomstedt, M. L., Slaughter, K. 2001. Result of a rapid appraisal study: Agricultural producers' perceptions of drought vulnerability and mitigation-Howard County, Nebraska.

Koochaki, E., Nasiri Mahdi, M., and Kamali, Gh. 2007. Iran Meteorological Indicators in Climate Change Conditions, Agron. Res, 5(1), 133-142.

Kumpulainen, S. 2006. Vulnerability concepts in hazard risk assessment. Natural and technological hazards and risks affecting the spatial development of European Region, Geological Survey of Filand, 42, 65-74.

Mabe, F. N., Sarpong, D. B., Osei-Asare, Y. 2012. Adaptive capacity of formers to climate chang adaptation strategies and ther effects on rice production in northern region of Ghana. RJOAS, 11(11), 9-17.

Maleki, T. 2014. Vulnerability assessment of farmers during drought: Droodfaraman village, Kermanshah Township, Master's Degree in Rural Development, Department of Agricultural Extension and Education, Razi University of Kermanshah.

Mckee, T. B., Doesken, N. J., Kleist, J. 1993. The relationship of drought frequency and duration on time scales. PP.179-184. In: 8th Conf. on Appl. Climatol. Anaheim, CA.

Mengistu, D. K. 2011. Farmers perception and knowledge of climate change and their coping strategies to the related hazards: Case study from Adiha, central Tigray, Ethiopia. Agric. Sci, 2 (2), 138-145.

Metzger, M. J., Leemans, R. and Schröter, D. 2004. A multidisciplinary multi-scale framework for assessing vulnerability to global change, Millennium ecosystem assessment conference, Alexandria, Egypt.

Multihazard Mitigation Council. 2002. Parameters for an independent study to assess the future benefits of Hazard Mitigation Activities. Washington, DC: National Institute of Building Sciences (July), 69pages. Retrieved from World Wide Web: http://www.nibs.org/MMC/images/July%202002%20Phase%20I%20Final%20Report.pdf

Nalbantis, I. 2008. Evaluation of a hydrological drought index, European Water, 23/24, 67-77.

Nazari, S., Pezeshki Rad, Gh., Sedighi, H., Azadi, H. 2015. Vulnerability of Wheat farmers: Toward a conceptual framework, Ecol. Indic. 52, 517-532.

Paavola, J. 2008. Livelihood, vulnerability and adaptation to climate change in Morogoro, Tanzania. Environmental Science and Policy, 11, 624-654.

Piya, L., Maharjan, K. L., Joshi, N. P. 2012. Vulnerability of rural households to climate change and exteremes: Analysis of Chepang households in the Mid-Hills of Nepal, International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguace, Brazil, 18-24 Agust.

Polsky, C., Neff, R., Yarnal, B. 2007. Building comparable global change vulnerability assessment: The vulnerability scoping diagram, Global Environ Chang, 17, 472-485.

Rajsekhar, D., V. P. Singh, and A. K. Mishra (2015), Integrated drought causality, hazard, and vulnerability assessment for future socioeconomic scenarios: An information theory perspective. J. Geophys. Res. Atmos., 120, 6346–6378.

Reed, M.S., Podesta, G., Fazey, I., Geeson, N., Hessel, R., Hubacek, K., Stringer, L.C., Thomas, A.D., 2013. Combining analytical frameworks to assess livelihoodvulnerability to climate change and analyse adaptation options. Ecol. Econ. 94, 66–77.

Şen, B., Topcu, S., Türkeş, M., Sen, B., & Warner, J. F. (2012). Projecting climate change, drought conditions and crop productivity in Turkey. Climate Research, 52, 175-191

Sengestam, L. 2009. Division of capitals What role does it play for gender-differentiated vulnerability to drought in Nicaragua? Community Dev, 40, 154-176.

Sharafi, L. 2017. Modeling drought early warning system in Kermanshah Township. Ph.D. thesis in agricultural development, Department of Agricultural Extension and Education, Razi University of Kermanshah.

Sharafi, L., Zarafshani, K. 2014. Drought management strategies of wheat farmers in Kermanshah, AgricWater Manag, 1(1), 1-12.

Sharma, U., Patwardhan, A. 2007. Methodology for identifying vulnerability hotspots to tropical cyclone hazard in India, Miting Adapt Start Glob Change, 13, 703-717.

Shewmake, Sh. 2008. Vulnerability and the impact of climate change in South Africa's Limpopo river Basin, International food policy research institute.

Shisanya, S., Mafongoya, P. 2017. Assessing rural farmers’ perceptions and vulnerability to climate change in uMzinyathi district of Kwazulu-Natal, South Africa. AFR J AGR RES, 12 (10), 815-828.

Silva, B. K. N., Lucio, P. S. 2014. Indicator of agriculture vulnerability to climate extremes: A conceptual model with case study for the Northeast Brazil. ACS, 4, 334-345.

Simelton, E., Fraser, E. D. C., Termansen, M., Forster, P. M. Dougill, A. J. 2009. Typologies of crop-drought vulnerability: an empirical analysis of the socio-economic factors that influence the sensitivity and resilience to drought of three major food crops in China 1961-2001. Environmental Science & policy, 12, 438-452.

Smit, B., Wandel, J. 2006. Adaptation, adaptive capacity and vulnerability, Global EnvironChang, 16, 282-292.

Sönmez, F. K., Kömüşcü, A. Ü., Erkan, A., &Turgu, E. (2005). An analysis of spatial and temporal dimension ofdrought vulnerability in Turkey using the standardized precipitation index. Natural Hazards, 35(2), 243-264.

Stenekes, N., Kancans, R., Randall, L., Lawson, K., Reevet, I., Stayner, R. 2012. Revised indicators of community vulnerability and adaptive capacity across the Murray-Darling Basin, Australian Government Department of Agriculture, Fisheries Forestry, ABARES, p.1-64.

Thurow, Th. L., Taylor, Ch. A. 1999. Viewpoint: The role of drought in range management. J Range. Manag. 52, 413-419.

Trærup, S. 2007. Coping with climate change vulnerability: issues related to development and agricultural linkages in developing countries, Department of Geography and Geology, University of Copenhagen. Retrieved from World Wide

Web:http://www.Diis.dk/graphics/_IO_indsatsomraader/fattigdom_og_naturresurser/P_E_may%2027_Tr%E6rup_cc

Vento, J. Ph., Reddy, V. R., Umapathy, D. 2010. Coping with drought in irrigated South India: Farmers' adjustments in NagarjunaSagar.Agric Water Manag, 1434-1442.

Wehbe, M. B., Seiler, R. A., Vinocur, M. R., Eakin, H. Santos, C., Civitaresi, H. M. 2005. Social methods for assessing agricultural producers' vulnerability to climate variability and change based on the notion of sustainability, AIACC working paper, Retrieved from the World Wide Web: http://www.aiaccproject.org.

Wilhelmi, O. V., Wilhite, D. A. 2002. Assessing vulnerability to agriculture drought: A Nebraska case study. Natural Hazards, 25, 37-58.

Wilhite, D. A., Sivakumar, M. V. K., Pulwarty, R. 2014. Managing drought Risk in a Changing Climate: The Role of National Drought Policy. Weather ClimExtrem, 3, 4-13.

Wilhite, D.A. 2013. Drought management and policy: Changing the paradigm from crisis to risk management. European Water, 60, 181-187.

Wisner, B. 2001. Vulnerability in disaster theory and practice: From soup to taxonomy, then to Analysis and Finally Tool, International work-conference disaster studies of Wagningen University and research center. Retrieved from World Wide Web: http://www.fema.gov/impact/chapter2-assessment.pdf.

Wisner, B. 2004. Assessment of capability and vulnerability (Edt.), Bankoff, G., Frerks, G. &Hilhorst, D. Mapping Vulnerability: Disasters, Development and People (2004). Earth scan: UK.

Wolfgang, G., Bollin, Ch. 2001. Disaster risk management: Working concept, the Gesllschaft fur TechnischeZusammenarbei (GTZ).

World Methodological Organization (WMO). 2012. Standardized precipitation index. User Guide. Chair, Publications Board.

Xiaoqian, L., Yanglin, W., Jian, P., Ademola, K., He, Y. 2013. Assessing vulnerability to drought based on exposure, sensitivity and adaptive capacity: A case study in Middle Inner Mongolia of China. China Geogr Sci. 23, 1, 13–25.

Zarafshani, K., Maleki, T., Keshavarz, M. 2019. Assessing the vulnerability of farm families towards drought in Kermanshah province, Iran. GeoJournal, DOI 10.1007/s10708-019-09994-0, 1-14.

Zarafshani, K., Sharafi, L., Azadi, H., Hosseininia, Gh., De Maeyer, Ph., Witlox, F. 2012. Drought vulnerability assessment: The case of Wheat farmers in Western Iran. Global Planet Change, 98-99, 122-130.

Zarafshani, K., Sharafi, L., Azadi, H., Van Passel, S. 2016. Vulnerability assessment models to drought: Toward a conceptual framework. Sustainability, 8 (6), 588.

Zarei, M., Kazemini, S. E., Bahrani, M. J. 2014. Effect of tillage systems and water stress on wheat growth and yield. Iranian Crop Research, 12(4), 793-804.

Zhang, J. 2004. Risk assessment of drought disaster in the maize-growing region of Songliao Plain, China. AgricEcosyst Environ, 102, 133–153.

Zhao, H., Xu, Z., Zhao, J., Huang, W. 2017. A drought rarity and evapotranspiration-based index as a suitable agricultural drought indicator. Ecol. Indic, 82, 530-538.