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Review

Vulnerability of wheat farmers: Toward a conceptual framework

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ABSTRACT

Vulnerability is expected to differ based on climatic conditions as well as socio-economic attributes of farming households. In this regard, attention toward vulnerability assessments is increasing within policy-making processes, to assist in selecting suitable coping strategies and policies to reduce farmers' vulnerability. Through identifying the main vulnerability indicators from a sustainability perspective (including social, economic, and environmental dimensions) among wheat farmers, this study is seeking an inclusive conceptual framework to assess their vulnerability to both socio-economic and environmental changes. Taking the main elements (i.e., sensitivity, exposure and adaptive capacity) of vulnerability into account, this paper tried to develop an inclusive systemic framework to understand the most important indicators of vulnerability for wheat farmers at various spatial and temporal scales. It is supposed that the framework is a useful guide for policymakers in identifying the vulnerable groups of wheat farmers and zones so that they can decide about proper coping strategies to effectively deal with adverse effects of climate and undesired socioeconomic changes in the wheat farming system.

Contents

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1. Introduction

1.1. Importance of vulnerability assessment

Vulnerability assessment is an effective tool to determine the systems that are sensitive to harm; mainly food security, water, public health, natural resources. Understanding the vulnerability level of a system is useful to recognize and create mitigation actions such as enhancing coping capacity and reducing the susceptibility and understanding the interactions between the various structures and processes that cause the vulnerability (Botero and Salinas, 2013). The evaluation of the vulnerability of farm families to global climate change is presently the main focus of agricultural policies, especially when food sector relies on irrigated farming and when agriculture sector is yet the main source for economy of a country (Aulong and Kast, 2011). The global agriculture in the twenty-first century will face significant challenges that call for an integration of the environmental, social, and economic dimensions of development to meet the needs of present generations without compromising the needs of future generations. The world population is expected to grow by almost 3 billion within the next 50 years, mainly in developing countries. Countries cannot launch any poverty alleviation and food security projects without first tackling concerns about sustainable agricultural and rural development. Moreover, climate change poses the risk of further depressing the economic performance of the agricultural sector (Aulong and Kast, 2011). Consequences of climate change on farming systems sustainability are straight forward: crop yields are decreasing with some years in which there was a significant loss of production as a consequence of droughts. Crop diversity is suggested as an adaptation strategy but with no stable empirical evidence (Reidsma and Ewert, 2008). Agriculture is significantly related to the relationship between the natural environment and human society and the degree to which climatic events can affect agricultural systems depends on a wide variety of factors including environmental and socio-economic. Considering the rapid population growth, identifying the social, economic, and environmental vulnerability of agricultural systems seems unavoidable as far as sustainable development is concerned (Fischer et al., 2002).

1.2. Current trends in vulnerability assessment

In recent years, the central focus of the global change and sustainability researches has been on the concept of vulnerability (Metzger and Schroter, 2006). This concept has been known and become familiar in association with climatic factors and natural disasters. IPCC (2007) defines vulnerability as a functional effect of climate variability exposed to a system which has susceptible defensive capacity to adverse effects. From the social science point of view, scientists should focus on those socio-economic, environmental and political structures and processes which can make people vulnerable, apart from the physical dimension of environmental threat (Luers et al., 2003; Schroter et al., 2005; Metzger et al., 2005; Adger, 2006; Metzger and Schroter, 2006; Birkmann and Wisner, 2006; Eakin et al., 2006; Berry et al., 2006; Villagran De Leon, 2006; Polsky et al., 2007; Fussel, 2007; Acosta Michlik and Espaldon, 2008; Chazal et al., 2008; Pearson and Langridge, 2008; Wisner, 2009; Pearson et al., 2011; Sangpenchan, 2011; Shrestha, 2011; Nicholas and Durham, 2012; Anderson and Mclachlan, 2012; Zarafshani et al., 2012). All these researchers have identified the critical components of vulnerability such as the exposure to stressors, the capacity to adaptation, cope with, resist and recover from natural hazards, and the consequences of stresses. Most studies have however focused on vulnerability to the direct or indirect physical or environmental impacts of global environmental problems, while socio-economic and political aspects have received much less attention (Anderson and Mclachlan, 2012). This has been also confirmed by Lindoso et al. (2012) who considered socio-economic, institutional and climate indicators for assessing the vulnerability of smallholder farming to climate change in a case study in Brazil. They emphasized that the vulnerability of smallholder farming is affected not only by climate drivers but also by socio economic and political-institutional factors. Therefore, the vulnerability of a region relies not only on its exposure to severe climatic variations, but also on its social characteristics that will influence the consequences of the unusual climate. Importantly, land use changes resulted from the institutional issues and their influences on rising vulnerability at different scales need to be taken into account (Máñez et al., 2011).

Majority of literature has considered environmental and social exposures as independent functions. This mono-disciplinary factor-driven vulnerability research has been criticized for oversimplifying the real-world context by neglecting the interaction of exposures (Kelly and Adger, 2000; Turner et al., 2003a; O'Brien et al., 2004; Reidsma, 2007; Deressa, 2010; Sangpenchan, 2011; Anderson and Mclachlan, 2012; Azadi et al., 2007, 2009). Given that, how to incorporate multiple and often conflicting values into the analysis of environmental systems and their vulnerability has remained as a continuous challenge for future works in global environmental change. Methods and frameworks that can account for multiple perspectives on vulnerability for particular people in specific locations are very few (Mclaughlin and Dietz, 2007; Chazal et al., 2008). To address these challenges, much effort has been put into better understanding the vulnerability and adaptive capacity of individuals, communities, industries and institutions in the face of global environmental change (Eriksen and Kelly, 2007; Fussel and Klein, 2006; Sangpenchan, 2011).

Agricultural systems are realized as one of the most vulnerable systems in the planet due to a high dependency on climatic conditions particularly on temperature and rainfall. In developing countries, the increase in temperature and reduce in precipitation have become more intense (Sivakumar et al., 2005), and climatic hazards (drought, flood, heat, and coldness) have been accruing more often with higher severity (IPCC, 2007). Surely, global agricultural production systems are being influenced by any variation in climatic condition (Valizadeh et al., 2014). Variations and long-term changes in climate variables pose challenges to farmers and their communities which rely much on the output of agricultural systems (Sangpenchan, 2011).

Farmers will have to adjust to both climate variations and socio-economic changes at the same time, and thus vulnerability must be taken into account from a multiple rather than limited perspective. It is hard for farmers, particularly those in developing countries to find a way to overcome climatic changes since they do not have required investments for implementing (new) adaptive practices so that they can preserve their properties and households (Thompson et al., 2007). In particular, families whose life depends on rain-fed agriculture are most vulnerable to these changes (Thorlakson and Neufeldt, 2012). Moreover, individual farmers are inevitably vulnerable to the negative impacts of climate change, and particular adaptation strategies (such as adopting new seed varieties, relocating the farm, or installing irrigation systems) are usually required. Even though agricultural effects are mostly discussed at larger scales, individual farmers are likely to confront and respond to the impacts resulting from this double exposure, and they are likely to be the most sensitive group in the agricultural production system. Therefore, the gains/losses from double exposure at the national level should not be extrapolated as the gain/loss at a lower level (e.g., an individual farmer). Hence, in addition to addressing larger-scale relationships, vulnerability at the farmer level should clearly be addressed (Sangpenchan, 2011).

Many researchers have explored the causal factors of farmer's vulnerability from different points of view. For example, Siwar et al. (2013) in their study, tried to explain the factors of vulnerability that affect the life of the paddy farmers in Malaysia. They found that climate change, economy and social vulnerability had a significant influence on the rice production and livelihood of farmers. Kyi (2012) also identified the environmental and socio-economic factors of farmers' vulnerability to climate variability in the central dry zone of Myanmar. Similarly, Aulong et al. (2010) have identified the main drivers of farmers' vulnerability to global change in Southern India according to the IPCC vulnerability approach to climate change. In line with these studies, Lindoso et al. (2012) determined indicators for assessing the vulnerability of smallholder farming to climate change in a semi-arid region in Northeastern Brazil. Deressa et al. (2008) have examined the vulnerability of farmers to climate change in Ethiopia through developing a vulnerability index and making a comparison of vulnerability determinants between regions. In another study, Deressa (2010) assessed farmers' vulnerability to drought at local and regional levels and analyzed the main variables of adaption measures and elements that affect perceptions toward climate change in the Blue Nile Basin. Khoshnodifar et al. (2012) in a study in Northeast Iran identified and measured drought vulnerability indicators (economic, social and technical) among wheat farmers. Climate change could significantly influence wheat as a crop that is the main feeding source for about 21% of global food and 200 million hectares of croplands all around the world (Ortiz et al., 2008). Maize, wheat and other major crops are significantly influenced by climate-related yield reductions of 40 megatonnes each year from 1981 to 2002 worldwide (Lobell and Field, 2007). Many studies reported the rise in temperature is the main factor in the yield loss of wheat as it leads to the fast growth and earlier flowering of the plant and consequently results in the reduction of the yield (Lal et al., 1998; Valizadeh et al., 2014). Similarly, Cabas et al. (2010) analyzed the impacts of climatic and non-climatic elements on the mean and variance of several main crops including winter wheat yield for southwestern Ontario, Canada during 26 years period. They found that when the temperature and precipitation increase, there is a reduction in the mean yield of wheat while its variance increases. In contrast, many studies have found that higher temperatures will reduce the yield of wheat (Lobell and Asner, 2003; Weiss et al., 2003; You et al., 2005). Moreover, crop inputs, technology, management and land quality are the main non-climatic factors affecting the yield as well (You et al., 2005). For example, in China, the world's largest wheat producer, 75% of the increase in wheat yields results from more utilization of physical inputs. Furthermore, according to the results of Cabas et al. (2010), technological advances are the main non-climatic drivers affecting yields with about 1% increase in winter wheat yields per year.

In recent years, Iranian wheat farmers have faced damages that were mainly induced by climatic conditions and incorrect agricultural policies. Obviously, compatibility with these damages requires a systemic understanding of the situation of wheat farmers' vulnerability. This study tries to explain the main components of wheat farmers' vulnerability by developing an inclusive model that covers environmental and socio-economic determinants simultaneously. Although vulnerability is a multidimensional concept used in many fields with various explanations (Alwang et al., 2001; Brooks, 2003; Füssel and Klein, 2006), vulnerability assessment is directly linked with the broader aim of sustainable development and sustainability science (Lobell et al., 2002; Schroter et al., 2005; Wisner, 2009). Therefore, developing a conceptual framework that account for the vulnerability of wheat farmers with diverse and complex linkages seems necessary for policymakers in identifying the main components of vulnerability and how they could most effectively be modeled. Given that, the objectives of the paper are as follows: (1) defining vulnerability and identifying its main components; (2) identifying the socio-economic and environmental determinants of wheat farmers' vulnerability; and (3) developing a conceptual framework of socio-economic and environmental vulnerability for wheat farmers.

Accordingly, this paper first introduces the vulnerability concept and briefly reviews existing approaches to quantify vulnerability. After identifying the indicators related to the social, economic and environmental driving forces affecting the total vulnerability of farmers, a conceptual approach to quantify the vulnerability of wheat farmers that integrates three essential concepts (sensitivity, exposure and adaptive capacity) is proposed in the context of sustainability dimensions (social, economic and environmental). Finally, a discussion on the implications of the presented model for future research and practice is elaborated.

2. Vulnerability

2.1. Definition

The word 'vulnerability' is generally related to natural hazards such as flood, droughts as well as social hazards like poverty and so on. Of late, the concept of vulnerability has been extensively used in a variety of research contexts to refer to the degree in which a system is likely to be harmed by various factors affected by a stressor (Burg, 2008; Deressa, 2010; Sangpenchan, 2011; Zarafshani et al., 2012). In the context of climate change, there are many studies on vulnerability and its definitions which vary due to the perception and background of different researchers. A brief review of various definitions is given below.

Adger (2006) believe that vulnerability is the state of susceptibility to harm from exposure to stresses associated with environmental and social changes and from the absence of capacity to adapt, hence, vulnerability of individuals to hazards is different and has different degrees (Eakin et al., 2006). Vulnerability is also defined as capabilities of a person or group to anticipate, resist, cope with, and recover from the impact of natural or man-made hazards (Paavola, 2008; Ethlet and Yates, 2005; Blaikie et al., 1994). One of the advantages of this definition is that it identifies vulnerable groups and areas in a community. Vulnerability is usually conceived as being established by elements that comprise sensitivity and exposure to disruptions or external forces, and the ability to adjust consist of three main aspects of vulnerability (Polsky et al., 2007; Adger, 2006). The concept of vulnerability has become an important part of food security analyses since 1980s. It is seen as two sides: exposure to external hazards; and an inability to cope with those shocks, attributed to social, political, and economic factors (Burg, 2008).

In this study, we follow Leichenko and O'Brien (2002) who proposed a working definition of dynamic vulnerability: "the extent to which environmental and economic changes influence the capacity of regions, sectors, ecosystems, and social groups to respond to various types of natural and socio-economic shocks". Dynamic vulnerability combines traditional notions of vulnerability with three components: exposure, sensitivity and adaptive capacity, but places these concepts within a rapidly changing socio-economic and environmental context. Therefore, according to this definition, vulnerability is conceptualized as an operation of three dimensions: exposure, sensitivity and adaptive capacity, which are influenced by arrange of biophysical and socio-economic factors (TERI, 2003). These three components are described as follows.

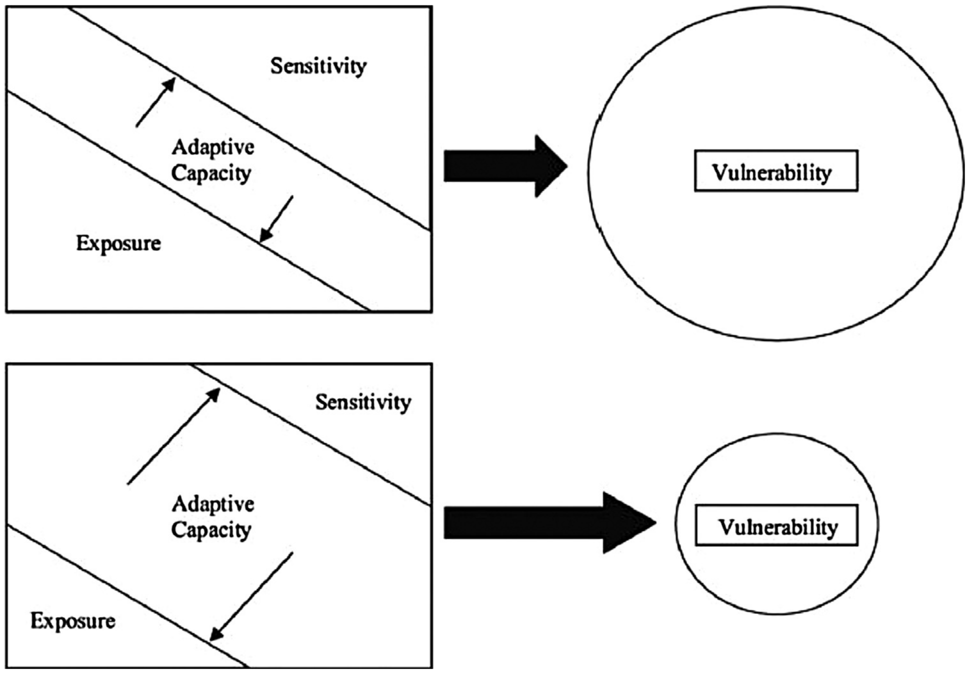

Fig. 1. The fundamental role of adaptive capacity in impacting vulnerability (Engle, 2011).

2.2. Dimensions

2.2.1. Exposure

Exposure is the essence and extent to which a set of procedures encounters with socio-economic or environmental stress. Exposure refers to stresses caused by changes in frequency, intensity, magnitude, frequency, duration and areal extent of the hazard and the nature of climate and non-climate stress (Luers et al., 2003; Adger, 2006; Sangpenchan, 2011).

2.2.2. Sensitivity

Sensitivity is the degree to which an individual or group (as the system of interest) is affected by exposure to stresses (climate, non-climate) (Adger, 2006; Deressa, 2010; Sangpenchan, 2011). This measure, which illustrates the ability of a system to respond to climatic impacts, is formed by both socio-economic and ecological situations and identifies the level at which a group will be influenced by environmental stresses (SEI, 2004). Sensitivity can be described as the probability of encountering with various extents of effects of being exposure to a disturbance or shock (Downing, 1990). Elasticity's price for cereals, for example, may identify the sensitivity to ongoing changes in international cereal prices, since they indicate the efficient effect of the exposure (Prosperi et al., 2014). Like exposure, sensitivity is directly associated with vulnerability.

2.2.3. Adaptive capacity

The potential effect on a system is determined by exposure and sensitivity together. Nevertheless, it is important to consider the fact that although a system might be significantly exposed and/or sensitive to stress and shock, it cannot be said that it is definitely vulnerable (Fellmann, 2012). The reason for this is that the capacity of a system to adapt with stresses cannot be described by exposure and sensitivity. Indeed, vulnerability is the net impact that continues to exist after considering an adaptation option (Fig. 1). Thus, the system's adaptive capacity influences the vulnerability by adjusting both exposure and sensitivity (Gallopin, 2006).

Adaptive capacity is the capability of a system to incorporate so that being able to deal with socio-economic stresses and environmental events or policy change and to increase the extent of variability that it can tackle with (Adger, 2006). Generally, the ability of a system to respond to the exposures and the effects in order to adjust to and cope with the impacts is referred to adaptive capacity (Fussel and Klein, 2006; Kelly and Adger, 2000; Sangpenchan, 2011). In other words, adaptive capacity refers to the extent to which a system can modify its circumstances to move to a less vulnerable condition. For example, a farmer may have adapted to drought over years by shifting management methods, such as using drip irrigation and taking measures to increase soil quality for water retention. This adaptation may lead the farmer to be less sensitive to drought. The farmer, however, may also have the potential to shift to more drought resistant crops or dig groundwater wells to further mitigate the sensitivity of his farming system to drought over the long-run (Luers et al., 2003). Hughes et al. (2012) propose to separate the components of adaptive capacity into different groups including capitals, learning, flexibility and social institution.

Within an institutional structure, adaptive capacity can be a representative of stakeholders' capacity reaction to tackle with variations (Prosperi et al., 2014). Through developing coping strategies and adapting opportunities, involved actors can respond to changes in norm economic, finance and social institutional context (North, 1991). The stakeholders try to find solutions among their human, physical, natural and social capitals in order to be able to change the environment as well as turning these assets into capabilities, which let them tackle with the stresses' effects and to be ready to respond to future shocks. For such features that determine adaptive capacity, the concept is usually related to the sustainability (Strunz, 2012).

Accordingly, vulnerability is conceptualized as a function of exposure, sensitivity and adaptive capacity of a system against a stress (Luers et al., 2003), where the sensitivity corresponds to the biophysical approach and adaptive capacity to the socio-economic approach (Deressa et al., 2008). It is important to note that researchers with different specialties have been conceptualizing vulnerability in different ways. Hence, it is difficult to have a commonly accepted definition and methodological approach to model vulnerability so that the suitability of a concept or method can be assessed. However, having information about existing conceptual approaches can assist in selecting a method, or a mixed method from the available ones, and further help analyze vulnerability for wheat farmers, as for the goal of this study. Adger (1999), Füssel and Klein (2006), and Fussel (2007) have reviewed the methodological and conceptual approaches available to vulnerability evaluation. For the purpose of this study, the current concepts and approaches for analyzing vulnerability will be reviewed in order to develop a conceptual framework for the vulnerability of wheat farmers.

2.3. Approaches

According to Deressa et al. (2008), socio-economic, biophysical and integrated assessment approaches are the main conceptual approaches in the assessment of vulnerability. The socio-economic vulnerability approach considers the social, economic and political statuses of vulnerable persons or social groups (Adger, 1999; Fussel, 2007). Generally, this approach determines the adaptive capacity of individuals or societies according to their internal attributes. Adger and Kelly (1999) used this approach where environmental factors in their study area in the coastal lowlands of Vietnam were considered and vulnerability was evaluated mainly according to differences in socio-economic characteristics of vulnerable people. The main limitation of this approach is that it only explains the differences within the society and does not focus on the environmental factors that can have major driving effects.

The biophysical approach focuses on the amount of loss that an environmental stressor poses on social as well as biological systems. Despite significant information that this approach provides, the major limitation is that this approach considers mainly some physical losses like yield, income, and the like. Overall, the biophysical approach takes sensitivity into account and ignores many aspects of the adaptive capacity of the social categories (Deressa et al., 2008).

The integrated approach accommodates both socio-economic and environmental methodologies to evaluate vulnerability. The hazard-of-place model developed by Cutter et al. (2000) is an example of this approach that merges both biophysical and socio-economic factors to identify vulnerability. O'Brien et al. (2004) conducted the vulnerability mapping approach which is another good example. In this approach, both socioeconomic and biophysical factors are incorporated to illustrate the vulnerability status by mapping. Despite the corrections made by the integrated assessment approach in order to bridge the gap between the two other approaches, it still has its own limitations. The real obstacle of this approach is the lack of standard methods for combining biophysical and socio-economic indicators. However, compared with the two others, this latter approach has significant advantages, especially, in relation to policy decisions (Deressa et al., 2008; Luers et al., 2003).

Overall, vulnerability has been considerably studied (Adger, 2006), and mainly focused on conceptualizing vulnerability and its linkage with adaptation. There are also other researches that considered vulnerability to poverty, sustainable livelihoods and socio-ecological systems' vulnerability. Many of the studies have provided straightforward conceptual frameworks suitable for constructing the vulnerability issue to climate change at global scales (Fussel, 2007; Ionescu et al., 2009). Other studies develop conceptual diagrams with particular focus on adaptation (Kelly and Adger, 2000; Brooks, 2003; Downing and Patwardhan, 2004; Brooks et al., 2005; Yamin et al., 2005; Füssel and Klein, 2006). Table 1 shows an overview of the most commonly used conceptual frameworks of vulnerability assessments. Among the existing conceptual frameworks in vulnerability studies, those that link vulnerability and sustainability include the vulnerability/sustainability framework proposed by Turner et al. (2003a); the sustainable livelihood approach originally developed by Chambers and Conway (1992) and the BBC conceptual framework which explicitly relates and integrates the sustainable development concept into the vulnerability approach (Birkmann, 2006). The following paragraphs give more insights into these specific conceptual frameworks that link vulnerability and sustainability.

The vulnerability/sustainability approach developed by Turner et al. (2003a), establishes an alternative concept of vulnerability to global change through placing local vulnerabilities within the larger settings that affect processes usually performing at local to global scales. Turner et al. (2003a) consider three main components for the vulnerability of a system (Fig. 2). The first dimension is the exposure to hazards that focuses on the frequency, duration and magnitude of the exposure. Second component is the sensitivity of the current condition of a system to the hazards. Both the environmental and human factors determine the sensitivity of a system. Lastly, the resilience of a system considers the future measures that can enhance its ability to tackle with external events. Adaptation actions are implementations or operations that assist in promoting resilience of farmers to extreme events and can encompass government policies, NGO programs and independent decisions made by people (Thorlakson, 2011). In this model, there is no explicit difference among exposure and sensitivity neither the beginning and ending location of vulnerability is clear. It works more efficient in qualitative assessments compared to the empirical analyses. Since the vulnerability/sustainability framework is yet a new approach, there is a lack of literature on its application to date (Cutter et al., 2009). For example, Turner et al. (2003b) conducted some primary case studies and Giannecchini et al. (2007) also utilized the socio-ecological systems approach to investigate land cover change and human-environment interactions in the rural areas of South Africa.

The next framework is sustainable livelihood approach which considers five key elements including human, natural, financial, social and physical household assets or capitals (Chambers and Conway, 1992). This approach comprises two major terms including vulnerability and sustainable livelihoods which were integrated by the Department for International Development (DFID) in 1999. According to the DFID, livelihoods are the means of living including the capabilities, and both material and social assets (DFID, 1999). This approach is usually helpful in designing development programs at the community level, as well as assessing the households' ability to cope with stresses and shocks (Chambers and Conway, 1992). Fig. 3 illustrates the sustainable livelihood framework showing that the vulnerability context has a direct effect on the livelihood strategies and outcomes, the community systems and processes, and is an important indicator for determining sustainability of livelihood (Botero and Salinas, 2013). Since this conceptual framework look at the mixture of intervention and response elements, it can be served as an important source of information and a useful list of required elements for other approaches that try to determine vulnerability and coping capacity of a system to natural hazards (Birkmann, 2006).

Finally, the BBC conceptual framework is proposed by Birkmann (2006) based on linking conceptual works of Bogardi and Birkmann (2004) and Cardona (1999). The BBC framework highlights the need to consider environmental, social and economic aspects of vulnerability. This framework, therefore, explicitly links and incorporates the sustainable development concept into the vulnerability context. The BBC conceptual framework underlines the necessity of considering exposure, sensitivity components and coping capacities at the same time into the vulnerability assessment. Moreover, it highlights the fact that vulnerability should be considered as a process and its reduction needs to examine both coping capacities and possible intervention measures with regard to social, economic and environmental dimensions at various scales. This approach stresses that organizational and institutional elements are important aspects that need to be examined within the three sustainability spheres (economy, social and environmental) (Fig. 4).

Table 1
Conceptual frameworks of vulnerability.

Framework	Description
Double structure of vulnerability	Based on this framework, vulnerability can have both external and internal side. The internal side refers to the capacity to forecast, tackle with, resilience and recovering from the hazard's impact while the external side relates to the exposure to stresses and shocks. Based on Bohle's (2001) conceptual framework, the double structure approach highlights the fact that vulnerability comes from the interplay between exposure to external drivers and the adaptive capacity of the impacted household, category or community.
Sustainable livelihood framework	The sustainable livelihood framework encompasses two major terms, sustainability and livelihoods. The original concept developed by Chambers and Conway (1992) that holds the vision that livelihoods is the means of gaining a living, comprising livelihood capabilities, and tangible and intangible capitals. Within the livelihood framework, the term sustainability is often related to coping capacity and recovering ability from risks and shocks as well as to keep the natural resource asset (DFID, 1999; Chambers and Conway, 1992).
Risk-hazard approach	This approach usually considers vulnerability, exposure and coping capacity as distinct components. The risk-hazard conceptual framework is useful for assessing the vulnerability to particular valued factors that come from their exposure to certain extreme events with particular significance (Burton et al., 1978; Kates, 1985). It is not easy to apply the risk-hazard approach to communities or groups whose exposure to natural events substantially relies on their acts and attitudes, as identified by socioeconomic drivers. As a result, the individual's vulnerability has often been considered simply as "exposure to hazards" (Hewitt, 1997, p. 27) or "being in the wrong place at the wrong time" (Liverman, 1990). Despite this approach has been recently utilized for various hazards, traditionally speaking, the risk-hazard framework hypothesizes that hazard events are static, rarely occur and well recognized (Downing et al., 1999).
Political economy approach	The political economy approach analyzes the effects of vulnerability on people, identifying the most vulnerable groups and the root caused for their vulnerability. This approach applies more in the poverty and development studies. Vulnerability refers particularly to individuals, and it is according to a descriptive model of socioeconomic vulnerability to multiple driving forces (Fussel, 2007).
Vulnerability/sustainability	This conceptual framework (Turner et al., 2003a) particularly identifies exposure, coping capacity, impacts reactions and adaptation responses as main components of vulnerability. The framework also takes into consideration the interaction of the multiple interplaying disturbances, drivers and shocks. This framework examines vulnerability within the wider and intimately related human–environment context. It also considers the adaptation concept, which is seen as a factor that promotes resilience. However, some challenges still exist, like whether the difference among factors and outcomes in such feedback-loop system is suitable (Birkmann, 2006).
Onion framework	The onion framework (Bogardi and Birkmann, 2004) describes vulnerability in relation to various hazard effects with regard to the economic and social aspects and it does not consider environmental vulnerability. Indeed, this approach explains the environment initially as the event sphere. The aspect of exposure is also not exactly included.
The pressure and release model (PAR model)	The disaster pressure-and-release (PAR) model first takes start with taking the risk-hazard framework into account, introducing risk as a result of vulnerability and hazard (Blaikie et al., 1994; Wisner et al., 2004). Afterwards, it provides a descriptive model of vulnerability that comprises world root causes, local vulnerable situations and regional pressures without exact definition of the concept of 'vulnerability'.
ISDR framework for disaster risk reduction	The UN/ISDR framework defines vulnerability as a key element identifying risk. Accordingly, vulnerability can be categorized into economic, social, environmental and physical spheres. However, the framework does not show how vulnerability reduction can also reduce the risk. For that reason, it is not easy to realize the importance of declining risk throughout reducing vulnerability and mitigating hazards.
Holistic approach	According to this framework, vulnerability situations not only rely on the exposure and sensitivity of physical drivers in vulnerable areas but also on socio-economic susceptibility and the absence of social resilience and capacity to cope. These elements can be a tool for the direct and indirect as well as complex effects of extreme events. Carreno et al. (2005) has developed the revised version of the holistic model that considers vulnerability as an interaction of the possible physical loss and the impact driver (economic and social susceptibilities and unavailability of resilience).
BBC conceptual framework	The term "BBC" is based on the conceptual frameworks developed by Bogardi and Birkmann (2004) and Cardona (1999). It came from three emphasizes on how connect human security sustainable development and vulnerability (Bogardi and Birkmann, 2004) and a wider argument on developing different approaches for calculating environmental degradation within the sustainable development context. This means, the BBC framework highlights the importance of considering social, environmental and economic spheres of vulnerability by integrating and linking sustainability into the vulnerability framework.

Adapted from Birkmann (2006) and Fussel (2007).

2.4. Methods

Based on the previously discussed approaches, there is a wide range of methods for assessing vulnerability. Vulnerability is a very dynamic phenomenon that cannot directly be observed. It is then very difficult to objectively measure or quantify it. Many studies have been conducted using different methods of analysis, namely the econometric methods and indicator methods. The econometric methods use household-level socio-economic field data to evaluate the level of vulnerability of various social groups. This technique includes three categories of assessment: "vulnerability as expected poverty, vulnerability as low expected utility and vulnerability as uninsured exposure to risk" (Hoddinott and Quisumbing, 2003). Given the general objective of this study; i.e., to develop a conceptual framework for assessing vulnerability of wheat farmers through a multi-dimensional (social, economic, environmental) approach, the indicator approach is applied. The indicator approach is the most common method utilized for assessing vulnerability in the global change environment and one of the most common methods in the vulnerability assessment of farming systems (Deressa et al., 2008). It is adopted to create more useful knowledge of the socio-economic and biophysical factors affecting vulnerability (Hebb and Mortsch, 2007).

The indicator approach uses a particular range or composite of indicators (representative indicators) and quantifies vulnerability through estimating variables, averages or weighted averages for those chosen determinants (Gbetibouo and Ringler, 2009). This is assumed as an integrated approach, in which the selected variables demonstrate both the biophysical situations of farming system and the socio-economic status of farmers. The indicator approach is useful for monitoring trends and identifying conceptual frameworks (Gbetibouo and Ringler, 2009). Leichenko and O'Brien (2002)

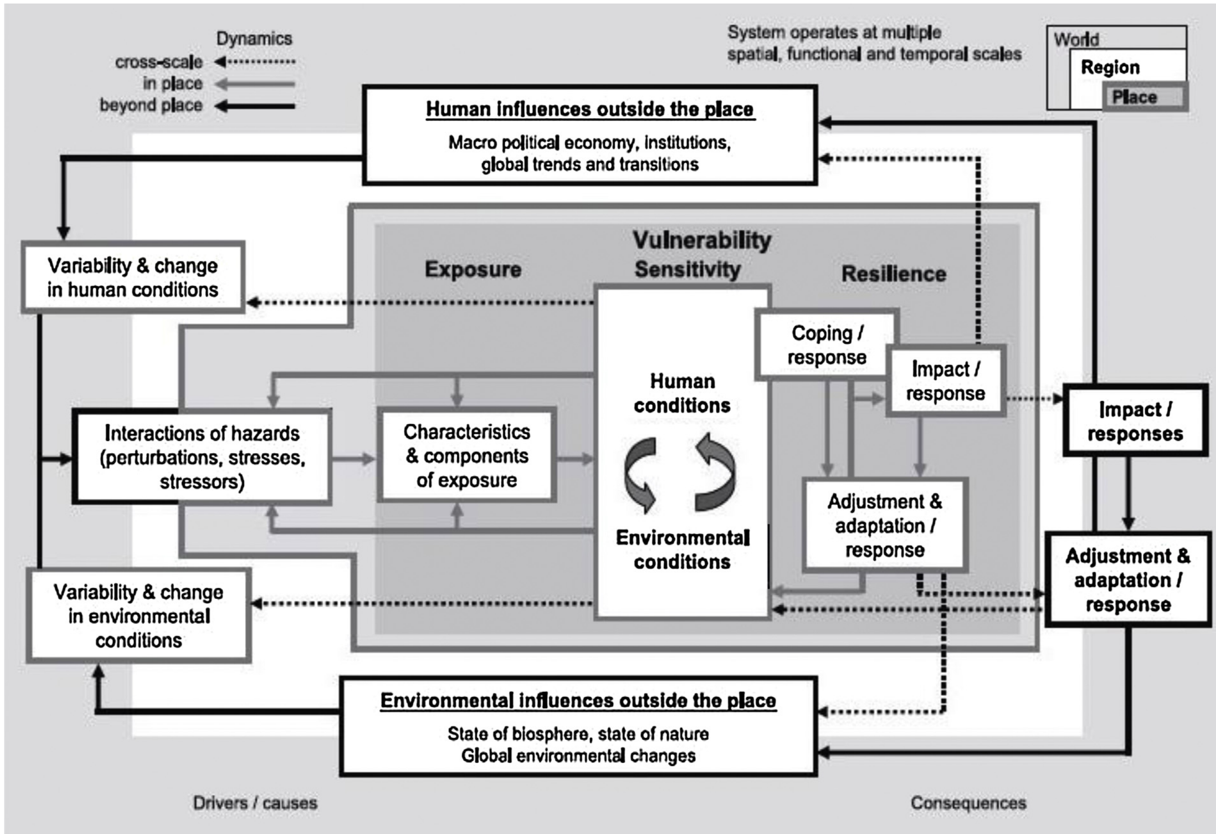

Fig. 2. The vulnerability framework (Turner et al., 2003a).

stated that combination of indices provides a multi-dimensionality approach for vulnerability that is more inclusive and understandable. Vulnerability determinants are necessary for applied decision-making procedures in order to supply policy makers with proper data regarding the exact locations of the most vulnerable people so that they can understand vulnerability, as well as making direct decision. According to Vogel and O'Brien (2004), identifying the various determinants of vulnerability is a fundamental stage for developing and performing policies that aim at sustainable development.

2.5. Indicators

One of the fundamental questions of this study is: "which social, economic and environmental drivers make wheat farmers vulnerable?" Several environmental and socio-economic indicators can

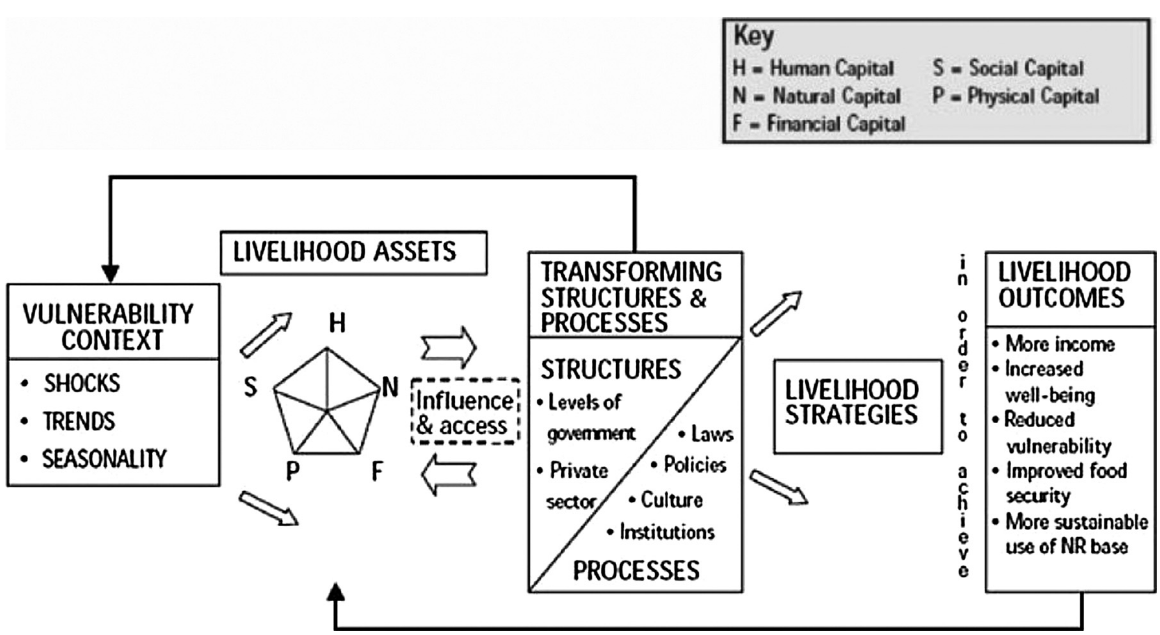

Fig. 3. The sustainable livelihood framework (DFID, 1999).

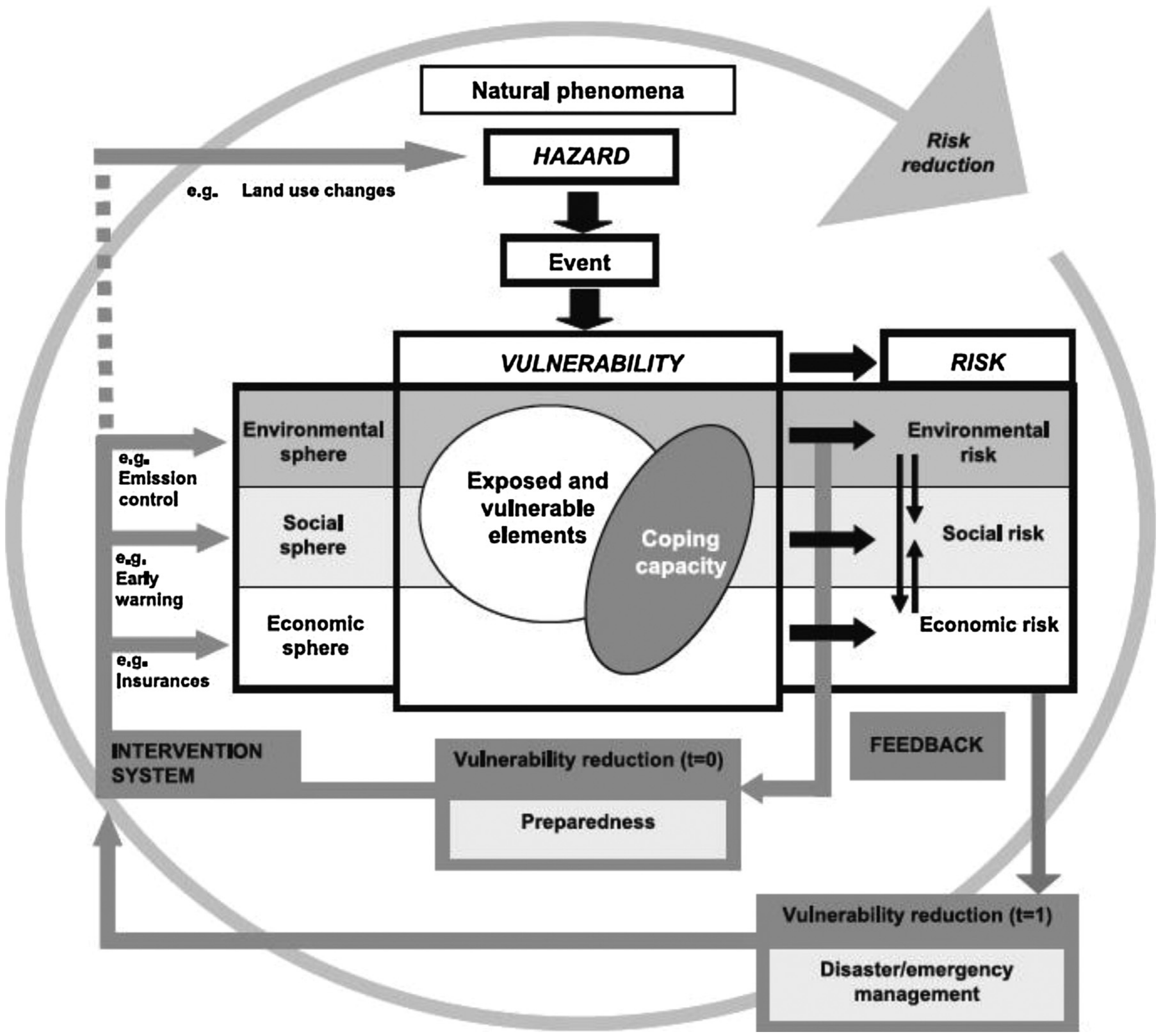

Fig. 4. The BBC conceptual framework (Birkmann, 2006).

be identified to reflect the three components of vulnerability of wheat farmers: exposure, sensitivity, and adaptive capacity. Two groups of factors can influence the performances of a farming system: (1) farm characteristics and their outcome, (2) regional conditions, such as long-term climatic conditions and socio-economic conditions. However, these factors strongly interact together and result in different responses among regions (Reidsma, 2007).

Climate variables are mostly defined as main factors affecting production yields and cultivated area (as the first-order impacts) and socio-economic activities and well-being (as the second or higher-order impacts) of farm households (Dabi et al., 2008; Sangpenchan, 2011). In a wheat production system, the yield in any given farm unit is affected by both internal and external factors to the system. For example, changes in regional temperature may affect plant growth, changes in national agricultural policies may influence farmer's cropping decisions, and variations in farm unit technological resources may influence planting and harvesting methods. Management is the only one of these factors that farmers can potentially manipulate toward a less vulnerable condition. The highest relative yield could be achieved every year with the appropriate management (Luers et al., 2003). Taking sustainability dimensions into consideration, followings introduce different indicators that should be considered to assess the vulnerability of wheat farmers.

2.5.1. Environmental driving forces

Environmental problems have recently become a big issue that contributes a lot to farmers' vulnerability. Natural resource degradation, high degree of pollution and intensification of floods and drought have increasingly reduced the productivity and increased production costs (Voisin, 2011). As mentioned above, exposure associated with extent to which a climatic variability pose stress over a specific part of a system under analysis. It may be caused through long-term changes in climate or by climatic variations, comprising the extent level and rate of occurrence of natural hazards (O'Brien et al., 2004). Sensitivity, on the other hand, characterized through the human–natural situations that can either make the extreme event more severe or pose an adverse impact. Following, we identified some major environmental indicators that may influence either the exposure or sensitivity of a wheat farmer.

Indicator 1: Climate variables (temperature and precipitation)

Climate change is considered as one of the main environmental problems of the 21st century (Azadi et al., 2011a). The impact of climatic variability is quite noticeable in the majority of small and marginal farmers especially those with lack of resources that prevent them to adapt to climatic variations. Farmers with small financial resources and agriculture systems with limited adaptive mechanisms to be able to mitigate or inverse harmful changes in climatic conditions are more sensitive to climate variability and may experience major constraints and income loss for almost few changes in crop productivity and yields (Shrestha, 2011).

Agricultural systems are vulnerable systems due to a high dependency on temperature and precipitation. Variations and long-term changes in these variables pose challenges to farmers and their societies that rely on the output of agricultural systems which are inevitably vulnerable to the adverse impacts of climate change. For example, wheat yield is lower in areas with higher temperature (Fussel, 2007; Reidsma, 2007; Zarafshani et al., 2012; Sharafi and Zarafshani, 2011). More importantly, if increased temperature and decreased rainfall are predicted, we would expect to see negative impacts on farm production in hot and water-scarce regions (Gbetibouo and Ringler, 2009). Similarly, Valizadeh et al. (2014) found that wheat production in the future will increasingly be affected by climate change in Southeast Iran, mainly due to the increase in temperature.

Furthermore, two types of climate events – droughts and floods – are the major concerns of wheat farmers in most developing countries (Sangpenchan, 2011). In regions with a higher frequency of droughts or floods, wheat production is more risky (Gbetibouo and Ringler, 2009). Drought is a creeping natural hazard that is a normal part of arid and semi-arid regions resulting in economic, social, and environmental consequences. In South Africa, one of the key constraints to agriculture is a high climate variability that has historically included numerous droughts and floods (Gbetibouo and Ringler, 2009). During the past 40 years, the Middle East, especially Iran, has experienced most extensive and severe drought leading to a significant yield loss (Kamali et al., 2012; Zarafshani et al., 2012; Khoshnodifar et al., 2012; Sharafi and Zarafshani, 2011). Furthermore, climate variation has major impacts on the soil organic matter. For instance, the amount of organic matter in agricultural soils in Iran is very low due to climatic conditions and lack of desirable agronomic management practices so that in half of the arable land, the amount of organic carbon is less than one percent to zero in some areas while it is desirable to be in the range of 2–3 percent (Kamali et al., 2012).

Indicator 2: Non-living stressors

Non-living stressors including drought, salinity, cold, heat, and haying off are the other environmental tensions for wheat farmers' vulnerability. These tensions have considerably contributed to wheat farmers' vulnerability in Iran (Kamali et al., 2012; Khoshnodifar et al., 2012). Consequently, farmers have to manage the irrigation water according to the importance of irrigation at different stages of plant growth. Moreover, the irrigation rate depends on the type of irrigated system that a farmer utilizes. For example, an irrigated system would have low sensitivity to short-term precipitation variability, whereas a rainfed system would have greater sensitivity to the same exposure (Gbetibouo and Ringler, 2009).

In addition, soil and water salinity are of the important environmental problems that limit plant growth and reduce dry matter. Cold stress in plant death occurs during the winter months. The decreased 7 percent of Khorasan (located in Northeast Iran) wheat production is due to damage from the winter season finale cold and early spring. Haying off on current photosynthesis and remobilization system is disrupted in grain filling stage and causing sharp fall crop (Kamali et al., 2012).

Additionally, land degradation reduces the productive capacity of land and therefore contributors to natural disasters and human activities. Areas with higher land degradation indices will experience greater negative impacts of climate variability and change (Gbetibouo and Ringler, 2009).

Indicator 3: living stressors

The other factor that contributes to environmental vulnerability of wheat production is related to living stresses (Lobell et al., 2002; Gregory et al., 2005; Eakin et al., 2006; Paavola, 2008; Mongi et al., 2010; Shrestha, 2011; Kamali et al., 2012; Khoshnodifar et al., 2012). These tensions (including diseases, pests and weeds), which have significant impacts on wheat production, are especially the case, in Iran where diseases (yellow rust, leaf rust), pests (sunn, wheat stem saw fly, cereal leaf beetle, cereal leaf miner, cereal ground beetle) and weeds (narrow leaves, broad leaves) are increasingly reported recently (Kamali et al., 2012; Khoshnodifar et al., 2012). Furthermore, small-scale farmers, generally subsistence farmers, are more sensitive to climate change and variability because they have less capital-intensive technologies and management practices. Thus, a region with a large number of small-scale farmers will be more climate-sensitive than a region with fewer small-scale farmers (Gbetibouo and Ringler, 2009).

Indicator 4: Dependency of farmers on crop and other resources and services

Resources and services dependency is a ratio showing to what extent households are dependent on regional resources that are susceptible to changing climate and its effects on their food safety, physical protection, economic status, or other socio-economic dimensions. Such resources may be natural, such as ecosystems and their services, or human infrastructure, such as roads, and other facilities comprising health centers, and utilities like power plants, plant machinery and water storages (Wongbusarakum and Loper, 2011).

2.5.2. Socio-economic driving forces

The socio-economic driving forces related to the socio-economical as well as political conditions of persons or groups of people in community (Adger, 1999; Fussel, 2007; Villagran De Leon, 2006; Deressa, 2010; Zarafshani et al., 2012). People in a society usually have different attributes such as different level of education, credit accessibility, gender, availability of technology and information, and social and financial assets. These variations can account for the extent of vulnerability (Villagran De Leon, 2006; Deressa, 2010). These variations are indeed ongoing processes that can pose direct or indirect effects on the agricultural sector through economic policy, market price, and crop yield (Sangpenchan, 2011). In this regard, socio-economic analysis according to five types of capital assets (physical natural, financial, social and human) can reduce the vulnerability of farmers through their adaptive capacity to the stress and sensitivities. In this regard, the previously discussed framework (i.e., sustainable livelihood approach) introduced by the Department for International Development (DFID, 1999) can be a useful source, specially throughout the five livelihood assets, for developing future approaches trying to measure vulnerability and adaptive capacity for hazards and stresses. The approach can also be connected to groups utilized in the hazard risk community such as extreme events, exposed and sensitivity factors, drivers/roots, and possible consequences and reactions (Birkmann, 2006). Considering such advantages, the DFID (2001) sustainable livelihood framework has been taken into account to discuss five main capitals in this study.

2.5.2.1. Human capital.

Indicator 5: Education

The educational attainment of farmers can reflect their vulnerability to stressors (Huffman, 2001; Acosta Michlik and Espaldon, 2008; Deressa, 2010; Zarafshani et al., 2012). According to Leichenko and O'Brien (2002), increased overall literacy levels reduce vulnerability by increasing people's capabilities and access to information, thereby enhancing their ability to cope with adversities. Adejuwon (2008) and Dabi et al. (2008), state that farmers' investments in higher education on the one hand, can result in labor productivity and the agricultural information accessibility because educated farmers can better understand and more participate in the technological and administrative processes in a modern economy than farmers with little or no formal education. On the other hand, farmers with high levels of education characterize higher mobility and flexibility (Huffman, 2001; Villagran De Leon, 2006; Deressa, 2010).

Indicator 6: Other demographic factors

Various groups within a region or community might encounter various levels of vulnerability to climate change. Some groups are called demographic vulnerable groups due to their specific social or demographic features comparing to other people in the larger community (Wongbusarakum and Loper, 2011). Certain demographic characteristics can result in different levels of exposure to particular kinds of natural events (e.g., property location, required infrastructure and resources associated with vulnerable areas), sensitivity of people to extreme events (age, job, health status, economic condition, or dependency on affected resources), and their capacities to adapt with stresses and shocks (opinions and education level, expertise, economic situation, social relations and affiliations such as religious, ethnic, and language, and ability and desire to change). Other demographic characteristics that may influence the vulnerability of rural people to changing climate encompass household size and structure, gender, literacy, migration status and access to means of living (electricity, drinking water, health care, telecommunications and transportation) (Wongbusarakum and Loper, 2011).

Indicator 7: Farm labor

Simelton et al. (2009) showed that agricultural productivity relies on the availability of capital and labor. Urbanization and industrialization can cause a farm labor shift from rural areas to urban areas for employment or educational opportunities. During the peak-working seasons, farmers from developing countries often complement the absent household members with the hired laborers to achieve production goals. However, small farm households may experience hardship if farm outputs do not generate enough income to meet the labor costs per unit of land (Sangpenchan, 2011).

Indicator 8: Farm management

Lobell et al. (2002) showed that most variables in the yield are variables beyond the physical activities of a farm but primarily attributing "management factors". Researchers suggest a range of agricultural management strategies to adapt to changing socioeconomic and climatic conditions. For example, wheat farmers may be able to exploit longer growing seasons by planting crops earlier (Yang et al., 2007), conserve soil moisture by mulching with between plants in semi-arid regions (Zhang et al., 2007a) or number and timing of irrigations practices (Lobell et al., 2002; Feng et al., 2007), amount and timing of fertilizer application, tillage and cultivation practices and pest control (Lobell et al., 2002), and cultivar changes (Nicholas and Durham, 2012). Management practices can also reduce the impact of limited water availability (Reidsma, 2007). Alternatively, management and agricultural research and development can introduce drought- and disease-resistant crops to help small holders and less favored areas where agriculture is important, and natural resource management practices can improve soil depth and fertility in less favored areas (Zhang et al., 2007b).

2.5.2.2. Financial capital.

Indicator 9: Household incomes and income sources

Households with low incomes, savings, and saleable assets are generally vulnerable to stresses from climate variability and socioeconomic changes (Adger, 1999; Luers et al., 2003; Eakin et al., 2006; Acosta Michlik and Espaldon, 2008; Dabi et al., 2008; Paavola, 2008; Segnestam, 2009; Sangpenchan, 2011; Zarafshani et al., 2012). With low financial status, the ability of farmers to invest in farm improvements (e.g., the purchase of farm inputs, farm equipment, and other farm technology) is limited. Furthermore, the low financial status reduces the capacity and ability of farm households because poor households are likely to focus on the survival and well-being of household members rather than the improvement of farm quality or the production system, which would decrease their vulnerability to future climate and socio-economic stressors (Osman-Elasha and Sanjak, 2008). Adger (1999) noted that the importance of non-farm income in households or, conversely, the dependence of the household on agricultural income, is also a measure of household sensitivity to stressors' impacts.

Much of the agricultural labor force has been released from grain cultivation and has been shifted to the secondary and service sectors. According to the study of Tang et al. (2013), the surplus labor of rural households began to engage in full-time or part-time employment from the township enterprises. The labor force also began to derive income from fruit sale and retail business. Such changes of livelihood strategies can improve the environment, diversify economic activities, and increase the income of farmers.

Indicator 10: Size of farm operation

The size of farm operation (i.e., farmland plus farm equipment) can measure the farm household vulnerability. Social vulnerability of small landholdings is higher. With more access to physical and material resources, large landholdings have greater flexibility and more stable financial status, which in turn increase their capacity to cope with a changing economy and environment (Huffman, 2001; Acosta Michlik and Espaldon, 2008; Sangpenchan, 2011).

Indicator 11: Land ownership and tenure security

The high rates of sharecropping prevent capital formation and productivity raising investments by farmers (Deressa, 2010). Farmers gain the opportunity to obtain financial credits and loans from banks to invest in the farm. It is the opposite for households that lack ownership and tenure and have less access to formal banks and rely on non-formal financial institutes or do without investment. With less accessibility to funds, farmers tend to use fewer farm inputs such as fertilizer, pesticide, and insecticide, which can result in relatively lower yields. Farmers without ownership or tenure are less likely to find room in their tight budgets to improve their agricultural system (Deininger and Feder, 2001; Sangpenchan, 2011).

Indicator 12: Cost of production

Agricultural pricing and marketing policies are controlling input and output prices (Deressa, 2010; Zarafshani et al., 2012). Repeated weather hazards in the context of global change, the constant rise in oil prices, and speculation on agricultural markets are some of the factors reinforcing volatility of wheat prices and aggravating food insecurity in numerous countries (Reidsma, 2007).

Energy prices are fundamental determinants of food crop production and prices. High-energy prices affect agricultural production by directly increasing the costs of operating machinery and using fuel-based inputs, such as fertilizers, pesticides, irrigation, and transport. Increase in demand for biofuel feedstock reduces supplies of cereals because farmers naturally convert their land to more profitable crops. Low supplies contribute to rapid price increases for cereal crops including wheat (Sangpenchan, 2011).

Indicator 13: Technology

Technological ability is represented by the input intensity (irrigated area, input costs of fertilizer and crop protection products) (Sheikh et al., 2003; Reidsma, 2007). For instance, fertilizers or pesticides are usually included within technology packages for drought-tolerant or varieties of crops at their primary stages of growing technology. Thus, the supplies of such inputs positively contribute to successful adaptation (Deressa, 2010). Sangpenchan (2011) and Nicholas and Durham (2012) conclude that agricultural adaptive capacity to climate change could substantially increase, using existing technologies such as adopting crop types and varieties suited, implementing farm irrigation, applying improved fertilizer, field rotation, tilling techniques, genetic inputs, water conservation, diversified and altered farming practices, pest and weed management, and seasonal climate forecasts to reduce production risks.

2.5.2.3. *Social capital.*

Indicator 14: Social networks and governmental support

Social networks play an important role in the decision-making process of farmers. Interaction allows farmers to perceive changes in the environment, but it may not necessarily cause farmers to take actions. The quality of social network (e.g., some members in the network have high intellectual and economic capacity) determines the rate of shift from interaction to actions (Acosta Michlik and Espaldon, 2008). Moreover, farmers' participation in local meetings has the potential to impact social networks which in turn will develop more social capital needed to cope with diverse effects (Zarafshani et al., 2012). Gangadharappa et al. (2007) have found that the social capital increases the diffusion of information and enhances mutual trust between local people. Participation in extension classes and local cooperatives plays an important role in farmers' vulnerability mitigation plan (George et al., 2007; Simelton et al., 2009; Zarafshani et al., 2012).

Governmental support and policy interventions that encourage (in)formal social networks can also promote group discussions and better information flows and enhance adaptation to environmental and socio-economic changes (Deressa, 2010). Government policies should strengthen existing adaptation strategies practiced by farmers and support the adoption of adaptation technologies that have the potential to reduce damages at farm level, such as crop diversification; the use of drought-tolerant crop varieties species; water harvesting; and resource conservation and management practices (Dabi et al., 2008; Deressa, 2010).

Indicator 15: Market channel

Market institutions and their structures within the local area indicate the strengths and weaknesses of domestic farm production systems. Agricultural markets provide fundamental functions for agricultural inputs/outputs distribution, post-harvest processing, and storage (Sangpenchan, 2011). The proximity to markets is an important determinant of adaptation, presumably because the market serves as a means of exchanging information with other farmers (Deressa, 2010).

The formation of local markets and communal marketing in the form of credit unions, farmer cooperatives, and wholesale-level cooperatives increases the capabilities of local farmers by facilitating bulk input procurement, negotiating price, and sharing transportation costs (Sangpenchan, 2011). In particular, markets should make households less vulnerable to (localized) covariate shocks. For instance, food prices will not increase as much in the aftermath of a local drought if traders can import food from other markets (Zhang et al., 2007a).

Indicator 16: Social equity (equitable access to resources)

It is often emphasized that governing equitable distribution and access to resources and the allocation of power by means of social institutions and arrangements at different local, national and international levels will improve the adaptive capacity (Mustafa, 1998; Adger, 1999; Adger and Kelly, 1999). The accessibility level of countries or communities to resources significantly affects their ability to cope with stresses and shocks (Mearns and Norton, 2010; Adger and Kelly, 1999). Some researchers believe that both *availability* and *access* to the resources by decision makers and susceptible subsectors of a community identify the adaptive capacity of a system (Adger and Kelly, 1999). A good example here is the study conducted by Wisner (1998) who concluded that inequality in access to resources by the rural people in Tokyo resulted in less capacity to cope with environmental hazards. Similarly, Bohle et al. (1994) investigated the vulnerability of people in Zimbabwe to climatic changes and found its considerable relationship with poverty, inequitable land distribution and the macro-political economy. Other elements such as demographic variables including age, ethnicity, gender, health and educational background are also cited in many studies as the contributors to adaptive capacity of a community (Chan and Parker, 1996; Scheraga and Grambsch, 1998). Such factors can be considered as the representations of a system's ability to limit or improve the adaptive capacity and consequently the vulnerability of communities (Smit and Pilifosova, 2001). deHaan and Zoomers (2005) emphasized that access to resources highly connected to the function of social relations, and thereby, more attention need to be devoted to the influence of power relations in sustainable livelihood since power differentials can play an important role in diminished adaptive capacity (deHaan and Zoomers, 2005; Mustafa, 1998; Adger and Kelly, 1999).

Indicator 17: Institutions

The role of insufficient institutional support is repeatedly mentioned in the literature as an impediment to adaptation. Adger and Kelly (1999) and Battista and Baas (2004) showed how institutional constraints restrict land rights and access to resources for rural communities in Vietnam and Mozambique respectively, and hence increase vulnerability. Similarly, Diagne et al. (2014) examined the role of institutional elements (legal security, land tenure and gender agency) in independent adaptation and enhanced the ability of farming households to cope with stresses and shocks in Tajikistan through livelihood diversification, strategies for tackling with climate-related stresses, sustainable land management actions. They found that farmers with enhanced tenure security through continuous land reforms are less vulnerable. Baethgen (1997) explained that incompatible and insecure agricultural policies have raised the vulnerability of the agriculture sector in Latin America. Severe economic changes and unstable policy situations are likely to make food production systems more sensitive to climatic variations. Magadza (2000) demonstrated how adaptation possibilities and practices in southern Africa are restricted by institutional and political inadequacies and resulting inequities in access to resources. It is frequently argued that established adequate institutions will simplify current climate-related risks management and also establish an institutional capacity to assist in coping with stresses related to the climate change in future (Smit and Pilifosova, 2001).

2.5.2.4. Physical capital.

Indicator 18: Basic infrastructure and services

The availability and accessibility of basic production infrastructure and services can determine the coping capacity of farm households. For instance, a well-conditioned road and short distance between the farm and the market place could reduce delivery time, which could also minimize yield-quality losses. Good roads also enable large pieces of farm equipment such as tractors and trucks to move from field to field with ease (Deressa, 2010; Sangpenchan, 2011). Additionally, improved infrastructure may reduce transactions costs, link the labor and product markets, and promote division of labor. Distance from markets (in terms of travel time) largely influences both the choice and the manner of farmer-market interactions (Zhang et al., 2007a).

2.5.2.5. Natural capital.

Indicator 19: Land and water quantity and quality

The expansion of urbanization and population draws upon the natural resources in the agricultural sector (Azadi et al., 2011b). Existing farmland is shrinking and demand and prices for that land is skyrocketing, especially in fertile areas with irrigation systems. Consequently, the price of fertile farmland with irrigation systems is too expensive for small landholders, pushing poorer farmers into more marginal areas. Farm households with limited financial resources can easily get vulnerable if they are forced onto lands with low fertility. Improving the quality of land for crop production requires expensive modifications and inputs. Furthermore, marginal areas are likely to have limited access to water sources and are far from irrigation systems (Osman-Elasha and Sanjak, 2008; Sangpenchan, 2011).

3. Discussion: conceptual framework

After identifying the whole set of potential indicators, the conceptual framework of vulnerability for wheat farmers is developed. As indicated earlier, our study is based on Leichenko and O'Brien's (2002) definition of dynamic vulnerability that incorporates the integrated approach of vulnerability assessment which focuses on both socioeconomic and biophysical determinants in evaluating vulnerability. Fig. 1 shows the conceptual framework of vulnerability for wheat farmers. The main contribution of this paper has been to propose an inclusive conceptual framework on vulnerability to climatic and non-climatic changes through identifying the main socio-economic as well as environmental factors for wheat farmers' vulnerability assessment. Our proposed framework can provide a useful source and checklist, particularly through the five livelihood capitals, for developing future approaches aimed at determining vulnerability and adaptive capacity for stresses and shocks.

As shown in Fig. 5, the framework for wheat farmers' vulnerability illustrates the three main components of vulnerability (i.e., exposure, sensitivity, and adaptive capacity) within sustainability dimensions (social, economic, and environmental) in which sustainability is considered in terms of available capital (natural, human, social, physical and financial) and an examination of the vulnerability context in which these assets exist. It considers the complexity and interactions involved in vulnerability analysis, drawing attention to the array of factors and linkages that potentially affect the vulnerability of wheat production system in a place. Similarly Deressa et al. (2008) developed a conceptual framework for assessing the vulnerability of Ethiopian farmers to climate change based on the integrated vulnerability assessment approach using vulnerability indicators including different socioeconomic and biophysical attributes. In line with their study, our proposed framework also shows that at the household level sensitivity and exposure are almost the same (Smit and Wandel, 2006). The first step is to analyze vulnerability into a number of indicators describing in the previous section, firstly, sensitivity to various human and environmental changes (the environmental and social aspects of sustainability), and secondly, farmers' adaptive capacity (related to the social and economic dimensions of sustainability).

Furthermore, as the figure shows, wheat farmers are affected by both chronical (mainly precipitation and temperature) and acute (mainly flood and drought) climate change. Exposure affects sensitivity means that exposure to more frequencies and magnitudes of climate risk substantially influence the consequences (e.g., income, yield, and health). Exposure is also associated with adaptive capacity. For example, higher adaptive capacity reduces the possible loss from higher levels of exposure. Adaptive capacity is the ability to adjust to changing environmental and socio-economic conditions. Similarly, sensitivity is the degree to which a system is affected, either adversely or beneficially, by environmental and social changes. Therefore, sensitivity directly affected by environmental as well as human conditions. Indeed, both human and environment situations of a system describe its sensitivity to different stresses and shocks. These situations encompass social as well as biophysical factors that affect the available coping strategies which are impacted by the experienced exposures and those coping mechanisms applied to tackle with the exposure (Turner et al., 2003a). Sensitivity and adaptive capacity are also linked meaning that in a steady level of exposure, the adaptive capacity impacts the sensitivity and vice versa. In other words, the more the adaptive capacity level (related to socio-economic driving forces) is, the lower the sensitivity (related to environmental driving forces) would be and vice versa. As a result, sensitivity and adaptive capacity contribute to the total vulnerability influenced by a range of environmental and socio-economic indicators (TERI, 2003).

Environmental, social, economic conditions create unwanted stresses to a wheat production system and those who are involved in the system (here, wheat farmers). Stresses on sustainability performance such as climate, drought, temperature, precipitation, non-living and living stressors, severe weather, and soil constraints cause an individual or group become vulnerable due to the exposure to stresses. So they have to make decisions and adopt various ways in order to adjust the system to cope with the stressors or reduce their vulnerability in the first place. The ability of farmers to effectively adapt to climate change depends not only on the degree of exposure to climatic change but more importantly the amount of knowledge, support and opportunities available to them in order to respond to that change. The proposed framework in this study provides a useful method of assessing major influences on farmers' vulnerability based on the assessment of five capitals: human, social, natural, physical, and financial capitals. Brown et al. (2011) used this approach and found that human capital's indicators including age and access to labor limit farmers' abilities to adopt and or trial new management options. Accordingly, our proposed framework identifies farm labor, education and management as the important factors in assessing socioeconomic vulnerability. Similarly, as our framework confirms, in Brown et al.'s (2011) study, natural capital scored relatively highly and included indicators that valued natural resources, particularly land capability and water access. Regarding

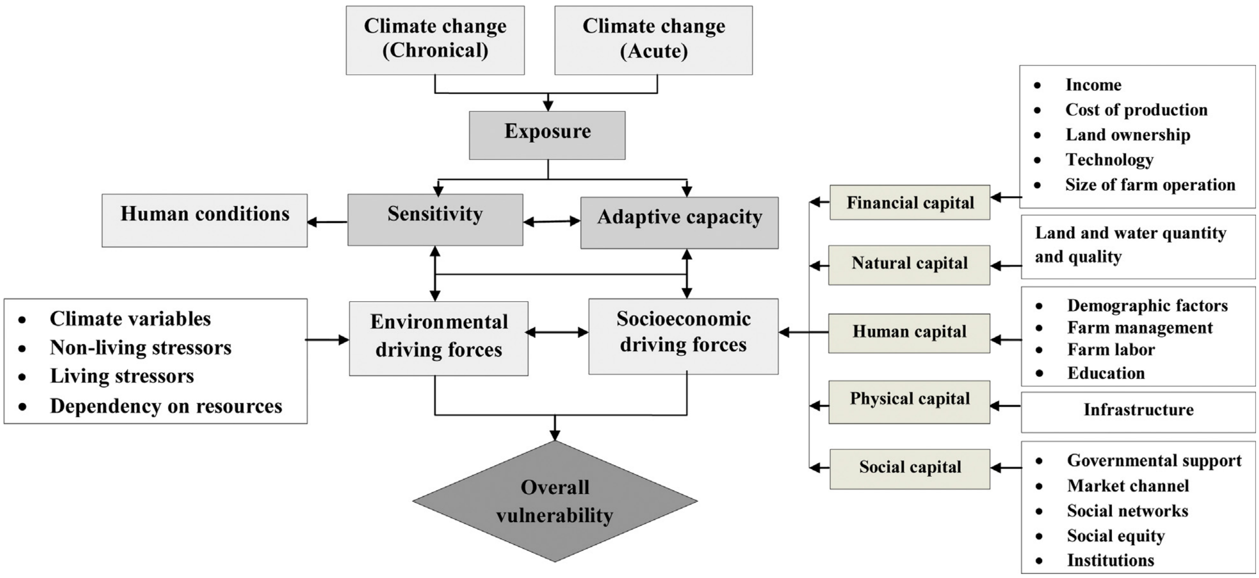

Fig. 5. Conceptual framework for wheat farmers' vulnerability assessment.

the physical capital, availability of infrastructures (such as communications, roads, rail, and processing and storage facilities) identified as the main indicator for assessing adaptive capacity of farmers both in our study and the study of Brown et al. (2011). According to O'Brien et al. (2004), areas with better infrastructure are expected to have a higher capacity to adapt to climate change. Gbetibouo and Ringler (2009) also identified the different indicators of the overall vulnerability. According to their study, social capital was represented by farm organizations (the number of farmers in organized agriculture) whereas literacy rate and HIV prevalence represented the main human capital's indicators. Moreover, financial capital was described by farm income, farm holding size, farm assets, percentage of people below the poverty line, share of agricultural GDP and access to credit and physical capital was related to infrastructure and access to markets. The indicators of financial are also in line with the study of Brown et al. (2011) who identified financial capital in relation to the cost of inputs, technology, land ownership issues and source of income. Eitzinger et al. (2011) also concluded that the vulnerability of smallholder farmer is very high in Jamaica because of their high sensitivity and low adaptive capacity in the three (human, social and financial capital) of five livelihood assets. Similarly, Botero and Salinas (2013) assessed farmers' vulnerability to climate change in Karnataka, India considering five types of household assets: natural, social, financial, physical, and human capital. They found that the financial and natural capitals had the largest contribution to the vulnerability of the study community.

Therefore, the proposed approach in our study is well suited to allow farmers to identify and prioritize adaptation options and barriers for any given change scenario (Brown et al., 2010). The concept of adaptive capacity depends on the level of strength and weakness and the balance between the capitals. Adaptive capacity also relates to the flexibility to substitute between the capitals in response to external pressures. Financial, social and physical capitals for example, can be transformed into human capital by increasing access to education. The analysis will not only identify regions that are more vulnerable than others, but will also provide insight into what is driving that vulnerability. For example, is the human capital low or the physical capital a constraint? This information will support a more targeted approach to regional policy setting by providing policymakers with insights into the regional drivers of vulnerability.

Adaptation approach needs to be taken into account at farm or farmer level, along with considering policy situation. Technological advancements can be the most appropriate response in dealing with issues during the long term. Governments also require suitable subsidy policy to confirm sustainability of financial status of farmers. For wheat farmers, a range of adopting measures should be taken into account, such as education, social networks, government support, market channel, basic infrastructure and services, farm management, cost of production and technology. Importantly, such social, economic and biophysical responses or coping mechanisms may influence each other and interact, in a way that a response to socio-economic system can make the biophysical system more or less capable to cope with the hazard, and vice versa. In fact, vulnerability should be considered for different groups of wheat farmers in relation to those especial socio-economic and environmental indicators that are representatives of their different statuses. Moreover, there should also be practical standards for wheat farmers instead of using indicators that represent an ideal situation. Therefore, we can bridge the gap between the current and the desired status of wheat farmers that reflects their extensional and educational needs. These identified gaps indicate the lack of necessities for assessing socio-economic and environmental indicators. As a result, researchers, planners, policy makers and decision makers may be looking for solutions and recommendations to overcome these shortcomings which reduce the vulnerability of wheat farmers and indeed, could be a feedback to the conceptual framework.

4. Conclusion

This study analyzed the vulnerability of wheat farmers from the sustainability perspective considering three main dimensions (social, economic and environmental) through identifying the potential vulnerability indices. To do so, this paper presented a review of the existing vulnerability conceptual models in order to define the social, economic and environmental dimensions, components and indicators of the vulnerability of wheat farmers at different scales. One main result is the fact that vulnerability needs to be understood in a wide context which spans many sectors, components, and levels. In many cases, vulnerability is defined as a combination of various components but there are no guidelines on how to assess each component individually, nor rules on how to link such components to gather a final figure of merit regarding vulnerability. Therefore, in order to advance on issues regarding the assessment of vulnerability, it is necessary to decompose it in a different way.

The proposed conceptual framework in this study revealed that the socio-economic change is an ongoing process that can pose a direct or an indirect effect on the agricultural sector through economic policy, government support, market price, crop yield, economic production, basic infrastructure and services, social networks, farm management, technology and education. This process can help mitigate the loss of or exacerbate the impacts on the existing agricultural system. Therefore, this study considered simultaneously the vulnerability of agricultural wheat production by taking into consideration the processes of climate change and socio-economic changes rather than focusing on a single process. It is, however, important to note that the identified indicators could be considered not only for wheat farmers, because many of the indices provide a better understanding of social behavior trends as well as a holistic and integrated view of the climate change, agriculture, and livelihoods processes shaping vulnerability. Therefore, many of the identified factors can be considered in assessing the vulnerability of different farmers in rural areas. However, there are some indices that could specifically be used only for wheat farmers such as some living stressors (e.g., “wheat rust”) that have made significant yield loss in wheat farmers (for example in Iran). More importantly, identifying proper indicators for vulnerability assessments is very challenging (OECD, 2008). Depending on different disciplines involved in the vulnerability assessment, different conceptual and methodological frameworks could be developed which may consequently identify different factors for farmers’ vulnerability across different social groups responsible for differences in their levels of vulnerability (Deressa et al., 2008). Obviously, the list of the indicators could never be wrapped-up completely. Depending on the specialty of different experts, they may introduce different indicators. Accordingly, the proposed list of indicators should be considered as “a work in process” which could further be completed by future studies.

Lastly, through introducing a conceptual framework for measuring vulnerability, this study can assist in increasing awareness among decision-makers at local, national and regional levels aiming at vulnerability reduction, especially for wheat farmers. This can be a step forward in developing practical techniques for vulnerability assessments and in reducing undesired impacts associated with wheat farmers. The proposed framework can assist in gaining more accurate understanding of the factors that determine farmers’ vulnerability, and to prioritize the potential areas for intervention. Taking the proposed conceptual framework, future research should focus on local levels, especially district or village levels, where actual dynamics of vulnerability to climate change take place to identify the main vulnerability factors and detailed investigation of factors that constrain or enable adaptive capacity at the local level. Additional recommendations for future studies are to include governance indicators, as civil and political rights and opportunities are very relevant for farmers’ vulnerability assessment (Brooks et al., 2005). Also, including global context could reveal important information for long-term vulnerability and predictions (Downing, 1991).

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