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Assessing drought vulnerability and adaptation among farmers in Gadaref region, Eastern Sudan

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ABSTRACT

Agricultural productivity in rural areas is severely affected by climate variability, and this elevates the vulnerability of rural households to food insecurity. This study examines the socio-economic vulnerability of farmers who are susceptible to droughts in the five agricultural-based regions of Gadaref, Eastern Sudan. A survey was carried out in 500 households to collect data on socio-economic and livelihood indicators. The data analyzed from these indicators were used to generate the three components of drought vulnerability: exposure, sensitivity and adaptive capacity. The analysis revealed that the regions deemed to be most vulnerable to both drought and climate variability were also projected to have the most vulnerable communities. The most exposed farming communities of Alfaw, Algadaref and Alfushqa regions showed a relatively low capacity for adaptation. Moreover, the study determined that vulnerability to drought and variability is associated with social and economic development in the Gadaref region. The results show that highly vulnerable regions are characterized by features such as low levels of productivity, elevated levels of financing, low crop diversity, agriculture as the primary income source and a low level of agricultural insurance. This research shows the importance of diversified livelihoods in building resilience against hazards linked to climate change.

1. Introduction

Most countries in the world depend primarily on rainfed agriculture for their food (Raju and Wani, 2016) and soils play a key role. This is because soils are a key component of the Earth System as they supply the nutrients, water and substrate for the crops (Mol and Keesstra, 2012). Therefore, soils are the strategic component of agricultural sustainability as the United Nations highlighted (Keesstra et al., 2014). As a result, agriculture is remarkably sensitive to changes in climate with a degree of seasonal variations, and this is attributed to the fact that climate change affects the two most significant direct inputs to agricultural production: precipitation and temperature (Gornall et al., 2010). According to Yang et al. (2017) and Delphine et al. (2014), climate change also has an indirect effect on agriculture by controlling the development and distribution of crops, extending the regularity and distribution of unfavorable weather conditions and reducing water availability.

As reported by Solomon (2007) some developing countries are expected to experience considerable adverse influences of climate change and variability in the future. Also, Serdeczny et al. (2016) predicted that the increase of temperature on the African continent would be above the global annual mean warming. Consequently, the adverse impact of climate change is predicted to be higher in the different African countries because of the continent's weak adaptive capability, the economic value of climate-sensitive sectors to these countries and their insufficient human, institutional and business ability to predict and respond to climate change and variability (Heltberg et al., 2009; Hertel and Rosch, 2010). The idea of vulnerability is analyzed as the net

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effect of potential impacts and the potential to ultimately cope with the consequences; where possible results combine the systems of exposure and sensitivity. This relationship is used to develop an implicit model, which can help as a basis for indicator development and measurement of the overall vulnerability (Adger, 2006; Hinkel, 2011; Smit and Wandel, 2006).

Vulnerability framework assessment for potential effects of climate change and variability has increased over the last two decades with increasing emphasis on climate change studies (Adger, 2006; Hinkel, 2011; Malone and Engle, 2011; Smit and Wandel, 2006). The different definitions and methods for assessing vulnerability have led to several attempts to simplify the concepts (Eakin and Luers, 2006; Hinkel, 2011; Turner et al., 2003; Wiréhn et al., 2015), classify the data on vulnerability into various approaches (Füssel, 2007; O'Brien et al.,2004) and analyse of the study to vulnerability indicators (Eakin and Luers, 2006). The idea of vulnerability is hard to define but usually, it is defined using components that cover exposure and sensitivity to external strains and the capacity to adapt it (Adger, 2006; Malone and Engle, 2011; Moss et al., 2001). The most common definition for climate change vulnerability was developed by the Intergovernmental Panel on Climate Change (IPCC), and it defines vulnerability as a purpose of the character, magnitude, and rate of climate change and adaptation to which a system is exposed, its sensitivity and its adaptive capacity. This definition showed vulnerability could cover several dimensions or aspects with more attention to the scarcity of resources and inequality. However, the recent assessment report of the IPCC defines vulnerability simply "as the propensity or predisposition to be adversely affected" by identifying vulnerabilities through societal risks (IPCC, 2014).

Several procedures have been adopted for assessing vulnerability to climate change like statistical methods, comparative analysis, geographical information system and mapping techniques, historical narratives, agent-based modelling and indicator-based approach. Recently an indicator-based approach for understanding vulnerability to climate change has been broadly used (Dovie, 2017; Pandey and Jha, 2012; Reed et al., 2013; Salik et al., 2015; Shah et al., 2013). Realizing that vulnerability is a complicated phenomenon that is difficult to estimate directly, an indicator-based approach is useful for taking the complex phenomenon with some chosen representatives or variables describing different aspects of vulnerability to climate change. Regardless of criticisms that vulnerability studies have emphasized the analysis of aggregate states rather than guidance on social processes that can be directed to decrease vulnerability (Eriksen and Kelly, 2007), it considers a valuable method in ranking vulnerable communities, areas and sectors to climate change for the policy-making process. It provides the combination of biophysical and socioeconomic components in the assessment of vulnerability and allows a public and policy-makers response in prioritizing adaptation methods (Gbetibouo et al., 2010; Yiran et al., 2017; Žurovec et al., 2017).

In Sudan, drought is one of the most prevalent climate change-related natural hazards affecting the country (Elagib, 2015). Repeated droughts form the main threats to the rural resources and food security of the country. Nearly each year, the country undergoes localized drought disasters leading to crop failure and endangering development activities (Elagib, 2015; Elagib and Elhag, 2011). As a consequence, the livelihoods and agricultural practices in the rural areas in the country are subject to continuous and comprehensive changes (Zhang et al., 2012).

This is a worldwide problem that is part of a multifaceted process of land degradation that intensively affect Sudan and the neighboring countries, which need a proper strategy to fight against Desertification (Mekonnen et al., 2016; Villacís et al., 2016; Mekonnen et al., 2017).

Gadaref region in eastern Sudan has semi-arid climate, characterized by high temperature, medium to low rainfall. The mean annual rainfall of the region is estimated to be 560 mm, while the mean annual monsoon rainfall is 473 mm, 84% of the annual rainfall (Sulieman and Buchroithner, 2009).

Even though the rainfall in southern part of the Gadaref region is quite high, in Alrahd and Algalabat regions, its distribution during the monsoon season is highly irregular and erratic.

Drought and floods occur often with varying frequency in the region. The regions of Alfaw and Alfushqa are among the least developed in Gadaref (Gbenga, 2008). The regions face high level of poverty, with around 50% of the population living below the poverty line and they are among the more agriculture drought-prone regions of the country (Mahgoub, 2014; World Bank, 2011).

This paper aims to study drought vulnerability of the farming community and to identify hot spot areas across five regions of Gadaref, Eastern Sudan. It examines the vulnerability among five regions exposed to drought. The study evaluates different components of Vulnerability Index (VI) among the communities in the study region. It further compares the level of vulnerability with the specific livelihood indicators at the region level. The study includes biophysical, social and economic indicators depicting the three components of drought vulnerability: exposure, sensitivity and adaptive capacity. A geographic information system (GIS) was then applied to produce vulnerability maps by taking the region as a spatial unit of analysis.

2. Materials and methods

2.1. The study area

Gadaref is one of the regional states located in the eastern part of Sudan. The region lies between longitudes 33–36° E and latitudes 13–16°N with an area estimate of 65,000 km^2. It borders Ethiopia and four other Sudanese states; Khartoum and Kassala States in the North, Gezira state in west and Sennar state in the south. Gadaref region is divided into five administrative zones (Alfaw, Alfushqa, Algadaref, Alrahad and Algalabat) (Fig. 1), and ten rural districts which include Gadaref, Central Gadaref, Alrahad, Alfaw, Eastern Algalabat, Alfashqa, Albutana, Western Algalabat, Galaa alnahal and Alquresha. The number of villages and towns in the state is 657 distributed in the localities of the district mentioned above (OCHA, 2012).

The region has a total population that exceeds 4.3 million people, about 80.5% of whom live in rural areas. The region belongs to the semiarid area where monsoon weather dominates throughout the year. In general, three distinct seasons can be recognized in Gadaref. The first is the main monsoon season that lasts from June to September, the second is the dry winter period from October to February and the third is pre-monsoon summer season from March to May. The local climate is marked by high spatial and temporal variations and periodic drought. Seasonal rainfall ranges from about 1000–1300 mm in some areas in the southwest to less than 260 mm in the northern part. The mean annual rainfall of the region is estimated to be 560 mm, while the mean annual monsoon rainfall is 473 mm, 84% of the annual rainfall (Sulieman and Buchroithner, 2009).

Agriculture is the main economic activity in the Gadaref region and constitutes most of the total regional gross domestic product. The importance of agriculture to the local economy can be estimated by the fact that it directly helps about 80% of the population with regards to employment and livelihood (Mahgoub, 2014; World Bank, 2011). Agricultural systems in the region are mostly rain-fed and dominated by small and large scale farmers; our study focuses on farmers with an ownership of less than 5 ha per family, who have been adopting low input and output rain-fed techniques combined with traditional farming technologies.

Gadaref region is dry for most of the year except during the rainy season. Repeated droughts form the main threat to rural livelihoods and food security. Almost every year, the study area experiences localized drought disasters causing crop failure and jeopardizing development activities (Elagib, 2015). As a result, rural livelihoods and agricultural systems in the region are subject to continuous and widespread changes in climate variability and seasonal shifts which have a direct impact on