Acta Ecologica Sinica 36 (2016) 340–349

Contents lists available at ScienceDirect

Acta Ecologica Sinica

journal homepage: www.elsevier.com/locate/chnaes

Drought risk analysis of maize under climate change based on natural disaster system theory in Southwest China

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ARTICLE INFO

Article history:
Received 31 July 2015
Received in revised form 7 June 2016
Accepted 8 June 2016

Keywords:
Southwest China
Maize
Drought risk
Climate change

ABSTRACT

Agro-drought risk analysis is helpful for improving the ability of regional disaster management and reducing potential drought risk under climate change. In this paper, we use daily meteorological observations from 60 stations and maize yield data in Southwest China during the period from 1961 to 2012. Based on natural disaster risk theory, maize drought risk assessment model is established from four factors: hazard, exposure, vulnerability, drought prevention and mitigation, and maize drought risk is zoned and analyzed in Southwest China under climate change. The results show that under climate warming, the high and sub high risk zones are decreased in Yunnan Province and emerged in central and northwest Sichuan Province, the low and sub low risk zones are largely reduced in Sichuan Province, Guizhou Province and Chongqing City, and the other increasing zones are mainly moderate risk zones. In summary, maize drought risk mainly depends on the maize drought hazard; the maize drought risk increases in the north and decreases in most of south under climate warming in Southwest China. Enhancing maize drought risk management helps to reduce the potential risk to agricultural production in southwest China under climate change.

Contents

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http://dx.doi.org/10.1016/j.chnaes.2016.06.001
1872-2032/

1. Introduction

Drought is one of the most severe meteorological disasters and has caused serious losses in agriculture production. Dai [4] showed that the rapid warming that has occurred since the late 1970s throughout most of the world has increased evaporation and has likely altered atmospheric circulation patterns, both of which have contributed to a recent terrestrial drying trend. This has caused drought to become a new climatic "normal", with an increasing frequency of drought, longer drought durations, greater inter- and intra-annual fluctuations, and more serious socioeconomic and ecological effects, especially for agricultural production [16].

IUGS has defined "risk" as the probability of health, property and adverse environmental events and the possible consequences. Drought has both direct and indirect adverse effects, and the intensity and frequency of these effects combine to create the drought risk [8], which objectively reflects the probability of direct harm caused by droughts. Many developed countries are actively studying this problem and establishing drought risk assessment systems, which attempt to objectively assess the risk and provide an early warning that would allow for defensive actions to be taken to prevent or mitigate drought impacts. Since the 1980s, researchers have studied the formation mechanisms of natural disasters and have made some progress. Maskrey [18]) proposed natural disaster risk assessment using the sum of the vulnerability and the hazard. Smith [23]) introduced the risk degree as the product of probability and loss. Okada et al. [20]) argued that the natural disaster risk interacts with the hazard factor, exposure and vulnerability of disaster bearing bodies. Zhang et al. [32]) considered the product of hazard, exposure, vulnerability and disaster prevention and mitigation as the natural disaster risk index.

Although researchers have studied the process of drought formation and the inherent characteristics of drought risk [7,21,25], considerable uncertainty remains. This is particularly true in the context of global warming. Climate warming exacerbates the complexity of this situation [16,19,22]; among other problems, the factors that affect drought risk become more diverse and their interactions become harder to predict. Under global warming, drought and its underlying processes are showing some new characteristics [2,6]. Understanding these problems and their consequences will increase our ability to prevent, mitigate, and manage drought.

China suffers frequent droughts, as most of the area is dominated by a monsoon climate [26], and the droughts have caused large economic and agricultural losses [10]. Droughts occur frequently, not only in arid and semiarid regions but also in wet areas. Southwest China has abundant rainfall and a humid climate, but several severe drought events lasting for years have occurred in this region in recent years, which have substantially damaged the local economy and have attracted widespread interest. Southwest China is vulnerable to climate change and is one of the most important regions for maize planting, accounting for approximately 15% of the total maize area and output in China [11]. Wang et al. [28]) showed that the frequent seasonal maize drought in the Sichuan province was caused by the uneven temporal and spatial distribution of precipitation. However, it is difficult to build public facilities for water storage because of the complex topography.

In recent years,many studies have been conducted for agriculture drought risk assessment [3,12]. However, most of these studies have concentrated on northern China [14,30]. In this paper, based on natural disaster risk theory, a maize drought risk assessment in southwest China has been performed. We separate four factors of the risk, including the hazard, exposure, vulnerability and prevention ability, and analyse the change of maize drought risk in Southwest China under climate change to provide a theoretical basis for the risk management of Southwest maize planting.

2. Materials and methods

2.1. Study area

Southwest China, which includes the entire Sichuan Province, Yunnan Province, Guizhou Province and Chongqing City, is one of the most important grain producing areas of China (Fig. 1). The climate in this area is characterized by humid summers, dry winters and abundant precipitation, controlled by the subtropical monsoon. In this area, gorges are widely distributed and many rivers crisscross. The landscape is dominated by plateaus, mountains and karst landforms. Maize planting areas are distributed in the mountains and semi-mountainous sloping fields and are mainly rainfed agriculture areas.

2.2. Climate data and yield data

Daily meteorological observations (mean air temperature, precipitation, sunshine hours, relative humidity, and wind speed) from 60 meteorological stations in Southwest China during the period from 1961 to 2012 have been provided by the National Meteorological Information Center of China. The yield data, including the maize planting area, maize per unit yield, and crop planting area of 60 southwest counties from 1961 to 2012, have been downloaded from the Chinese planting information network (http://202.127.42.157/moazzys/nongqingxm.aspx).

2.3. Research methods

According to the different growth periods of maize of Southwest China [15], this study divided the study area into six districts (Fig. 2). Table 1 shows the maize geographical distribution and growth period in the different districts.

Based on natural disaster risk forming mechanisms [32], the disaster risk degree is the product of the hazard, exposure, vulnerability, disaster prevention and mitigation capability.

Ma et al. [17]) showed that the annual average temperature in Southwest China has had an obvious ascending trend in the last 40 years. By running an M-K test, 1994 was identified as an abrupt year of change in the annual average temperature in the southwest in the period from 1961 to 2012 (Fig. 3). Therefore, two periods with the same length are chosen to analyse maize drought risk changes before and after the abrupt year, i.e., 1975–1993 and 1994–2012.