International Journal of Disaster Risk Reduction 7 (2014) 109–121

Contents lists available at ScienceDirect

International Journal of Disaster Risk Reduction

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

Modelling impact of agro-drought on grain production in China

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ARTICLE INFO

Article history:
Received 19 December 2012
Received in revised form
3 September 2013
Accepted 3 September 2013
Available online 13 September 2013

Keywords:
Agro-drought
Food security
Grain production
Climate change
Modelling

ABSTRACT

Agro-drought is a powerful natural force shaping significant impacts on food security in a country like China with huge population and relatively limited cropland resources. Quantitatively modelling the relationship between agro-drought and Chinese grain production had not been reported in scientific literature. In this paper we developed an applicable approach to model the impact of agro-drought on grain production in China using the statistical data on agro-drought at various levels of severity. Our hypothesis was that grain production in China should be higher than the actual one shown in statistical yearbooks for the same cropping structure and farming inputs if there was no drought. To test the hypothesis, a modelling procedure to link agro-drought at various levels with grain production had been established at provincial level of China. Statistical data on agro-drought and grain production with consideration of cropping structure were used for the modelling. Our results indicated that the impact was very obvious. Each year ~24 Mha (million hectares) of cropping land in China were under drought attacks at various levels. Average drought intensity defined as ratio of grain acreage under drought attacks to total grain acreage was 13% during 1990–2011 taking moderate attack as a unity, which is defined as grain loss of ~45% under drought attack according to statistics system in China. Annual loss of grain production as a result of drought attacks was ~26 Mt (million tons), shaping an impact of 5.2% to grain production in China. The loss is almost equal to the total grain production of such a big grain producer as Hebei, Jilin or Hunan in China and can feed ~75 million people. Spatially intensive impacts of agro-drought on grain production were observed in northeastern, northwestern and southwestern provinces, where drought intensity was higher than 15% and the impact was over 6%. Our study reveals that food security of China under drought attacks is with a probability of above 92% and grain storage of ~20 Mt is required for China to minimize the threat of drought attacks on its food security. This significant impact of agro-drought on grain production might suggest the risk for Chinese food security that needs to be globally concerned under circumstance of climate change.

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http://dx.doi.org/10.1016/j.ijdrr.2013.09.002

1. Introduction

Climate change has significant impacts on agriculture [15,4,26,19] hence on food security [25,3]. One of the impacts is through drought [34,17]. Climate change does not only lead to warming or cooling of the atmosphere but also result in occurrence of extreme climate events such as drought. It has been observed that many severe droughts were caused by anomaly of atmospheric dynamics driven by climate change [13,9,28].

Drought as a result of climatic anomaly has obvious effect on grain production in China [14] which has vast territory, diverse terrains and complicated climate [32,22]. The effect is not only economical but also environmental. Economically drought decreases the productivity of cropland to threaten food security [27,16] in a country like China with huge population and relatively limited cropland resources [12,32,23]. Environmentally water shortage and high temperature as a result of drought could alter soil fertility fundamental to grain farming [1,6]. Each year several severe drought events occur in various parts of China to shape significant impact on food security of the country [36]. In 2010 severe drought occurred in southwest China especially in Yunnan Province. In 2011 the drought-effected region extended from southwest China to middle Yangtze River basin of the country. In 2012 severe drought occurred in both northwest and southwest China and in 2013 very severe drought was observed in winter-wheat growing region of north China. Quantitative analysis of the impact could provide essential data for decision-making to propose anti-drought measures for food security and environmental sustainability [17].

Relationship between drought and agriculture was a classical topic for scientific studies, which mainly focused on drought monitoring and production estimation using remote sensing, ecosystem modelling, and statistical analysis [8,2]. Potential impact of global change on food supply and price was examined in Rosenzweig and Parry [19] using a compatible crop model. Drought monitor developed by Svoboda et al. [24] began a new era of drought monitoring across North America [11]. In recent decades several drought indices were proposed for remote sensing of drought and several monitoring systems had been developed for local application [20,17]. An approach had been developed in Qin et al. [18] to retrieve land surface temperature from MODIS satellite data for drought monitoring in China. Gao et al., [7] proposed a practical method for remote sensing monitoring of drought severity and validated it through applying to Guangdong Province in south China. Jayanthi et al. [10] used the standardized precipitation index from satellite estimated rainfall to model the drought risk in southern Malawi. Zhou [37] examined valuation of economic loss caused by drought and estimated the loss to be 7.1–11.8 billion RMB in early 1990s. Using an interpolation approach, Zhang [35] estimated the potential food loss due to drought during 1980–1997 in Fujian Province of China. Wu et al. [29] proposed a model to assessment of agricultural drought risk for corn and soybeans in northeast China. Zheng and Huang [36] developed a statistical model to estimated drought-induced grain production loss in China and reported that average annual loss of grain production for the period of 1950–1990 was 33,800 Mt (million ton) in China. Recent data on grain production loss induced by drought attack and its impact on food security in China had not been reported.

In this study we intended to quantify drought's impact on grain production in China during the last 22 years, i.e. 1990–2011. Our hypothesis was that each year grain production in China should be greater than actual output for the same cropping structure and farming inputs if there was no drought happening. To test the hypothesis, we developed an approach to link grain production with the statistic data of drought areas at various levels in China. After describing the approach for quantitative analysis of the impact, we presented the preliminary results from our analysis in Section 3 and gave a brief conclusion in Section 4.

2. Methodology

The approach for the study was a modelling procedure on the basis of the mechanism linking agro-drought with food security (Fig. 1) using the available data on drought, cropping, and grain production from statistics. Discussion of the available data and the models for the simulation was thus very necessary.

2.1. Chinese statistics on agro-drought

To reveal the impacts of agro-drought on food security, we had to know the available statistical data on agro-

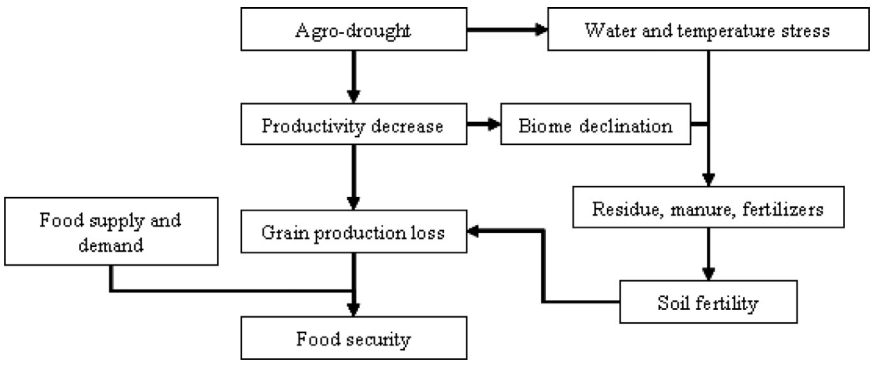

Fig. 1. Mechanism linking agro-drought with food security.