Acta Ecologica Sinica 36 (2016) 311–320

Contents lists available at ScienceDirect

Acta Ecologica Sinica

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

Studies on changes and cause of the minimum air temperature in Songnen Plain of China during 1961–2010☆

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ARTICLE INFO

Article history:
Received 4 December 2015
Received in revised form 22 June 2016
Accepted 22 June 2016

Keywords:
Minimum air temperature
Land use change
Influence
Songnen Plain

ABSTRACT

In this study, we took Songnen Plain of China as the study area, collected the observed minimum air temperature, the minimum air temperature reanalysis data (ERA-40), and the minimum land surface temperature from 1961 to 2010, the nighttime land surface temperature (MOD11A2) from 2000 to 2010. Further, with the obtained and processed data, we analyzed the mechanism and impact of land use change on minimum air temperature within the recent 50 years in the Songnen Plain of China using climate tendency rate, Observation Minus Reanalysis (OMR) and spatial analysis methods. The analysis results can be summarized as follows. (1) The areas of agricultural land, built up, unused land, and forest land have increased and the areas of grassland and water have decreased from 1960 to 2010. In particular, the areas of unused land and built up have increased significantly with about 22 times and 9 times respectively compared with their areas in 1960. (2) During 1961–2010, with the land use change in the Songnen Plain, the maximum air temperature and diurnal temperature range trend has decreased, the minimum air temperature trend has increased, and impact of land use change on minimum air temperature trend is greater than maximum air temperature trend. (3) The unused land has the highest minimum air temperature, nighttime land surface temperature, and minimum land surface temperature than any other land uses, and all corresponding temperature is lower in the agricultural land and the lowest in the forestland. (4) The conversion from any other land uses to the unused land will result in the increasing of the temperature and to the agricultural land and forest land will cause the decreasing of the temperature.

1. Introduction

In recent 100 years, the global climate have greatly changed, with the global warming as its main feature, the global annual mean temperature rose by 0.6 °C [1]. According to the fifth report from the Intergovernmental Panel on Climate Change (IPCC), the climate change is more serious than our initial imagine, and these changes have a 95% probability of being anthropogenic in nature [2]. In addition to the emission of greenhouse gases, land cover change has been considered as another important human activity that influences the global temperature change. In general, land cover change can influence local climate through affecting the latent heat flux, net radiation flux, land surface albedo, ground hydrologic cycles, and greenhouse gas sources and sinks [3–6]. Many scholars have done a lot of research on the impact of land use change on the average temperature. Some studies show that, the whole effect of global land use change is the main reason for the near surface atmospheric warming [7]. The temperature rising rate of the unused land is much faster than any other land uses and land covers in the Northern Hemisphere [8]. The surface temperature covered by winter wheat growing is lower than its of harvested fields in the south of the United States [9]. Furthermore, the unused land (such as sandy, Gobi area) and the region with high intensity of human activity has experienced significantly increasing of the land surface temperature, but the increasing of the temperature in vegetation covered areas are relatively weak [8,10]. The areal increases of the impervious surfaces in urbanized area have been confirmed as one of the most important factors for explaining the increasing of the temperature [11], and the temperature change rate can be descend sorted as built up, agricultural land, grassland, and forest land [12,13]. Bounoua found that land cover change resulted in the warming of temperature and decreasing of diurnal temperature range at the tropical and warm regions [14]. They also found that the stronger land use/land cover change area is always associated with obvious decreasing of diurnal temperature range [15]. But then further studies discovered that the maximum and minimum temperature always presented increasing trend in different regions, while the minimum temperature trend with larger increment than that of the maximum temperature trend [16–19], and the increase rate of the

☆ Foundation item: Under the auspices of National Natural Science Foundation of China (no. 42171217, 41571199), Post Doctoral Fund Project of Ministry of Education (no. 20132329110001).
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http://dx.doi.org/10.1016/j.chnaes.2016.06.009
1872-2032/

minimum temperature is 2.78 times more than the maximum temperature [20]. It means that global warming is mainly caused by the minimum temperature warming [21], and it increased more distinctively in high latitude of Northern Hemisphere [22–24]. For the moment, most works are only limited to the sensitivity study of the impact of land cover change on the average air temperature change, and less studies were conducted about the impact of land cover change on the minimum air temperature.

Northeast is the most significant warming region in China [25–29]. Specifically, the Songnen Plain within Northeastern China has experienced almost one hundred years reclamation, about 80% meadow has been reclaimed as agricultural land [30]. Moreover, in the past century, the total population of Songnen Plain has increased from 2.21 million in 1911 to 58.33 million in 2010, the areas of the agricultural land has increased from 0.145 million hm^2 in 1860 to 13.138 hm^2 in 2010 [31]. With the high intensified agricultural development in the past century, nowadays the Songnen Plain is covered about 11.2% by sand, 22.64% by saline land, and 11.05% by degraded land. Due to human reclamation activities, the land surface properties of the Songnen Plain has been changed dramatically, and the Songnen Plain has already become one of the most classic regions for examining the impact of human activities on land cover change [15] and the impact of land cover change on the climate change. In this study, we quantified the impact of land cover change on the minimum air temperature with the observed minimum air temperature data, NCEP reanalysis data and land use data (1960 and 2010) within the Songnen Plain of China.

2. Study area

The Songnen Plain is situated in the center of Northeastern China (Southwestern Heilongjiang Province and Northwestern Jilin Province), and lies between latitudes 42°30′N and 51°20′N, longitudes 121°40′E and 128°30′E (Fig. 1). The Songnen Plain is a part of the Northeast Plain and is formed by the flashing effect of the Songhua River and the Nen River. It covers approximately 23.75×10^4 km^2, and it's about 2.47% of the total areas in China. Songnen Plain consists of 36 cities and counties in Heilongjiang Province and 18 cities and counties in Jilin Province. Songnen Plain is an important national agricultural base and accounts for 12% grain production in China. It's located in the temperate continental semi-humid and semi-arid monsoon climate zone, climate is varied significantly by season. In winter, it's very cold and dry, and in summer, it's warm and coupled with much more precipitation. The annual precipitation is about 400–600 mm, and the amount of precipitation is decreasing from the east to the west of the Songnen Plain.

3. Data sources

3.1. Air temperature

Air temperature data: the observed maximum air temperature and minimum air temperature data was collected from 20 weather stations (e.g. Beian, Keshan, Hailun, Qiqihar) within the Songnen Plain from 1961–2010. Moreover, in order to improve the accuracy of the interpolated maximum and minimum air temperature for further analysis, the observed maximum and minimum air temperature data from the surrounding 28 weather stations (e.g. Sunwu, Qingan, Jiamusi) was also obtained (Fig. 2). All the air temperature data can be assessed from the website of China Meteorological Administration (http://cdc.nmic.cn/home.do).

The air temperature reanalysis data: the ERA-40 reanalysis data from the European Center for Medium-Range Weather Forecasts was collected and used in this study [32]. In particular, the monthly maximum and minimum air temperature data of the ERA-40 in Northeastern China was collected with totally 195 cells and the spatial resolution of 1.875° (http://data.ecmwf.int/data/d/era40_moda/). In this study, a spatial interpolation was conducted first to generate the spatial distribution map of the monthly maximum and minimum air temperature throughout the whole Northeastern China, and then the clip function was employed to obtain the monthly maximum and minimum air temperature reanalysis data within the Songnen Plain of China.

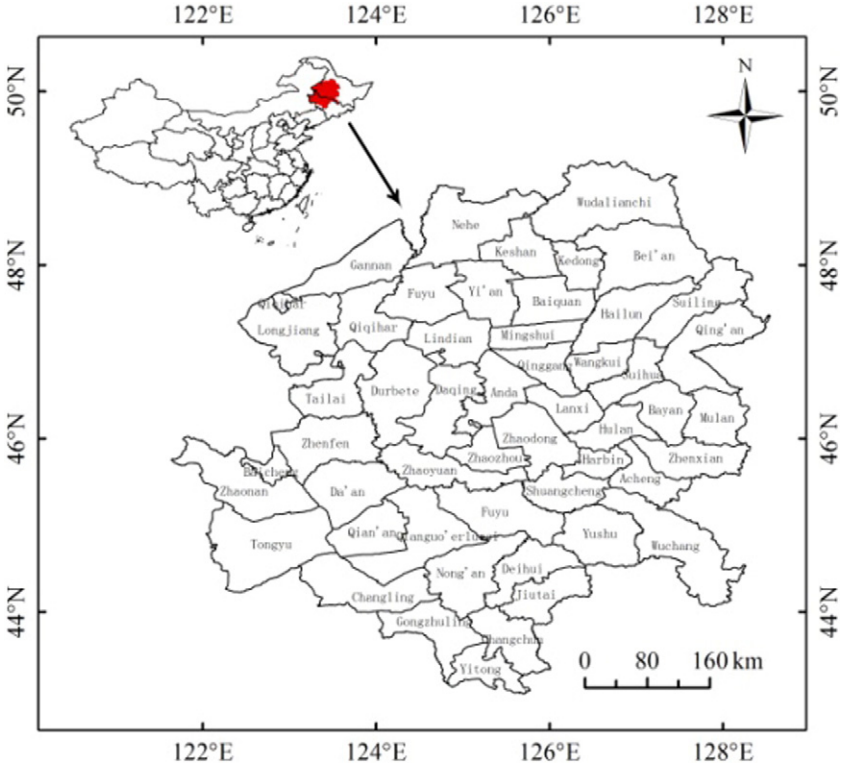

Fig. 1. The location of study area.