Investigation of forest fire characteristics in transboundary area using Remote Sensing data

Yao Yu, Chengde Piao, Ri Jin*
Department of Geography, Yanbian University, China; Address: 977 Park Road, Yanji City, Jilin Province China
*Correspondence: Ri Jin, Lecturer, Tel: +86-130-0908-3971;Email: jinri0322@ybu.edu.cn

Abstract: As the vital natural resource in the world, forest is important to the development of human beings and environment, especially for trans-boundary areas. Trans-boundary areas (China, North Korea and Russia) are abundant in forest resources. However, with forest fires' suddenness, it's difficult to control the fire resources. Moreover, there are jurisdiction limits of different countries and various forest fires management policies, which result in huge losses of forest resources. And because of the inaccessibility of such areas, it's impossible to obtain ground information or conduct the on-site inspections. In this essay, to analyze forest fires features, Medium-Resolution Image Spectrometer (MODIS) data from Land Process Distributed Active Archives Center (LPDAAC)(http://modis.gsfc.nasa.gov/) during 2000 to 2018 are combined with global land cover data on Global Ecosystems and Environment Observation Analysis Research Cooperation website (http://www.chinageoss.org/geoarc/). After comparing and researching the results, the following conclusions are drawn: 1) Fires in Russian border areas are mainly distributed in south border forests of Amur and Zabaykalsky Krai (ZK), Jewish Autonomous Oblast (JAO) of eastern, the wetlands of Primorskiy Kray (PK) and Khabarovsky Krai (KK) in Ruassia. 2) Fires in the territory of China are mainly distributed in Great Xing'an Mountain (GXM) and Small Xing'an Mountain (SXM) of Heilongjiang Province, followed by the Sanjiang plain area in Liaoning Province and the trans-boundary area between Heilongjiang Province (China) and Russia. 3) Forest fire in North Korea were scattered throughout the whole country. 4) Forest fire damaged frequency in the Russian part and the North Korea (NK) part show a downward trend except that in the territory of China. 5) There are two related stages in the territory of China: in 2000 to 2010, forest fire was the main fire type, followed by farmland fire, in 2011 to 2018, the farmland fire occurrence increased quickly, replacing forest fire and becoming the dominant fire type. 6) For transboundary areas for China, NK and Russia, each year fires occur frequently from March to May and September to November.

Key words: Forest fire; Remote sensing; MODIS fire product; Trans-boundary areas

1. Introduction

As the important resource in earth, forests are vital to the development of human beings and environment, which can not only conserve water and prevent soil erosion, but also improve people's living environment by absorbing carbon dioxide and releasing oxygen (Wenshan Wang et al., 2011). Without forests, most living creatures on the land will disappear. With less oxygen and more carbon dioxide in the air, the temperature will go up. Then natural disasters will occur frequently (Lu Zhou et al., 2015). Therefore, it's really important to protect forest ecological resources.

Due to its suddenness, long combustion time, wide burning area, high fire intensity and complex influencing factors, forest fire can bring out serious economic losses. Once beyond human control, it will expand fast in the forest, which will result in great losses of human lives and property. And because of the severe harm to ecological environment, forest fires have aroused the attention around the world. That's why it's so urgent to bring out effective forest fire detection.

Trans-boundary areas (China, NK and Russia) are jurisdiction limits of different countries and various forest fires management policies. Moreover, because of the inaccessibility area such as trans-boundary, it's impossible to obtain ground information or conduct the on-site inspections. In that way, remote sensing monitoring has become an effective means to prevent forest fires and control the spread. In the meantime, the survey is focused on Russian border areas, Northeastern China and NK. With such wide coverage and fire timing uncertainty, it's needed to use MODIS data to acquire forest fire locating information with its extensive spectrum range and high updating frequency.

2. Material and methods

2.1 Study area

In this essay, Russian border areas, Northeastern China and NK be used as the researching subjects. Among which, in Russian border areas there are large forest and mountain areas and in Amur State, Habarovsk Frontier, PK,ZK and Jewish Autonomous Region. About 43% of the forest areas in Russia is concentrated in Far East area (Wenqing Wang et al., 2011). For Northeastern China, inner Mongolia, Heilongjiang, Jilin and Liaoning Provinces are involved, which include GXM， SXM and Changbai Mountain. With 37% of the national forest area, those areas account for one quarter of wood disposal capacity (Yuan Cao et al., 2011). In NK, there are mainly mountain areas, covering 80% of the national land and mainly concentrated on north and east

areas. The terrain is complex and diverse, and the mountains, hills, plains and basins are scattered in those areas. It's clearly seen the environment situations from west to east, the western area is dominated by low mountains and hills. While in the east area, sediment deposition from Tumen River builds plains and swamps, among which there are also a few low mountains and hills. Though cross-boarder areas of China, NK and Russia are abundant in forest resource, the areas of woods are decreasing as the result of forest fire frequent occurrence(Fig.1).

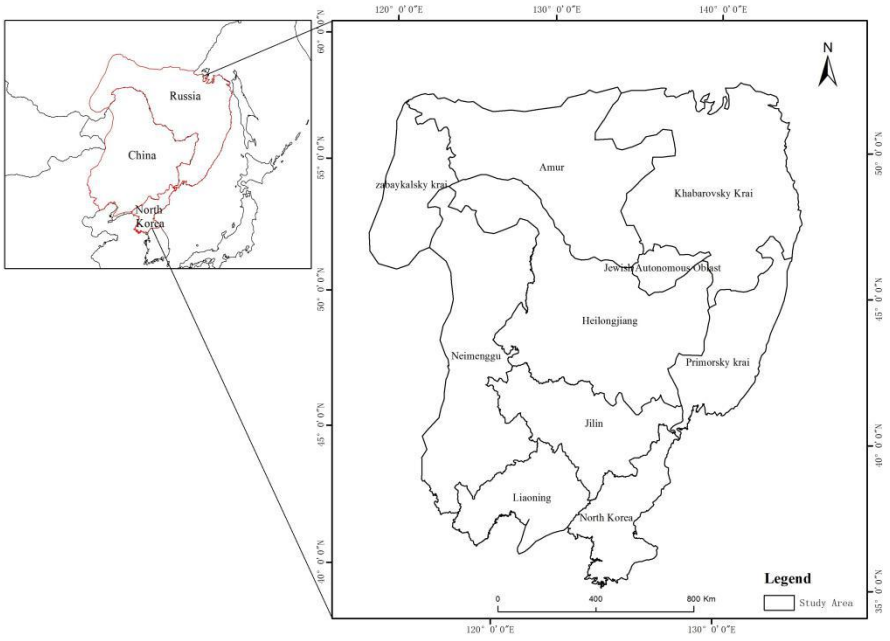


Figure 1. Study Area

2.2 Data used

2.2.1 MODIS fire products

The Moderate Resolution Imaging Spectroradiometer (MODIS) located on board of the polar orbiting satellites, Terra and Aqua, of the NASA Earth Observing System collects data covering various parameters. The present study is based on the MODIS Active Fire Product(MOD 14) data, that has been gathered since 2000 (Justice et al., 2002),with subsequent algorithm improvements (Giglio et al., 2003).In this research, MODIS data from 2000 to 2018 be chose to evaluate the fire distribution features in areas of trans-boundary areas (China, NK and Russia).

2.2.2 Land use land cover data

Land use land cover maps of world for the year 2010 were downloaded from http://www.chinageoss.org/geoarc/.These Maps were prepared by Roy et al. (2015) utilizing Landsat ETM+ and LISS IIII Data with a spatial resolution of 1000m. The 2010 satellite data were

aggregated into 19 International Geosphere-Biosphere Programme (IGBP) classes from the available 150 classes using hierarchical class merging approach and converted to a vector map using WebGIS tool. The errors and discrepancies were corrected using the ground truth data and ancillary information supplemented from existing maps (Roy et al., 2015).

2.3 Methods

In this research, the burned areas were extracted from MODIS data by MRT, which had been geometrically corrected(Including the map projection of Universal Transverse Mercator (UTM) and the correction of World Geodetic System (WGS) 84). The burned scars with 7/8/9 pixel value were extracted and the areas were calculated.Then they use ArcGIS were superimposed with the land data to explore the changing trend of different types of land fires in the same region (Table 1).

Table 1. MOD14A1 fire-mask classes (Source: LP DAAC).

Value	Class
0	missing input data
1	not processed (obsolete)
2	not processed (obsolete)
3	water
4	cloud
5	non-fire
6	unknown
7	fire (low confidence)
8	fire (nominal confidence)
9	fire (high confidence)

3. Results

During the survey from 2000 to 2018, there is a generally rising trend of the area destroyed by the fire, increasing from 5 million hectare in 2000 to 6.5 million hectare in 2018. Due to their different geological environment situations, the main reasons leading to fires are slightly different (Fig.2).

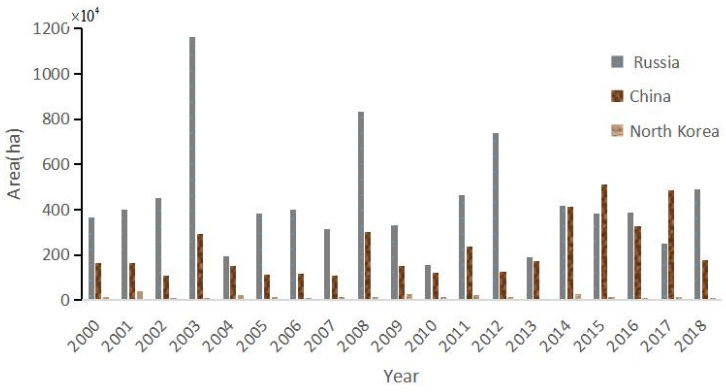
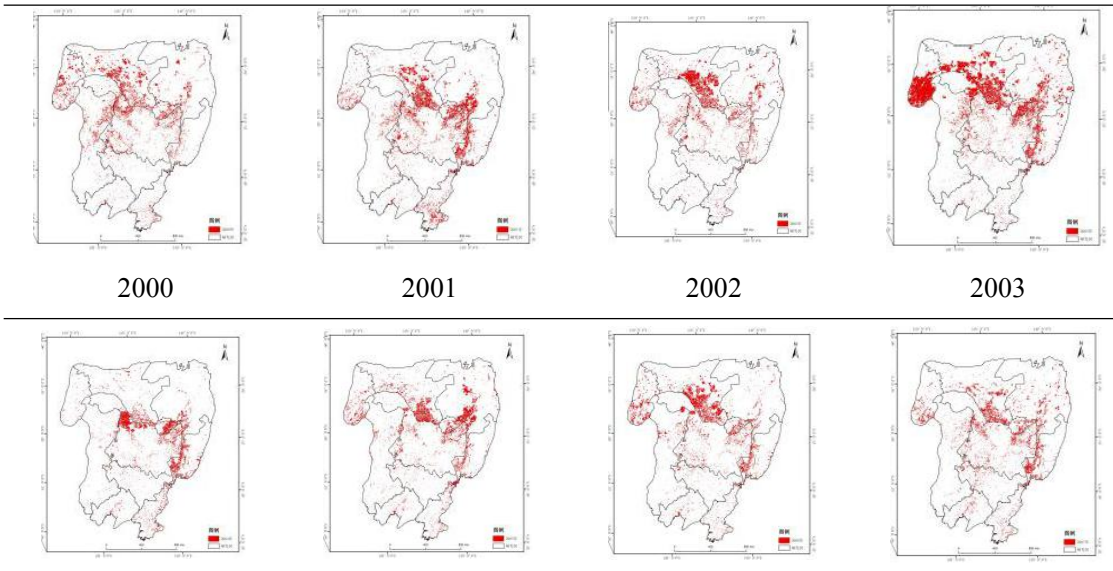


Figure 2. Fire area of every country

Based on MODIS data, most fires occur at the cross-border areas, including Amur, Binhai Frontier Area and Outer Baikal Frontier Area and Heilongjiang Frontier Forest Area, as well as the cross-border areas between NK, Liaoning and Jilin provinces. In additionally, the eastern part of the Jewish Autonomous Prefecture, the Habarovsk Frontier area and the wetlands in PK belong to high frequency areas of fire. In Northeastern China, most of the fire happens in the GXM and SXM of Heilongjiang provinve, followed by the plain areas of Liaoning Province. Forest fire in NK were scattered throughout the whole country. It is also found by the survey that the fire damaged area of 2003 and 2008 was one time higher than last year. And the fires mostly occurred in forest areas, especially in the cross-border forest areas in Russian border areas (Fig.3) .



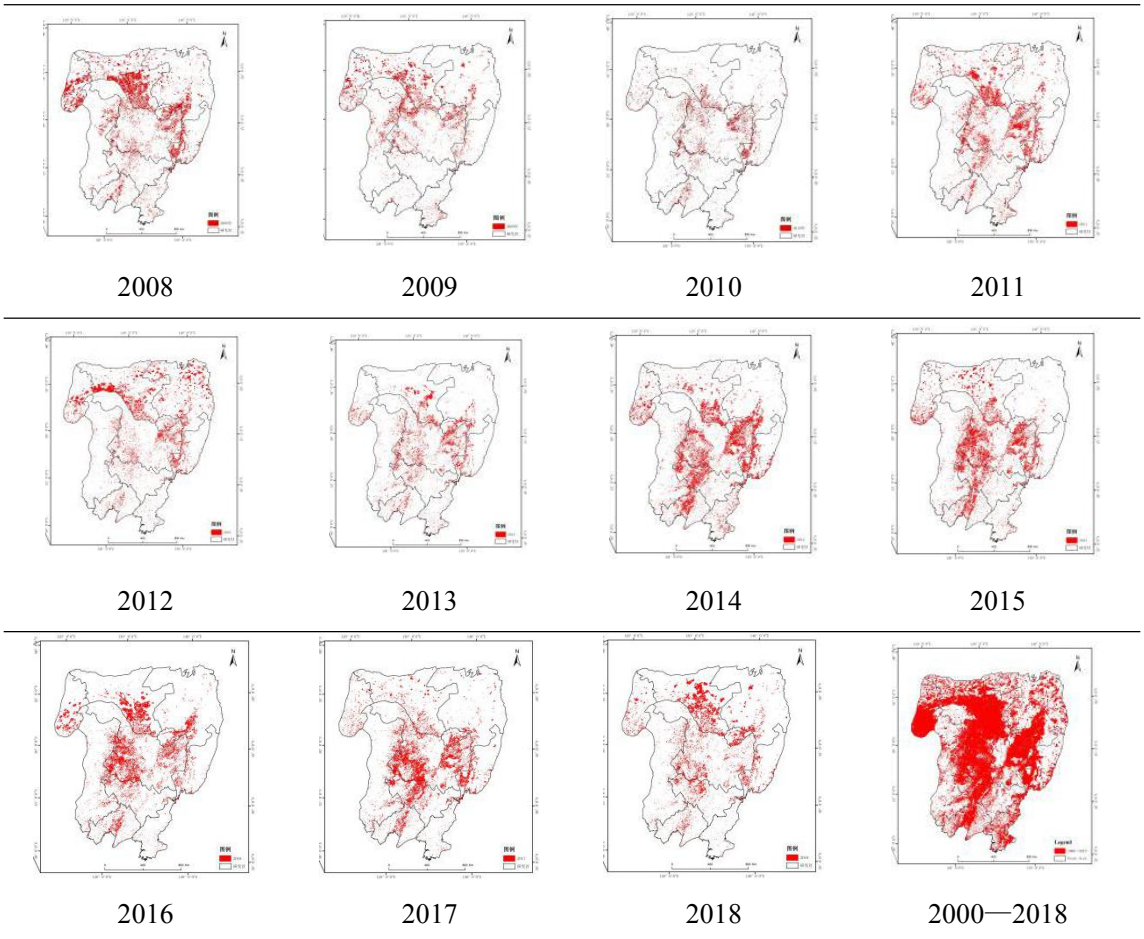
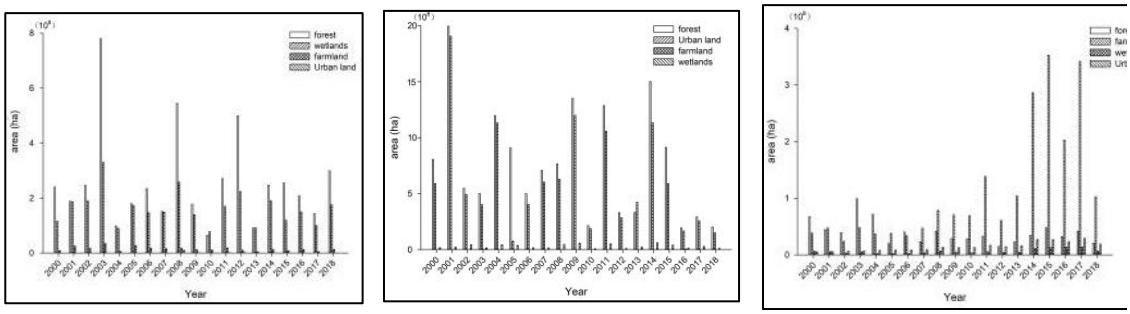


Figure 2. Forest fire characteristics in every year

In Russian border areas, most fire happens in the forests, followed by the wetlands. During 19 years of researching, forest fires covered more than 60% of the total fires, and wetland fire covered about 30%(Fig.4a). In the northeast area of China, most fires happened in the farmland, followed by the forest areas. During the 17 years of researching, farmland fire covered the 47% of total fires, and forest fire covered 33%. Through the survey, it is also found that in 2000 to 2010, forest fire was the main fire type, followed by farmland fire, in 2011 to 2018, the farmland fire occurrence increased quickly, replacing forest fire and becoming the dominant fire type (Fig.4b). Because there are relatively more mountain areas in NK, fires mostly happen in the forests, which cover more than 56% of the total fire area (Fig.4c).



a. Russian border areas of fire area

b. northeast area of China's fire area

c.NK of fire area

Figure 4. Forest fire of transboundary areas

There is also big change in the aspect of fire area monthly distribution, with two different peak duration. During March to May, the first peak be observed. April be regarded with the highest fire occurrence frequency. The second relatively smaller peak be found during September to November, and fire mostly happen in October.

4. Discussion

By comparing MODIS data of the fire distribution features in cross-boarder areas of China, NK and Russia, it's found that fires in farm and urban account for small proportion, being on a declining trend. For cross-border area of China, forest fire was the main fire type in 2000 to 2010, followed by farmland, urban land and wetland fire. In 2011 to 2017, the farmland fire occurrence increased quickly, replacing forest fire and becoming the dominant fire type, followed by forest, urban land and wetland fires. During the 19 years of research, farmland fire decreased rapidly, while the forest fire was on the trend of declination.Forest fire in NK were scattered throughout the whole country.

In the researching period (from 2000 to 2018), there was a seasonal mode for the fire occurrence, which was consistent with the agriculture combustion. Most fires happened during May to April and September to Novermber. During that time, a lot of crop residues were burned to fertilize the soil. It's the harvest period from September to November, a lot of crop residue as Platycodon grandiflorum in the field be burned. The time change caused by such phenomenon may be attributed to the growth season, human being activities and the cleaning working in farmland after harvest seasons. It last from the month of burning agricultural residues to the

harvest season end, which is same with the result of fire cycle based on MODIS data.

5. Conclusion

Combining MODIS data and global land cover data, it's shown that fires mainly happen in Spring at the cross-boarder areas of China, NK and Russia. And forest fires cover more than half of the total fire type, which usually occur in the cross-border area and be on the increasing trend. In Russian border areas, forest fires belong to the most fire occurrence type. Despite the forest, fires often happen in wetland, accounting for 37% of the fire incidents. In northeastern China, the farmland fire increased rapidly, becoming the main fire type. And the second be forest fires. Forest fire in NK were scattered throughout the whole country. There is also seasonal feature of the fire occurrence, each year fires occur frequently during March to May and September to November.

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