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The Effect of Plantation on Sand Dust-storm Weather Near Newly Planted Forest Based on Geographic Information System: A Case Study in Tongliao City, China

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Abstract. As desertification has become a vital environmental problem in recent years, incidental natural disasters such as sandstorm weather and greenhouse effect harm human life and increase. To ease the problem, various methods of sand fixation have been applied. Among them, the regeneration of plantations is thought to be the most effective and widely used worldwide. This study takes Tongliao city as an example, and applies the technology of GIS and satellite images as well as extreme weather data to analyze the plantation's effect on sand fixation and desertification prevention. Results show that plantation positively affects sand fixation, because sand storm weather decreases significantly as the plantation rate increases gradually. But for further protection, special areas such as saline soil area, where planting trees is not applicative, methods such as adding chemical reagent and planting applicable plants are used to improve soil quality and was proved to be useful. Also, discovering and applying plants that are suitable for desert growing environment can be a solution to the problem.

Keywords: Desertification, Treatment, Saline-alkaline soil.

1. Introduction

As one of the most severe environmental problems in the twenty-first century, desertification has been widely discussed and investigated by scientists worldwide. As mentioned by the UN Convention to Combat Desertification, desertification is the degradation of various types of arable land, including arid, semi-arid, and sub-humid land. It may lead to serious environmental crises like soil depletion, ecosystem degradation, and an increase in sandstorm weather. Moreover, it affects human's quality of life and causes severe inequality. The current methods to treat desertification are decreasing the total number of trees cut down each year, developing renewable energies, and protecting biodiversity. Among them, the regeneration of plantation is the most common way applied by central and local governments. However, it is worth mentioning that forest regeneration needs a long period of time to be effective. Theoretically, a tree's root can fix the soil and prevent it from losing or being eroded, but it may take hundreds of years for the trees to grow up and have the expected function. Therefore, it is difficult to get the results from people's observations.

Tongliao is a city in the Inner Mongolia region of China that suffers from sandstorm weather all year round. It is located in the hinterland of the Inner Mongolia desert, and the total area of sandy land

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occupies 45.4% of the total land area. The total grassland area of the city is 8.44 million arcs, and the available area is 7.71 million arcs. Among them, the degraded, desertified and salinized grassland covers 82% of the total grassland area and 90% of the available grassland area [1]. Since the end of last century, Three-North Shelter Forestation Project has been applied in a large area in China, including the city of Tongliao. This project aims to increase the vegetation coverage rate in northern China, which greatly impacts China's overall environment. Over forty years since the project started, the forestation coverage rate increased from 5.05% to 10.51% all over the country (Figure 1).

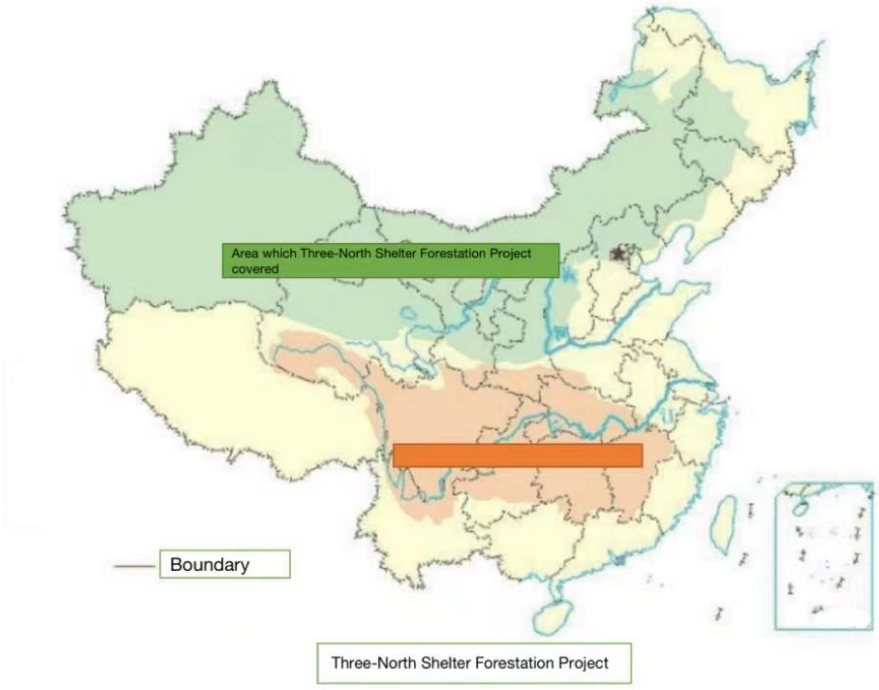


Figure 1. Three-North Shelter Forestation Project. Green represents the area it covered [2].

Therefore, this study takes Tongliao city as an example, applies the technology of GIS and satellite images to visualize the plantation coverage situation since 1998, connecting with the analysis of extreme weather data over these years, and analyzes the plantation's effect on sand fixation and desertification prevention.

2. Background

2.1. Sandstorm weather

According to the Sandstorm weather Grade published by the Chinese government in 2006, sand-related weather is divided into five levels based on ground-level visibility: floating dust, blowing sand, sandstorm, strong sandstorm and extremely strong sandstorm. Floating dust refers to the weather phenomenon which has no wind or an average wind speed that is less than or equal to 3 meters per second, dust floats in the air and the horizontal visibility is less than 10,000 meters. Blowing sand refers to the weather when the wind can blow the dust on the ground, and the horizontal visibility is less than 1000 meters. A strong sandstorm is a weather phenomenon in which the wind blows sand and dust on the ground, making the air very cloudy and the horizontal visibility less than 500 meters. An extremely strong sandstorm is a weather phenomenon in which the horizontal visibility is less than 50 meters [3]. To distinguish the relationship between dust-storm weather and the rate of plantation coverage, only weather conditions above sandstorm level are taken into consideration in this passage to get more accurate results.

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2.2. Background of the study area

Tongliao city is located in the southeast of Inner Mongolia, which is in the mid-latitude region of the northern hemisphere (Figure 2).



Figure 2. The location of Tongliao city.

Tongliao city has a topography with high south and north side and low central area, formed a saddle shape. In the transition zone between the alluvial plain in the middle and the mountains around the city, dunes and deserts cover most of the area. The relatively gentle terrain in the central area causes less friction near the ground, and forms windward slopes around the city, which is more conducive to the continuous movement of dust and the triggering of convection conditions.

Tongliao has a temperate continental and semi-arid monsoon climate. The basic characteristics of this type of climate are dry spring, hot summer, high precipitation in the hot seasons. The average annual precipitation is about 350mm, and the evaporation is nearly 5 times the precipitation, which is the result of its dry weather. The annual average wind speed is 3-4.4m/s, and the number of sandstorm days is 20-30 days [4].

As a city which has topographic situation and climate factor for the formation of sandstorm weather, as well as abundant sand source, Tongliao city has became a vital experimental unit in this project and was greatly influenced as well. In addition, the city is surrounded by the Hunshandake Sandy Land, the Xilin Gole Grassland, the Ulan Buhe Desert, the Badan Jaran Desert and the Tengger Desert. To the northwest is the Gobi Desert (also known as the Great Gobi), which occupies a quarter of Mongolia's land area (about 1.3 million square kilometers). Therefore, Tongliao has abundant sand source condition, which leads to the emergence of sandstorm disasters.

3. Data and Methods

3.1. Data

The selected data range is the daily ground observation data and historical data of 11 national observation stations in Tongliao city from 1981 to 2012 (32 years). The reasons for selecting the above years are as follows: this year range is the period of the latest 30-year data compilation, and relatively speaking, there are various and completed. And according to the requirement of ground automatic station automation observation, years after 2013 employed a visibility meter automation observation method for measuring sandstorm weather, which means that the standard of observation

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instrument and result of observation may have a difference, so choosing the data of 1981-2013 to study about is more objective, and is more convenience efficient to be compared [3].

To get weather results, especially sandstorm weather, data were accessed on the website of Tongliao city government and weather bureau website. Data from 1998 to 2012 were accessed and organized by the location where sandstorm weather happens and by the year when it is happened. The pattern can be clearly shown by comparing the result of sandstorm weather in the same location but different years.

3.2. Methods

To analyze the plantation coverage rate, Geographic Information Systems (GIS) technology gives satellite images of certain locations between different years. It is the product of the intersection of many different subjects. It is based on geographic space, by adopting the method of geographic model analysis, to provide a variety of spatial and dynamic geographic information in real-time. It is a kind of computer technology system for geographic research and decision-making. Its basic function is to convert tabular data into geographic graphics display, and then browse, operate and analyze the display results. Overall, it is a very important spatial information system. It is a technology to collect, store, manage, process, analyze, display and describe the relevant geographic distribution data in the whole or part of the earth's surface under the support of computer hardware and software systems.

In the GIS application, same band ratio (4-3-2 true color band ratio) is used to analyze plantation coverage, which have more precise results than the one with different band ratios. In this band ratio, green represents the area with plantation, brown as well as purple represents land without any cover, and white represents saline and alkaline land.

4. Results

Figure 3 shows the sandstorm weather data accessed from Tongliao Weather Bureau website. Results show that there are variations among each year's weather situation, the overall trend of sandstorm weather is decreasing through these years.

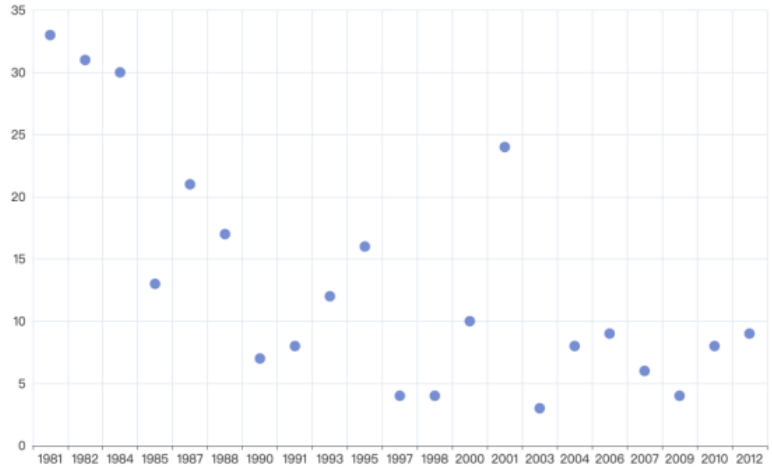


Figure 3. Scatter plot of sandstorm weather from the year 1981 to the year of 2012 x-axis represents year, and the y-axis represents the number of days of sandstorm weather [1].

Figures 4 and 5 show the overall plantation situation in Tongliao city. The maps cover the whole city. In these two maps, purple and brown represent bare land with no cover, while green represents plantation. Comparing the two maps, it can be concluded that the overall plantation rate increased significantly because the green color covers a bigger range in the year 2020 than before.

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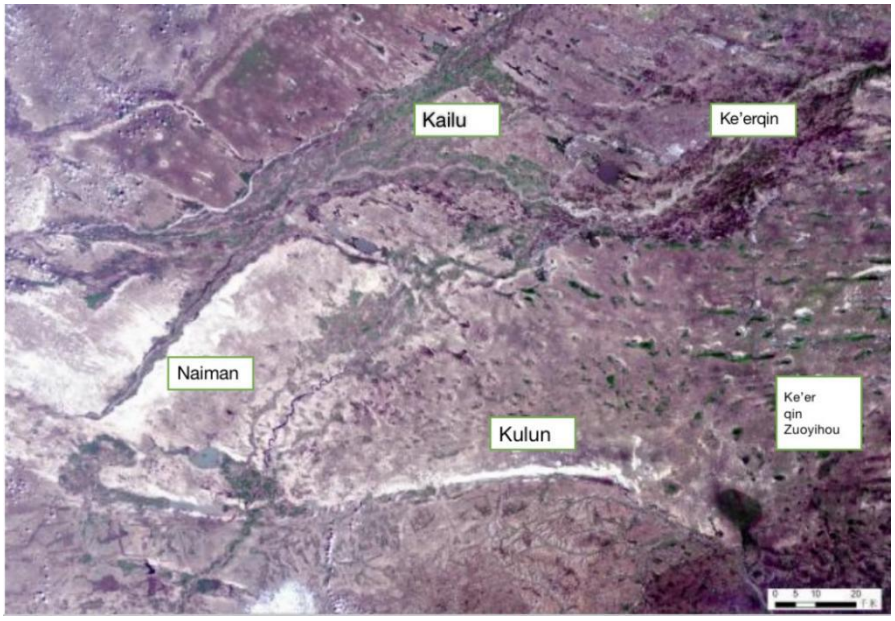


Figure 4. GIS map of entire Tongliao in the year of 1985, green represents vegetation.

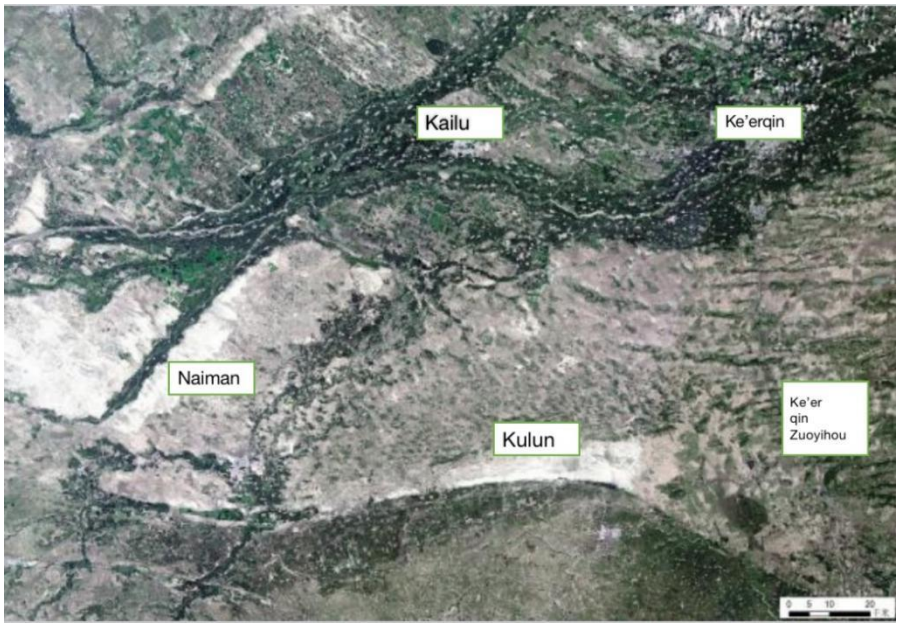


Figure 5. GIS map of the entire Tongliao in the year 2020. Green represents vegetation.

Figures 6 and 7 show the plantation situation in an area of Tongliao city. This area suffered from sandstorm weather significantly in the past because there is hardly any plantation. In these two maps, purple and brown represent bare land with no cover, white represents saline soil, while green represents plantation. Comparing the two maps, it can be concluded that the plantation rate increased significantly in the south of this area. The possible reason is that saline-alkali soil covers most part of the middle and north in this area, and this kind of soil is difficult for plants to grow.

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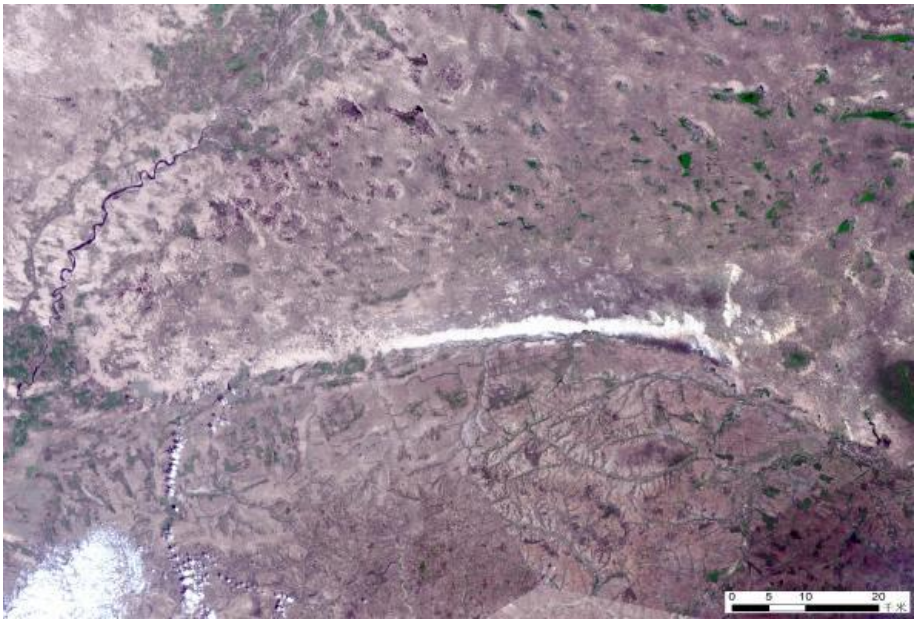


Figure 6. GIS map of sandy land Kulunqi area in the south Tongliao in the year 1985, green represents vegetation.



Figure 7. GIS map of sandy land Kulunqi area in the south Tongliao in the year 2019. Green represents vegetation.

5. Discussion

5.1. Evolution of desertification situation

Overall, the pattern of sandstorm weather shows a trend of decreasing and will still decrease as the plantation area increases in the future. However, some years are shown to be outliers in this graph. There are two reasons for this phenomenon.

First, some areas in the Inner Mongolia desert are featured with saline-alkali soil. This soil has few nutrients and cannot support plant growth. The high pH in alkali soil causes a reduction in the

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availability of plant nutrients such as phosphorus, calcium, nitrogen, iron, copper, manganese and zinc. Under saline-alkali conditions, there may be actually transitional stages, from high salinity-low alkalinity to low salinity-high alkalinity. Under such conditions, the crops may suffer due to high salinity as well as to unfavourable effects of alkalinity [5]. Therefore, the plantation project cannot cover these areas. However, they mostly constitute the highest values of sand loss, and the desertification rate in these areas has a high probability of increasing alarmingly unless treated with suitable conservation measures. This might be the reason for the observed rise in sandstorm weather even after the implementation of conservation measures.

Second, there are two major types of sandstorm weather in China: the one that origins from the North China, and the one that origin from Gobi desert in southeastern Mongolia and the desert in southeastern Kazakhstan. Yang argued that the dust weather that origin in adjacent countries, which is a problem brought by atmospheric circulation, mainly belongs to the transiting dust storm for China. It indicates that the anti-desertification project, including the three-north shelter belt, mainly weakens dust by controlling the amount of dust released on the surface and has a very limited impact on the sand brought by atmospheric circulation [6].

Zhang hold that the role of shelter belts is mainly reflected in the effect of wind protection and sand fixation on the local sand source areas. Some sand-dust weather process is obviously affected by upstream transmission, and the role of shelter belts on this kind of sand-dust transmission is limited. Shelter belts mainly inhibit sand and floating dust near the ground, but their influence and effect on the whole wind field is very limited. Especially in this very strong weather process, shelter belts have a relatively low impact on sand dust and a small impact on the scope.

5.2. Further solutions for the problem

The total area of saline-alkaline soil in the world is about 1 billion hectares, distributed in more than 100 countries and regions, and the annual growth rate is between 1 million to 1.5 million hectares. According to estimation, it is expected that by 2050, the saline-alkaline farmland will reach 50% of the world [7]. These areas tend to cause the most severe sand erosion and desertification. It needs to take factors into consideration to solve the problem completely.

Saline-alkali land improvement is a complicated and extensive control system project. The common solutions includes water conservation measures, biological improvement measures, agricultural improvement measures, chemical improvement measures, and other comprehensive control techniques. This study primarily focuses on two solutions, including improving alkali land quality and investigating new plant species.

5.2.1 Improvement of alkaline land quality The common treatments to alkali land include two sides. First, biological improvement techniques, cultivating salt-tolerant species, particularly nitrogen fixation and salt-tolerance species, can lower soil salinization. It can also improve the physical properties of soil, increase organic matter and soil microbes, and lower the pH value in order to improve the surrounding ecological environment.

Second is chemical improvement measures, including adding Gypsum, phosphoric acid, slag, polyacrylic acid solution, and other amendments in salinized soil, to lower the amount of salt and alkali in the soil. However, it is worth mentioning that applying amendments requires the procedure of washing them with a lot of water, which is difficult and expensive since water resources are limited.

5.2.2 Investigation of new plant species The investigation of new plant species is a more effective solution that can give quick results. It is proved to be effective in the Qaidam Basin in northwest China. For example, Burgundy is a plant specie which is featured by high adaptability, high resistance to drought, salt and alkali, and high resistance to extreme temperature and infertility. It is a typical plant in desert areas and desert plains, and it is an indicator plant of saline soil in various climate areas [8]. It can also be the most efficient and direct way to compensate for traditional agriculture's shortcomings and overcome the saline-alkali environment's restriction on food production by

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identifying natural halophytes that have edible or commercial value and cultivate them. By doing this, a saline-alkali agriculture is created, which is distinct from traditional agriculture and let plantation cover the saline-alkali environment directly. Saline-alkali wastelands can be used for food production without modification if wild halophytes with potential for food or environmental value are chosen and materialized.

There are three common biological improvement methods for saline-alkaline land in recent years. The first is the research of plant salt tolerance physiology and the enhancement of plant salt tolerance. The second is to cultivate salt-tolerant plants and commercially useful halophytes on saline-alkaline soil. The third is to develop novel salt-resistant types and produce plants with salt-resistant genes, using the conventional hybridization and genetic engineering techniques. Comparatively, the second method requires less money and produces results faster, allowing for the efficient use of a vast area of saline soil without the need for technical improvements while simultaneously improving the qualities of both alkali and saline land [9,10].

6. Conclusion

This study takes Tongliao city as an example, applies the technology of GIS and satellite images to analyze the plantation's effect on sand fixation and desertification prevention.

The overall trend of sandstorm weather after plantation is continuously decreasing, which means that the situation of desertification is getting less and less severe. However, some years show a result of an increasing number of the sandstorm. The possible reason is that the sandstorm makes it difficult for forests to block. Also, some area cannot be included in the plantation regenerating project, because the soil quality is not suitable for plant's growth.

Rehabilitating degraded landscapes and protecting high-potential areas from further degradation are among the main objectives of the treatment of desertification. However, the improvement of saline-alkali land is a complex project. Changing the quality of soil with chemical methods and cultivating plants that can provide environmental value are the common methods people used nowadays. Identifying and cultivating natural halophytes with edible or commercial value is another efficient and direct approach to compensate for traditional agriculture's flaws and overcome the saline-alkali environment's restriction on tree plantation.

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