ABSTRACT

Land Subsidence is a kind of slow evolution geological hazards which needs effective way to monitor. The causal and developments of land subsidence are complex. The monitor of land subsidence is also difficulty. So it is hard to analyze it in independent data source. This paper uses multiple source data to extract the high temporal and spatial resolution result. The deformations of land surface obtained from PS-InSAR method cover the whole land subsidence area in Tianjin from 2004 to 2008. This paper uses multi-source data field, such as the PS-InSAR land subsidence result, geologic structure data and groundwater flow field data to take further analysis. The paper analyzes the land subsidence distribution and evolution, the cause of the land subsidence and the relationship between land subsidence and groundwater flow field. Those can provide important reference to groundwater exploitation and urban planning.

Keywords: land subsidence, PS-InSAR, multiple source data field, groundwater flow field, Tianjin

1. INTRODUCTION

Land subsidence is a kind of slow reduction of ground-level environmental and geological phenomena, it is caused by many factors and can become geological hazards in serious situation [1]. The observation cycle of land subsidence is long and the monitoring area is huge. For the subsidence area, it needs the long-term and highly effective way to take monitoring. The origin of subsidence is complex,
so the sole data source cannot take deep analysis of the influence and the variation. It needs to take the multiple source data field generalized analysis.

Interferometric Synthetic Aperture Radar (InSAR) is a kind of new technology to extract surface deformation by using the interferometric of the radar satellite [2], [3]. Its characteristic is the high spatial resolution of the land subsidence, so it can combine with the general monitoring methods, such as GPS and leveling methods, to take system monitoring [4]. Persistent scatterers (PS) interferometeric is a development of conventional InSAR method. It uses the PS pixels to detect the deformation, so it can take the long-term subsidence research [5]. The results of PS-InSAR can offer the high coverage fraction result for the multi-source data source research.

Tianjin is suffered the land subsidence since 1950s[6]. Several studies have used the general methods, like GPS, leveling [7] and InSAR method [8] to detect the land deformation in Tianjin. But there is still lack of a research to study the Spatio-temporal Variation and causal based on multiple source data field.

This paper takes the land subsidence area in Tianjin as the study area. The paper integrates the high precise deformation field from the PS-InSAR method, the groundwater flow field from the foundation geological investigation, the geological fault data and the groundwater mining data in the history to analyze the origin and the development of land subsidence.

2. DATA AND METHOD

2.1. Study area

Tianjin is located from 38°34′ N to 40°15′ N, 116°43′ E to 118°04′ E. It is the centre of Link Bohai Sea area in politics, economical and population, so it is the important area in China. From north to south, the terrain turns from mountainous area into plain area. The southern plain area can be further divided into the alluvial plain, alluvial plain of marine and coastal plain sediments. And the land subsidence often happens in the south plain of Tianjin. The human activity is another main influencing factor of the Tianjin land subsidence. The surface water is deficient in south plain, so the main drinking water exploited from the groundwater. Due to the long-term and excessive exploitation of the groundwater in the history, the south plain suffers the heavy land subsidence. The figure 1 shows the study area. Because Tianjin's land subsidence concentrates in the south plain area, therefore the choice graphical representation scope and it has covered all the land subsidence area basically.
2.2. Data and method

This paper bases on the multi-source data field to develop the research. Both the origin reason and the evolution of land subsidence are complex, so the single data cannot take the systematic research. The paper based on the construction of the three-dimensional monitor system by assemble the remote sensing monitoring system, the ground monitoring system and the groundwater flow field monitor system. This three-dimensional monitoring system can offer high spatial and temporal resolution surface deformation result, the groundwater flow field data and the basic geological data. The figure 2 shows the example of three-dimensional monitor system in the land subsidence research.

The main research data is the surface deformation information which is extracted by the optimization PS algorithm in the study area. We built the atmospheric correction model based on the Meris water vapor data and GPS monitoring data, then the model is incorporated into the StaMPS (Stanford PS method) to form the optimization PS algorithm. This algorithm can take PS-InSAR monitoring in the large, non-urban area. The data source of PS-InSAR method is the ASAR data from the Envisat satellite.
of ESA. We use 16 ASAR data from 2004 to 2008 to extract deformation value. The “10-Mar-2006” ASAR data is chosen as the master image for the analysis of temporal baselines and spatial perpendicular baselines. The algorithm can obtain the average settlement rate and the deformation between master image and other images.

3. RESULTS

The figure 3 shows the deformation between the master image and other slave images. Due to the characteristics of PS-InSAR method, the deformations take the master image as the reference standard. Therefore, the deformations of previous results before master image are opposite to the actual subsidence direction. By the analysis of the result, we can find the Tianjin's surface has been subsidence. The area of land subsidence area is becoming larger as time goes. The land subsidence in the centre area is much bigger than the around area. The land subsidence in Tianjin belongs to the differential subsidence, so the differential subsidence can cause the neighboring region surface height difference enlarging. It is dangerous for the city infrastructure, especially for the subway, the high-speed railway and the buildings. It needs to strengthen the observation and the prevention of the land subsidence.

Figure 3: 3D visualization between master image and slave images
4. DISCUSSION

4.1. The relations of land subsidence and geologic structure
The geologic structural characteristics are the important influencing factor for the land subsidence. The Tianjin land subsidence affects by various factors. The geologic structure, ground water mining as well as the human activity bring the static load and dynamic load are the important factors to study the land subsidence.

Through the superimposition analysis between land subsidence area’s yearly average subsidence value and Tianjin geological fault zone chart, we can discover that the Tianjin’s subsidence is controlled by the geological structure. The figure 4 shows that the land subsidence is influenced by the geological fault zone. We can find that the subsidence in the research area takes two boundary zones controlled by the Haihe fault and the Hangu fault. The subsidence value and area in the south of Haihe fault are bigger than the north. And the whole land subsidence area is focused on the south of Hangu Fault. The land subsidence in the Cangdong fault area is also higher than the other areas. Through the analysis of all the faults, we can get a conclusion that Tianjin land subsidence is influenced by the geologic structure.

![Figure 4: The land subsidence and the fault zone](image)

4.2. The relations of land subsidence and groundwater
Since the 1970s, Tianjin has been begun to over-exploit the depth-groundwater. In the 1990s, the exploitation in south plain of Tianjin has reached to the highest value in the history. The table 1 shows the groundwater exploitation data in the history [9]. The long-term excess mining groundwater causes the subsoil water level which continues to drop in the large scale. Recently years, the study area has formed several groundwater landing funnels, such as the urban district, the south area of Tianjin and
Tanggu. And for the urban district, the south area of Tianjin and the Binhai area, the subsoil water level funnels have been linked up into a single one. The long-term excessive mining groundwater drops the subsoil water level in the large scale, thus forms the groundwater landing funnel. Because of the soil structure in south plain of Tianjin, these groundwater landing funnels can further lead to the land subsidence. Through the figure 5-8, we can see that the urban district, south area of Tianjin and Tangku groundwater funnel areas all suffer the serious land subsidence and the contribution of different aquifer to the land subsidence is also distinct.

<table>
<thead>
<tr>
<th>Area</th>
<th>1970s Exploitation (10k*m^3)</th>
<th>1970s Intensity (10K*m^3/year *km^2)</th>
<th>1980s Exploitation (10k*m^3)</th>
<th>1980s Intensity (10K*m^3/year *km^2)</th>
<th>1990s Exploitation (10k*m^3)</th>
<th>1990s Intensity (10K*m^3/year *km^2)</th>
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<tr>
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<td>4100.00</td>
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<td>5161.11</td>
<td>7.5565</td>
<td>1583.3700</td>
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<tr>
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<td>33.3750</td>
<td>8289.67</td>
<td>20.7242</td>
<td>3912.8167</td>
<td>9.7820</td>
</tr>
<tr>
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<td>3.9708</td>
<td>9793.22</td>
<td>6.2219</td>
<td>10764.4000</td>
<td>6.8389</td>
</tr>
<tr>
<td>Dongli</td>
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<td>3.2003</td>
<td>2032.22</td>
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<td>2680.9075</td>
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<tr>
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<tr>
<td>Jinnan</td>
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<td>11.2041</td>
<td>4518.6667</td>
<td>10.8413</td>
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<tr>
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<tr>
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<td>2340.00</td>
<td>4.9149</td>
<td>2782.9475</td>
<td>7.3134</td>
</tr>
</tbody>
</table>

Table 1: The groundwater exploitation data in the history [9]
4.3. The static and dynamic load

The human activity is one of the most important effects of land subsidence. Form this year, along with the swift growth of population and the economy, the constructions of high-rise buildings and the infrastructure will lead to the highly increase of static load. The subway, high-speed railroad and other municipal transportation are also increase. The high frequency and high speed movement of transportation bring the much pressure on the land subsidence region. These will bring the high dynamic load. The static load and dynamic load cause the aggravating of land subsidence together. Figure 9 shows the comparisons between the TM image and the land subsidence image. We can find that the land subsidence in Tianjin concentrates in the urban area which has the densely population and high static and dynamic load area. Along with present establishment of national link Bohai Sea special economic zone, Tianjin is being in the fast development, therefore it cannot neglect the land subsidence and its harm. So it needs to develop the effective measure to monitor, to prevent and to control the land subsidence.
5. CONCLUSION

This paper bases on the multiple source data fields. The study analyzes the various influencing factors of the land subsidence. The land subsidence is a complex geologic hazard. The harm which brings from the loss of terrestrial reference elevation and differential subsidence cannot be neglect. For the further research, it needs to strengthen the establishment of 3D monitoring system for the land subsidence. The research of land subsidence needs to collect data from multiple methods. It will provide the technical support to prevent the surface subsidence and control the harm which the surface subsidence brings.

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REFERENCES


