Risk Assessment of Snow Disaster in Guoluo Prefecture of Southern Qinghai Province Based on GIS

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Abstract. We evaluated snow disaster risk in 44 towns of Guoluo Prefecture by combining the methods of Analytic Hierarchy Process (AHP) and cluster analysis. Data were gathered from meteorological stations in Qinghai and Sichuan Provinces with GIS and RS tools. We considered snow depth, the duration of snow days, the area ratio of snow as three indicators for such evaluation, we can say Guoluo Prefecture is a higher hazard area of snow disaster. From the spatial distribution, we can see that the mild grade areas are Huashixia town in Maduo county, Zhalinghu village and Dongqinggou village, Lajia town in Maqin county; the moderate and minor severe grade areas are distributed basically in every county. And the minor severe grade areas cover almost every town in Dari county and Gande county. However, the severe grade areas only distribute in Sanrima village, Tehetu village of Dari County and Dangluo village of Maqin county.

1. Introduction
Snow disaster results in livestock casualties and impact herdsmen’s daily activities, and may also be associated with such consequences as traffic jam, power and communication line interruptions. Guoluo Prefecture is located in the southeast of Qinghai Plateau. Animal husbandry is the main economic productivity of the region. Assessing the degree of snow disaster risk in Guoluo prefecture provides reference and basis for the development of local animal husbandry, and serve for disaster prevention, reduction work in this region[1-4].

Due to high altitude and low average annual temperature, Guoluo Prefecture is a major snow disaster impacted area in the Qinghai Plateau, especially in the mid or late October until May of the following. There are many heavy snowfall weather in this area, the snowfall is large, the snowfall lasts for a long time, and the temperature is low, the snow is difficult to melt, resulting in the death of a large number of livestock, and to the people's lives and property safety brought serious losses[5].

In this study, the risk of snow disaster in 44 towns and villages in Guoluo region was evaluated, which based on the field investigation of 44 towns and villages in Guoluo Prefecture. Three indexes of risk caused by snow disaster, including snow depth, snow duration and snow area ratio, were classified in order to study the degree of risk caused by snow disaster in towns and villages in Guoluo Prefecture. Taking towns as the basic unit, the risk degree of snow disaster in Guoluo area was evaluated in detail, which was also a significant breakthrough in the study of snow disaster in Qingnan Plateau. The significance of evaluation at the township level is to improve the specific application and practice of disaster prevention, relief and disaster resistance. Evaluation at the township level is an important breakthrough and highlight in this study compared with previous ones.
2. Study Area Overview

Guoluo Tibetan Autonomous Prefecture is located in the southeast of Qinghai Province, east longitude 96°54' ~ 101°51', north latitude 32°31'~35°37'. The total area of the region is 76,442km. The average altitude of Guoluo is approximately 4,200m. The areas with altitudes between 4,000 to 5,000 meters account for about 80% of the total territory. Prolonged freezing or low temperature duration, hypoxia condition, strong light radiation and temperature difference between the day and the night are the main climatic characteristics of the region. The annual average temperature is -4°C and there is no absolute frost-free period throughout the year. The annual precipitation of the region is between 400 and 760 millimeter. The vegetation type is alpine meadow, which is suitable for raising a mixture of domesticated livestock including sheep, yak and horse. Agricultural land in the land use type 69,500 square kilometers, of which 65,300 square kilometers are grassland, accounting for 85.5% of the total area of the prefecture. The prefecture's population is 185,600, of which 175,500 are Tibetan, accounting for 91.86% of the total population. It has jurisdiction over 44 towns and townships of six counties, namely Maqin, Banma, Gande, Dari, Jiuzhi and Maduo[6].

3. Materials and Methods

3.1. Data Sources

The data used in this study mainly include three types. First, weather data were collected from 58 Meteorological Stations based in Qinghai and Sichuan (39 Meteorological Stations in Qinghai and 19 Meteorological Stations in Sichuan). The data on snow cover area of Guoluo prefecture was downloaded from the international scientific data service platform. TM remote sensing images of Guoluo region were downloaded through landsat-7 satellite. The orbit number of Landsat satellite where Guoluo region is located is p132r36, p133r36, p135r36, p131r37, p132r37, p133r37. The time period of the selected remote sensing image is from October 2000 year to May of the following year in a typical year in weather condition wise. This time period is same months for which the snow cover depth and snow cover duration were calculated. Second, data on Guoluo County administrative district map and Guoluo township district map were collected. Third, through interviews with local herdsmen from different townships in Guoluo, we investigated snow disaster measures such as depth of local snow cover, the duration of snow cover and the disaster status.

3.2. Research Method

Snow disaster in the southern Qinghai generally occurs from October to May of the following year. In this study, data on snow depth and snow duration from October to May in following year from 1960-2012 gathered from 58 available meteorological sites were selected to calculate annual mean values (Figure 1). Kriging interpolation approach and the Area Class Statistic methods of ArcGIS were used to obtain snow depth and snow duration information of 44 towns in Guoluo region (Table 1).

![Figure 1. The location of Guoluo Tibetan Autonomous Prefecture in Qinghai Province, China.](image-url)
Table 1. The data on three snow disaster status indicators of 44 towns in Guoluo Prefecture, Qinghai Province, China.

| township    | snow depth(cm) | snow days (day) | snow cover ratio (%) | township    | snow depth(cm) | snow days (day) | snow cover ratio (%) |
|-------------|----------------|-----------------|----------------------|-------------|----------------|-----------------|----------------------|
| Daka        | 4.39           | 7.13            | 40.38                | Xiazangke   | 4.40           | 6.15            | 7.35                 |
| Duogongma   | 4.43           | 6.39            | 17.74                | Shanggongma | 4.29           | 8.32            | 29.29                |
| Jiangritang | 4.47           | 5.74            | 18.94                | Ganglong    | 4.39           | 6.50            | 27.95                |
| Makehe      | 4.43           | 6.39            | 45.36                | Xiagongma   | 4.38           | 7.05            | 23.56                |
| Jika        | 4.40           | 6.63            | 32.76                | Mentang     | 4.57           | 6.46            | 4.32                 |
| Sailaitang  | 4.41           | 5.89            | 14.60                | Wasai       | 4.50           | 6.46            | 10.99                |
| Dengta      | 4.46           | 5.57            | 38.78                | Suohurima   | 4.59           | 6.44            | 18.16                |
| Yaertang    | 4.45           | 5.67            | 48.90                | Zhiqingsong duo | 4.60 | 6.80 | 16.08 |
| Zhiqin      | 4.39           | 6.20            | 15.78                | Waeryi      | 4.48           | 6.52            | 10.35                |
| Tehetu      | 4.12           | 9.64            | 58.59                | Baiyu       | 4.52           | 6.10            | 31.42                |
| Sangrima    | 4.18           | 9.12            | 39.89                | Huashixia   | 3.63           | 6.91            | 25.29                |
| Jianshe     | 4.29           | 8.80            | 5.64                 | Zhalinghu   | 3.49           | 7.46            | 6.27                 |
| Jimai       | 4.36           | 7.81            | 34.80                | Heihe       | 3.67           | 8.40            | 24.48                |
| De’ang      | 4.43           | 6.88            | 5.91                 | Huanghe     | 3.90           | 9.04            | 28.89                |
| Wosai       | 4.38           | 7.61            | 16.46                | Xiadawu     | 3.81           | 7.01            | 49.15                |
| Moba        | 4.34           | 8.01            | 17.17                | Xueshan     | 3.94           | 6.60            | 33.65                |
| Mazhang     | 4.42           | 6.82            | 4.54                 | Lajia       | 4.10           | 5.39            | 7.92                 |
| Shanghongke | 4.22           | 7.89            | 23.65                | Dawu        | 4.11           | 6.20            | 60.97                |
| Xiaohongke  | 4.29           | 7.51            | 38.31                | Dongqinggou | 4.05 | 5.91 | 14.09 |
| Qingzhen    | 4.24           | 6.68            | 53.21                | Chuangmahe  | 3.99           | 8.65            | 26.96                |
| Jiangqian   | 4.27           | 6.07            | 20.23                | Youyun      | 4.14           | 9.31            | 20.54                |
| Kequ        | 4.31           | 7.43            | 28.84                | Dangluo     | 4.24           | 8.75            | 46.87                |

The TM image of the month with the greatest snow cover was obtained from the Geospheric Data Cloud (http://www.gscloud.cn/). The remote sensing images were mainly selected from days with less cloud cover. Interpretation keys were established based on methods used in previous related studies. The images were processed by supervised and unsupervised classification methods, and the best classification results were selected by comparing the original images in ERDAS 9.3. Using clustering and removal operations, binary images were made through recode, and each image was montaged and then cut with the new boundary of Guoluo. Finally, superposition analysis was carried out with the rural boundary map in ArcGIS to obtain the amount accumulated snow in each township. The classification method in this study mainly adopts K-means clustering method, which generally adopts the square error criterion, and it is defined as:

\[ E = \sum_{i=1}^{k} \sum_{p \in C_i} \left| p - m_i \right|^2 \]

Where, \( E \) represents the sum of squared errors of all objects in the data set, \( p \) represents the given data object, \( m_i \) represents the average of cluster \( C_i \) (\( p \) and \( m \) are multidimensional). The purpose of this criterion is to make the generated clusters as compact and independent as possible. The specific calculation process of snow depth, duration, area ratio and hazard grade in each township is as follow:

1. The Analytic Hierarchy Process (AHP) is used to calculate the weight of each index of snow cover depth, snow cover duration and snow cover area ratio (Table 1). After calculation, the weight of three indices of snow depth, duration and area ratio is 0.374, 0.374 and 0.252 respectively (Table 2).
2. (2)
Table 2. The weights of three snow cover indicators by the methods of Analytic Hierarchy Process (AHP).

| target   | depth | duration | area ratio |
|----------|-------|----------|------------|
| depth    | 1     | 1        | 3          |
| duration | 1     | 1        | 3          |
| area ratio | 1/3   | 1/3      | 1          |
| weight   | 0.374 | 0.374    | 0.252      |

(2) Three indicators were added into analysis tool of the SPSS and z-score was selected before clustering to standardize the data for the three indicators. Then three index data calculated by ArcGIS were standardized. The standardized numerical calculation formula for each township is:

\[H = w_1D + w_2T + w_3A\]

In formula, \(H\) represents the hazard risk index caused by snow disaster in each township, \(D\) represents the standardized value of snow depth, \(T\) represents the standardized value of snow cover duration, \(A\) represents the standardized value of snow cover area ratio, \(w_1, w_2\) and \(w_3\) are the weight coefficients of snow cover depth, duration and area ratio calculated by AHP respectively.

(3) Clustering analysis is conducted according to similarity and difference. Similarity can be characterized by similarity coefficient, while difference can be reflected by distance. K-means clustering method was adopted to cluster the three indicators, Euclidean Distance was adopted for distance, and the classification method was adopted for average clustering. Z-score was selected before clustering, that is, data were standardized. First, the original data of snow cover depth, duration and area ratio were analyzed by using k-means clustering in SPSS, which were divided into four categories. According to the original standardized value and weight formula, hazard risk \((H)\) of snow disaster was obtained. Based on the combination of hazard risk index of snow disaster and four clustering results, the clustering category with average hazard risk index \((H)\) was severe, and the clustering category was successively divided into four grades: severe, heavy, moderate and mild.

4. Results

4.1. Snow Depth by Township

Results (Figure 3) showed that the degree of snow depth in each township has a distributional trend of decreasing from southeast to northwest, which may be mainly due to the influence of southeast monsoon. The precipitation in general shows a trend of decreasing from southeast to northwest. In other words, precipitation is greater in the southeast than it is in the northwest in Guoluo prefecture. Combined with the original data, the hazard risk of snow disaster by using k-means cluster analysis in SPSS was classified into four grades, namely mild, moderate, heavy and severe levels. Results showed that the area with mild snow hazard level accounted for 6.81%; moderate grade accounted for 18.19%; heavy grade accounted for 25%; and severe grade accounted for 50% of the total area.

4.2. Duration of Snow Cover in Each Township

The study results (Figure 3) showed that the during of snow cover by days among the townships has a general rule of decreasing from the west to the east, which may be mainly due to the fact that the average altitude in the west of Guoluo is higher than that of in the east. The temperature correspondingly is lower in the west than that of in the east. Thus, temperature differences tend to be a major cause for such discrepancy in snow cover duration among the townships of Guoluo. Specifically, snow cover remains longer period of time in the townships located in the western part of the prefecture than that of in the east. Considering duration of snow cover as an indicator of snow hazardous level, areas with mild hazardous grade accounted for 25%; moderate hazardous grade accounted for 38.64%;
heavy hazardous grade accounted for 20.45%; and severe hazardous grade accounted for 15.91% of the total areas of the townships in Guoluo Prefecture.

4.3. Snow Area Ratio
Study results (Figure 3) showed that snow area ratio had no obvious distributional trends across the townships. However, it can be learned from the results (Figure 3) that severe level snow hazardous areas included surrounding areas of Animachen Mountain, suggesting that snow area may be affected by factors such as topography and physiognomy as well combination of these factors with altitude. Thus, snow cover by area ratio is greater in high mountain areas where it also remains longer period of time due to the low temperature and high altitude. Taking account of snow cover ratio as an indicator for hazardous level, areas with mild snow cover grade accounted for 20.45%, moderate grade accounted for 34.10%, heavy grade accounted for 29.54%, and severe grade accounted for 15.91% among the townships considered.

4.4. Hazard Risk Degree of Each Township
The snow hazardous risk index results showed that the mild degree of snow disaster hazard in each township accounted for 9.1%, which mainly included Huashixia Township and Zhalinghu Township of Maduo County, Dongqinggou Township and Lajia Township of Maqin County. Townships with moderate grade of hazardous risk accounted for 31.82%, which included partial areas of each county. The Townships with heavy hazardous risk grade accounted for 52.27%, which included almost every county of Guoluo Prefecture, among which Dari County and Gande County were more pervasively exposed to heavy hazardous risk grade. The Townships with severe hazardous risk grade accounted for 6.81%, which included Sangrima Township and Tehetu Township of Dari County, as well as Dangluo Township of Maqin County. The snow hazard levels in towns and townships of Guoluo Prefecture fall within moderate and heavy grades, accounting for 84.09% of the total area. From large-scale circulation background perspectives, the reason for high snow disaster hazardous risk in Guoluo Prefecture in the southern Qinghai Province could mainly attributed to the Indian Subtropical High, which leads to heavy snow fall and cover.

Figure 2. The hazard levels and hazard indexes in Guoluo Prefecture of Qinghai Province

5. Conclusion
The results showed that the towns with mild disaster risk accounted for 9.1% of the total number of townships; the townships with moderate risk accounted for 31.82%; townships with heavy risk accounts for 52.27%, and townships with severe risk grade accounted for 22.6%. In sum, the townships with high level of risk from snow disaster hazard accounted for 74.87%. Therefore, in can to concluded that Guoluo Prefecture is a region with high hazardous risk from snow disaster. In terms of spatial distribution of hazards, the mild grade of hazard occurred in Huashixia Township and Zhalinghu Township of Maduo County; Dongqinggou Township and Lajia Township of Maqin
County. Moderate and heavy grades of hazardous snow disaster occurred in almost every county. Heavy grades of hazardous snow disaster happened in Dari County and Gander County. The areas with severe grade snow disaster were distributed in Angrima Township and Tehetu Township of Dari County, and Dangluo Township of Maqin county. The study provides basic scientific understanding of the scale of snow disaster in Guoluo Tibetan Autonomous Prefecture, and informs policy makers for risk prevention and disaster relieve efforts.

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