Research on Villages Location Optimization Based on MOP Method

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Abstract. At present, the integration of urban and rural areas in China is still developing. Some villages are restricted due to unreasonable selection of site. This paper aims to build a model combing nonlinear stochastic multi-objective programming (MOP) with ethnic beliefs. The models take these factors that have a significant influence on villages into consideration, such as religion, geological disasters, infrastructure and so on. Besides, this paper takes four villages in Sichuan of Tibet as an example. Editing coding, based on the RGB value of the picture, is intended to extract village coordinates and boundary range. Finally, the simulated annealing algorithm is used to obtain the best location of the village, and the analytic hierarchy process (AHP) is used to grade it. The results show that it will improve the utilization rate of land, realize the scientific management of land resources and promote the purpose of urbanization. Thus, it can provide some reference for the village site planning and resource utilization.

1. Introduction
With the continuous development of urbanization in China, the shortage of land resources is restricting the sustainable development of China. The western plateau region is often limited by the poor natural conditions and the lack of land resources. The existing studies mainly focus on the discussion of the different types of Tibetan villages [1] and the religious environment inhabited by settlements [2], as well as the geological distribution, the causes of geological disasters [3], the distribution and factors of geological disasters [4]. In general, the current study focuses on one or several aspects. It is even rare to find a comprehensive study of multiple factors, especially the combination of village selection and sustainable development.

This article aims at the problem of village location in the northwestern Tibetan areas of Sichuan Province. Because Barkam is a plateau canyon area, the altitude changes greatly, while the Batang County terrain is relatively flat and broad, the village location has more certain reference and promotion. In addition, their populations are mainly Tibetan, and have great similarity in religious culture. Secondly, they in the resources and industrial structure, traffic conditions and so on are similar. So the paper takes Batang County as an example. And the paper introduces the safe distance to avoid the geological disasters area. On this basis, through determining the radius of village activities can make sure the religious buildings and infrastructures as close as villages possible. A nonlinear stochastic multi-objective programming (MOP) [5] model is established, and MATLAB is used to
obtain the location of village migration through simulated annealing algorithm [5], and the analytic hierarchy process (AHP) [6] is used to grade the comprehensive development of villages. Thus it can ensure the feasibility of the results. The rest of the paper is organized as follows: Section 2 introduces the process of building a multi-objective programming model. Section 3 introduces application examples and the compute of the mathematical models. The conclusion is introduced in Section 4.

2. MOP model

2.1. Mathematical model

Phase I. The establishment of the model considers not only factors such as infrastructure, religious beliefs and keeping the village far away from the geological disasters areas, but also the balanced development of the environment, society and economy of the village. Based on four main aspects that are closely related to the village migration, the MOP model is established.

Step 1. Infrastructure model:

The infrastructure is very important to the development of the village. Therefore, the plan of the migration is that the villages after migration (VAM) are closer to the infrastructure than before one.

First of all, the VAM should be close to the central village as far as possible:

\[
\sqrt{(X^{AM} - X^{CT})^2 + (Y^{AM} - Y^{CT})^2} > \sqrt{(X^{BM} - X^{CT})^2 + (Y^{BM} - Y^{CT})^2}
\]  

\((X^{AM}, Y^{AM})\) : Village coordinates after migration. \((X^{BM}, Y^{BM})\) : Village coordinates before migration. 
\((X^{CT}, Y^{CT})\) : Coordinates of Center Village.

Then, there should be at least one hospital, school and other infrastructure closer to the VAM:

\[
x_i \sqrt{(X^{AM} - X^{iH})^2 + (Y^{AM} - Y^{iH})^2} < \sqrt{(X^{BM} - X^{iH})^2 + (Y^{BM} - Y^{iH})^2} + \sum_{j=1}^{k} y_{j} \geq 1 \text{ or } 1
\]

\((X^{iH}, Y^{iH})\) : Hospital coordinates. \((X^{SC}, Y^{SC})\) : School coordinates.

Step 2. Religion model:

Most people in Tibetan region have religious belief, therefor, religious building is another important factor in the process of village migration. VAM should not be far away from the religious building, and maximize positive and negative deviation of distance from the religious building:

\[
x_i \sqrt{(X^{AM} - X^{iR})^2 + (Y^{AM} - Y^{iR})^2} < \sqrt{(X^{BM} - X^{iR})^2 + (Y^{BM} - Y^{iR})^2} + \sum_{j=1}^{k} y_{j} \geq 1 \text{ or } 1
\]

\((X^{iR}, Y^{iR})\) : Religion coordinates.

Step 3. Geological disaster model:

For different geological disaster areas, village migration should be far away from high-risk geological disaster area and close to low one. \(d_{11}, d_{12}, d_{13}\) mean the distance between VAM and three kinds of geological disaster areas. (prefix 1,2 stand for village before and after migration, suffix 1,2,3 stand for high, medium and low-risk areas of geological disaster.)

If distance is used as the evaluation criteria, it must be multiplied by the corresponding distance coefficient and defined as the safety distance. For the same distance, the actual meaning of it is different, so the distance coefficient is also different. Thus the parameters need to be set in the model for
the virtual distance. Through analogue simulation, the final parameters are set as \( \alpha_1, \alpha_2, \alpha_3 \). Its mean the distance coefficient of high, medium and low incidence area of geological disaster, and \( \alpha_1 \ll \alpha_2 \ll \alpha_3 \).

The VAM must lie in one of the three kinds of geological disaster areas, so \( d_1 + d_2 + d_3 = 0 \). There will exist some special situations that the safety distances of different villages are equal, so the safety distance needs to be corrected and the virtual distance is introduced. The virtual distance is the product of the larger distance and the distance coefficient in its own area:

\[
\bar{D} = \sum_{i=1}^{3} \alpha_i d_i + \frac{1}{e} \sum_{j=1}^{3} \sum_{k=1}^{3} \left( \min \{ \alpha_j d_{j1}, \alpha_j d_{j2}, \alpha_j e \} \cdot \max \{ \alpha_i d_{i1}, \alpha_i d_{i2}, \alpha_i d_{i3} \} \right), \quad e = 1.0 \times 10^{-5} \tag{4}
\]

\( \alpha_1, \alpha_2, \alpha_3 \): Safety distance coefficient of high, medium and low geological disasters.

\( e \): Reference quantity, Minimal numbers, Desirable \( 1.0 \times 10^{-5} \).

Step 4. Balanced development model:

The village migration also needs to consider the balanced development of society, economy and environment. According to the reality, the utilization of different resources is divided into four types. The first type includes religion, mineral resources, infrastructure and lakes. The second type includes cultivated land area per village, average agricultural output value per village and output value of average livestock husbandry per village. The third type includes the national road and the central village. The last is geological disasters.

Type I Resources: \( k_i \) is number of resources near villages. \( s_j \) is distance from resources to village site, and \( e_j \) are the number of resources within the scope \( r_j \), \( j \) is the rank of index:

\[
r_j = \frac{1}{k_j} \sum_{i=1}^{s_j} s_i \quad \text{and} \quad \bar{RB}, \bar{IS}, \bar{LK}, \bar{MR} = e_j / k_j \tag{5}
\]

\( \bar{RB} \): Utilization ratio of Religious. \( \bar{IS} \): Utilization ratio of infrastructure. \( \bar{LK} \): Utilization ratio of Lake. \( \bar{MR} \): Utilization ratio of mineral resources.

Type II Economic index: \( l_1, l_2, l_3, \ldots, l_p \) stand for distance from villages to neighboring towns that are after migration, there are \( n \) villages within the scope \( r_i \), \( c_i \) is economic indicators of villages, \( m_j \) is economic indicators of all villages, \( i \) is the rank of villages, \( j \) is the rank of economic index:

\[
r_j = \frac{1}{p} \sum_{i=1}^{l_j} l_i \quad \text{and} \quad \bar{PL}, \bar{PA}, \bar{PH} = \left( \frac{\sum_{i=1}^{c_i}}{n} \right) / \left( \sum_{i=1}^{m_i} \right)
\]

\( \bar{PL} \): Utilization rate of agricultural output value in village. \( \bar{PA} \): Utilization rate of average cultivated land in villages. \( \bar{PH} \): Utilization rate of average animal husbandry output value in village.

Type III Effective distance: \( d \) is the shortest distance between the village that need migration and the National Road, and \( d_i \) is the shortest distance between natural village and National Road:
\( d_i \) is the distance from village that is after migration to central village, \( d_i \) is the distance from village that is before migration to central village, \( d_i \) is distance from central village to county.

\( \tilde{Cd} \): Efficiency of national road distance. \( SD \): The efficiency of the village center distance.

Type IV Geographical security: \( w_1 \) is the safety factor of village that is before migration, \( w_2 \) is the safety factor of village that is after migration:

\[
\tilde{GD} = \begin{cases} 
1 & w_2 > w_1 \\
\frac{w_2}{w_1} & w_2 \leq w_1
\end{cases}
\]

(8)

\( \tilde{GD} \): Regional safety of geological disasters.

Letters with arcs are all utilization rates. And each utilization rate ranges from 0 to 1.

Through the AHP method, we can get the weight in the model:

Table 1. The weight in the model

| \( \eta_1 \) | \( \eta_2 \) | \( \eta_3 \) | \( \zeta_1 \) | \( \zeta_2 \) | \( \zeta_3 \) | \( \psi_1 \) | \( \psi_2 \) | \( \beta \) |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 0.0605    | 0.0270    | 0.1808    | 0.0656    | 0.0655    | 0.1532    | 0.0301    | 0.0247    | 0.0826    | 0.0099    |

Phase II. In summary, the village site optimization model based on MOP method is:

\[
\begin{align*}
\text{max } GD & = \sum_{i} \alpha_i d_{i2} + \frac{1}{2} \sum_{i} \sum_{j=1}^{3} (\min \{\alpha_i d_{i2}, \alpha_j d_{j2}, \alpha_j d_{j3}\} \cdot \max \{\alpha_i d_{i2}, \alpha_j d_{j2}, \alpha_j d_{j3}\}) \\
\text{min } IS & = \sum_{i} \sqrt{(X_{i}^{w} - X_{i}^{m})^{2} + (Y_{i}^{w} - Y_{i}^{m})^{2}} + \frac{1}{2} \sum_{i} \sum_{k=1}^{3} (\min \{\alpha_i d_{i2}, \alpha_j d_{j2}, \alpha_j d_{j3}\} \cdot \max \{\alpha_i d_{i2}, \alpha_j d_{j2}, \alpha_j d_{j3}\}) \cdot (1 - \gamma_i - \gamma_j) SD \\
\text{max } BD & = \eta_1 RB + \eta_2 IS + \eta_3 LK + \eta_4 MR + \eta_5 PL + \eta_6 PA + \eta_7 PH + \eta_8 \tilde{Cd} + \eta_9 SD + \beta \tilde{GD} \\
\text{max } RB & = \sum_{i} \sum_{j} Rd_{i} - \sum_{i} \sum_{j} Rd_{j}
\end{align*}
\]

(9)

\( E. R. P \) Represents the total number of each facility. And it indicates that each facility is equal in status.

\( d_{i}^{*} \), \( d_{i} \): Distance deviation between before migration and after migration.

\( \gamma_1, \gamma_2, \gamma_3 \): The weight of School, hospital, main road. \( SD \): Shortest distance of National Road.

\( \eta, \eta_1, \eta_2, \eta_3 \): The weights of religious, infrastructure, lake and mineral resources utilization.
\( \psi, \psi' \): The weight of national road distance. The weight of the efficiency of the village center distance.
\( \xi, \xi', \xi'' \): The weight of the average cultivated land area, the agricultural output value of the village and the utilization value of the livestock output value of the village. \( \beta \): The weight of the regional safety of geological disasters. \( GD \): Geological disaster. \( IS \): Infrastructure. \( BD \): Balanced development.
\( RB \): Religious belief. \( AC \): The coordinate set of the whole search area.

3. Case analysis

3.1. Samples selection
The experiment is carried out in Batang County which is located in Ganzi Prefecture in the northwest of Sichuan Province. It has 16 villages, 18 religious buildings and national highway 318 across it. A total of 4 villages are selected as research objects, they are Xiasangka, Renai, Shangede and Yudi village. Xiasangka village is selected as the center village and other natural villages are selected as the villages to be relocated.

3.2. Data sources and processing
In this paper, we use Batang County Twelfth Five-Year Plan as the data source combined with field visits and expert advice. Due to the lack of data from the relevant departments, we use the 2015 and previous data. According to Batang County geological disaster investigation and zoning report, Batang County is divided into three levels of prone areas for geological disasters.

According to the relative position of Batang County in the map. Using Photoshop modify the size of all images to 5480*10960. According to each Batang County map's pixel RGB values, this paper uses the MATLAB programs to extract the coordinates of the pixels on the map to determine the range of the solution and mark the locations. Then using the program again gets the coordinate matrix of these indicator resources. The matrix is normalized to a separate point to simplify the constraint and make it as realistic as possible (Figure 1).

![Figure 1. (a) Division of geological disaster prone area and resource distribution (b) Solution scope (c) Results](image)

3.3. Analysis
In the process of solving the model, the weight of the geological disaster model is set to 0.5, the infrastructure model is 0.3, and the religion and balanced development model are both 0.1.

The reason why the weight of geological disaster is 0.5 is that the specific environment we studied is bad, so the geological environment should be given priority. Secondly, the allocation of infrastructure is
sub important. We consider that the weight of the balanced development is low. The whole objective function focuses on the utilization of geographical environment resources. When the overall objective function gets maximum number, there is sufficient evidence to show that the final solution is better. Because there are so many points in the actual search area that can’t traverse all the points. Therefore, only the global optimal solution can be used to replace the real optimal solution. For this reason, we adopt simulated annealing algorithm. The parameters of the simulation algorithm are set as follows:

**Table 2. Simulated annealing algorithm parameters**

| Markov length | Decay scale | Step factor | Temperature | Tolerance |
|---------------|-------------|-------------|-------------|-----------|
| 10000000      | 0.95        | 0.02        | 30          | 1         |

Convergence rate of solution:

Through the establishment and study of the model, combining with the actual situation, the model is solved by MATLAB, the final solution can be clearly defined as a range and there are many solutions, so only 22 solutions are taken here.

**Table 3. The coordinates of the solution**

| No. | E   | N   |
|-----|-----|-----|
|     | 1   | 2   | 3   | 4   | 5   | 6   | 7   | 8   |
| 9   | 99°14′17″ | 29°06′52″ | 99°14′58″ | 30°00′27″ | 99°14′11″ | 30°03′26″ | 99°16′42″ | 30°11′20″ |
| 10  | 99°13′27″ | 30°11′21″ | 99°14′06″ | 30°03′38″ | 99°14′38″ | 30°03′35″ | 99°15′25″ | 29°55′31″ |
| 11  | 99°14′28″ | 30°06′16″ | 99°13′27″ | 30°03′38″ | 99°14′06″ | 30°03′35″ | 99°15′25″ | 29°55′31″ |
| 12  | 99°17′41″ | 30°15′32″ | 99°12′13″ | 30°05′57″ | 99°15′55″ | 30°00′36″ | 99°16′32″ | 30°01′23″ |

4. Conclusion

This paper takes four villages in northwest Sichuan province as an example. Based on Twelfth Five-Year Plan of Batang County and combining field investigation with expert opinion, village location optimization model is established. In this paper, the MOP is combined with simulated annealing algorithm, and AHP is used to analyse the results of MATLAB to ensure rationality. Finally, a reliable site selection scheme is put forward according to the result of the solution. The villages are close to the central village, so as to carry out the local urbanization. It can not only realize the centralized and economical use of land, but also improve the utilization rate of the land and ensure the sustainable development of land resources. The villages should also find suitable development directions after their relocation. Furthermore, the center village should also be integrated with local characteristics and geographical advantages so as to achieve sustainable development.

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