A Study of Settlement Planning Strategy of Tableland Village, in Gully Regions of Loess Plateau, China

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Abstract. As the smallest social unit in gully region of Loess Plateau, “Tableland” villages own large amount of agricultural population. Using the analysis of ecological carrying capacity into the villages’ settlement planning within small areas, this paper research on the relationship among maximum ecological carrying capacity, the current ecological carrying capacity and the current supporting population. Through the analysis of this relationship, to make the decision which villages owns the ability to accept more immigrations and which villages need to be integrated into other villages, at the same time, the villages were graded. Among the six grades of ecological carrying capacity villages, type I village is suitable to be extension, and type VI village needs to be relocated.

1. Introduction

Gully regions of Loess Plateau, mainly refer to Wei Bei Loess Plateau, Shan Bei Loess Plateau and Long Dong Loess Plateau, including 7 cities, 18 counties, a population of about 4.3 million, a total area of about 14.8 thousand square kilometers [1] (figure 1) and (table 1). Since the end of last century, the construction of new socialist countryside carried out in the Loess Plateau, human settlements enter a drastic transform period.

![Figure 1. Location of Gully region.](image-url)
"Tableland" village (figure 2), as the smallest social unit in gully regions of Loess Plateau, owns large amount of agricultural population. Nowadays, large numbers of residents live in gullies move to tableland. Until now, the number of "Tableland" villages is over 75% of total village numbers in this region, the ratio of population there is over 85% of total (figure 3) [2]. On the one hand, it caused the disappearance of the slope villages and gully villages; on the other hand, it increased ecological pressure of tableland, where was densely populated originally, and make the original weak ecological environment much worse, all of which force us to figure out a suitable developing way and sustainable villages planning method.

| Region                        | Sub-regions                      | Provinces | Cities       | Land areas (km²) | Total population (mil.) |
|-------------------------------|----------------------------------|-----------|--------------|------------------|-------------------------|
| Gully region of Long Dong Loess Plateau | Gan Su                           | Qing Yang | Ping Lang    | 9213             | 4.3                     |
| Gully region of Shan Bei Loess Plateau | Shaanxi                          | Yan'an    | Tong Chuan   | 3505             |                         |
| Gully regions of Wei Bei Loess Plateau | Shaanxi                          | Xian Yang | Bao Ji city  | 2058             |                         |

Table 1. Space distribution in gully regions of Loess Plateau.

Figure 2. Tableland villages

Figure 3. Schematic diagram of the phenomenon "Population move to tableland area"
Thus, how to do the ecological and sustainable planning, how to efficiently use and save energy and protection environment, and how to improve residents’ productivity conditions and living environment of "Tableland" villages, the solutions of these questions is very important to both the development of rural habitats and also the ecological development of whole gully regions.

Based on ecological carrying capacity to plan and design human settlements are one of the significant bases for the scientific construction of new countryside [3]. Through the analysis of the relationship among maximum ecological carrying capacity, the current ecological carrying capacity and the current supporting population, it can make the decision which villages owns the ability to accept more immigrations and which villages need to be integrated into other villages. At the same time, "Tableland" villages are graded and the future human settlements environment can be further analyzed and predicted, which can be used as a planning guideline for the future villages’ movement and integration in gully regions of Loess Plateau.

2. Methodology

2.1. Restrict factor analysis method in "Tableland" villages’ ecological carrying capacity analysis

At present, the common ecological carrying capacity research methods are ecological footprint [4] [5]; measurement of natural vegetation as first productivity [6]; balance between supply and requirements [7] [8]; state space method [9], model forecast method [10]. In order to select the most suitable analysis method and meet the accurate requirements of ecological carrying capacity analysis, several research methods are compared in the following (table 2).

| Analysis methods | Theory | Advantages | Deficiency |
|------------------|--------|------------|------------|
| Ecological footprint | Use equivalent productivity land as measure index, quantitative characterization of human activity load on ecology and the natural carrying capacity, to check the security. | 1. Ecological footprint analysis method is a systematic, fairness and comprehensive index system. 2. Comparable. 3. Understandable. | 1. The results in over general, cannot be used in small area. 2. Ignore on the land multi-functions. 3. Equivalence factors’ selection is not very reasonable |
| Measurement of natural vegetation as first productivity | Through the assessment of natural vegetation as first productivity, the index of ecological carrying capacity in certain areas can be fixed. And by practical measurement, the results can show the gap between present ecological environment quality and assessment. | 1. It is an important index for evaluating ecological system construction and its functions. 2. It can reflect the productivity of natural system and its recover ability after the outside disturbance. | 1. Equations for measurement are too complex. 2. Limited in the research of vegetation. 3. In China, the document for vegetation yield is few, and the accuracy is low, thus it is difficult to use. |
| Balance between supply and requirements | Ecological carrying capacity is valued by two kinds of dispersion relationship: the dispersion between the resources supplied by local ecological system and the requirements of social and economic development; the current ecological environment and people’s equipment. | 1. This method can analysis and forecast the ecological carrying capacity simply and effectively. 2. This method is widely used in the evaluation of basin ecological carrying capacity. | 1. It is hard to analysis the exact carrying capacity for the coming years. 2. This method cannot show the social and economic developing level and people’s living standards. |
| State space method | This method is essentially an area analysis method, composed by three-dimensional space made from different factors. Using the point of carrying in space, the state of carrying capacity can be showed in a certain time. | 1. This method is common used in multivariate time series; it can show the constructional construction and the quantitative relation between vectors and measurement. 2. This method can describe the carrying capacity in the measurement area. | It is just visual expression form to show the analysis results, but cannot be used to calculate the ecological carrying capacity. |
| Model forecast method | With the support of computer, ecological carrying capacity can be analyzed by a series of mathematical models. | This method can greatly improve the research qualified level and degree of accurate. | Difference will show by the different mathematical models it selected. |

Table 2. Comparative analysis of the common analysis methods for ecological carrying capacity.
Because of the shortage of statistical data and documents on “Tableland” villages in the gully region of Loess Plateau, What is more, the fragile ecological environment, shortage of water and cultivated land, these self-characteristics of this area, the measurement results of general ecological carrying capacity do not have great value of the area human settlements construction. Model forecast method analysis ecological carrying capacity by some different models, the selection of models depends on the requirements of accurate, and thus this method can be adopted as a suitable analysis method for "Tableland" villages in gully region of Loess Plateau.

The restrict factor analysis method is the most common used method in the model forecast method, the main restricting factors are selected within the ecological system in a certain research area, and then these restrict factors can be used to fix the ecological carrying capacity. The common restrict factors are usually food, water resource, land, energy, green area, can also be selected as restrict factors. If the restrict factors are more than one, the supporting population should be calculated one by one based on the minimum value of ecological carrying capacity.

Based on the restrict factors analysis method, the analysis of the ecological carrying capacity of "Tableland" villages in gully regions of Loess Plateau is more reasonable. On the one hand, through the analysis of the restrict factors, the main factor that influences ecological carrying capacity, can be figured out, thus it can be used to guide the future planning of these villages. On the other hand, the complex ecological carrying capacity analysis can simplify into several restrict factors, this method is more feasible.

2.2. The improvement of restrict factors in human settlements planning of "Tableland" village

Ecological carrying capacity is the carrying capacity of the ecological system and the sub-environmental system, the ability to maintain certain social and economic activities, and the ability to supporting a certain amount of population. Factors that can restrict ecological carrying capacity are a lot, which can be figured out according to three main factors: recourse factor, environmental factor, and social factor.

Based on the characteristics of geology, landform, climate, water, vegetation and land of gully region in Loess Plateau, the situation of water loss and soil erosion, threaten from sand and wind and drought are all very serious. Cultivable land and water resource are the two main factors own significant influence on human settlement in this area, thus this two factors can be selected as main restrict factors. At the same time, the lag development of economy, imperfect infrastructure and the imbalance distribution of social resource, are also the obvious present situation in gully region, thus infrastructure can also be selected as important restrict factor.

Among the main restrict factors of ecological carrying capacity in gully regions of Loess Plateau, the policy, factor is mainly influenced by national land policy, population planning policy and environmental protection policy. Water resource factors own close relationship with the construction of main infrastructure and water conservancy facilities. Land resource factor is mainly restricted by cultivable land area and construction land area. According to the site survey, construction land area is relatively smaller than the cultivable land area in most "Tableland" villages, thus this research just put cultivable land into consideration as the land resource factor for the analysis of ecological carrying capacity.

3. The analysis of ecological carrying capacity of “Tableland” village

3.1. Analysis of ecological carrying capacity based on the restrict factor of cultivable land

According to the amount of population that total cultivable land in a "Tableland" village can support, the cultivable land is used as the restrict factor to do the estimation of village ecological carrying capacity. The equation is PG=S/Smin. Cultivatable land per person can be calculated by the food requirements of per person. The minimum cultivatable land per person can be calculated by related research or the published number by national departments [11]. In order to know the food
requirements of per person, not only the food for the basic existing, but also the national food safety requirement should be put into consideration [12] (table 3).

**Table 3. Aims of Chinese food safety.**

| Strategies                              | Food requirement per person (kg) | Per capita food (kg) |
|-----------------------------------------|---------------------------------|---------------------|
| 2010 (Basic well-off society)          | [National food and nutrition consultant committee (2004)] 391 | 420                 |
| 2020 (All-round well-off society)      |                                |                     |
| 2030 (Transition period for rich stage)|                                | 472                 |
| 2050 (Rich stage in all-round)         |                                | 500                 |

According to the requirement of per capita food, the followed (table 4) can be used as a reference to show the per capita cultivable land requirement for the different food demand level. Thus, the requirements of per capita of cultivable land in different times, in this area can be known (table 5).

**Table 4. The requirement of cultivable land area for different food demand in Loess Plateau (hm²)**

| Years | \( S_{400} \) | \( S_{450} \) | \( S_{500} \) |
|-------|----------------|----------------|----------------|
|       | A   | B   | C   | A   | B   | C   | A   | B   | C   |
| 1995  | 0.254 | 0.253 | 0.208 | 0.286 | 0.284 | 0.234 | 0.317 | 0.316 | 0.260 |
| 2020  | 0.204 | 0.203 | 0.163 | 0.230 | 0.229 | 0.183 | 0.255 | 0.254 | 0.203 |
| 2030  | 0.175 | 0.175 | 0.136 | 0.197 | 0.196 | 0.153 | 0.219 | 0.218 | 0.170 |
| 2050  | 0.152 | 0.152 | 0.115 | 0.171 | 0.171 | 0.129 | 0.190 | 0.190 | 0.144 |

(This table was made from the: Research on Threshold Value of Per Capita Cultivable Land in the Whole Country and Some Regions [12]. \( S_{400} \), \( S_{450} \), \( S_{500} \) represent the cultivable land required for the 400kg, 450kg, 500kg production field. A, B and C represent different methods of cultivable land calculation, A means the total cultivable land, B means the land expect vegetable land, and C represents cultivable land only for grain production.)

**Table 5. The requirement of cultivable land per capita in Loess Plateau (hm²).**

| Years | A   | B   | C   |
|-------|-----|-----|-----|
| 2010  | 0.229 | 0.228 | 0.186 |
| 2020  | 0.217 | 0.216 | 0.173 |
| 2030  | 0.208 | 0.207 | 0.162 |
| 2050  | 0.190 | 0.190 | 0.144 |

(The food requirements per capita is calculated according to Chinese food safety goals, made by National Food and Nutrition Consulting Assistance, takes Chen Bai Ming’s data as reference. The cultivable land area in 2010 is calculated by 400kg food requirement per capita for the average land demand in 1995 and 2020. In 2020, the land area is calculated by 400kg and 450kg food requirement per capita. In 2030, the land area is calculated by 450kg and 500kg food requirement per capita.)

The actual areas of cultivable land in each period can be known by local governments’ land forecast and their related policy about reverting farmland to forest and grassland. Based on this, the demand proportion of total cultivable land area and cultivable land per capita can be calculated, thus the ecological carrying capacity in a certain period time can be forecasted.

3.2. Analysis of carrying capacity of water resource

The analysis of water carrying capacity is a very complex research system, not only include the social, economic, environmental, ecological and water resource, but also include the influence comes from society, economy, culture, traditions and so on. At present, the limitation of human, material, and financial resources, especially the technology, it is difficult to comprehensively analysis developing regulations.
Gully region of Loess Plateau is one of the most water shortage areas in China, just some land in gully bottom can be irrigated, and most of lands in the gully slope and tableland area are non-irrigated land, totally depend on natural precipitation. The water supply from artificial wells is very limited, even hard to supply the water for human living in some villages. The present water carrying capacity analysis aims to check whether the existing water resource can meet the demand for the present population and even more population. The construction of artificial wells directly influences the amount of water supply. Therefore, the water carrying capacity can also be analysed by the water infrastructure.

Because water resource owns huge impact on villages’ ecological carrying capacity, it can be analysed as one of the restrict factors, based on the water supply infrastructure. After the field investigation, it is found that the water supply in Chun Hua County of Shaanxi Province is only supplied by artificial wells, thus the analysis of water carrying capacity can be calculated by the water supply of artificial wells and the water demand per capita. According to the rural water safety and sanitation regulations, the safety level should not lower that 40-60L, and the basic needs amount is 20-40L. In order to improve the living standard in rural areas and realize the integration of urban and rural areas, the urban water requirements can be used as a reference. The average water consumption in urban areas of Shaanxi Province is about 209L per capita per day.

### 3.3. Analysis of carrying capacity of infrastructure

Rural infrastructure refers to the materials and technologies that service for the rural production, living and development, including economic infrastructure and social infrastructure, all of these are the developing conditions for rural economic and social development.

The infrastructure is the developing basis for the rural areas, also important part of components in the village system, it should be developed with the development of villages [13]. There are several different classification methods for rural infrastructure, one of the most common used is classified according to the different functions. Village own many functions, such as productivity, people’s living, and ecology. Thus, the infrastructure can be divided into three types: Productivity infrastructure, Living infrastructure, Ecological infrastructure.

| Table 6. Classification of the levels of public infrastructure [14]. |
|-----------------|-------|-------|-------|-------|
|                 | G1    | G2    | G3    | G4    |
| Village health clinic | ●     | ●     | ●     | ●     |
| Service center | ●     | ●     | ●     | ●     |
| Senior center | ●     | ●     | ●     | ●     |
| Kindergarten | ●     | ●     | ●     | —     |
| Market | ●     | ●     | ●     | —     |
| Primary school | ●     | ●     | —     | —     |
| Village committee | ●     | ●     | —     | —     |
| Nursing home | ●     | ●     | —     | —     |
| Cultural station | ●     | ●     | —     | —     |
| Middle school | ●     | —     | —     | —     |
| Bank | ●     | —     | —     | —     |

| Table 7. Classification of public service infrastructure in villages [14]. |
|-----------------|-------|-------|-------|-------|
| Villages Average income >6500 CNY/Y (≥1000 USD/Y) | Villages Average income 4000–6500 CNY/Y (615–1000 USD/Y) | Villages Average income 4000–6500 CNY/Y (615–1000 USD/Y) |
| Over 2000 people | G1 | G2 | G3 | G4 |
| 800–2000 People | G3 | G3 | G2 | G3 |
| Less than 800 people | G3 | G4 | G3 | G4 |

At present, the research on carrying capacity of infrastructures in "Tableland" villages is in a gap, most of the analysis does the research limited on urban infrastructure. The situation in villages is very...
different from cities, they have different developing levels, population structure, and thus the research on urban areas cannot be used in rural areas. Theoretically, each basic infrastructure should be analysed to get the total carrying capacity for certain population. However, the systematic evaluation of the basic rural infrastructure is not available, so the carrying capacity cannot analyse systematically. According to the present situation of infrastructure in gully region of Loess Plateau, the public service infrastructure shown in (table 6) and (table 7) can be used as one of the most available methods to get the calculation of the supporting population. For example, if a village has a clinic, service centre, and old people activity centre, which meet the demand of G4 for village public infrastructure, the supporting population should not more than 800 by the calculation of public infrastructure.

The movement or integration of villages in gully regions of Loess Plateau usually refers to the natural villages below 800 people. The above methods are difficult to analyze the carrying capacity of infrastructure for such small-scale villages. Thus, in this case, the research also evaluates the carrying capacity of infrastructure according to interview and questionnaire distribution.

4. Tableland village human settlement planning strategy

4.1. Ecological carrying capacity comprehensive analyses of rural habitat in the small region

The small areas that tableland villages located in, and the developing conditions and ecological carrying capacity of its surrounding villages have the direct and indirect influence on the developing direction of these Tableland villages. The analysis of restrict factors for the ecological carrying capacity in small areas is based on the total distribution situation of all the restrict factors, which can be used to research on the distribution of ecological carrying capacity of villages in small areas. Based on these analyses, the ecological carrying capacity conditions and the distance of each village can be further researched on and the results can be used as guideline for the future development of these villages.

This research take the following four neighbourhood “Tableland” villages as an example, the detailed analysis can be done for the following four steps:

1) Step 1: Analysis of bearing capacity of cultivable land area
   Combining the site research on cultivable land and (table 3), (table 4), (table 5) that the data about cultivable land per capital, the population these land can support can be calculated, thus the village cultivable land carrying capacity can be calculated too.

2) Step 2: Analysis of carrying capacity of water resource
   According to the document and water resource distribution situation investigation, the village productivity, lifestyle, water use habits and artificial water supply volume also be investigated, the population each village can support can be calculated and the water resource carrying capacity can be calculated too.

3) Step 3: Analysis of carrying capacity of infrastructure
   The distribution and service area of infrastructure can be got from the investigation. Take the rural infrastructure classification Table3.7 and Table3.8 as reference and based on the importance evaluation of infrastructure to meet the requirement of villagers, the carrying capacity of these infrastructures can be classified.

4) Step 4: Analysis of the ecological carrying capacity based on each restrict factors
   All the restrict factors that have influence on ecological carrying capacity should be collected in one figure (figure 4). In gully regions, water resource is got from underground water besides the natural rainfall and Ground Rivers, thus water resource and the related infrastructure can refer as restrict factors, which can be adjusted according to their requirements. Cultivable land, as one of the restrict factors that is hard to be changed, acted as direct factor that has the influence on the maximum ecological carrying capacity. Three restrict factors: cultivable land, water resource and infrastructure, the weakest one have the most influence on villages’ ecological current carrying capacity.

   According to the analysis results, villages A, B and D, the population have already over their current ecological carrying capacity. The ecological carrying capacity of village B is the lowest, even
after the improvement of basic infrastructure, its ecological carrying capacity is the lowest, and this village may come to be the ecological immigration village in the future development. Village A, the water resource carrying capacity is high, but the cultivable land is limited, the ecological carrying capacity is also low, while it can be improved by the improvement of infrastructure. Village C is the current highest ecological carrying capacity village, and it can also be improved by the further improvement of infrastructure. The ecological carrying capacity of village D is lower than village C, but it can over village C by increasing the usage of underground water.

![Figure 4. Analysis of ecological carrying capacity by restrict factors](image)

4.2. Guideline about the relocation and combination of “Tableland” village

Adopting the ecological carrying capacity analysis as a guideline during the relocation and combination of villages can avoid effectively the loss of ecological environment and unnecessary waste of natural resource in process of un-planning village movement and integration. Comprehensive analysis of ecological carrying capacity by the restrict factors within small-scale areas can roughly get the relationship among maximum carrying capacity (Pmax) of the villages in the research areas, the current ecological carrying capacity (Pc) and current supporting population (Pp). Through the analysis of this relationship, the village who can own the ability to support more immigrants, the village that should be integrated with others to improve the human settlement environment, all of this information can be got. Finally, tableland villages’ grades can be fixed (figure 5).

According to the ecological carrying capacity, the Tableland villages can be divided into six grades. Type I is suitable to be extension and Type VI village is suggested to be moved. In order to achieve the aim of national ecological civilization construction, and the four strategic tasks "excellent, energy saving, environmental protection and construction" in the report of 18th people’s congress, do the construction of new socialist countryside scientifically, the villages in Loess Plateau should be moved and integrated following the below rules:

1. The ecological carrying capacity should be the basis for the future village planning. According to the ecological carrying capacity, the villages should be moved and extended can be fixed. The villages should be moved priority for their overpopulation (Type VI village). The Tableland village for extension should be I village, the ecological carrying capacity also should put into consideration.

2. The improvement of human settlement environment should always be the basic starting point. The aim of village relocation and combination is to improve human settlement environment, thus the
natural resource, infrastructure should put into consideration to make sure the living conditions and living environment can be improved. For those villages with over population, such as IV, V and VI, the better way is to move out a certain amount of population or move the whole village.

(3) Village movement to far places or neighbor places should be avoided. Energy saving and sustainable development should be proposed. Large scale movement or long neither distance movement nor only consume lots of manpower and material resources, but also destroy the original village culture, which will cause the loss of traditional culture in villages. During the movement, the natural resource and infrastructure should be adapted as much as possible to avoid the abandon the original buildings, also should prevent the labor and money waste. According to the six grades ecological carrying capacity, to decrease the manpower, money and investment, it should be necessary to reduce the relocation to Type III and Type IV villages.

(4) Protection of traditional cultures in gully regions of Loess Plateau strengthens rural spiritual civilization construction. During village movement, village consanguinity, geopolitical and industry relationship should be protected, and traditional culture should be carried forward.

(5) Expanding basic-level democracy and respecting villagers’ suggestions. During the relocation and combination, the villagers’ opinions should be asked and their legal right should be protected. The loss of villages should be avoided effectively by the decisions made by leaderships.

**Figure 5. Tableland village grades according to the ecological carrying capacity**

5. Conclusion
In the gully region of Loess Plateau, the ecological environment is fragile and economic development situation is lagging. It is very important to use the analysis of ecological carrying capacity to forecast and planning the future human settlement places. For the complexity and the suitability of the calculation of ecological carrying capacity, using restricted factors by the model forecast method may not be very accurate, but it can simplify the calculation process, and the results can be used as a rapid and efficient reference for the future human settlement environmental planning.
Through the analysis of local ecological carrying capacity to analyze and predict the present and future human settlements environment, it can adopt as an important guide for the local villages’ relocation and combination. Combining quantitative analysis and qualitative analysis, weighting ecological carrying capacity of the distribution for factors, is an efficient way for the villages’ settlement planning. Therefore, selecting a reasonable analysis method is very meaningful for doing accurate evaluation on villages. Ecological carrying capacity analysis method based on restrict factor analysis can show the villages’ ecological carrying capacity situation intuitively.

In order to achieve the strategic goal of national ecological civilization construction, positively response to the report mentioned about the “good, energy saving, environmental protection and construction” aims of 18th Congress of China Communist party, and achieve the goal of establish new socialist countryside, this paper supply here as planning guideline for the future villages’ movement and integration in the gully regions of Loess Plateau.

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