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STUDY ON ECO-DEVELOPMENT METHODOLOGY OF "TABLELAND" RURAL HABITAT IN GULLY REGION OF LOESS PLATEAU IN CHINA

The University of Kitakyushu
Faculty of Environmental Engineering
Department of Architecture
Fukuda Laboratory

Zhang Tao
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Abstract

The gully region of Loess Plateau is one of the subtype regions and natural geographical units in Loess Plateau. Compared to other regions in Loess Plateau, although it is full of gullies and has serious soil erosion, the broad tableland area is very suitable for farming, which is also the reason why many towns and cities are located there and comes to a population dense area. Because of the backward economy and fragile ecology, the development of rural area restrained and even contracted for a long time. As the Chinese reforming and opening in 1980s, especially, as the implementation of west development strategy, this region experience an unprecedented development with the improvement of social productivity, ecological environmental construction and soil and water conservation, the longtime stagnant situation was changed and came to a rapid developing period.

Since the implementation of construction of new socialist countryside in 2005, this region has developed amazingly. However, because of the lack of ecological and sustainable development theory as the guideline, many areas just pursue construction speed and the convenience of operation, and simply copy the urban construction model, and use "modern" high energy consumption high pollution materials, all of these cause the separation of rural habitat construction with regional characteristics. Furthermore, the environmental and climate suitability of these new residences are low, which cause several social problems, such as the further destruction of the ecological system, ecological service function degradation and a series of ecological and geological disasters.

Tableland village, as the smallest social unit in Loess Plateau, owns a large amount of agricultural population. During the new socialist countryside construction, large numbers of residents lived in gullies and moved to Tableland under the influence of governmental policy and residents' subjective wishes. On one hand, the phenomenon of population movement to Tableland caused the disappearance of the Slope villages and Gully villages; on the other hand, it increased ecological pressure of tableland where it was originally densely populated. Until now, the number of Tableland villages was over 75% of total village numbers in this region; the ratio of the population there is over 85% of the total. Therefore, during the new socialist countryside construction, ecological and sustainable planning, saving energy and protecting the environment, and improving residents' productivity conditions and living environment were important things to consider for both the development of Tableland rural habitats and the ecological development of gully regions.

Based on the analysis of fragile ecological environment and the achievement of the rural habitats' sustainable development, tableland rural habitats in gully regions of Loess Plateau is the research object. With the adoption of ecological and sustainable development theory, this research focuses on the methods of how to realize the ecological and sustainable development, establish the ecological development format, and optimize the model for future construction.

Lots of field investigation and interviews are done in Tableland rural habitats in different areas of gully regions of Loess Plateau, qualitative research is mainly used and combined with quantitative research. Based on the investigation documents, the statistical data, and the data from field investigation and interviews, this research analyzes the human settlement planning method in tableland rural habitats at the macro level. Based on the climate analyses and software simulation, the importance of space layout types and characteristics of current new countryside construction are analyzed. Combined with the traditional courtyard layout of gully regions in Loess Plateau, the new ecological layout method of vernacular dwelling is put forward. Using the theory of full life cycle, the energy consumption of different residential buildings in life cycle are analyzed at the micro level, and the results can be used as the basis for further research on residential buildings and the ecological design method of tableland rural habitats.

The aim of this research is realizing the ecological and sustainable development of tableland rural habitats in Loess Plateau. Systematic research adapts to local conditions, and the ecological and sustainable development methods are explored in this research. All the results of this research can make up shortages and fill the gap of ecological planning in the new countryside construction. This paper hopes to be used as the reference for the construction technology and methods in the future ecological and sustainable development of rural habitats in Loess Plateau.

Keywords: eco-development; tableland rural habitats; gully region of Loess Plateau; new socialist countryside construction; human settlement planning; vernacular dwelling; residential building

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CHAPTER 1
INTRODUCTION

1 Introduction

1.1 Research background

1.1.1 International background

Since the end of the 20th century, human society changed from an industrial society to an ecological society. From industrial civilization to ecological civilization and from an industrial development model to an ecological development model, all of these have become general consensus. The concept of sustainable development as a new development concept and value orientation originally came from the "ecological sustainability" for resources and environment. It also can be understood in order to maintain or extend the productive use of resources and the integrity of the resource base, so that resources can be used by man forever, and will not affect future generations because of depletion of production and life. In 1987, World Environment and Development Commission submitted the "Our Common Future" report to the United Nations General Assembly; the official presentation of the sustainable development model and the concept of sustainable development were described as what meets the needs of the present without compromising future generations to meet their development needs. In 1991, the International Congress of Ecological Societies and the International Union of Biological Sciences, from the perspective of ecological attributes and gave definition for protecting and strengthen the production capacity of the environment and update the system , that sustainable development is to seek an optimal ecosystem to support ecological integrity and the realization of human desire, so that human existence can be sustained.

The core idea of sustainable development is emphasizing the premise of sustainable use of resources and ecological environment to achieve social and economic development. The technical viewpoint is concerned about the ecological rationality of human activities. The basic requirement is that the development of human society achieves three interrelated sustainability: ecological sustainability, economic sustainability, and social sustainability. We can say that during the past century, human beings' most important innovation is the establishment of the concept of "sustainable development" and the concept of ecological ideas. It is the results of a longtime struggle between the natural sciences, and the humanities, social sciences, critical theory, and global social movements. It triggered a reflection of the whole community, and eventually became the common consensus in the new century. It is the human social and economic development model for the 21st century, and another leap forward in the history of human civilization; it has sufficient critical, inclusiveness, constructive, and forward-looking. With the spread of sustainable development, ecology, because of its unique characteristics, becomes general and the scientific method, that can solve all issues related to sustainable development.

Currently, sustainable development as a new conception of survival and development has entered all walks of life. The living environment is an important part of the ecosystem; human settlement construction is an important human activity, thus promoting participation in the cycle of ecological environment is a universal topic at the forefront of contemporary international attention and an important research area carried out extensively and through in-depth study by many international organizations and countries. In 1971, initiated by UNESCO "Man and the Biosphere Program." made it clear that research on the problems of cities and urban ecosystems should be studied from the viewpoint of ecology, and ecological concepts and methods; it should create a full integration of technology and human nature optimal activities space, promote the ecology theory that can combine human settlements research and construction in the whole world. In 1976, the United Nations convened the first International Conference on Human Settlements in Vancouver, Canada and established "UN-Habitat" in Nairobi. In 1992, the United Nations Environment and Development Conference was held in Rio de Janeiro, Brazil, and formulated "Agenda 21," which put the protection and promotion of human health, and the promotion of sustainable development of human settlements, as the goals for all countries in the world. In 1993, UIA 18th General Assembly of design catered toward fixing "Towards a Sustainable Future" as the theme and called on the world's architects to regard environmental sustainability and social responsibility as their careers and duty core. In 1996, the Second United Nations Conference on Human Settlements held in Istanbul focused on goals and principles, commitments and global agenda, put forward the goal of the habitat's environmental sustainability as: the social and economic development should be harmonious with environmental development, and change production and consumption patterns, policy development and ecological patterns within the carrying capacity of the ecosystem. Thus, to reduce the pressure on the environment and promote efficient and sustainable use of natural resources, and to provide a healthy and safe living environment for all residents, especially the poor and vulnerable groups, there needs to be a smaller ecological footprint of human settlement environments so that it is in harmony with the natural and cultural heritage, and makes contributions to the sustainable development of the country.

Sustainable development is the ideal development of human society, and ecology is the main way to achieve sustainable development. Vernacular dwellings in gully villages of Loess Plateau combine the human settlement environment and ecologically sustainable development together; this type of combination conforms to the basic requirements of sustainable development.

1.1.2 Domestic background

The "National Ecological Environment Construction Plan," the "National Ecological Environment Protection Platform," "China's Agenda 21," and a series of programmatic theories for the ecological construction in gully villages of Loess Plateau were formulated and implemented. The Chinese government attaches great importance to sustainable development. In the Party15 report, it pointed out that our country is a country with large population and a relative shortage of resources, and has to implement a sustainable development strategy in the process of modernization. In 1994, Chinese government promulgated the "China Agenda 21", which systematically discussed the relationship between China's economy, society and environment, and built a framework for a comprehensive, long-term, gradual implementation of sustainable development strategies and put into national economic and social development. The "Nine Five" plan made it clear that sustainable development is one of the major strategies to promote Chinese modernization. In 1998, China developed a long-term guide that has significant meaning for ecological and environmental construction called the "National Ecological Environment Construction Plan." By the end of 2000, China issued the "Outline of National Eco-environment" and the "Program of Actions for the Sustainable Development of China," which determined priority research areas and action plans for sustainable development in the beginning of the 21st century for China. During this period, the national ecological construction and environmental protection investment reached 380 billion Yuan; compared to the "Eight five" plan, it increased by 1.75 times [1].

Since the 21st century, the "Tenth five" plan proposed milestones in areas of sustainable development, and formulated some key environmental protection projects and ecological construction. With the rapid development of urbanization, rural construction develops steadily in the "Tenth five" period, but because of the impact of long-term urban-rural dual structure, the vast majority of the rural village appearance is still relatively backward, there are still many problems in rural development. The "Eleventh Five-Year Plan" proposed "the crucial period for building a moderately prosperous society, the economic and social development into a comprehensive, coordinated and sustainable development track." In October 2005, "Eleventh Five-Year Plan's recommendations National Economy and Social Development" Party Plenum adopted that "building a new socialist countryside is one of the main tasks in the process of China's modernization. Building a new socialist countryside is under the socialist system, in accordance with the requirements of the new era, do the construction for rural economic, political, cultural and social aspects, and ultimately the rural development into economic prosperity, facilities and beautiful environment, civilization and harmonious new socialist countryside. In accordance with the requirements of "production development, well-off life, rural civilization, clean and tidy village, democratic management, " the construction should be based on the rural reality, and respect the wishes of farmers by solid and steady progress in the new rural construction[2]. In October 2010, the Fifth Plenary Session of the 17th CPC China resolution put forth the "Twelfth Five-Year Plan Proposal," which explained that according to the demand for the integration of urban and rural and improve the socialist new rural construction and new rural planning, it should strengthen rural infrastructure and do public services construction, further improving the rural living environment quality. The "eighth" session of the Third Plenary allows rural collective construction land operating lease, and sell shares, and the implementation of state-owned land with the right to the same price in the same market. The proposed policy protects the legitimate rights and interests of farmers, and can be used as foundations for land concentration and intensive production, while also providing the conditions for agricultural modernization.

The top priority of China's social development is the "rural" issue and the difficulty of building a well-off society in rural areas. On one hand, there is the industrialization of agriculture to solve this issue; on the other hand, there is the transfer of rural surplus labor and surplus population to small population towns and cities. Population distribution on the Loess Plateau overall located in small towns of large rural areas, where there is an important area of new socialist countryside construction. Therefore, exploring the suitability of development strategies and planning methods to adapt to local conditions for the construction of villages in the regions is an important research topic with practical guidance.

1.1.3 Regional background

Loess Plateau crosses multiple geographical areas; the ecological environment there has obvious regional characteristics. Since the causes of ecological problems are regional, the regional natural ecosystems, industrial structure type, social, economic, cultural practices, and ways of living are all very different.

Gully region is an important sub-type area on the Loess Plateau and is urban-intensive area, and is therefore the main area for doing the environment construction and preventing ecological damage, and environmental pollution; its ecological living environment becomes an important part of sustainable development of the living environment on Loess Plateau [3]. A large number of rural habitats are located in gully regions, they have a long history on the one hand, and it reflects the harmonious relationship between human beings and nature contains profound regional culture and philosophy. On the other hand the harsh natural conditions and a single, backward mode of production have not only seriously hindered the economic development, but also makes the rural habitats living environment construction and development very slow for a long time.

After the reform and opening up, especially since the implementation of the western development strategy, the process of urbanization in gully regions accelerated. With soil and water conservation, ecological environment construction efforts, and rising social productive forces, urbanization entered a rapid development period. In recent years, along with new rural construction, the construction of rural habitats began to have rapid development, but until now, there are a series of social problems in the development of rural habitats in gully region of Loess Plateau, such as lack of systematic research on ecological planning concepts and techniques. There are still gaps because of the neglect of the ecological carrying capacity analysis and the lack of a scientific method to human settlement planning.

(1) The phenomenon "Population move to tableland area" is intensified

For traditional rural habitats in Loess Plateau, large-scale changes started from the late 1980s, after the reform and opening up, especially after the implementation and subsequent implementation of the land contract responsibility system in rural areas and the Forest Strategy. Land ownership changes in general and rural economic development and income of local people increase; all of these have a severe impact on traditional rural habitats. "Population move to tableland area" as the change of demographics and urbanization forms, comprises at least two meanings. The first is the population migration, which will inevitably lead to the passage of the social structure changes, the flow of economic factors and industry. The second is to change the landscape, which is caused by changes in land use patterns and diverse resource utilization Figure 1.1. These changes will generate the evolution of the urban system and urban ecological planning, land planning, industrial layout, residential construction, transportation, and important influence on the accelerated process of population. Traditional rural habitats generally showed two distinct evolution trends: first, more and more migrants continued to move to tableland area, which caused disorder and village distribution fragmentation. Second, gully villages and slopes villages are abandoned. This not only caused a lot of waste of valuable land resources on the tableland, but also traditional villages with unique local history and culture were abandoned and extinct.

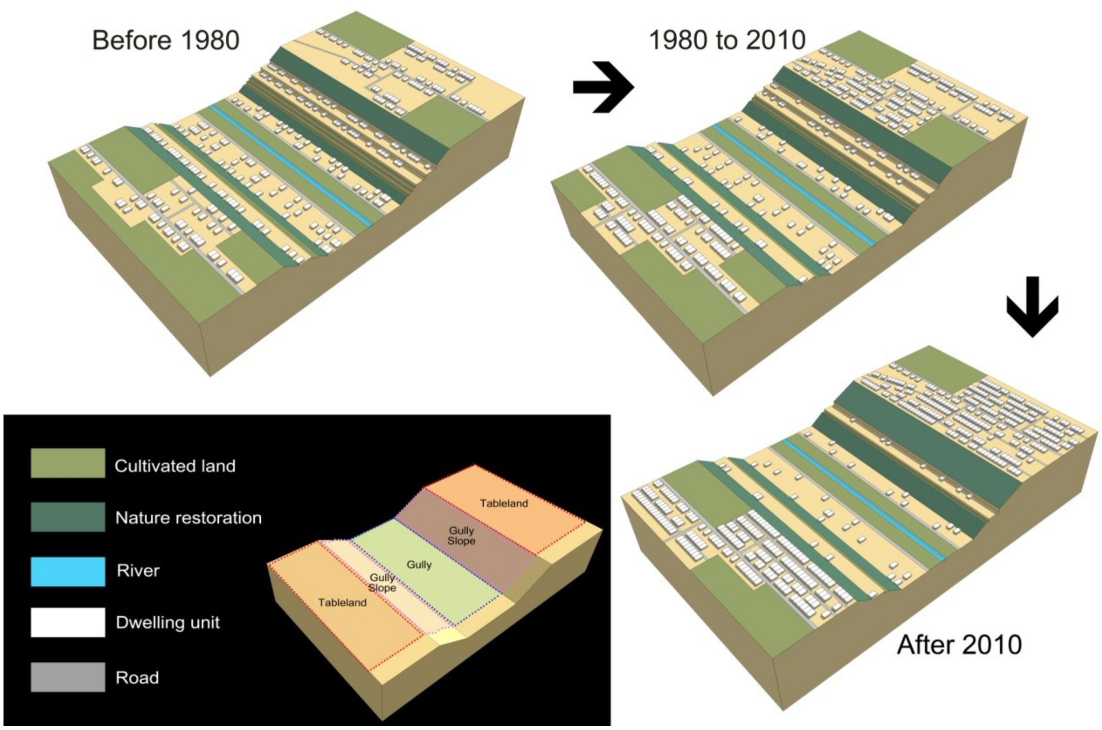


Figure 1.1 Schematic diagram of the phenomenon "Population move to tableland area"

(2) The ignorance of ecological environmental carrying capacity in the process of New Countryside Construction of rural habitats in gully region of Loess Plateau

The new countryside construction proposed the "large centralized" developing model will naturally put dispersed habitats together. This development model appears to have its outstanding advantages, in a short time because it can effectively improve the appearance of villages and realize the rapid development of rural economy and society on the surface. However, there are huge hidden worries in this "Centralization" developing model, because it ignored the development influence on the natural carrying capacity, especially in the fragile ecology environment in gully regions of Loess Plateau.

It caused the separation of villages' construction from the fragile ecological environment and the loss of ecological assets and biodiversity, also the functional degradation of ecological service system and ecological and geological disaster, thus causing a huge loss for the villagers' life and property. The separation of construction from local conditions resulted in the long-term model of planning standards and technologies used in the construction of urbanization in plain regions; the similarity of construction in gully regions and plain regions makes the suitability capacity for the fragile ecology worse.

Until now, there is no systematic research on the sustainable development of human settlements in gully villagers. In addition, the ecological planning and technology use are still in a gap; all of these show the unharmonious relationship between human beings and nature. It is in urgent need of comprehensive research on human settlement, cities and villages, and social and environmental problems. An ecological and sustainable developing way that is suitable for the local conditions for the human settlement in gully villages should be researched by using theories of epistemology, methodology, game theory and technology.

(3) Problems in ecological development of "Tableland" rural habitats in gully region of Loess Plateau under the new countryside construction

Tableland village, as the smallest social unit in gully region of the Loess Plateau, has large agricultural population. In the new countryside construction, a large number of people who originally live in the gully and gully slope move to the tableland areas for governmental policy and farmers' subjective desire. Up to now, the number of tableland villages has exceeded 75% of total villages in the whole Loess Plateau, and the population is more than 85% of the total population. Because of lack of theoretical planning guidance suitable for the local conditions, the current large-scale tableland rural habitats' construction in new countryside construction completely abandoned the traditional local development model and the good experience in traditional habitats construction was not successfully inherited and caused the following phenomenon:

1) Because of the lack of scientific planning in the construction, the disordered construction is very common, and the pressure of population upon the limited land resource in the gully region is getting worse.

2) Land waste. The traditional lifestyle causes large amounts of land waste. According to the national standards, most rural homesteads are too large. At the same time, many rural habitats' development is a kind of extensive development, which causes a large number of idle land and land waste.

3) Renewal period for houses is shorter and shorter and causes serious waste of money. According to the field investigation, the main incomes of local residents are used to build new houses or renew houses. For the area with large scale of apple plantation, when villagers' income increased, the newly built trend formed and renewed works are increased; at the same time, there are no scientific designs. On the one hand, money is waste for housing construction instead of developing production; on the other hand, the quality of human settlement actually is hard to be improved.

4) Public service infrastructure is backward and environment there is bad. Because of the shortage of financial guarantee, basic infrastructure is backward, and there is no centralized water supply system in most villages. The water quality is bad and sewage and garbage can be seen everywhere in the village.

5) Conception about planning is weakness. Most local residents think that the original traditional living model and building are the symbol of conservation and are backward. They just pursue the housing model and space layout of cities.

What is more, there are common comparisons of psychology among them, which makes the related planning hard to apply. Without proper design, drawings and backward technology caused the low quality and bad functions of the newly built houses. Under such conditions, a large number of rural habitats are reconstructed, which will cause many quality problems.

Most of the newly built rural habitats in the gully region, lack protection awareness for the traditional culture, Vegetation is often destroyed and there is a lack of green. The architectural format is simple. There is not enough space for interpersonal communication, which causes the loss of local characteristics of traditional habitats and weak residents' identity, belonging, and intimacy for the environment. There are several main reasons for the above problems and it will show as the following:

1) Backward planning conception. Governments at all levels do not pay enough attention to the villages' construction and do not put the national strategy about "city supporting countryside" into the countryside construction.

2) Lack of financial support. Most villages in gully regions are economically backward; there is no money and villagers are unwilling to pay money for the planning. The local governmental funds are usually used for supporting industry, and cannot put enough money for supporting the villagers' planning and infrastructure construction or supply public service to improve people's living quality.

3) The team for planning and design is in weak. There are not enough professional rural habitats planning and design and there is a lack of organizational support. In most regions, there are just a few staff in the local planning management department and the technical capacity is weak. Because of the low cost of village planning, people with higher design ability are not willing to work there.

4) Lack of long-term investment mechanism. In recent years, although local government increased the investment on rural construction and villagers' living conditions are gradually improved, there are still no long-term investment mechanisms; the fund is difficult to be assured and it is clear that local government is powerless.

(4) Ecological and sustainable development should be the choice for the future development of villages in gully region of Loss Plateau

Traditional habitats in gully regions are the living areas formed by labor practice in a long period in the certain landscape and natural ecological environment. The location selection has obvious advantages for energy and land saving. Although the living conditions are not good now, we cannot use the relationship between human beings and nature as the cost to improve living conditions. We should respect the natural conditions in these regions and strengthen the ecological environmental protection, and use suitable ecological technologies to improve local people's living quality.

Village construction should seize the opportunity of Chinese western development and the new countryside construction policy, based on the reality and use scientific planning to combine the ecological construction and agricultural structure adjustment together, thus to improve the local ecological environment and improve people's living conditions. The improvement method and management format will be formed during this process and the ecological planning and design method and ecological construction methods should be summarized and used in the whole process.

1.2 Research objective and significance

1.2.1 Research objective

Since 2008, the author began to do the research on the rural habitats development in gully regions of Loess Plateau, and join in the National R&D Infrastructure and Facility Development Program of China (2007DKA32300-12), which is a program mainly focused on the research of human settlements environment in gully regions of Loess Plateau. The author mainly did the research on gully villages in these regions. During the field investigation, review, and data analysis, the author gained a deep understanding of the influence on human settlement from regional difference. In 2011, the author participated in the science and technology research and development project of Shaanxi Province (2010K01-123), which is a research program focused on the scientific construction method of green habitats in gully regions of Weibei Loess Plateau.

During the research, it is found that the rural society structure and villages' types are experiencing huge change as long as the new countryside construction and the implementation of national macro-control policy. Especially, with the progress of "population transfer to tableland", A large population that used to live in slope villages and gully villages gradually moved to the tableland. On the one hand, it caused the disappearance of the slope village and gully village. On the other hand, it increased ecological pressure of tableland where it was densely populated originally. Meanwhile, under the impact of exotic architectural culture, the eco-technology, traditional building materials and traditional forms that are contained in the traditional dwellings have been neglected. It leads to the traditional residential system replaced and gradually disappears.

The ecological and sustainable development in tableland habitats comes to be the urgent priority research in the whole research of sustainable development in the gully regions. Systematic ecological developing methods should be figured out, thus villages can be continuously developed, the traditional characteristics can be inherited and the living quality can be improved. Therefore, the aim of this paper is to realize the ecological and sustainable development in the gully region of Loess Plateau by the systematic research and explore the developing methods according to the local conditions. The results of this research can make up the gaps in the construction of new countryside, and the gaps in ecological planning conceptions and technologies, all of which hopes to be used as reference in the future ecological and sustainable construction in gully regions of Loess Plateau.

1.2.2 Research significance

(1) Theoretical significance

Rural habitats in gully regions of Loess Plateau are the important carrier for the local social development. Through the scientific construction of the villages, which has harmonious relationship with the natural environment in gully region, the construction can not only protect the ecological environment for the gully region but can also make the history and culture inherited; all of these will improve villagers' awareness of their living environment.

This research is based on the analyses of ecological environmental carrying capacity in tableland villages, which can not only be used as reliable scientific base for the tableland villages' planning and construction in gully regions, but can also avoid the previous "large centralization" and "extensive construction". The research results also can be used as new research method and in the new countryside construction in all of Loess Plateau and even the whole country.

Climate software simulations are used in the analyses of ecological construction in tableland villages, and also the energy consumption in the full life cycle of architecture is used, and both the results are used as the base for quantitative research. This research is more scientific and cautious than others, when do the research on the ecological design method in vernacular dwellings in tableland villages, which will fill the gap of ecological construction methods shortage in the whole region.

Therefore, no matter if it's from the perspective of economics or social development, or from the environment and culture protection, this research owns its significance.

(2) Application value

At present, the construction of green rural habitats in gully regions is lacks of scientific guidance, and the theory and practice research is seriously backward. If the construction is done blindly, the fragile ecological environment will be further destroyed and the traditional rural habitats and vernacular dwellings with important historical and cultural values will disappear. Therefore, the research on the planning and construction in this region is what they need urgently and it can be used as reference in the future construction.

The ecological construction in gully regions of Loess Plateau can save large amounts of energy and resources. If the "large centralization" is used as the single movement method, it means the reinvestment of resource and the destroying of original resource, actually is not good for the sustainable development of ecological environment. Although there are many problems in the current human settlement in the traditional rural habitats, there are still lots of resource and materials in there. The research on the scientific construction methods in tableland rural habitats in gully regions can be used in the future new countryside construction, which can maximize the conservation of resources, save energy, protect the environment and realize the harmonious relationship between human beings and nature. At the same time, the research results can play a positive role in the promotion of sustainable development of those traditional rural habitats.

1.3 Present domestic and foreign theory research situation

1.3.1 Foreign research situation

Comparing with domestic research on rural construction, foreign countries have already done a lot of research on rural planning, management, governmental support, villagers' participation awareness education and so on, all of these are valuable for us to study and take as reference. In the middle of the 19th century, France began to change from traditional villages into modern villages. In order to develop those undeveloped rural areas, Canada implemented the "Canadian Rural Partnership Program" in 1998[4]. In 1984, the German geographer J.G. Kohl published his book Traffic Colonial Relationship with Local Landscape, which did the comparative research on different types of villages [5]. Since then, many geographers started to pay attention and do research on rural areas. In Japan, the "Economic Redevelopment in Rural Areas" and the book Japanese Rural Settlements written by Hiro Ishida, marked the research of rural areas across to the scope of human geography, and began to pay attention to rural social revolution and economic development. In South Korea, the new rural construction started in 1971 by the definition promoted by Jin He Zhe, Jing Hua and Piao Kuan Zhe [6], and they did a lot of research on new countryside construction in South Korea.

There is much foreign research on rural settlement systems, such as the research on the relationship among human settlements, environment and architecture, the theoretical research on rural geography, and the research on the relationship of vernacular dwelling forms, architectural materials and geographic environment. This research is mainly focused on the formation, evolution, types and planning; the village's social and economic change became the new research directions in recent years. The foreign research results are mainly based on the foreign background; even some experience and developing methods have the inspiring function, but cannot be copied and used in our country. The development of gully regions in Loess Plateau own their own local characteristic, and need to do the targeted research.

1.3.2 Chinese domestic research situation

The research on gully regions of Loess Plateau started in the early PRC, mainly focused on the soil and water conservation, land use issues from the perspective of ecology, geography and economics. But for the regional rural development research, it started relatively late, in the early time, the exploration of green architecture system in vernacular dwellings and the basic human settlements forms were researched by Zhou Ruo Qi, Wang Zhu, Zhou Qing Hua, Wang Jun and some others[7]. In 2005, Liu Hui put forth research from the perspective of landscape ecology. Then, Yu Han Xue and some other scholars put forth research on human settlement construction in gully regions from the perspective of rural planning. Through the literature search in Chinese Academic Journal database[1] Figure 1.2, the results can be summarized as following:

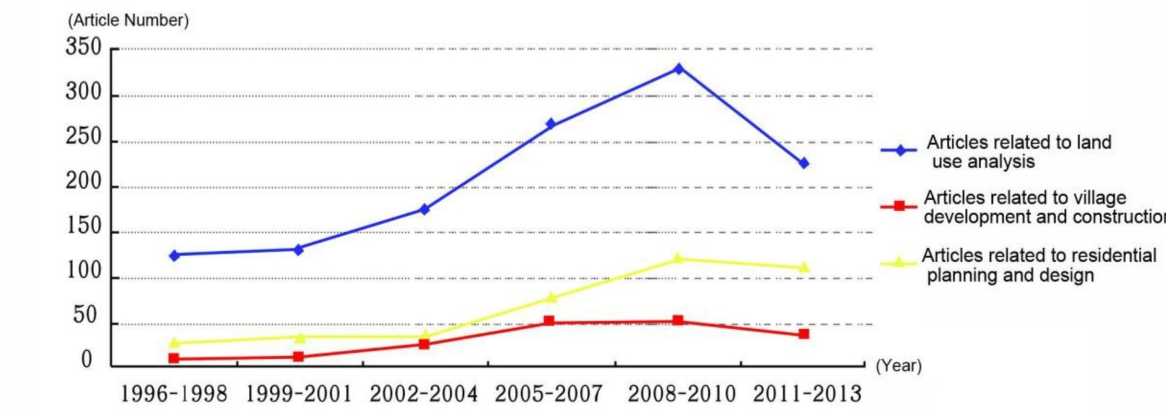


Figure 1.2 Related articles numbers about rural construction in Loess Plateau in the Chinese academic Journal database from 1996 to 2013

(1) Articles related to land use analysis

In the research on land use in gully regions of Loess Plateau, Zhang Hui and other scholars researched the regional landscape and drew the landscape maps, land use situation maps and land type maps by geographic information system software ARCGIS[8]. There are also scholars who research the types of space units from the perspective of landscape ecology, and divide it into three kinds of ecological units: mountain, river plain type and tableland type [9], and they established land security standards. Ecological sensitive areas, such as gully slopes and gullies are defined as ecological buffer areas and ecological protection. The tableland areas that do not belong to ecological sensitive area are defined as comprehensive land use areas. Finally, according to the concrete ecological environment, the tableland area can be planned [10]. Jin Yi Bing and some other scholars researched the principles of planning, design and land using methods from the perspective of resource carrying capacity [11].

(2) Articles related to rural habitats development and construction

Wang Jun did a large amount of field investigation and analyzed the special layout method for the traditional vernacular dwellings, such as near the water, on the mountain, and facing to the sunshine, suitable for the local climate. He also put forward that the traditional cave dwellings can be renovated

[1]The Chinese Academic Journal include: 《城市规划》、《城市规划汇刊》、《城市发展研究》、《新建筑》、《建筑学报》、《建筑师》、《建筑与文化》、《华中建筑》、《小城镇建设》、《地理学报》、《人文地理》、《山地学报》、《干旱地区农业研究》、《人民黄河》、《中国农业资源与区划》、《建筑科学与工程学报》、《农业现代化研究》等。

by adopting modern ecological technologies and some green architectural technologies [12]. For the fragile ecological environment and limited land resource in gully regions, Zhou Qing Hua put forward that the villages' expansion should be coordinated with the local ecological environment and the space layout should be in the shape of a belt for villages and farmland [13]. For the dispersion of towns and villages, Cao Xiang Ming and some other scholars put forward the originally dispersed villages should be moved and integrated, and form the layout of large scale of dispersion and small aggregation [14]. Based on different natural and ecological environment, social economic conditions, some scholars think there are three developing formats for villages in gully regions; they are integrated into cities and keep the original villages and ecological immigration.

(3) Articles related to residential planning and design

Yu Chuan Rong and other scholars proposed that the villages' construction should be divided into different units: ecological protection zone restricted developing zone and village developing zone [15]. In order to ease the negative pressure on ecological environment by the villages' construction, Liu Hui proposed the construction models: tableland villages can be built along the edge of tablelands in the form of surrounding island [16]. Yu Han Xue proposed three construction models by using landscape ecology; they are the square shape with several centers, dispersed shape with several centers and a a long line with several centers.

This previous research has important guiding functions for the future exploration of land intensification and developing strategies of countryside construction, but the research is macro research, mainly focused on human settlement construction in gully region of Loess Plateau, the detailed and specific research on villages' planning and design are still very limited. Therefore, the future research should focus on the following contents: on the one hand, the research should start from the reality that the scientific planning, the rural habitats' construction, ecological improvement and people's living improvement should be combined together, thus making the suitable developing strategy for the rural habitats' construction in gully regions. On the other hand, do the comprehensive research on the problems in human settlements, environment, society, economy and some others, to explore a suitable planning method and use it as important theory and methods to guilde the future scientific construction.

1.4 Research methodology and contents

1.4.1 Research methodology

The human settlement environment of tableland rural habitats in gully regions of Loess Plateau is the research object. This research deeply discusses the sustainable developing methods in tableland rural habitats in gully regions, and mainly completed in three parts: research on the planning methods in tableland rural habitats; research on the ecological layout of vernacular dwellings in tableland rural habitats; and research on the ecological design methods for residential buildings in tableland rural habitats. The research pays attentions to the notion that the research should be more scientific and the results should be more operability, which can be shown as the following:

(1) Scientific village investigation methods

Through large amounts of field investigations in tableland rural habitats for different areas in gully regions, the present human settlements situation were investigated in detail; its influences on people's production and living by national policies in the socialist new countryside construction were fully understood, and the village planning in tableland villages and the whole construction process of vernacular dwellings were mastered.

(2) Systematic analyses and comprehensive research

The human settlement ecology in gully regions of Loess Plateau is a systematic project, including the research on villages' planning, layout of courtyard in vernacular dwellings, and the residential buildings; the relationships among these are close for the ecological research. This research pays more attention to the wholeness, relevance and suitability of the systematic research, with research on each factor from micro to macro, and do some research in multidisciplinary.

(3) Guidance based on the theory of ecological carrying capacity

Based on the research of related theories on ecological carrying capacity at home and abroad, restraint factors are improved according to their local characteristics. In addition, this research puts forward a more efficient and feasible analysis method for the ecological carrying capacity in tableland villages, and research on the demolition or integration for the original villages based on the map of ecological carrying capacity distribution.

(4) Guidance based on the theory of architectural full life cycle

In China, the current report on architectural environmental influence is mainly qualitative analysis, and lack of quantities analysis [17]. Therefore, after suitable parameter acquisition and data correction, this research takes the LCA architectural energy consumption calculation method in abroad as reference, and establishes energy consumption models for the full life cycle in vernacular dwellings in tableland rural habitats of gully regions according to the present construction situation and characteristics. These models can be used as a measurement to calculate the energy consumption in its full life cycle for different vernacular dwellings.

(5) Theoretical research and the combination of construction with the reality conditions

This research pays attention to the combination of regional economic and social development together in gully regions of Loess Plateau, and the combination of theoretical research and construction; the research results should be more operability.

1.4.2 **Research contents** Figure 1.3

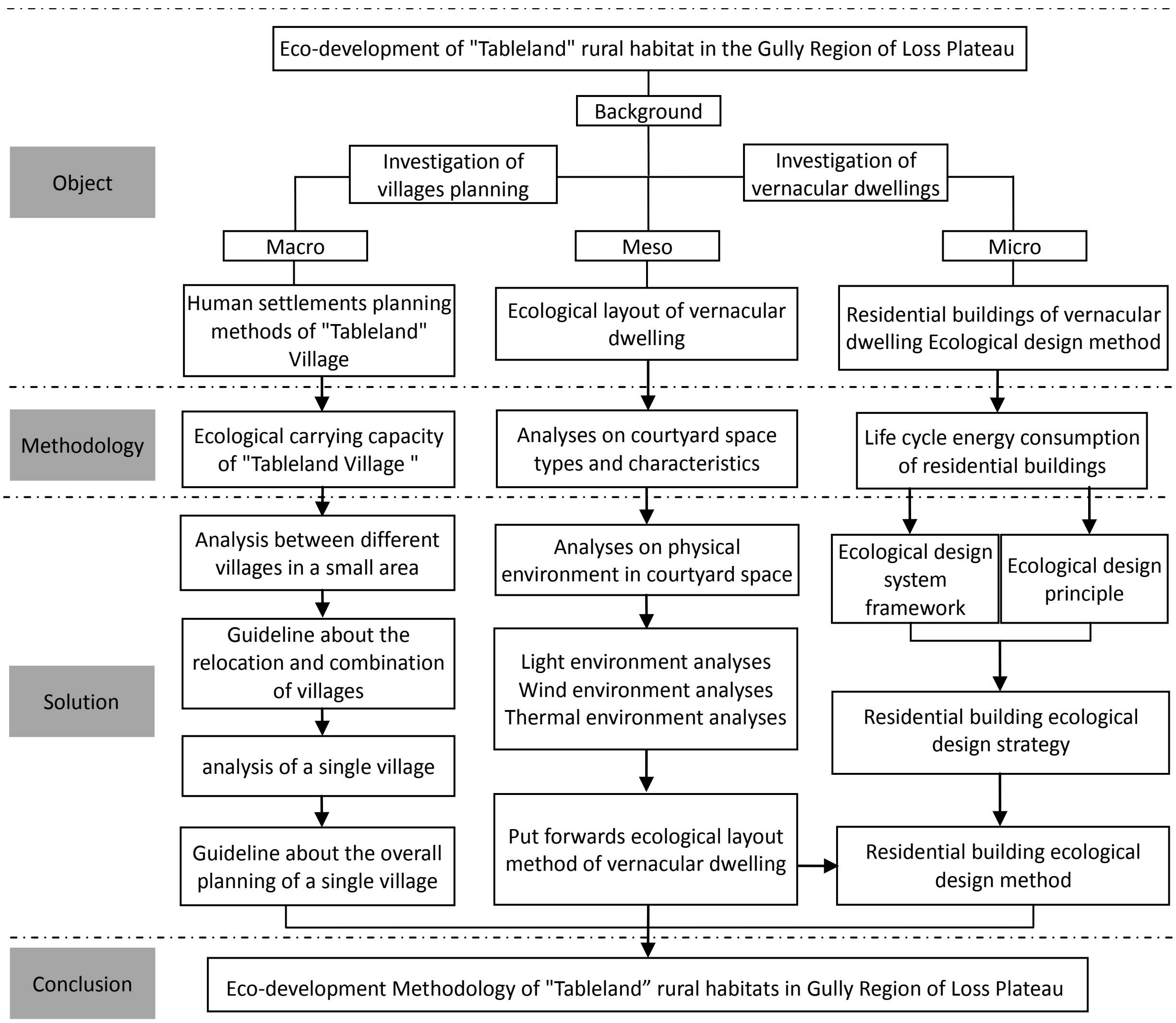


Figure 1.3 Research contents

1.5 **Research framework** Figure 1.4

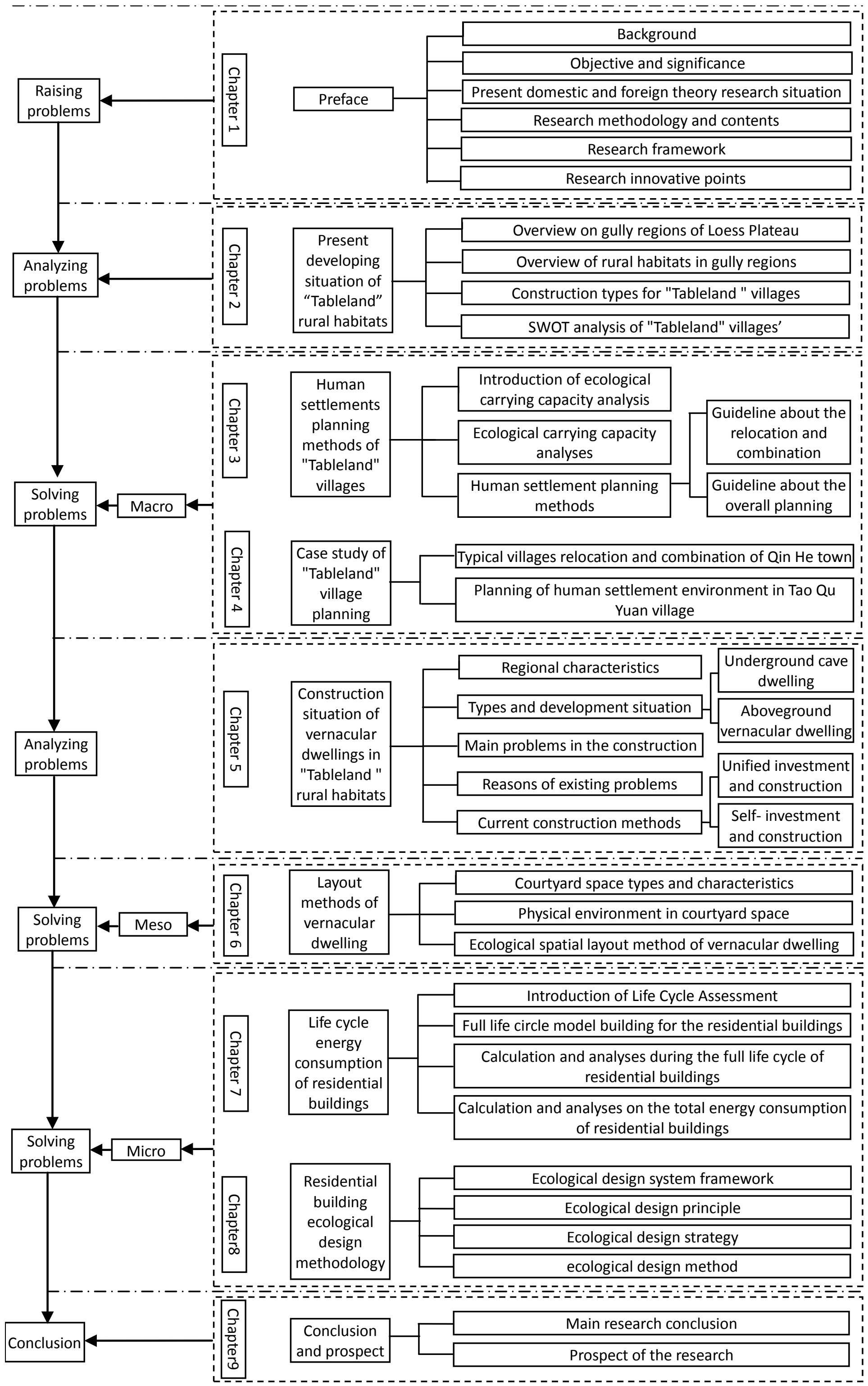


Figure 1.4 Research framework

1.6 Research innovative points

This research hopes to have creativity in both research ideas and methods, which can be shown in the following:

(1) Under the background of new countryside construction, the ecological construction of human settlements in gully regions of Loess Plateau, not only has a relationship with material environmental construction; but also with the ecological recovery and reconstruction. The ecological construction is not only influenced by the outside conditions, but also can be influenced by the rural habitats' conditions themselves, which actually is a systematic project that combines nature, society, economy, and so on. The systematic research starts from the research on rural habitats' sustainable development to the villages' self-development and planning, then to the ecological layout of vernacular courtyards, and finally to the design of residential building.

(2) Based on the analyses of related theories on ecological carrying capacity at home and abroad, in the research of restraint factors for ecological carrying capacity, the factors can be divided into two kinds according to their different adjusting ability, which avoids the one side analysis and improves the accuracy of ecological capacity analysis. During the ecological carrying analysis, the relationship among maximum carrying capacity, the current ecological carrying capacity and the current supporting population are shown to explain the village ecological carrying situation. By using website analyses, the village ecological carrying capacity distribution map was drawn, which is good for using the analyses results in the future human settlement planning.

(3) Based on the field investigation, and according to the present space layout and land centralization method, this research divides the tableland village construction methods into three types: newly construction, extension construction and improving construction. By using SWOT analysis, this research detailed analyzes the different advantages, disadvantage, opportunities and challenges in these three types. Based on the analyses result, the present villages' layout and planning are analyzed and several main problems are put forward. All the results can be used as basis for exploration of a suitable developing strategy and planning method for rural characteristics inheritance, ecological environmental protection and economic development.

(4) Combined with the experience of using full life cycle analysis in the research of architectural energy consumption at home and abroad and based on the theory of full life cycle analysis, this research completed many basic field investigations on the vernacular dwellings in tableland rural habitats of gully region in Loess Plateau. Using LCA mathematic theory to establish energy consumption model for the residential building and calculate the energy consumption in each period of the full life cycle,

then analyze and compare these data. This research actually is an exploration of the architectural energy calculation methods for the present Chinese situation and climate characteristics, which can be used as the basis for the future research on the ecological design methods for vernacular dwellings.

CHAPTER 2
ANALYSIS OF PRESENT DEVELOPING SITUATION OF TABLELAND RURAL HABITAT

2.1 Overview of gully region of Loess Plateau

2.2 Overview of villages in gully regions of Loess Plateau

2.3 Classification of construction types for Tableland villages

2.4 Analysis of Tableland villages' characteristics based on SWOT analysis method

2.5 Summary

2 Analysis of present developing situation of Tableland rural habitats

2.1 Overview of gully regions of Loess Plateau

2.1.1 Overview of Loess Plateau

The Loess Plateau is located in the west of China, covered with 30m—300m calcareous yellow soil Figure 2.1, which is the powder sand and dust brought by the period monsoon from the inner area of Asia 12 million years. The Loess Plateau from east to west across about 11 longitudes and north to south about 6 latitudes, and it is one of the birthplaces for Chinese civilization [18]. The yellow soil there is mature, is distributed continuously, and comes to be a complete and unified soil layer. The vast Loess Plateau owns long history with the prosperity and decline of this area.

Figure2.1 Location of Loess Plateau

Loess Plateau is mainly distributed in the middle and east of Gan Su province, the south of the Ningxia Hui Autonomous Region, the north of Shaanxi province and the west areas of Shanxi province Table2.1. It is about 530 thousand square kilometers, accounting for 1/l8 of total Chinese territory [19]. Because of the different influence factors, in this region, gullies and terrains are complex; tableland, slope, and ditch form the basic terrain features. Generally, the Loess Plateau, economy is relatively backward, living conditions are not good, and the construction of infrastructure is not enough, what's more, the living and ecological environment there is fragile, all of which cause lower population density there than other areas in the southeast of China.

Table 2.1 The distribution of Loess Plateau [19]

Province	Area (10,000 Square kilometers)	Percentage in total area(%)
Qing Hai	0.118	0.33
He Nan	0.748	2.09
Inner Mongolia	0.785	2.19
Ning Xia	2.561	7.14
Gan Su	9.473	26.42
Shaanxi	10.365	28.91
Shanxi	11.8	32.98
Total	35.85	100

2.1.2 Overview of gully region of Loess Plateau

(1) The definition of gully region of Loess Plateau

Research on the definition of gully regions of Loess Plateau is the basic work for the further research of human settlement environmental ecology, and it is a process of knowing the natural environment and people's lifestyles. Because there are many different definitions and the focus points are different, this research tries to give the deification and boundary about this region firstly. This region mainly refers to the gully regions of 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 [20] Figure 2.2 and Table 2.2.

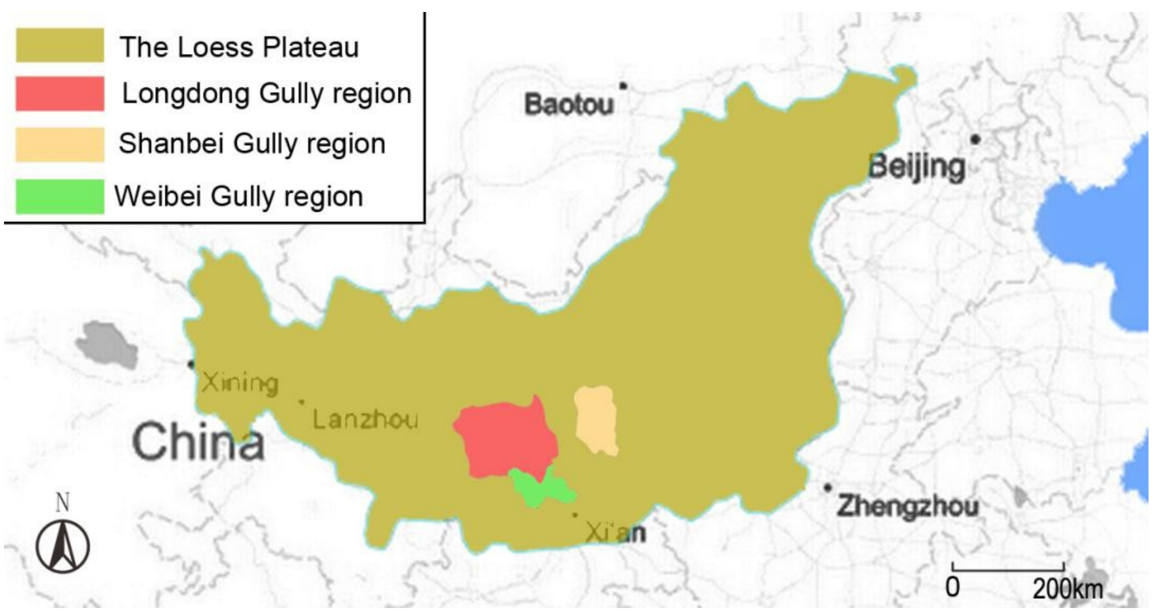


Figure2.2 Location of Gully region

Table 2.2 Space distribution in gully regions of Loess Plateau

Region	Sub-regions	Provinces	Cities	Land areas(km^2)	Total population(mil.)
Gully region of Loess Plateau	Gully region of Long Dong Loess Plateau	Gan Su	Qing Yang	9213	4.3
			Ping Lang		
	Gully region of Shan Bei Loess Plateau	Shaanxi	Yan'an	3505	
			Tong Chuan		
			Wei Nan city		
	Gully regions of Wei Bei Loess Plateau	Shaanxi	Xian Yang	2058	
			Bao Ji city		

(2) Natural characteristics of gully region in Loess Plateau

Gully region is a typical landscape in the whole of Loess Plateau, which is serious erosion and the land surface fluctuates largely, and similar to the landscape of the mountain, composed by tableland, gully slopes and gullies Figure 2.3. This region is full of gullies and crushing landscape, tableland, slope, and gully form the basic landscape [21].

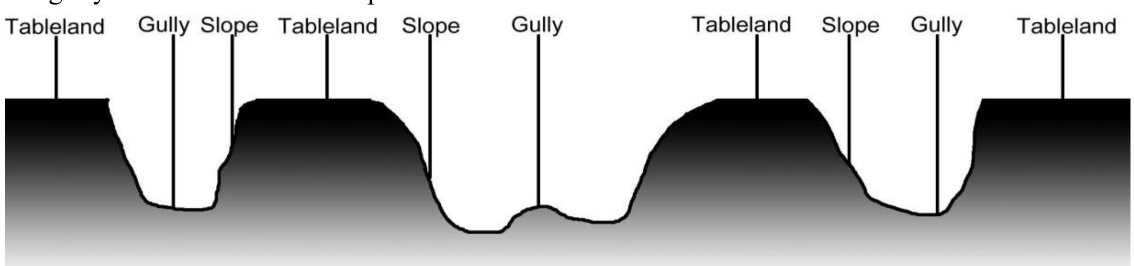


Figure2.3 Schematic diagram of landscape profile in gully regions of Loess Plateau

The landscape of gully regions in Loess Plateau is very complex and the ecological environment is very harsh. Because of the collapsibility of yellow soil, when rainwater flows into rivers, it will cause serious erosion for the surface part of land and finally comes to be gullies. It is common that the gully slopes fall down, collapse and landslides will happen after storm rain, and deep gullies can be ten to hundred meters deep with a large width. The profile shows as a trapezoid [22] Figure 2.4.

Figure2.4 The typical gully in gully region of Loess Plateau

The special landscape makes the natural environment in this region is very fragile; the soil there is loose, the vegetation rate is very low, and the water and soil loss is a common phenomenon. The climate of this region is influenced by the latitude and its special landscape has the typical continental monsoon climate: four seasons, dry and windy spring, hot and rainy summer, cool quickly in the fall, cold winter and less snow. The average precipitation is about 550mm, and mainly in July, August and September, drought and shortage of underground water happen time to time.

(3) Characteristics of economy and culture in gully regions of Loess Plateau

The special landscape and ecological environment form the unique human settlements, cave dwellings and villages on slopes and form the unique settlement landscape and cave dwelling culture in gully region of loess plateau. The economy and culture own significant differences among different areas and different developing degrees in the whole gully region of Loess Plateau. In the backward area of north board of Shaanxi province, the productivity form is single, farming and animal husbandry is the main income. However, the local farming is backward, which is a kind of extensive farming. Such kind of farming aggravates the worse of ecological environment, and agriculture usually is "farming for one place, then getting it devastated, and then changing another place and farming it again." On the contrary, in the developed area, the agriculture method is advanced, commercial is relatively prosperity, economic developing level, people's life and education level are relatively higher. In these developed areas, farming-reading culture is the social culture characteristic and the influence from religion is huge.

2.2 Overview of rural habitats in gully region of Loess Plateau

2.2.1 Distribution characteristics of rural habitats

Because of the long time self-sufficiency economy and the natural landscape, the urbanization level is relatively low and owns the characteristics of large distribution and small centralization [23]. The distribution of rural habitats in this region is dispersed and owns obvious local characteristics, mainly distributed in the tableland, slope, and gully.

(1) Village scale and settlement density are small

Generally, because of the relatively backward economy, bad living conditions, the shortage of infrastructure and low ecological carrying capacity, the population density in gully region of Loess Plateau is much lower than the plain areas in the southeast of China. Moreover, the limitation of special landscape, villages own the characteristics of small and dispersed, which is suitable to the environment and the demand for productivity.

(2) Unevenly distributed villages

The distribution of villages in gully regions is very different from area to area. The conditions of living and farming are better on tableland areas, so it owns more population and convenient transportation. For gully and slope areas, the living and farming conditions are worse, the population and living density are both small for lacking of flat lands, the inconvenient of water supply and transportation.

(3) Villages are distributed along roads

Villages of the Loess Plateau are usually established along rivers in gullies; at the same time, they are also distributed along roads. Houses are generally near highways or villages' road, which is easy for them to connect with the outside world and an important factor for village distribution Figure 2.5.

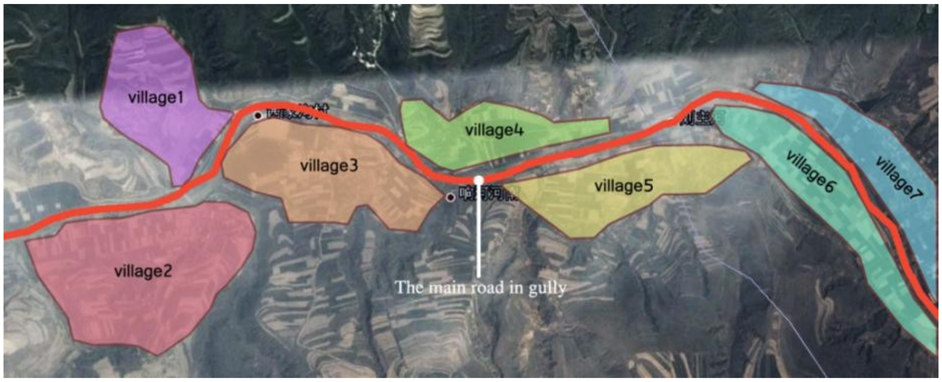


Figure2.5 The villages distribute along the roads of Black River area in Chang Wu County

2.2.2 Classification of villages

The village forms can be divided into centralized villages and dispersed villages [24]. Centralized villages are distributed in a relatively accumulating way, which are mainly Tableland villages. Others are flake form villages, which are planned by regular roads or net roads; and there are other flake form villages planned by irregular roads system. The dispersed villages are mainly Slope villages and Gully villages Figure 2.6.

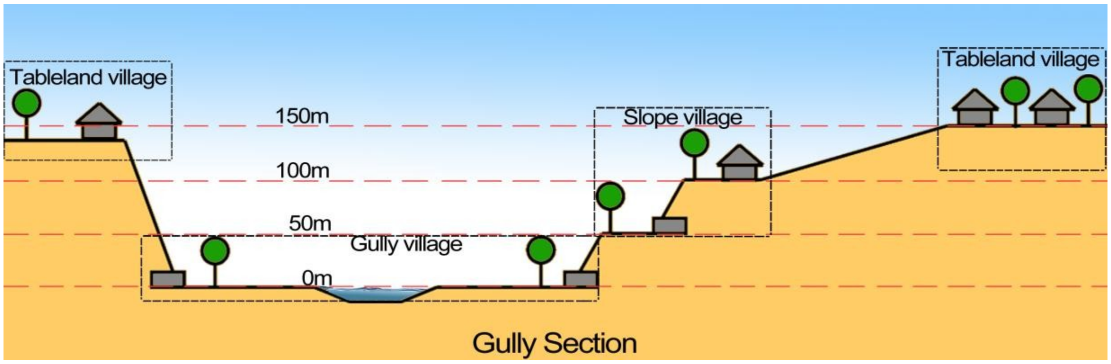


Figure 2.6 Cross section to show villages' types in gully region

(1) Tableland village(Figure 2.7，Table 2.3)

Figure 2.7 Tableland villages

Table 2.3 Characteristics of Tableland villages

Characteristics	Contents
Distribution patterns	Cultivable land and villages are distributed along roads at the equidistance from the road. Villages are usually distributed densely and in the form of spot and circle distribution.
Road	Roads in the gully are generally along the banks of rivers and the roads for connecting tableland roads are in the form of contour.
Cultivable land	Although many bottom areas of gully have the flat cultivable land as tableland areas. But the land in tableland areas are usually own better productivity for the better soil with high organic matters and convenient irrigation system.
Industry	Planting and sideline industry own better development. The high productivity land and plenty water resource can be used not only for planting grain, but also for planting economic crops and developing fishing, thus the economic development situation there is better.
Scale	For the better natural conditions, most of Tableland villages scale are usually large. Especially the villages located in the joint area of rivers and the board land along the bank of river have the population even larger.

Tableland villages located in the tableland area is the most of one of the typical village types in gully regions. There are broad tablelands where the slope is smaller than 5 degrees, and is suitable for farming and housing construction. What is more, the transportation system is mainly distributed on the tableland in gully region, thus most villages are located there. With gentle slope and better conditions of light, heat and soil, tableland area is the main farming area in all of Loess Plateau and the main nesting zone for population and industry. Since the end of the last century and the construction of new socialist countryside carried out in the Loess Plateau, human settlements enter a drastic transform period. During the relocation project in recent years, a large population who used to live in Slope villages and Gully villages gradually moved to the tableland. At present, the ratio of Tableland villages is more than 75% of villages in the whole area.

(2) Slope village (Figure 2.8，Table 2.4)

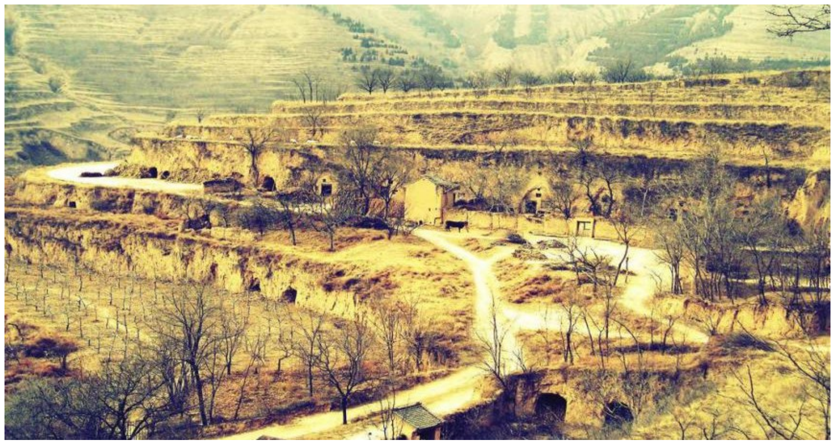


Figure 2.8 Slope village

Table 2.4 Characteristics of Slope village

Characteristics	Contents
Distribution patterns	Due to the broken topography, cultivable land and villages are distributed in disperse. Generally, residential buildings are facing to the sun, and established along contour line. Most of these villages are back on cliff.
Road	Due to the broken topography and dispersed distributed villages, roads are usually in zigzag and difficult for large vehicle to use.
Cultivable land	Cultivable land is usually distributed on the same contour line in the spot form with low productivity.
Industry	Planting is the main industry. Agriculture population is the main part of the villages′ population, the economic situation there is not good.
Scale	Due to the poor land, single industry model and inconvenient transportation, both of the population and village area there are small.

Slope villages are usually located in the gentle and sun faced slope, and the slope there is about 5° to15°, which is good to change the sloping land into cultivable land. Because of the gully division, the distribution of slope land is uneven and villages there are also distributed in dispersed. These slope villages are not the priority living areas. When the human settlement developed to a certain degree that the ecological resource of original villages cannot support more population, the population moves to the slope and establishes villages there. These villages reflect the traditional human settlement conception "Feng Shui": slope is gentle and faces the south, which can be barriers to prevent cold wind in winter; underground water is good and sometimes has spring water; land on slopes is suitable for farming. However, it is found that many slope villages have already been abandoned during the population movement to tableland. Currently, the ratio of existing slope villages takes only around 5% of the total villages.

(3) Gully village (Figure 2.9，Table 2.5)

Figure 2.9 Gully village

Table 2.5 Characteristics of Gull village

Characteristics	Contents
Distribution patterns	The land there is long and cultivable land and village distributed in dispersed. Villages are distributed along the road in dispersed belt shape.
Road	Due to the broken topography and dispersed distributed villages, roads are usually in zigzag and difficult for large vehicle to use.
Cultivable land	The broken topography makes cultivable land is dispersed, the productivity is low, while the cultivable land per capita is large.
Industry	Grain planning is the main agriculture form and can be self-efficiency; the economic situation is not good.
Scale	Located in the ecological sensitive area, these villages are far away from the tableland, the transportation there is inconvenience, thus the population is generally small.

Gully village is located at the bottom of the gully; the location indicates the space distribution of Chinese traditional mountain village characteristics, back on the mountain, circled by water and protected in the front. The necessary condition of these villages is enough land to guarantee the development. Gully villages are usually near to perennial rivers and the gully bottom areas are in the shape of a "U". These kinds of villages are widely distributed in the whole gully region of Loess Plateau, taking 15% the total number of villages.

2.2.3 Developing history of villages

Villages in the gully region came out along the settlement of human beings, showing different characteristics along with development of productivity, social conception, and economy, cooperated with the different developing stages of human civilization. The village location, scale, and distribution are all different in the different social developing stages. There are mainly three stages for the gully villages in Loess Plateau Table 2.6.

Table 2.6 Different developing stage for the village space distribution in Loess Plateau

Stages	Space distribution	Space functions	Main space	Main influence factors
Disorder developing stage	Random	For surviving	Simple living space	Natural environment conditions
Expansion stage	In certain area	For survive and production	Living and agricultural space	Agricultural production resource
Rapid developing stage	Centralized in tableland	Multi-functions	Living, agricultural , industrial and modern service space	Market economic conditions

(1) Disorderly developing stage

Before liberation of the People’s Republic of China, the development of villages in gully region of Loess Plateau had a long time in disorderly developing for the shortage of villages' planning theory. The village planning was mainly to solve the problem of houses taking cultivable land, no further research, thus most villages still disordered.

(2) Expansion stage

Since the 1960s, the research on planning and construction of villages in gully region of Loess Plateau started with theoretical research and practical exploration, and came to an expansion stage. As the development of social productivity and population increase, villages’ planning and construction were improved a lot, and those villages with good developing conditions came to be the center village or town.

(3) Repaid developing stage

Since the reforming and opening in the 1980s, the traditional economic system was gradually replaced by market economy, and the long time stable rural labor was changed; the economy developed rapidly. The individual became the interesting subject and there was free choice of occupation and places to live, which made the population move to tableland. As the rapid development of socialist new countryside construction in the 21 century, the policy of conversion of cultivated land to forests accelerates the speed of movement to tableland. All of these make the great change of villages in gully region of Loess Plateau, economic factors and industry, and the use of land and resource diversified.

2.2.4 Cultural characteristics of the villages

A village is a human settlement unit based on nature; thus, it is the intermediate carrier between human beings and nature. During the long history of coexistence of human beings and nature, the scale and history of village developed continuously. The traditional characteristics of villages in gully region of Loess Plateau mean the unique landscape of Loess Plateau and the culture and history after thousands years' inheritance. For these traditional characteristics, some of them are common to the ordinary villages, and others are unique by themselves. The following can show this:

(1) Blood and geo-relationship

Traditional villages are based on the blood relationship of most villagers; they live in relatively centralized areas, which is their common area for productivity and living. The geo-relationship is the visible link for villagers that live together, and blood relationship is the invisible link for them. These traditional villages usually make the blood relationship and religion as the base to build the friendly and kind neighborhood, and they own their own culture and spirit[25]. In the gully region of Loess Plateau, the traditional gully villages without war and outside immigration, usually almost all the villagers own the same one or several family names, even for the large-scale villages that also have the same one or several family names. Therefore, people living there respect themselves for their blood relationship and live within certain areas.

It is found that blood and geo-relationship have influence on the investigated gully villages. Take Ma Chang village as an example. It is located in Chang Wu county, Xian Yang city, Shaanxi province, and it is found that there were just two families in the earliest village Figure 2.10. That is also the reason why 90% of villagers own the same family name after 300 years' development. Such kind of blood and geo-relationship makes all the villagers well known to each other and creates a harmonious neighborhood Figure 2.11.

Figure 2.10 Panorama of Ma Chang village in Chang Wu county, Xian Yang city, Shaanxi province

Figure 2.11 Harmonious neighborhoods in Ma Chang village

(2) Farming culture and self-sufficiency characteristic

The land is the main resource of village life and the important natural resource for survival. Village cultural owns obvious farming characteristic and farming makes the connection among people. Villagers usually work together in a certain area of land at the same time according to the farming season. The combination of small village economy and cottage industry is the main manifestation form in these regions.

The farming economy decides the self-efficiency characteristic. Under the low productivity, most of the labor forces are put into the grain production, which means that villagers can just survive on the land resource to maintain their existence. If farming is the single production form, the characteristic of self-efficiency will be obvious. However, as the improvement of production technology conditions and labor productivity, if there are surplus products, villagers must use them to exchange to meet other requirements and service. In most gully regions, the economic level cannot supply enough consumption; rural economy is still a kind of self-sufficient economy.

(3) Closure and openness

Closure is one of the significant characteristics of the traditional villages in gully region of Loess Plateau. Because of the farming characteristic, traditional villages are located intensively in a certain area of land; they mainly rely on land and farming to be self-sufficient. All of these make villages in closure, especially for those villages far from town and city without convenient transportation. Usually, villages in remote gullies own higher closure [26].

With the rapid development of urbanization, the modern traffic system is gradually made perfect and media technology is improved. Traditional villages in gully region of Loess Plateau also began to change from the originally closed village to open themselves to the outside world. Villages with good locations get much more influence from outside and have already formed the developing format along the railway, highway and other transportation ways. While, for those villages far away from towns and cities; the closures have also been changed; and start to open to the outside. For example, depending on their self-characteristics, some traditional villages start to develop their tourism and change into a developing way, and attract scholars and tourists to visit at home and abroad Figure 2.12.

Figure 2.12 Tourism villages: Yuan Jia village in Li Quan county, Shaanxi province

2.2.5 Main problems of villages during the new construction countryside process

(1) The cultivated land reduces, the contradiction between people and land have become increasingly prominent

With the continuous expansion of rural housing land, cultivated land is gradually reduced, and the contradiction between people and land becomes increasingly prominent[27]. The unreasonable land planning system is also one reason that makes the situation more serious. During field investigation, it is found that lots of unsuitable public squares Figure2.13 and government office buildings Figure2.14 are built there and take large areas of cultivated land, but the aim of that is just for the local government to show their achievement.

Figure 2.13 Large area public square of Zhaoyang Village in Qianyang County

Figure 2.14 Government office buildings in Xiaozhai Village in Qianyang County

(2) Lack of planning methods to act according to local conditions in the villages' construction process

In recent years, because of the requirements of economic development, ecological management and human settlement improvement, the original gully villages and slope villages are gradually moved to the tableland area by the subsidies given by local government. During the process of new countryside construction, because there is no theory about villages' planning for a long time and lack the cooperation among different subjects, the current planning just copies the construction format of villages and cities in other plain areas of China, while ignoring the traditional villages' characteristics. The results are that the development orientation of new villages is not clear and lacks local characteristics.

1) Lots of villages' planning just simply copy the planning method of the city block, which makes the inner village public space is neat and uniform but lacks local characteristics. Different areas own different functions; roads are always straight and houses planned as military camp. All of these make the original local characteristics lost and kinship among villagers is lost Figure 2.15. The uniform of housing design, the European style houses with foreign style roof and blue glass, make every house look the same, losing their characteristics. The original characteristics, such as small-scale villages, mix functions area and local materials are all gradually lost.

2)Some villages' planning ignores the local villagers' working and living habits and irreconcilable with the traditional living style. The reason is that there are no participates in the planning and construction for local residential; the local living habits are ignored and some spaces actually are waste. In some villages, the public square is too big and the equipment there is installed randomly causing the low usage inefficient. Also in some villages, there are no warehouses planned; villagers can only put the farming tools and straw in their yards or out of the main doors.

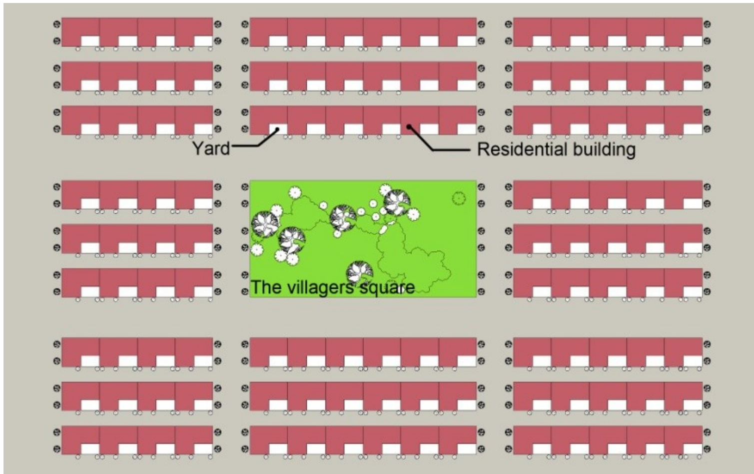


Figure 2.15 Houses planned as military camp

(3) Large number of hollow villages

As the implementation of household contract responsibility system and the agricultural mechanization continues to be strengthened, large numbers of surplus labor in rural areas appear. At the same time, large numbers of the rural population work in cities, which causes the phenomenon of people separated from their houses. Thus, many houses are idle and useless, and a large number of "hollow villages" appears, seriously reducing the usage rate of cultivated land Figure 2.16.

Yangpo village in Qianyang county   Taoquyuan village in Chunhua county

Figure 2.16 The hollow village in Gully Region of Loess plateau

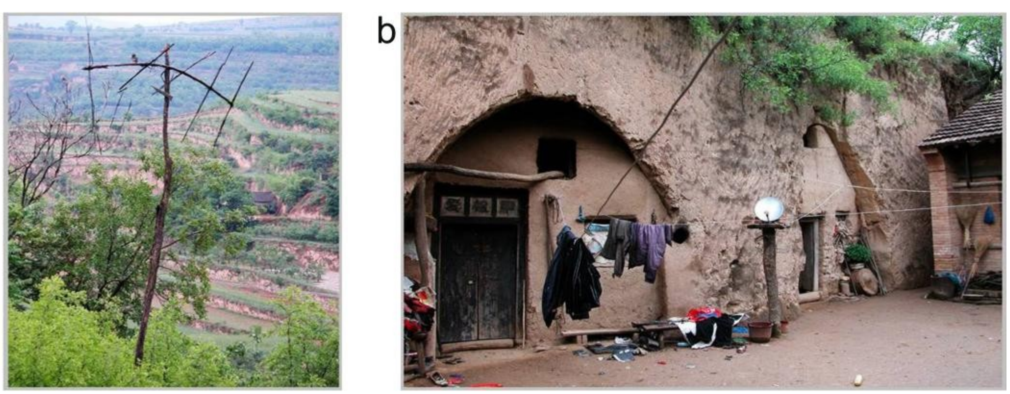
(4) The management of village construction is chaotic

Because of the shortage of necessary planning and management in rural construction, the gully region has already been far from other areas. What is more, there are many problems, such as many villages are scattered, lands are taken unplanned, net roads are short of reasonable planning, the chaotic traffic system and so on. In order to connect all villages, the local government constructs roads blindly without reasonable and symmetrical planning at the expense of people's interest, which makes people move out their original living area Figure 2.17. It seems that, such kind of action increase the local GDP, but people's interests are scarified and cannot improve people's living standards. What is more, many roads are built blindly and abandoned after it is completed.

Figure 2.17 A viaduct bridge takes large area of land in Yang Po Village of Qian Yang County

(5) Village infrastructure is backward, which cannot satisfy modern life

With the improvement of people's living standard, residents who live in the gully region of the Loess Plateau have more requirements for their life. However, the original cave dwellings cannot meet their requirements because of the backward infrastructure, such as communication, water supply, power supply, heating and so on. There are also other environmental problems; for example, improper waste disposal is very serious. However, comparing with the original cave dwellings, there are also many problems for the newly-built village, such as single house type, unrepeatable function design and most of the houses are built by poor technology and in poor quality Figure 2.18.



(a) Backward infrastructure (b) Villagers are in poverty

Figure 2.18 Backward infrastructure and living conditions in Ma Chang village of Chang Wu County

2.3 Classification of construction types for Tableland villages

Since the 21th century, as the smallest social units，Tableland villages enter a rapid development period, which takes more than 75% of all villages and owns large amount of agricultural population in gully regions of Loess Plateau in China. Along the construction of new countryside, the outlook of local Tableland villages and developing ways are very different from traditional villages there. This research selects Tableland villages as the representative villages in the gully regions of Loess Plateau, and combined with local natural environment, culture, history and landscape, to research the construction types and characteristics of Tableland villages from the direction of land usage and space distribution.

2.3.1 The selection and overviews of research area

Yongshou County is located in the west-central Shaanxi province, Figure 2.19 which is the typical area of the gully region of Loess Plateau. There are 12 towns, 249 villages, and the land area is about 889 square kilometers. It has a population of 208.5 thousand, with the agricultural population accounts for 96%, cultivable land per capita is 2.4 mu(0.16 ha), and income per capita is 830USD[28]. The tableland area of Yongshou County is relatively small. The northwest part of Yongshou is on the edge of the gully region of plateau, and the landscape there is fractured. Because of the complex terrain, the traffic is relatively inconvenient and restricts the development of some villages since a long time ago [29].

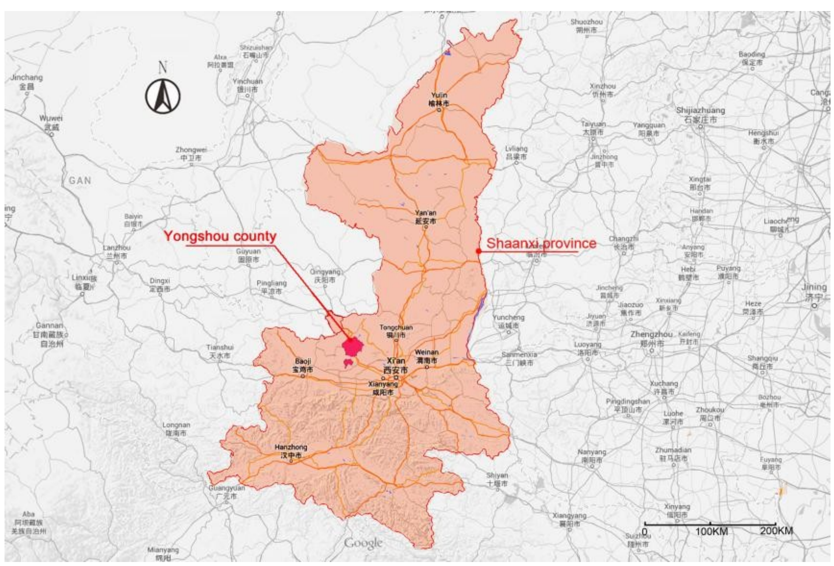


Figure 2.19 Location of Yongshou County in Shaanxi province

During the relocation project in the recent years, a large population who used to live in slope villages and gully villages gradually move to the tableland. From the field investigation, it is found that there are around 90% villages in Yongshou are located in tableland area by now. The Tableland villages near county center own better traffic conditions and economic developing conditions, these villages are generally much larger scale than others. While the Tableland villages that are in a poor traffic condition or located far from the county center tend to have relatively poor economic development, and the village scale is relatively small.

The investigation chose the Tableland villages in two towns of Yongshou County as the research object. One is the Jianjun town, which is closed to the county center, and the other one is Yujiagong town which is far from the county center Figure 2.20.

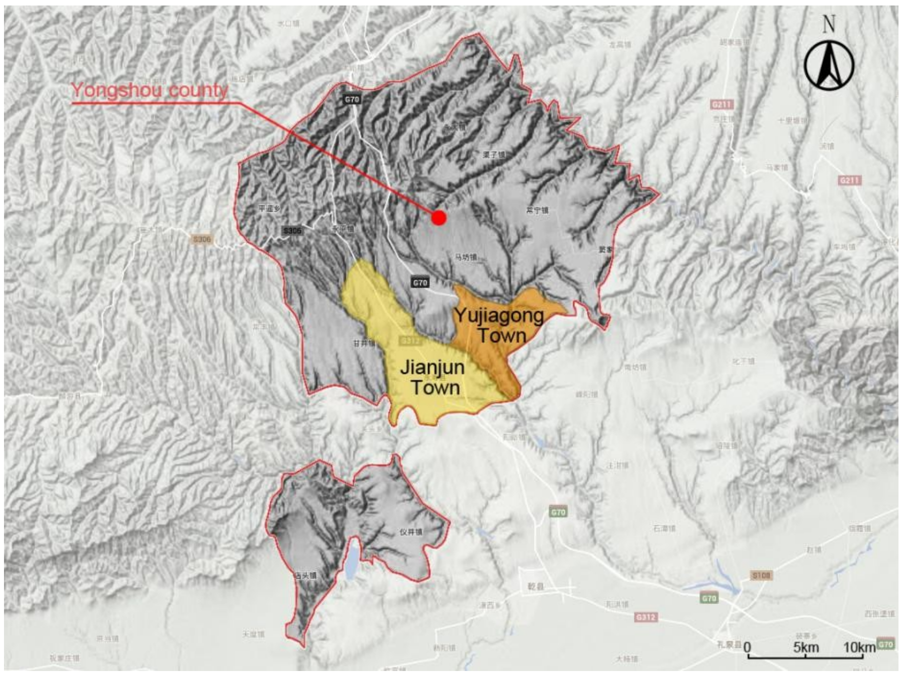


Figure 2.20 Location of Jianjun town and Yujiagong town

Jianjun town is located in the south of Yongshou County. There are 27 villages, with a population of 37390, a total area of 88.3 square kilometers, and arable land area of 36.56 square kilometers. In 2015, the annual per capita income was around 1700 USD [29]. Because these villages are near the county center, and flat topography, the economic development of the villages is relatively good, and the people's living standards are relatively high.

Yujiagong town is one of the earliest towns, which has been carried out the construction of new countryside. It is located 9 kilometers northeast of the county center. There are 15 villages, with a population of 9382, a total area of 47.5 square kilometers, and arable land area of 20.20 square kilometers. In 2015, the annual per capita income was around1400USD [29]. Because of the distance away from the county center, the economic development of the villages is relatively poor, and the people's living standards are relatively low, compared with Jianjun town.

2.3.2 Classification of construction types for Tableland villages

Through the field investigation of the current spatial distribution, land-use options, and combined with the actual situation of the new rural construction, this research classifies the construction types of Tableland villages into rectification construction type, expansion construction type, and newly-built construction type.

(1) Village of rectification construction type

The Tableland villages that are rectification construction type usually have two kinds of situations. One is the villages near the county center, which have good economic development; the other is the central villages, which are far from the county center, but traffic is very convenient. Both of the two kinds of Tableland villages have some common characteristics, such as long development history, large land scale and population, and relatively good economic development. The people living in these villages have a big difference in economic conditions. The well-off households usually have their own new brick-concrete structure houses before the new rural construction projects. Some of them are two-storey and high construction standards. However, many poor households live in the adobe houses and basic brick-concrete structure houses Figure 2.21.

Figure 2.21 Different kinds of residential houses in Minfeng village of Jianjun Town

The village of rectification construction type improves the overall condition mainly by rectifying the spatial organization of village and reforming the vernacular courtyards Figure 2.22. The construction contents include reconstruction of existing village infrastructure and residential buildings, improvement of the traffic system and human settlements quality of village, to improve the living conditions of villagers Figure 2.23.

After the rectification, the layout of most villages is multi centers and sheet distributions. Generally, the multi centers are village committee, medical station, and other public facilities. This model has the advantages of improving distribution rate of public infrastructure, enriching the functional space of the villages, and increasing the public intercourse space of the villagers.

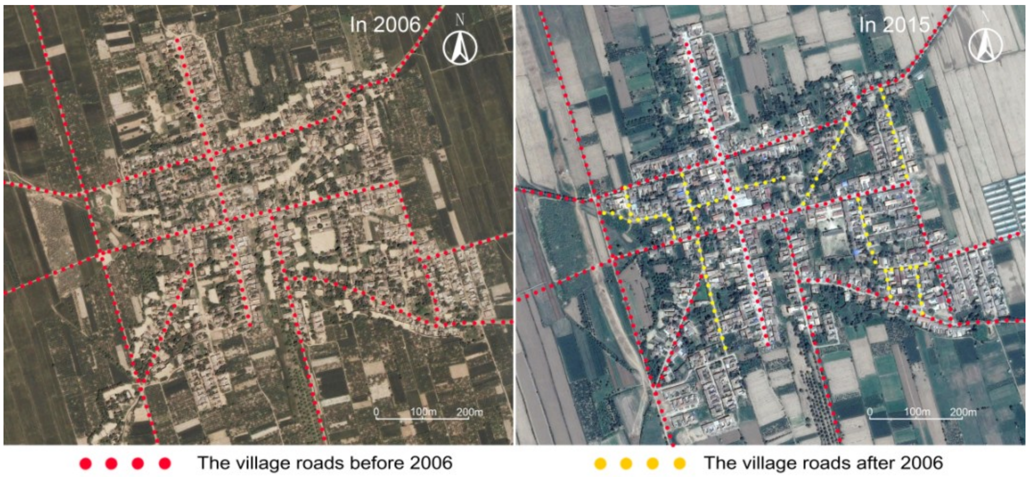


Figure 2.22 Rectification construction of Minfeng village from 2006 to 2015

Figure 2.23 Current human settlements situation of Minfeng village

(2) Village of expansion construction type

The Tableland villages that are expansion construction type also have two kinds of situations. One is in the medium development level villages of the towns, which are near the county center. Generally, the economy of this kind village can be driven by radiation effect of county center, but because of inconvenient traffic and poor geographical environment, the development of village is also limited. The other kind of villages is in the high development level villages of the towns, which are far from the county center. Because of the relatively remote location, their economy can barely affect by economic radiation of county center.

During the construction of New Socialist Countryside, the expansion construction type villages tend to absorb the population of surrounding Slope villages and Gully villages that are small-scale, poor nature, and economic conditions. Thus it can make the scale of expansion construction type villages larger Figure 2.24. The new expanded residential areas are centralized arrangement by expanding the construction land in the periphery of the villages or reclaiming new construction land along main roads Figure 2.25.

Figure 2.24 Expansion construction of Shuangmiaoyuan village from 2009 to 2015

Figure 2.25 Layout of the new expanded residential areas in Shuangmiaoyuan village

The main advantage of this construction model is that the new expanded residential areas can share public infrastructure with the former residential areas; there is no need to change the land-use structure of the village. However, usually such models lack analysis of ecological carrying capacity. Thus, it will lead to village arbitrary for the expansion of the scale, and break the balance of ecological environment.

(3)Village of newly-built construction type

Generally, the village of newly-built construction is combining the villages that are far from county center and inconvenient transportation situation. The living conditions and the environment in these original villages are usually very poor and need to be improved. Meanwhile, the government gives more financial support to these poor villages for the newly-built construction. Therefore, the desire of relocation for people living in these villages is really strong. At present, there are two methods to construct new villages.

One method is reconstructing the slope villages and gully villages that are in poor natural conditions and backward infrastructures to the tableland nearby where the land-use condition is better Figure 2.26, Figure 2.27. After the villagers move to the new village, the land of original villages will be reclaimed as cultivable land or restored to nature reserve.

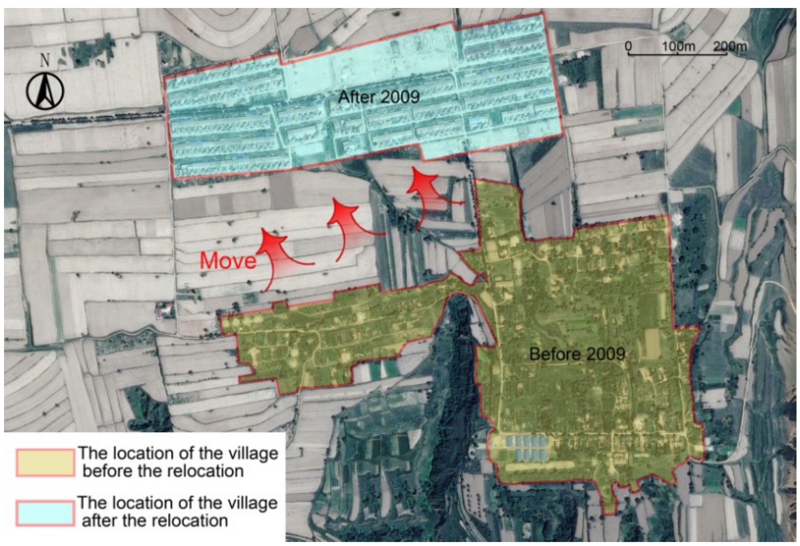


Figure 2.26 Gun village in Yujiagong Town reconstructed to the tableland nearby

Figure 2.27 Present situation of Gun village

Usually the residential houses in the economically backward Tableland villages are simple and crude, and distribute dispersed. Therefore, the other method is doing the demolition of all the original dwellings and reconstructing the village in the same place Figure 2.28, Figure 2.29.

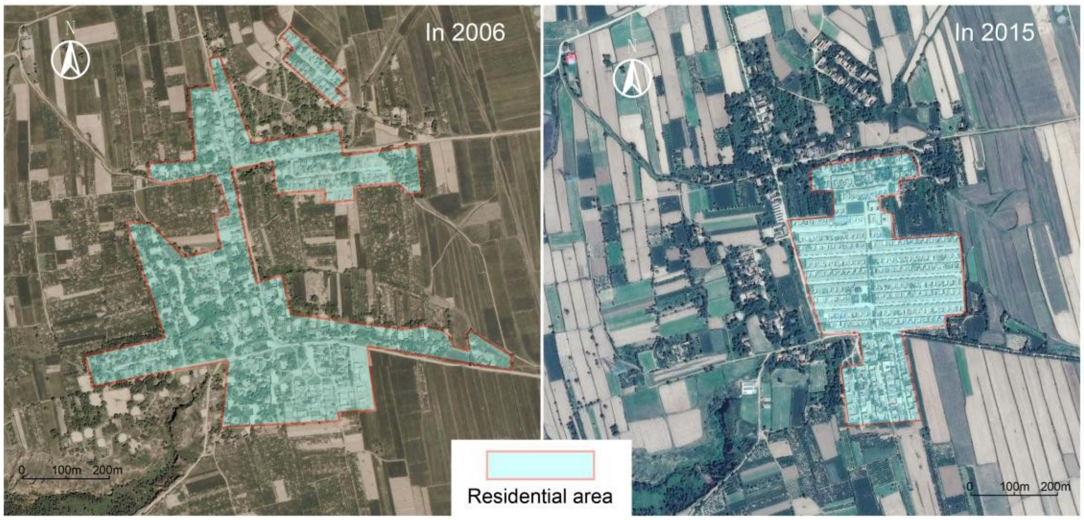


Figure 2.28 Zhujie village reconstructed the village in former address

Figure 2.29 Present situation of Zhujie village

The spatial distribution of newly-built construction type villages is compact and the residential areas are concentrated. It increases land-use efficiency and saves land. Therefore, the land saved can be used for commercial facilities, medical facilities, educational facilities and other public infrastructure. However, the lack of systematic and scientific planning, the spatial form of most newly-built villages are monotony in format, houses are arranged like barrack, lack of local cultural characteristics and vibrant public intercourse space Figure 2.30.

Figure 2.30 New village construction planning of Gun village

2.4 Analysis of Tableland villages' characteristics based on SWOT analysis method

Since many factors and complex contents should be put into consideration, this research devotes to analyzing the characteristics of different kinds of construction types of Tableland villages by SWOT analysis method, which can improve the accuracy of the research Figure 2.31.

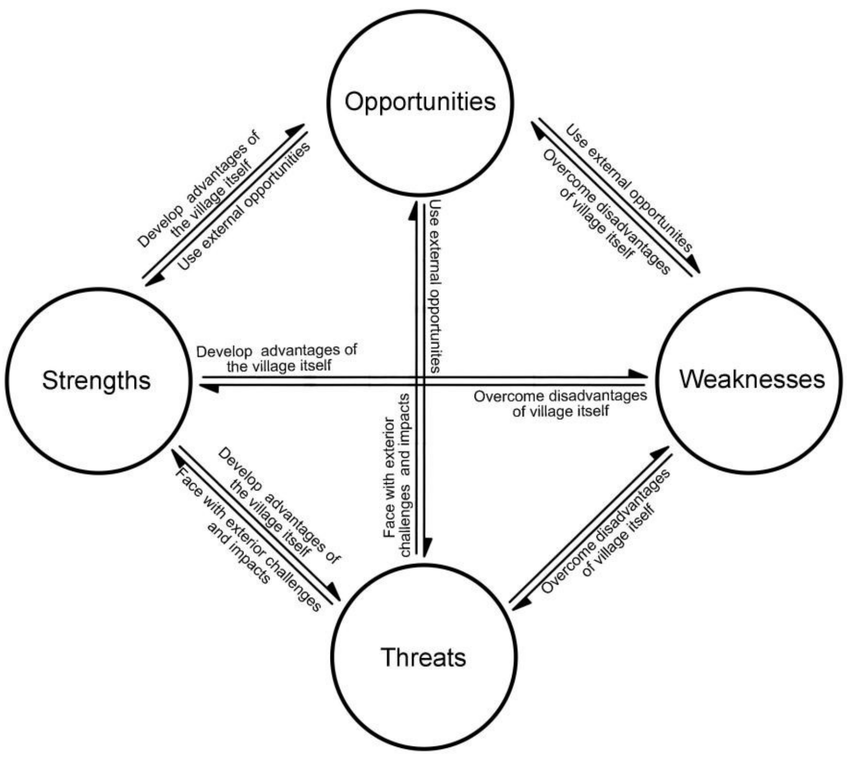


Figure 2.31 Swot analysis diagram of each conclusive element

2.4.1 Characteristics analysis of rectification construction type village

Rectification construction used to be the main method of village construction in earlier stages of new countryside construction [30]. It has the advantages of small amount of demolition and low cost.

However, during the field investigations, it was found that most rectification construction villages were lacked scientific planning and design basis. In the process of rectification, they simply modeled on the construction of urban area, and did not fully take into account the scale of population and demand for the user. Instead, they were more like image constructions which were used to show off the achievements of local government [31] Figure 2.32. Therefore, it is hard to show actual effects of the construction after completion.

Figure 2.32 Flashy image constructions in rectification

In addition, the follow-up maintenance and management of some villages are not good. Destruction and many infrastructures are not properly maintained, resulting in a greatly reduced life and expectancy, which also causes the waste of resources Table 2.7.

Table 2.7 Swot analysis of rectification construction type village

Strengths	Improve the human settlement of village
	Small amount of demolition
	Low costs of infrastructure construction investment
Weaknesses	Slow rectification process
	Lack of reasonable planning for infrastructure
	Lack of follow-up maintenance and management
Opportunities	Promotion of urbanization process
	New rural construction in full swing
	Desire for improving living environment of residents
Threats	The establishment of long-term management mechanism
	Financial investment
	The improvement of living environment is a long-term task

2.4.2 Characteristics analysis of expansion construction type village

Expansion construction type villages absorbs the population of surrounding small-scale, scattered villages. On the one hand, it can change the situation of complicated management mechanism that causes a large number of small natural villages and simplifies the administrative institutions [32]. Thereby, it increases the scale of the expansion construction type village and transforms itself into a central village. On the other hand, expansion construction type village can integrate the scattered land, thus to improve the land-use efficiency. It is conducive to the concentration and intensive management of cultivatable land [33].

However, the migration of surrounding natural villages exacerbated environmental carrying capacity [34]. Hence, without systematically calculating carrying capacity of village's ecological environment, it is possible to trigger a new ecological crisis by random expansion of village scale. Meanwhile, it needs to provide a corresponding scale of hardware facilities for the migration by village. Nevertheless, most of the expansion construction type villages cannot meet these needs of villagers, which will become another serious problem on the road of village development Table 2.8.

Table 2.8 Swot analysis of expansion construction type village

Strengths	Improve the human settlement of village
	Solve the problem of ecological migration
	Intensive use of land
	Expand into central village
Weaknesses	Limited ecological carrying capacity
	The land-use of original village do not give its full play to its potential
	Lack of systematical and scientific overall planning of village
Opportunities	Promotion of migration project by government
	Implementing of the moving and merging village policy
	New rural construction in full swing
Threats	Problem of systematically calculating ecological carrying capacity
	The possibility of ecological crisis
	Problem of equipping with supporting infrastructure

2.4.3 Characteristics analysis of newly-built construction type village

Newly-built construction type village improves the living environment and housing conditions directly and effectively. It promotes the level of intensive land utilization by unified and centralized construction of the new residential area. In addition, it can alleviate the pressure of ecological environment by relocating the population in ecologically fragile areas to tableland. After the population migration, it can restore natural vegetation to protect the ecologically fragile areas or reclaim the original village land [35].

However, tableland resources in the gully region of Loess Plateau are very limited, and the number of the population that needs to be relocated is large [36]. Therefore, for the newly-built construction type village, how to use the limited land resources in tableland area is a serious challenge. What is more, the standards of village planning and construction are low, and lack of ecological and long-term considerations [37]. During the investigation, it was found that most residential area planning of newly-built construction type villages in Yongshou County are in the form of multi-row layout. Thus, the spatial distribution of villages is monotonous and there are few parking lots, grain drying fields and other public spaces. The cars have to park on the road and grain can only dry on the pavement Figure 2.33.

Figure 2.33 Monotonous spatial distribution of Wuyi village

Table 2.9 Swot analysis of newly-built construction type village

Strengths	Improve the human settlement of village
	Intensive use of land
	Restore natural vegetation
	protect the ecologically fragile areas
Weaknesses	Limited resettlement capacity of tableland area
	Lack of systematical and scientific overall planning of village
	High requirement for environmental conditions of new location
	Low speed of furnishing and equipping with follow-up of infrastructure
Opportunities	Promotion of migration project by government
	Emphasis on the protection of ecological environment
	New rural construction in full swing
	Desire for improving living environment of residents
Threats	Problem of systematical and scientific overall planning of village
	Problem of economic compensation and employment of immigration
	Large number of population need to be relocated.

The low speed of furnishing and equipping with follow-up of infrastructure, such as water supply, power supply and other ancillary facilities, affected the life and production activities of the villagers. Furthermore, the mode of whole village relocation destroys the original neighborhood relationship of residents [38] Table 2.9.

2.5 Summary

This chapter is the main research on the general situation of villages in gully region of Loess Plateau, the developing history, different characteristics of different village types and the main problems in the process of new countryside construction. Based on field research of Tableland villages in Yong Shou County of Shaanxi Province, this chapter combines the present spatial distribution, land utilizing mode with the requirements of new rural construction, and divides Tableland villages' construction model into three types: (1) Village of rectification construction type, (2) Village of expansion construction type, (3) Village of newly-built construction type.

Through the analysis of these three kinds of construction model by SWOT, advantages and disadvantages, developing chances and challenges are summarized, and main problems of the present developing planning are figured out. The results of this chapter can be used as the basis and theoretical base for the future research of human settlements planning in the following chapters.

CHAPTER 3
RESEARCH ON HUMAN SETTLEMENTS PLANNING METHODS OF TABLELAND VILLAGES, BASED ON ANALYSIS OF ECOLOGICAL CARRYING CAPACITY

3 Research on human settlements planning methods of Tableland village , based on analysis of ecological carrying capacity

3.1 Introduction of ecological carrying capacity analysis of Tableland village, based on restrict factor analysis method

Villages in gully region intensively move to the tableland areas, cause vast land waste, and go over the ecological carrying capacity, thus making the original weak ecological environment much worse, all of which force us to figure out a suitable developing way and sustainable villages planning method.

Based on ecological carrying capacity to plan and design human settlements are one of the significant basis for the scientific construction of new countryside [39]. 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.

3.1.1 Conception on ecological carrying capacity

Since the first industrial revolution, the conceptions of resource carrying capacity [40][41], environmental carrying capacity[42], and ecological carrying capacity[43][44][45][46] were submitted gradually as the rapid development of human society, the deteriorate of global environment and shortage of resource.

In China, Jixi Gao defined ecological carrying capacity as the ability to self-maintain its ecological system, and self-adjustment ability, the ability of resource and sub-environmental system that supports certain social and economic activities and own a certain amount of the population. He also further explained that resource carrying capacity is the basic condition for ecological carrying capacity, and environmental carrying capacity is the constraint condition for ecological carrying capacity [47].

Besides, there are also some scholars define it as an ecological system that can do self-adjustment and can develop sustainably within a certain period of time and space. At the same time, such systems can support a certain degree of resource consumption, environmental pollution, and support social and economic development and a certain amount of the population. This definition puts the concept of time and space into the content of ecological carrying capacity [44].

3.1.2 Advantage of analysis of the evaluation of villages' ecological carrying capacity based on restrict factor analysis method

Because ecological carrying capacity is the most important basis for doing ecological environment management and making policy for sustainable development, the analysis of it should be the key contents for the carrying capacity research. According to the research areas and the characteristics of research questions, researchers submitted a series of research methods from different research directions. 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 3.1 Comparative analysis of the common analysis methods for ecological carrying capacity

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 economical development; the current ecological environment and people's equipments.	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.

(1) Comparative analysis of different analysis methods about ecological carrying capacity

At present, the common ecological carrying capacity research methods are ecological footprints [48] [49]; measurement of natural vegetation as first productivity [50], balance between supply and requirements [42] [51], state space method [52], model forecast method [53], and so on Table 3.1. These methods are different for their different theory background, so the advantages and disadvantages are different. In the process of ecological carrying capacity analysis, different methods should be selected according to the requirements and the functions of analysis results.

Because of the shortage of statistical data and documents on villages in the gully region of Loess Plateau, ecological footprint, measurement of natural vegetation as first productivity, balance between supply and requirements and state space method are all difficult to do the accurate measurement. 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 villages in gully region of Loess Plateau.

(2) Commonly used measurement models for ecological carrying capacity in model forecast method analysis

With the support of the computer, the model forecast method could use different kinds of mathematical models to analyze ecological carrying capacity. In the book The Development of Research on Ecological Carrying Capacity in the World, Gao He and Zhang Hongye defined and summarized the common measurement models into six types. In the six commonly used models of model forecast method, the method of the restrict factor analysis method is relatively simple, and the results can show the restricted factors for the ecological carrying capacity; and owns guiding functions for the future human settlement planning.

(3) The conception and analysis theory of restrict factor analysis method

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.

(4) Advantage of restrict factor analysis method in villages' ecological carrying capacity analysis

Based on the restrict factors analysis method, the analysis of the ecological carrying capacity of 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 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.

3.1.3 The improvement of restrict factors in human settlements planning of village

During the analysis of villages' human settlement planning, natural resource, cultural environment, social and economic development level, all these factors should be analysis. Some of these restrict factors are adjustable, such as the carrying capacity of infrastructure can be improved by reasonable planning and construction. It is partial that just fix the ecological carrying capacity by restrict factors that the minimum population they support. According to the characteristics of human settlement planning, the restrict factors can be divided into two kinds; one is those factors that are difficult to be changed by humans, such as water resource, land resource. Another is the adjustable factors that can be improved, such as green land areas, energy supply.

Based on the ecological carrying capacity to do villages' planning, actually is based on those unchangeable restrict factors, through the improvement of the adjustable factors, that it can greatly improve human settlement environment of villages, and then it can further come to be a green, economize and sustainable development villages in gully region of Loess Plateau.

3.1.4 Selection of restrict factors

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 Table 3.2.

Table 3.2 Main restrict factors that have effects on ecological carrying capacity

Restrict factors	Resource factor	Land resources factor
		Water resources factor
		Forest resources factor
		Mineral resources factor
	Environmental factor	Atmospheric environmental factor
		Water environmental factor
	Social factor	Infrastructure factor
		Human factor
		Political factor

According to the characteristics of geology, landform, climate, water, vegetation and land of gully region in Loess Plateau, the situation of water loss and soil erosion, as well as threats from sand, wind, and drought, are all very serious. Besides these natural reasons, the gully and fragmented landform and the imbalance ecological system of this areas are also caused by the human activities, such as rapid population increase, steep slope reclamation, extensive cultivation and unreasonable land use and vegetation destroy, all of these activities are not follow the natural regulation and economic regulation, and make soil erosion even worse. 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 lagging development of the economy, imperfect infrastructure and the imbalance distribution of social resource, are also the obvious present situation in Loess Plateau, thus infrastructure can also be selected as an important restrict factor.

According to the questionnaire done by this research in Tableland villages of gully region in Loess Plateau, the results of 78 effective respondents are showed in Figure 3.1, in which cultivated land, water resource, infrastructure and governmental policy are widely agreed that own great influence on the village construction. These factors can be selected as main factors, and should be analyzed comprehensively during the ecological carrying capacity analysis, thus give the government as a reference for the future planning. The developing planning made by the government should put the human living environment and ecological civilization construction.

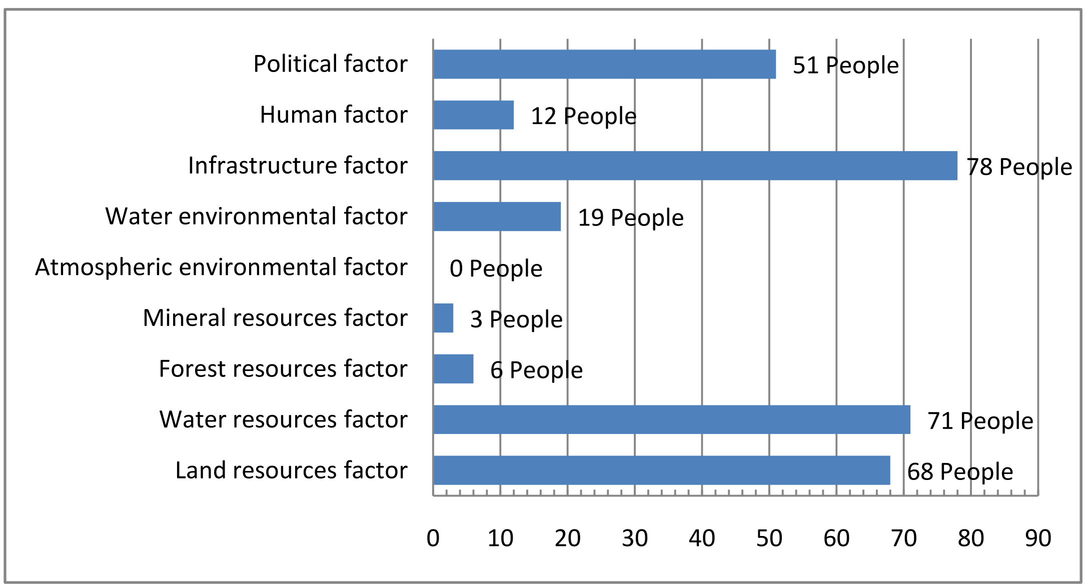


Figure 3.1 Statistics results of the main restrict factors of the analysis ecological carrying capacity in gully region of Loess Plateau

Among the main restrict factors of ecological carrying capacity in the gully regions of Loess Plateau, the policy, factor is mainly influenced by national land policy, populationplanning 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, the 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.

3.2 The analysis of ecological carrying capacity of Tableland village

3.2.1 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 village can support, the cultivable land is used as the restrict factor to do the estimation of village ecological carrying capacity. The equation is $PG=S/S_{min}$, PG means the village ecological carrying capacity by the cultivable land restrict factor, S means the total cultivable land area in the village, and S_{min} means the minimum cultivatable land per person.

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[54]. 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 Table 3.3.

Table 3.3 Aims of Chinese food safety

Strategies	Food requirement per person (kg) [National food and nutrition consultant committee (2004)]	Per capita food (kg) [Aims of food safety calculated by Chen Baiming (2002)]
2010 (Basic well-off society)	391	420
2020 (All-round well-off society)	437	—
2030 (Transition period for rich stage)	472	450
2050 (Rich stage in all-round)	—	500

According to the requirement of per capita food, the followed Table 3.4 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 3.5.

Table 3.4 The requirement of cultivable land area for different food demand in Loess Plateau (hm^2)

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 Table 2. 3. 4. 5 from the : Research on Threshold Value of Per Capita Cultivable Land in the Whole Country and Some Regions [55]. S400、S450、S500 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 3.5 The requirement of cultivable land per capita in Loess Plateau (hm^2)

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 pro portion 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.

3.2.2 Analysis of ecological carrying capacity based on the restrict factor 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. In rural area, the natural resource development degree is far away from the natural bottom line. Thus, the calculation of rural water resource carrying capacity cans not only analysis the natural rain and underground water. Nowadays, there are lots of water resource carrying capacity research, but most of them focus on the whole city, cannot use in the analysis of rural areas, and those research result cannot be used to guide the rural human settlement planning.

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 analyzed by the water infrastructure.

Because water resource owns huge impact on villages' ecological carrying capacity, it can be analyzed 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.

3.2.3 Analysis of ecological carrying capacity based on the restrict factor of infrastructure

(1) Definition and classification of rural 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.

Village infrastructure has board and narrow definitions. The narrow definition refers to public infrastructure, in the book: The Regulations of Village Planning, 1993, it can be defined as public project planning, roads and other transportation planning and vertical planning, in which the project planning includes electricity project, drainage project, water supply project, postal project and flood protection project. The board definition refers the total of factors that give the public service for rural economy, society, culture and people's living, and the infrastructure that gives the insurance for rural production and villagers' life, including the infrastructure for supplying water and electricity, transportation and post service, environmental sanitation, transportation, also the facilities for culture, education and productivity service. 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 [56].

Table 3.6 The classification of infrastructure in rural areas [57]

First type	Second type	Third type
A Productivity infrastructure	A1 Transportation infrastructure	A11 Road facility A12 Parking areas A13 Stations A14 Bridges A15 Dock
	A2 Energy infrastructure	A21 Electricity infrastructure A22 Gasoline infrastructure (gas, natural gas, liquefied petroleum gas, biogas) A23 Coal, firewood, straw A24 Fuel facilities (gas station, gas pipes) A25 Renewable energy infrastructure (solar power and wind power infrastructure) A26 Post infrastructure (post and telecommunication infrastructure)
	A3 Productivity infrastructure	A31 Agricultural technology training, technology development research site A32 Animal and plant epidemic prevention A33 Grain quality examination infrastructure A34 Grain warehouse (warehouse, store room and market) A35 Basic farmland establishment, high quality farmland A36 Infrastructure built for animal
	A4 Irrigation infrastructure	A41 River, dam, gully river A42 Soil improvement infrastructure A43 Irrigation infrastructure (wells, rainwater reservoir)
B Living infrastructure	B1 Disaster prevention infrastructure	B11 Fire protection infrastructure B12 Flood protection infrastructure B13 Earthquake protection infrastructure
	B2 Water supply infrastructure	B21 Intensive water supply infrastructure B22 Dispersing water supply infrastructure (water taking, water purifying , and water transported)
	B3 Public service infrastructure	B31 Education and cultural infrastructure (kindergarten, primary school, middle school, library and old people's nursing home) B32 Hospital infrastructure (rural health support infrastructure) B33 Management infrastructure (village committee and other management agents) B34 Commercial service infrastructure (mini-supermarket, shops, hotels, restaurant, barbershop, bathroom and so on) B35 Cultural and entertainment infrastructure (fitness room) B36 Others (public activity center, temples and so on.
C Ecological infrastructure	C1 Drainage infrastructure	C11 Drainage pipes C12 Water resource protection C13 Sewage treatment infrastructure
	C2 Environmental improvement infrastructure	C21 Waste collection infrastructure C22 Waste treatment infrastructure C23 Public toilet
	C3 Ecology protection infrastructure	C31 Garden greening C32 Forest lines C33 Green landscape corridor

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 Table 3.6.

(2) Analysis of the carrying capacity of infrastructures in villages

At present, the research on carrying capacity of infrastructures in 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 analyzed 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 analyze systematically. According to the present situation of infrastructure in gully region of Loess Plateau, the public service infrastructure shown in Table 3.7 and Table 3.8 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 center, and old people activity center, which meet the demand of G4 for village public infrastructure, the supporting population should not more than 800 by the calculation of public infrastructure.

Table 3.7 Classification of the levels of public infrastructure [58]

	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 3.8 Classification of public service infrastructure in villages [58]

Villages	Average income >6500 RMB/Y (>1000 USD/Y)	Average income 4000~6500RMB (615~1000 USD/Y)		Average income <4000RMB (<615 USD/Y)
Over 2000 people	G1	G2	G1	G2
800-2000 People	G3	G3	G2	G3
Less than 800 people	G3	G4	G3	G4

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 analyse the carrying capacity of infrastructure for such small-scale villages, and thus based on interview and questionnaire distribution , the carrying capacity can be evaluated by Table 3.6.

3.2.4 Analysis of ecological carrying capacity between different villages in a small area based on the comprehensive analyses of restrict factors

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. The detailed analysis can be done for the following four steps, the following four neighborhood Tableland villages are showed here as examples to show these steps.

(1)Step 1: Analysis of bearing capacity of cultivable land area

Combining the site research on cultivable land and Table 3.3, Table 3.4, Table 3.5 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 table 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 Figure3.2. In gully regions of Loess Plateau, 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.

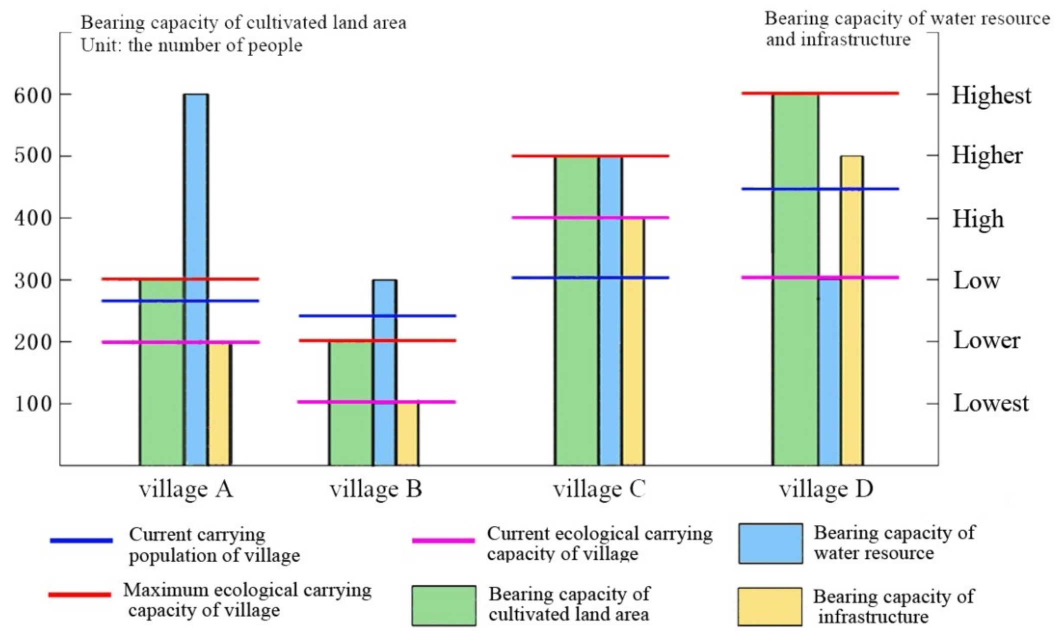


Figure 3.2 Analysis of ecological carrying capacity by restrict factors

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.

3.2.5 Analysis of ecological carrying capacity of single village based on each restrict factors

The planning rationality has the direct relationship with human settlement environment and people's living quality. Base on the ecological carrying capacity analysis in small area, the analysis of each Tableland village will give the direct and efficient guideline to the future village planning and construction. Take village C as an example, the ecological carrying capacity can be analyzed by drawing water distribution map and infrastructure distribution map Figure 3.3. The analysis can be done by the following three steps:

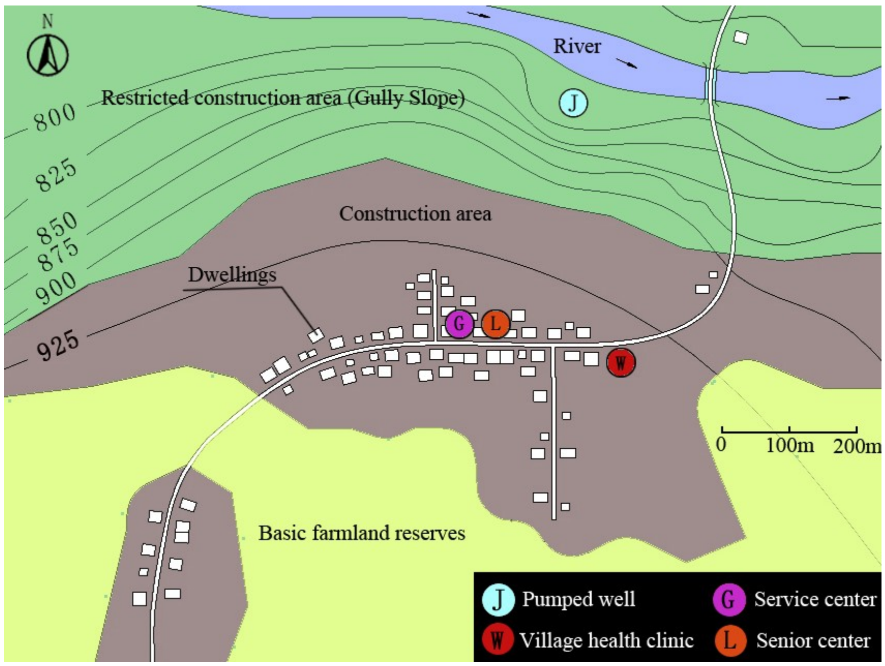


Figure 3.3 Present map for Tableland village C

(1)Step 1: According to the largest ecological carrying capacity to fix the future developing scale

It is shown that the present support population in village C is about 300 people, the cultivable land carrying capacity is 500 people, and if there are no improvements to the infrastructure of water resource, the water resource carrying capacity can also support 500 people. In present, because of the limited infrastructure conditions, the population is about 400 people. In future, if the infrastructure is improved, the village ecological carrying capacity can support 500 people, thus the planning for the future village should be 500 people, and the additional population should be 200.

(2)Step 2: Drawing the distribution map for the water resource and infrastructure in villages

The distribution map is based on the ecological carrying capacity of total restrict factors of water resource and infrastructure, which can show the space distribution of ecological carrying capacity in research areas. During the drawing of ecological carrying capacity distribution, grid computing is the basic method adopted, which can transfer the macroscopic and single ecological carrying capacity into microscopic index space distribution. Thus, the results can be used as theoretic guideline for ecological planning and space management. For the future use of ecological carrying capacity distribution map in the village planning, the research object houses size should be designed as 20m X 20m.

In Loess Plateau, water is very scarce; artificially pumped wells is the main water supply equipment in Tableland villages, and the ecological carrying capacity distribution is mainly decided by the distribution of water supply equipment. Therefore, investments for these water supply equipment should be put into consideration. During drawing the distribution of water carrying capacity map, firstly, the water resource situation in the research areas should be investigated, the main contents of these investigations are the present situation of water supply infrastructure and the distance of water resource with these investigated sites. The investigation and evaluation of main water resource supply levels Figure3.4, the ecological carrying capacity situation of these villages can be divided into six degrees. The higher water carrying capacity in the area means that, the water supply equipment is better, the water pressure is larger and less investment can support more population. Oppositely, the lower water carrying capacity means the shortage of water supply equipment, and large investments should be put in to meet the water demand. Therefore, the construction and present water situation should be put into consideration in this whole process.

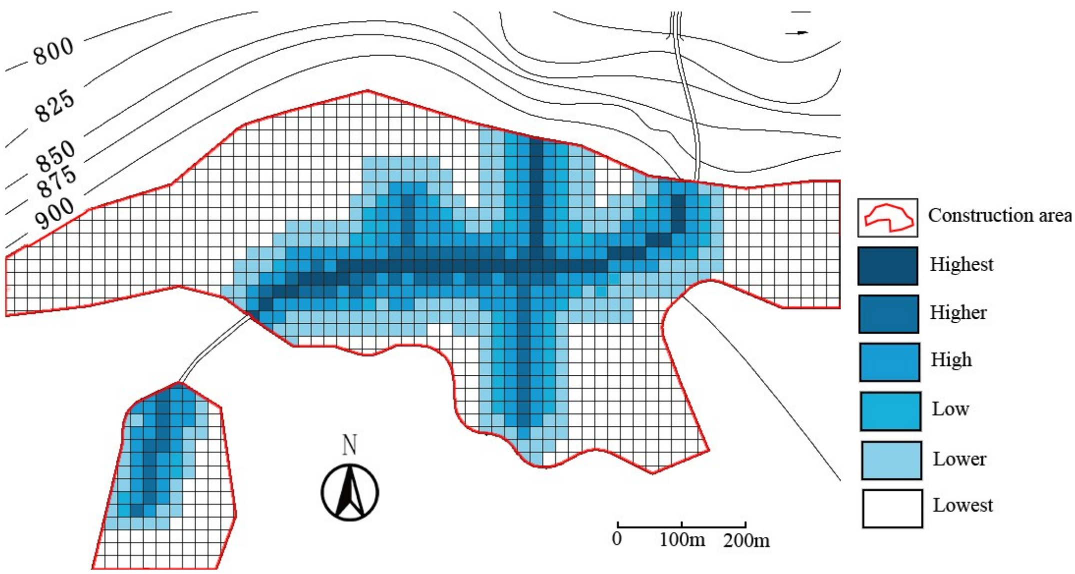


Figure 3.4 Distribution map of carrying capacity of water resource in Tableland village C

The infrastructure distribution drawing is similar to water carrying capacity distribution drawing. Although the water resource carrying capacity also refers to the carrying capacity of water supply equipment, the water resource has the important influence on this region, so it should be analysis as a single factor. During the evaluation of basic infrastructure, infrastructure of productivity, living and ecological and the distance of these infrastructures also should be evaluated. All of these evaluations are based on site investigation and the analysis of the importance of these infrastructures on the villages' development; the influence index also should be done the quantifying assessment.

Generally, in gully region of Loess Plateau, the infrastructure of transportation, electricity supply equipment, commercial areas, sanitation service, all of these infrastructures own influence, but the water supply equipment is not put into consideration. In the present research, the systematic evaluation of basic infrastructure carrying capacity is deficiency. In this research, six degrees of evaluation are introduced in Figure 3.5.

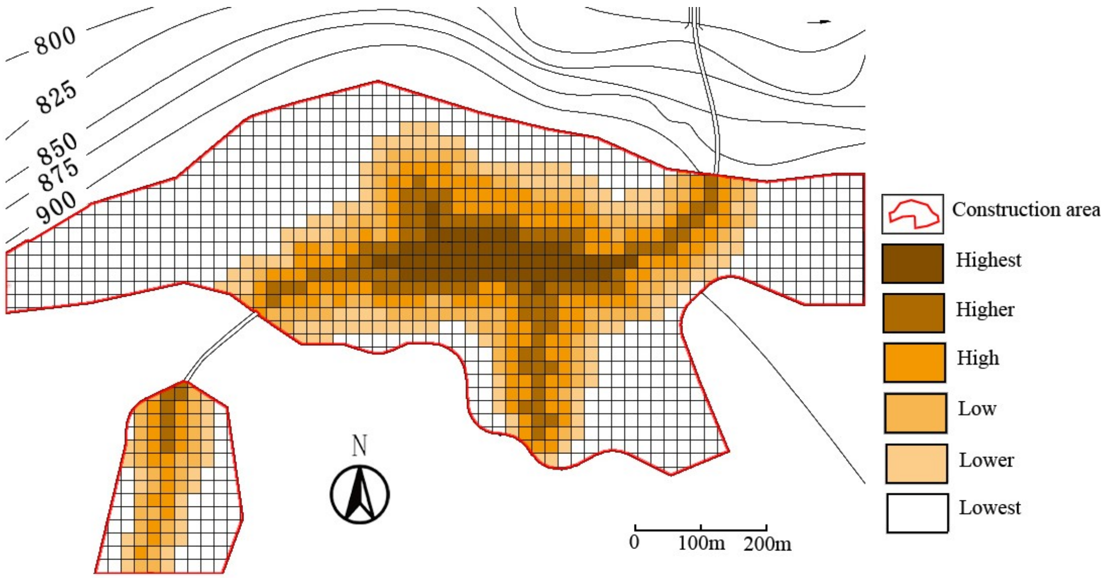


Figure 3.5 Distribution map of carrying capacity of infrastructure in Tableland village C

(3)Step 3: Comprehensive analysis of ecological carrying capacity

Water resource carrying capacity distribution map and distribution map of infrastructure carrying capacity, can just show the space distribution of water resource and infrastructure. If these two can be added together Figure 3.6, it can comprehensively reflect the ecological carrying capacity distribution situation, and it is very meaningful to the future villages' planning.

Put two drawings into together cannot be added simply, the weight for water resource and infrastructure of ecological carrying capacity should also be put into consideration, which is influencing index. According to the influence index value, the two distribution drawings should be designed into transparent and put in the superposition by Photoshop.

Getting the influence index is a complex process, the water supply equipment, other infrastructure investment cost, and both influences on human settlement environment should put into consideration. There are no such kinds of research now and the author uses questionnaires to collect villagers' opinions on these two, and the questionnaire results can be used to make the certain value of influence index.

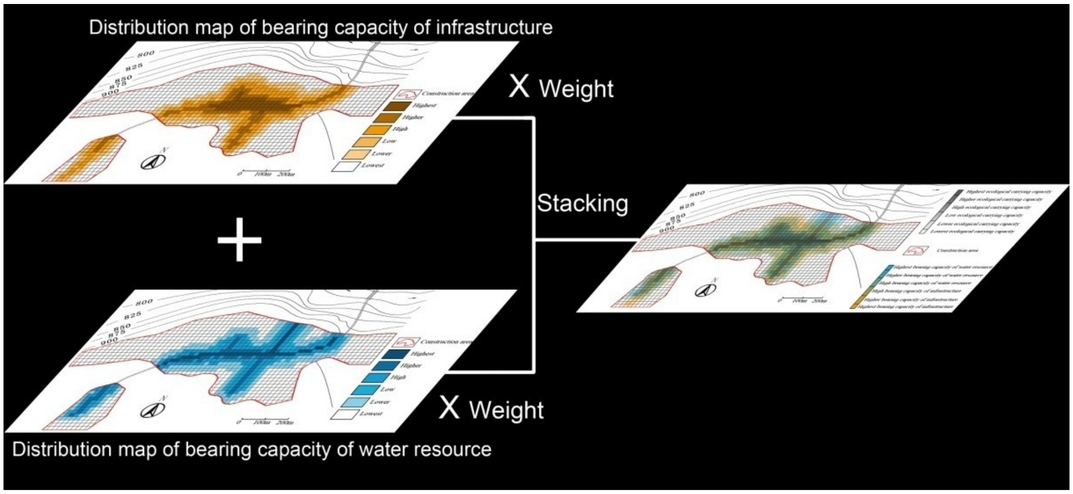


Figure 3.6 Superposition treatment of distribution drawings of water resource and infrastructure carrying capacity in Tableland village C

By the above superposition method, the distribution drawing of water resource and infrastructure carrying capacity is made as Figure 3.7. It can show the ecological carrying capacity level and reflect the present ecological carrying capacity distribution situation in these villages.

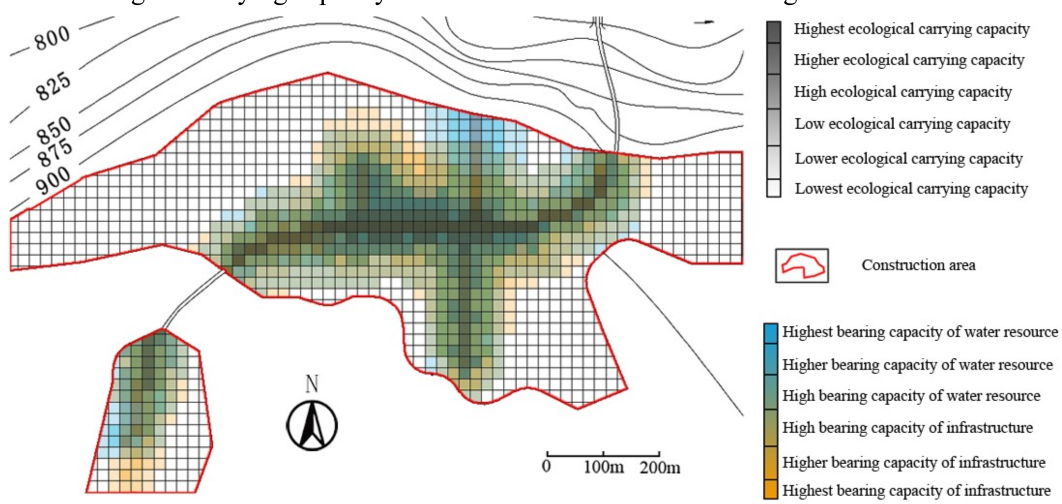


Figure 3.7 Distribution maps of the carrying capacity of water resource and infrastructure in Tableland village C

The drawing of distribution of water resource and infrastructure is showed by different colors lightness; the lower of lightness means the ecological carrying capacity is higher. The colors hue shows the main limitation factors for ecological carrying capacity. If the color tends to be blue, it means the water resource carrying capacity is higher, and the infrastructure carrying capacity is lower. The color saturation can show the proportionality of ecological carrying capacity of this area, the lower the color saturation means the water resource and infrastructure carrying capacity is almost the same, the higher the saturation means there is a great difference between them.

3.3 Tableland village human settlement planning method based on ecological carrying capacity analysis

Ecological carrying capacity is the direct index that influences the rural population and industry developing scale. The analysis of ecological carrying capacity can be use as the important reference for the future planning of village human settlement planning, and the important content for ecological culture establishment. Different ecological carrying capacity analysis owns the different functions for the village planning. For the gully regions of Loess Plateau, analysis of ecological carrying capacity of the villages in a small scale will give the guideline for villages' movement and integration. In addition, analysis of ecological carrying capacity of village level can be used as a scientific basis for development of Tableland village itself.

3.3.1 Guideline about the relocation and combination of Tableland villages

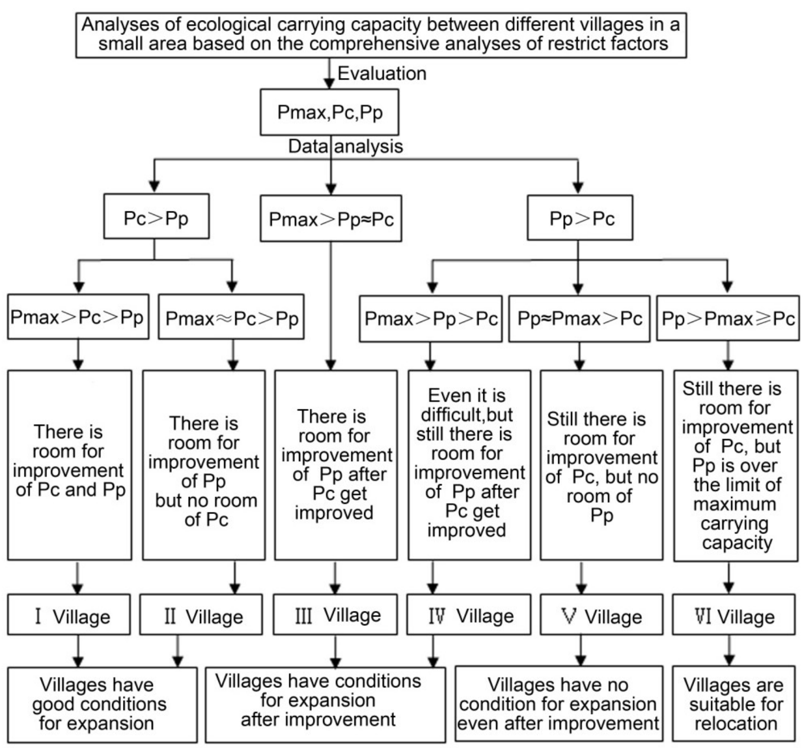


Figure 3.8 Tableland village grades according to the ecological carrying capacity

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 the unnecessary waste of natural resource in the 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 (P_{max}) of the villages in the research areas, the current ecological carrying capacity (P_c) and current supporting population (P_p). 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, the Tableland villages' grades can be fixed Figure 3.8.

According to the ecological carrying capacity, the Tableland villages can be divided into six grades. Type Ⅰ is suitable to be extension and TypeⅥ 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 (TypeⅥ 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, Ⅴand 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 the gully regions of Loess Plateau, strengthens the rural spiritual civilization construction. During the village movement, the village consanguinity, geopolitical and industry relationship should be protected, and traditional culture should be carried forward.

(5) Expanding the 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.

3.3.2 Guideline about the overall planning of Tableland village

During the movement and integration of village, the integrated village human settlements environmental developing directions should be put into consideration. If the village scale should be boarded, the relationship between human and land should be carefully deal with, and make sure the harmoniously development. According to the analysis of ecological carrying capacity, the villages' natural resources and social resource distribution can be generally mastered, which can be used as the scientific basis for reasonable use village resource and avoid unplanned construction.

For the problems existed in the planning of human settlement environment in gully regions of Loess Plateau, the following parts should be paid attentions:

(1) The population should be controlled according to the whole villages' ecological carrying capacity levels, to make sure the basis for village human settlements construction. Reasonable population, on the one hand, shows the respect for ecological environment, prevents the destroy of forest resource and grassland resource, and reduces ecological pressure; on the other hand, making sure the improvement of natural resource and social resource is the basis for improving human settlement environment. Currently, the population has already near the threshold of current ecological carrying capacity, so it should improve the current ecological carrying capacity by the improvement of infrastructure, workforce and financial investment.

(2) With the extension the small-scale villages, the priority construction areas can be fixed by the analysis of ecological carrying capacity distribution. Give the priority to develop those areas owns higher ecological carrying capacity that can efficiently save social resource and avoid the unnecessary basic infrastructure construction. When the priority developing areas cannot meet the requirements of the newly-immigrated population, the next grade areas can be put into consideration, this process should be continuous to the time that the whole village population nears the threshold of current ecological carrying capacity.

The priority areas can be fixed by the comprehensive analysis of current ecological carrying capacity distribution map. According to the water resource and infrastructure carrying capacity distribution, the village ecological carrying capacity can be divided into six grades, also the relationship between water resource and infrastructure carrying capacity can be fixed. The series for development can be roughly fixed, and the rules are shown as follows:

1) At the start point of development, the areas with higher comprehensive ecological carrying capacity, the ecological carrying capacity of water resource and infrastructure are near, these areas should be put into priority (on the map, the area with lower color lightness , tend to be gray and saturation is low). This kind of development owns higher economic and ecological benefits.

2) The development cost and construction period should be put into consideration to fix the next developing land. It is not true that the higher level of comprehensive ecological carrying capacity should be put into priority development and lower level in the end. In the practical process, there are more factors to be considered, such as some area the ecological carrying capacity is high but infrastructure is very low (on the map, color lightness is low, and tend to be blue, and saturation is high), some other area, the ecological carrying capacity is in medium grade, but the water and infrastructure carrying capacity is near (on the map, color lightness is medium, the color tends to be gray and saturation is related low.) According to the related department budget and research, the latter area owns lower developing cost and short construction period; it should be put in the second developing areas.

3) The last developing area or low ecological carrying capacity areas. The development of these areas needs large cost and it is hard to be developed. Thus, it is good for saving social resource to avoid such kind area to be developed.

(3) If the extension area is large, the ecological carrying capacity levels should be put into consideration when decided the land, the choice of land should base on the rule of saving resource. Rural water conservancy facilities and infrastructures are usually distributed along roads that mean the villages along roads usually own higher ecological carrying capacity. When do the extension of villages, intense development of priority area along roads may cause the same outlook for all the villages, and it is not good for improving villages' living environment. Under this situation, the villages with less developing cost and more economic and ecological benefits should be intensively developed.

(4) Take the advantages of centralized planning villages as reference; make the best use of the advantages and bypass the disadvantages. Because of the shortage of distribution analysis of ecological carrying capacity, blindly pursuit the centralized usage of land and resource Figure 3.9, it causes the common phenomenon that all the villages come to be the same outlooks. Base on the analysis of ecological carrying capacity, the fully understand of its distribution can help to construct villages, which actually is not the total negate the centralized distribution before.

(a) Xiaozhai village in Qianyang County

(b) Longquansi village in Qianyang County

(c) Wangjia village in Qianyang County

(d) Sipo village in Qianyang County

Figure 3.9 The single outlook of villages because of centralized village layout

Restricted by the factors, such as history, conception, policy, there are many problems in the process of villages' construction. Usually, village scale is small and living pattern dispersed and village houses are built in random, the investment in infrastructure is not enough, the houses functions are single, the construction are simple, and layout is dispersion. There are serious land and resource waste; the limited social funds cannot be used fully. All of these slow down the improvement speed of villagers living quality and new rural construction. In the area that owns high ecological carrying capacity, the centralized construction not only can save energy, but also can be the public central area for the village, supply public area for villagers to do social activities and communication with each other.

(5) Improve village infrastructure construction and the ecological carrying capacity of these infrastructures. In order to make the new rural construction can improve people's living quality, the

socialist rural construction needs to be development of productivity, make people's life rich, local custom development, clean and tidy villages and democrat management. To make sure the real development of productivity and make people's life rich, the infrastructure must be improved, which is the necessary conditions for the economic development and the guarantee for improving villagers' living quality.

3.4 Summary

In order to use the analysis of ecological carrying capacity into the villages' movement and integration planning within small areas, this chapter 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.

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 chapter supply here as planning guideline for the future villages' movement and integration in the gully regions of Loess Plateau.

CHAPTER 4
CASE STUDY OF ANALYSIS OF ECOLOGICAL CARRYING CAPACITY USED IN TABLELAND VILLAGE PLANNING

4 Case study of analysis of ecological carrying capacity used in Tableland village planning

Qin He town in Chun Hua County of Shaanxi Province located in An Zi tableland, which is the smallest tableland area in Weibei gully region of Loess Plateau, and the landscape there is relatively complex Figure 4.1. This tableland area is located in the middle of Ya Zi gully and Zhi Yu gully of Chun Hua County in Xian Yang City, Qin He town is one of the typical towns there and owns typicality and reasonability. One the one hand, the landscape there is complex, including almost all the landscape characteristics of gully regions in Loess Plateau, villages in this research areas owns significant difference for their ecological carrying capacity, and some of them need to be moved or integrated during the new countryside construction. On the other hand, using administration town, as research unit is easy to collect data and good for the adaptation of analysis results, owns high operability.

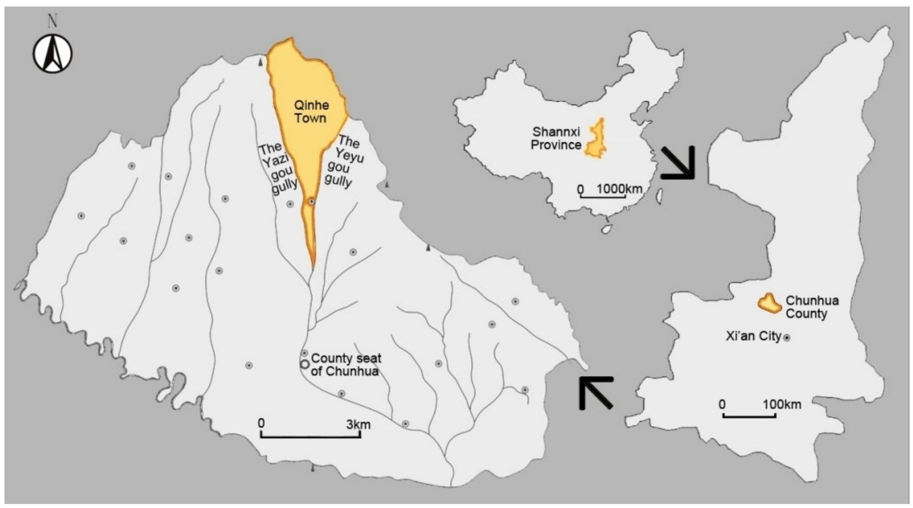


Figure 4.1 Location of Qin He town

4.1 Research on typical villages relocation and combination of Qin He town, Chun Hua County

4.1.1 Overview and research area selection in Qin He town

Qin He town owns complex landscape with lag economic development, which located in the north of Chun Hua County. Town government is located in Qin He village, which is 13km far away from the county. There are 14 incorporated villages, including two county-levels demonstration villages, 70 unincorporated villages, 1916 families, 8228 people, and the total area is about 136.8 square kilometers and the cultivable land is about 28556 Mu [59].

(1) Landscape

The south areas of Qin He town belong to Loess Plateau, middle and north belongs to slope area, the north edge belongs to mountain area. The tableland is fragmented landform with high and low slope, the gully is deep and the density of gully is 2.31 kilometers per square kilometers. The landscape is not good, but with lots different combination with light, heat and water, owns special potentials.

(2) Population statistic, cultivable land and benefits distribution

The document about population structure, cultivable area, and benefits distribution Table 4.1 were collected from the departments of Qin He town government. These documents can be used to do the perimeter analysis ecological carrying capacity and do the selection of certain research areas.

Table 4.1 Population components, cultivable land area, and benefits distribution in Qin He town, 2004

Village name	Population				Total cultivable land (Mu)	Cultivable land per capita (Mu)	Total value of industry, agriculture (10,000 Yuan)	Income per capita (Yuan)
	Family (No.)	Total population (No.)	Agriculture population (No.)	Non-agriculture population (No.)				
Gao Ai Tou	58	222	218	4	840	3.784	636	6267
Qin Po	96	408	405	3	1599	3.919	1508	8023
Qian Bai Fu	85	400	396	4	2703	6.758	1011	5497
Hou Bai Fu	71	270	266	4	1560	5.778	515	4168
Bei Po	225	882	880	2	4631	5.251	2264	5548
Tao Yuan	167	758	755	3	3962	5.227	2093	5977
Qin He	178	940	686	254	3208	3.413	1926	6053
Nan Ping	169	689	683	6	2266	3.289	1772	5880
Qin Wa	163	689	684	5	2956	4.290	1499	4725
Tao He	169	663	660	3	2002	3.020	1735	5672
Pan Jia Ao	158	668	662	6	3168	4.743	1322	4306
An Zi Wa	176	838	635	203	2732	3.260	1304	4427
Dong Yuan	105	408	406	2	1004	2.461	708	4109
Zhou Shan	124	419	418	1	2292	5.770	770	3968
Total	1944	8254	7754	500	34923	4231	18560	5313

(3) Analysis of carrying capacity of cultivable land in villages and choose the typical research area

According to the cultivable land per capita in gully regions of Loess Plateau, in 2004, the per capita cultivable land is about 3.43mu (0.229 hm^2). In 2020, it will change into 3.25mu (0.217 hm^2) Table 3.5.

The primary ecological carrying capacity analysis can be done from the analysis of cultivable land Figure 4.2, Dong Yuan village, An Zi Wa village, Tao He village, Nan Ping village and Qin He village, the cultivable land per capita in these five villages are not enough.

The selection of research area should own all the different ecological carrying capacity Tableland villages in gully regions of Loess Plateau. Thus, Tao He village, Qin Wa village, Qin He village and Tao Yuan village and their surrounding areas can be selected as typical research and analysis area Figure 4.3. The reason for choosing these areas and moving or integrating villages there, on the one hand, is because these several villages are close to each other, on the other hand, the ecological carrying capacity there is low and need to be moved, also the relatively higher ecological carrying capacity villages should be integrated.

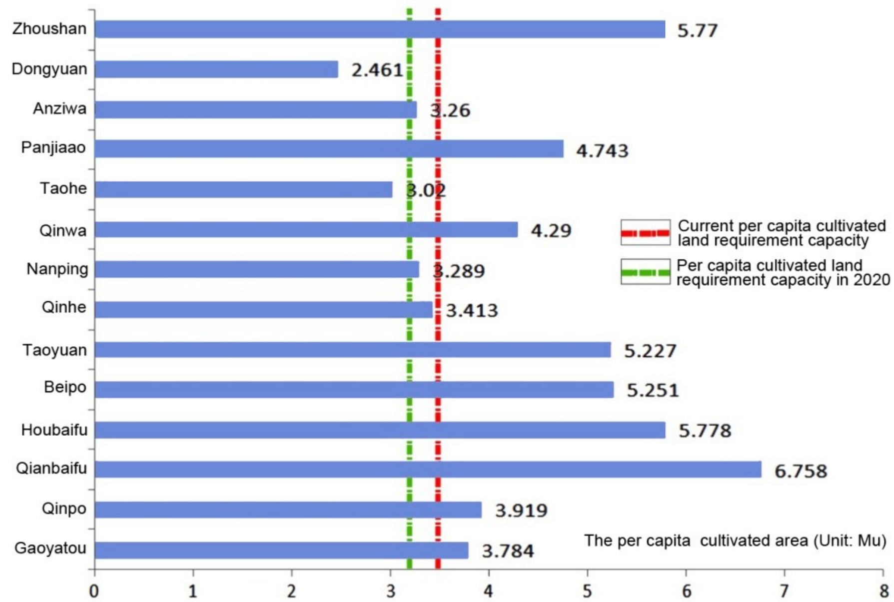


Figure 4.2 Analysis of carrying capacity of cultivable land in each village of Qin He Town

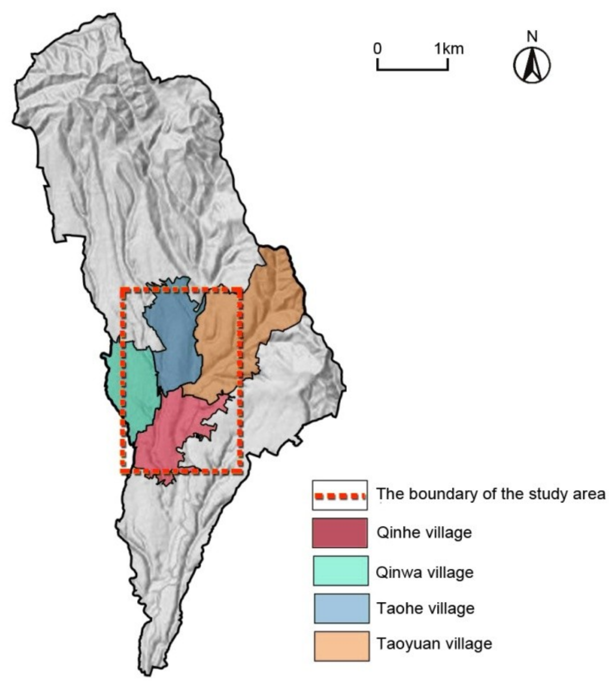


Figure 4.3 Selection of research area in Qin He Town

4.1.2 Present situation of human settlement environmental construction in the typical research area

The selection area is located in the middle of Qin He town with typical landscape of gully region in Loess Plateau Figure 4.4, there are eight Tableland villages, the population is less than 800 people expect Qin He village, all of them are small-scale villages Figure 4.5. Qin He village is the town government's location and Tao Qu Yuan village is a tourist area.

Figure 4.4 Landscape of typical research area

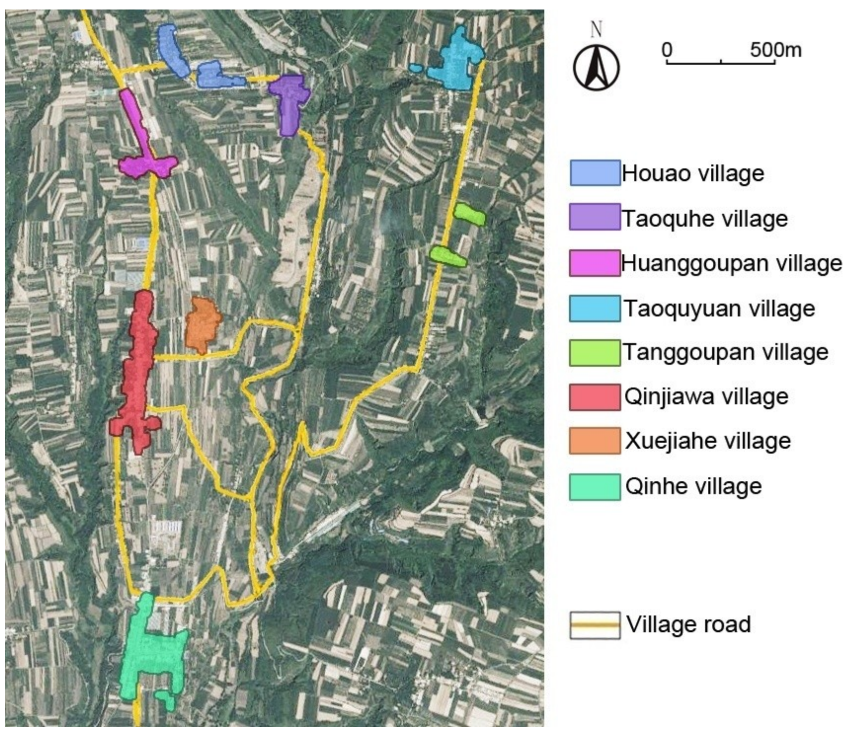


Figure 4.5 Space distribution of Tableland villages in typical research area

According to field investigation of the eight villages, the basic information about present human settlement environment can be showed as following:

(1) Economic developing level

The economic conditions in villages of the research area are not good, the agricultural people income per month is less than 4000 RMB (615USD). Except for Qin He village, it is the location of town government, some of the villagers can do business, and Tao Qu Yuan village is a tourist village, others all depend on agriculture.

(2) Situation about cultivable land resources in villages

According to the documents supplied by Chun Hua Land Resources Bureau, cultivable land per capita is very different in each village. The cultivable land in Tao Qu Yuan village and Qin Jia Wa village are much more than current cultivable land per capita in Loess Plateau, but it is much less in Tao Qu He village and Huang Gou Pan village. Because of recent national policy about returning the grain land to forestry, most of the cultivable lands are centralized in tablelands, and some on gully slopes.

(3) Water resource situation

Water shortage is a common phenomenon in Tableland villages of gully region, agricultural water shortage is very serious in this area, and most cultivable land is dry land, just some land at the bottom of gully owns water to irrigation. Besides this, the water infrastructure is serious in shortage. It is found that local villagers' water usage is just about 30 L. In the new countryside planning 2006, Qin He village is supposed to have the water supply for 150L per day, but it is still not achieved, and compared with urban water usage 209 L per day, the village water usage is very low. Most of this area water is supplied by artificial pump wells that just can meet the demand for people's living water need.

The aim of new countryside construction is to improve people's living standards, the water usage volume cannot designed by the lowest water consume per capita, while the improved living standards will have more water need, that should be the design basis. Therefore, in the research area, the water supply equipment cannot meet the demand for new countryside construction now.

(4) Infrastructure situation

The infrastructure in research area is backward. The energy supply is not enough, the basic electricity is enough, but gas and energy infrastructure is not enough, and fuel oil infrastructure is seriously lacking. The transportation system is relatively good and can meet the requirements of the villagers' common life. There are usually 18cm thick concrete roads and the width is from four meters to six meters Figure 4.6. Communication facilities is not good, there are no post and telecommunication service sites. Besides the quality examination site for agricultural products, there is no industry facility in these research areas. Living and ecological infrastructure are serious in shortage.

Figure 4.6 Present situation about roads in typical research areas

(5) Present situation about village planning and vernacular dwelling construction

There are no hollow villages among the eight investigated villages; only a few villagers are working in town, but still living in their houses of village. Around 70% vernacular dwellings are newly built and the traditional caving dwellings are almost abandoned, just a few are left for storage space. The existing adobe houses are less than 30% in the vernacular dwelling. The newly built residential buildings are almost one-storey brick houses and facades of new houses are almost same. The cost of a new brick vernacular dwelling is about 65,000 RMB (10000USD) Figure 4.7.

(a) Abandoned cave dwelling

(b) Existing immature soil house

(c) Old brick houses

(d) Newly-built brick houses

Figure 4.7 Present situation of human settlement in typical research areas

According to the interview of town governmental leader, most of the current villages' development in Qin He town is natural without special planning. Tao Qu He village and Tang Gou Pan village are the only two villages planned by county planning bureau. For Qin He village and Tao Yu Yuan village, there were some planning before, but it did not carry out for the shortage of funds about eight years.

4.1.3 Evaluation of ecological carrying capacity of each village based on restrict factors

The aim of ecological carrying capacity analysis is trying to use the results in the future human settlements planning. Because of the timeliness of planning work, the analysis should be put in certain period in the future; the new countryside planning in this county is mainly in 2015 or 2020. Actually, because of the low population increasing rate and small population in this area, the population growth to 2020 can be neglected. There are no relative statistics data in the local government, all the data used to analyze ecological carrying capacity is through the field investigation and interview with local villagers and villages' leaders. Thus there will be some errors, but for the rough analysis of ecological carrying capacity still is very useful.

(1)Analysis of the carrying capacity of cultivable land in the villages within research areas

Before analysis the carrying capacity of cultivable land, it needs to know the needed cultivable land per capita. According to requirement of cultivable land per capita in Loess Plateau, the current needed land per capita is about 3.435 mu (0.229 hectares), and in 2020 year, it will be 3.255 mu (0.217 hectares), the cultivable land here refers to the land for producing grains and vegetables.

Table 4.2 Current population, cultivable land areas and the supporting population in research areas

Villages	Current population (No.)	Real cultivable land area (mu)	Real needed cultivable land per capita (mu)	Current support population by cultivable land (No.)	2020 year, the cultivable land support population (No.)
Qin He village	876	2483	2.83	723	763
Qin Jia Wa village	402	1266	3.15	369	389
Fan Jia Ping village	155	547	3.53	159	168
Tang Gou Pan village	146	483	3.31	141	148
Huang Gou Pan village	207	526	2.54	153	162
Tao Yu He village	374	935	2.50	272	287
Tao Yu Yuan village	508	2550	5.02	742	783
Hou Ao village	187	647	3.46	188	199
Total	2855	9437	3.31	2747	2899

Combing the statistic results of current population and cultivable land and the needed cultivable land per capita in 2020, the population that cultivable land can support in 2020 can be estimated Table 4.2. Actually, the current needed cultivable land per capita and 2020 are different, so the carrying capacity of cultivable land will change even in the same total cultivable land areas.

The results of Table 4.2 show the cultivable land carrying capacity in current and 2020 Figure 4.8. If the current population is lower than the cultivable land carrying capacity, it means that this village has the ability to support more population. If the current population is over the cultivable land carrying capacity, it means the cultivable land cannot ensure good living quality for current residents.

The cultivable land is unchanged restrict factors, and it directly decides the maximum ecological carrying capacity. The threshold value can be known by the analysis of cultivable land carrying capacity, and the population threshold value is a very important reference value of making the decision on village movement and integration.

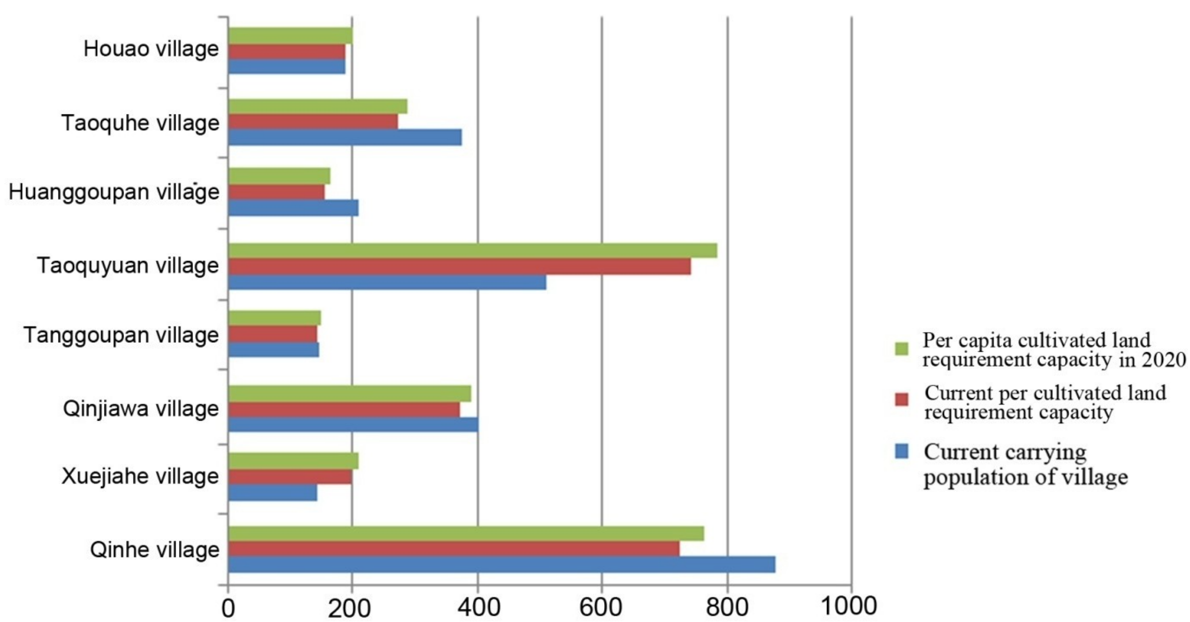


Figure 4.8 Current and 2020, cultivable land carrying capacity of the villages

The above figure shows that the actual population in Qin He village, Tao Yu He Village, and Huang Gou Pan are far over the cultivable land carrying capacity, and Tao Qu Yuan Village and Xue Jia He Village still can support more population.

(2) Analysis of carrying capacity of water resource in the villages within research areas

Water demand per capita should be put into priority when doing the analyses of water resource carrying capacity, which cannot be the same standard as safety water usage per capita in villages. In order to improve villagers' living standards and further improve its urban-rural integration, the rural living conditions should be close to urban areas after planning, and the urban water consume volume per capita per day 209 L in Shaanxi Province was designed as reference.

Through the site investigation of eight villages about their water usage in productivity and living, the water resource carrying capacities of these villages are shown in Table 4.3. Because the structure of rural undertaking here is relatively single, the production water consumed can be neglected and the living water consumed is almost the only one that needs to be analyzed in the carrying capacity analyses. In the investigation, it found some villages are separate water supply, and some villages are union village centralized water supply. The water supply volume of each village (W_n) is designed by pumped wells (W_d) and the support population（$P_1+P_2+\cdots+P_n+\cdots+P_m$）and the research village population (P_n): $W_n= W_d / (P_1+P_2+\cdots+P_n+\cdots+P_m) \bullet P_n$.

Table 4.3 Statistics about water supply situation of villages within research areas

Villages	Current population (No.)	Current water supply volume (L)	Ways of living water supply	Actual water demand volume (L)	Water quality	Water resource carrying capacity (No.)
Hou Ao	187	28000	Centralized	39083	Standard	134
Tao Qu He	374	48600	Centralized	78166	Standard	233
Huang Gou Pan	207	31000	Centralized	43263	Standard	148
Tao Qu Yuan	508	167600	Separated	106172	Worse	802
Tang Gou Pan	146	32100	Centralized	30514	Standard	154
Qin Jia Wa	402	112600	Centralized	84018	Fine Standard	539
Xue Jia He	143	40000	Centralized	29887	Standard	191
Qin He	876	131400	Centralized	183084	Good	629
Total	2843	591300		615087		2829

According to the water usage volume per capita in urban area of Shannxi Province, and combined with Table 4.3, Figure 4.9 shows the water resource carrying capacity in villages within research areas. The water resource carrying capacity of Tao Yu Yuan village, Qin Jia Wa village and Xue Jia He village, is far beyond its current population, while other villages are lack of water supply, for example, the population in Qin He village and Tao Yu He village is much more that its water carrying capacity.

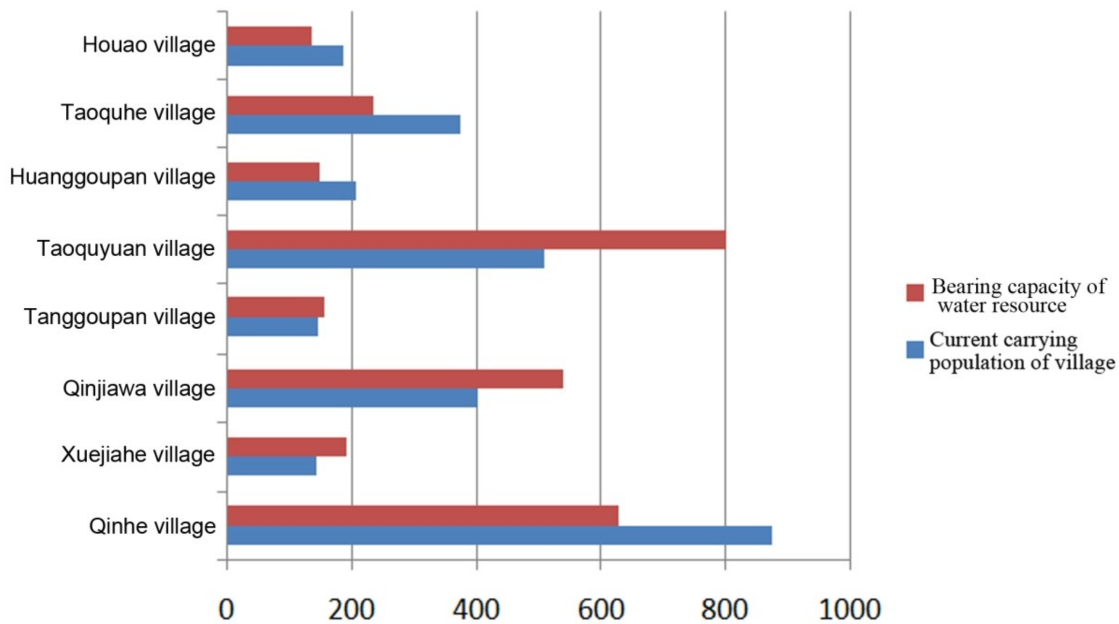


Figure 4.9 Evaluation on carrying capacity of water resource in the villages

(3) Analysis of carrying capacity of infrastructure in the villages within research areas

Compared with cultivable land and water resource, infrastructure is difficult to do the quantitative analysis. It is a research gap to analyze the carrying capacity in domestic research field. There is not a complete and series evaluation system to calculate its supporting population. Because the population is less than 800, it is hard to grade the infrastructure carrying capacity by public service infrastructure grades evaluation table.

Table 4.4 Public service infrastructure situation in the villages

Villages	Clinic	Service center	Old people center	Shops	Kindergarten	Primary school	Market	Nursing home
Hou Ao	—	—	—	●	—	—	—	—
Tao Qu He	●	●	●	●	—	—	—	—
Huang GouPan	●	●	—	●	—	—	—	—
Tao Qu Yuan	●	●	—	●	—	—	—	—
Tang Gou Pan	●	●	—	●	—	—	—	—
Qin Jia Wa	●	●	—	●	—	—	—	—
Xue Jia He		●	—	●	—	—	—	—
Qin He	●	●	—	●	●	●	—	●

In this research, the carrying capacity of village infrastructure is graded by public infrastructure supporting facilities Table 4.4.and village infrastructure classification table. Through site investigation, the relationship infrastructure construction situation and its supporting population can be calculated and the carrying capacity can be roughly evaluated. Table 4.5, Table 4.6, Table 4.7, Table 4.8 are about public infrastructures, which can be drew combined with basic infrastructure classification (productivity infrastructure, living infrastructure and ecological infrastructure).

Table 4.5 Situation about roads and bridges in the villages

Villages	Width of main road	Surface of main road	Width of branch road	Surface of branch road	Satisfaction degree on roads	Parking area	Bridge
Hou Ao	4 M	Cement concrete pavement	—	—	General	No	No
Tao Qu	6 M	Cement concrete pavement	4 M	Cement concrete pavement	Good	One parking lot for 20 cars	No
Huang Gou Pan	6 M	Cement concrete pavement	4 M	Cement concrete pavement	Good	One parking lot for 10 cars	No
Tao Qu Yuan	12 M	Cement concrete pavement	4 M	Cement concrete pavement	Good	Two parking lot for 50 cars	No
Tang Gou Pan	6 M	Cement concrete pavement	4 M	Cement concrete pavement	Good	No	No
Qin Jia Wa	4 M	Cement concrete pavement	2.5 M	Soil surface pavement	General	No	One bridge
Xue Jia He	4 M	Cement concrete pavement	—	—	General	No	No
Qin He	24 M	Cement concrete pavement	12 M	Cement concrete pavement	Very good	No	No

Table 4.6 Situation about drainage projects in the villages

Villages	Water supply volume	Water supply pressure	Water supply methods	Water towers	Disperse drainage or not	Rain water drainage	Living waste water treatment
Hou Ao	General	General	Centralized	No	Yes	Concreted ditch	No
Tao Qu He	Tension	General	Centralized	Yes	Yes	Concreted ditch	No
Huang Gou Pan	General	General	Centralized	No	Yes	Concreted ditch	No
Tao Qu Yuan	Adequacy	intensity	Separate	Yes	No	Concreted canal	No
Tang Gou Pan	General	General	Centralized	No	Yes	Concreted canal	No
Qin Jia Wa	Adequacy	intensity	Centralized	No	Yes	Concreted ditch	No
Xue Jia He	Adequacy	intensity	Centralized	No	Yes	Concreted ditch	No
Qin He	Tension	General	Centralized	No	No	Concreted canal	Pipes collection

Table 4.7 Situation about waste collection in the villages

Villages	Waste collected intensively or not	Separating treatment or not	One waste collection site can meet the demand of 30 family or not	Times of collection	Landfill or not	Different waste treatment methods
Hou Ao	Yes	No	No	Once three weeks	No	Incineration
Tao Qu He	Yes	No	Yes	Once two weeks	Yes	Landfill
Huang Gou Pan	Yes	No	No	Once three weeks	No	Incineration
Tao Qu Yuan	Yes	No	No	Once two weeks	No	Landfill
Tang Gou Pan	Yes	No	Yes	Once three weeks	No	Composing
Qin Jia Wa	Yes	No	No	Once three weeks	No	Incineration
Xue Jia He	Yes	No	Yes	Once three weeks	No	Landfill
Qin He	Yes	No	Yes	Once one weeks	Yes	Landfill

Table 4.8 Situation about other infrastructures

Villages	Indoor or outdoor toilet	Toilet types	Have septic tank or not	Major energy	Popularizing rate of solar energy	Culture heritage
Hou Ao	A majority of Indoor	A majority of dry toilet	No	Coal	15%	No
Tao Qu He	A majority of Indoor	A majority of dry toilet	No	Coal	15%	No
Huang Gou Pan	A majority of Indoor	A majority of flush toilet	No	Coal	30%	No
Tao Qu Yuan	A majority of Outdoor	A majority of dry toilet	No	Coal	20%	City level heritage
Tang Gou Pan	A majority of Outdoor	A majority of dry toilet	No	Coal	10%	No
Qin Jia Wa	A majority of Outdoor	A majority of dry toilet	No	Coal	10%	No
Xue Jia He	A majority of Indoor	A majority of dry toilet	No	Coal	10%	No
Qin He	A majority of Indoor	A majority of flush toilet	No	Coal	30%	No

Although the villages' infrastructure carrying capacity cannot be calculated accurately by the investigation and interview in villages within research areas, the developing levels of villages' infrastructure can be divided into six grades, the higher the grade means the better of infrastructure Figure 4.10. These research results can be used as valuable reference for analysis of village movement and integration.

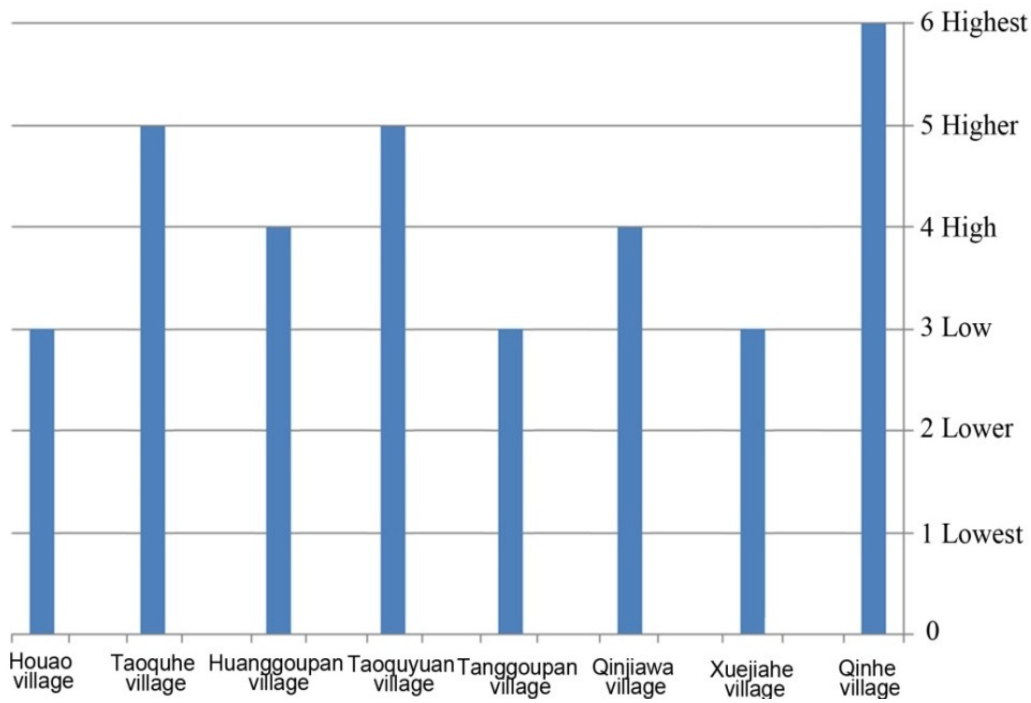


Figure 4.10 Evaluation on carrying capacity of infrastructure construction in the villages

(4) Analysis of ecological carrying capacity of villages within research area based on restrict factors

Figure 4.11 shows the results of analysis of cultivable land, water resource carrying capacity and infrastructure; it can be used to conclude the ecological carrying capacity situation of villages within research areas. Cultivable land, as one of restricts factors, is hard to be changed and have the direct influence on villages' maximum ecological carrying capacity. Between cultivable land and water resource carrying capacity, the smaller value is the current ecological carrying capacity value. The infrastructure carrying capacity cannot be qualified analyzed, thus it can be used as a reference base for planning the village movement or integration. Because of the timeliness of planning, cultivable land carrying capacity is calculated by the land demand per capita in 2020, and water resource carrying capacity is based on the water consume volume per capita in urban areas of Shaanxi Province.

According to the analysis results of ecological carrying capacity based on restricting factors in villages within research areas, the relationship among maximum ecological carrying capacity (P_{max}), current ecological carrying capacity (P_c) and current supporting population (P_p), can be figured out, thus it can be used as basic reference to analyze village population distribution in the future village construction and planning.

In Figure 4.11, red line (maximum ecological carrying capacity) is decided by village cultivable land, shows the future population threshold value. The green line (current ecological carrying capacity) refers to the current ecological carrying capacity levels. The blue line (current population) refers to the current villages' population.

The relationship between the red line and green line shows that there are improved space for villages' ecological carrying capacity or not. The relationship between the red line and blue line shows the threshold value and that population has already exceeded its ecological carrying capacity. The relationship between green line and blue line shows how much current population over its ecological carrying capacity.

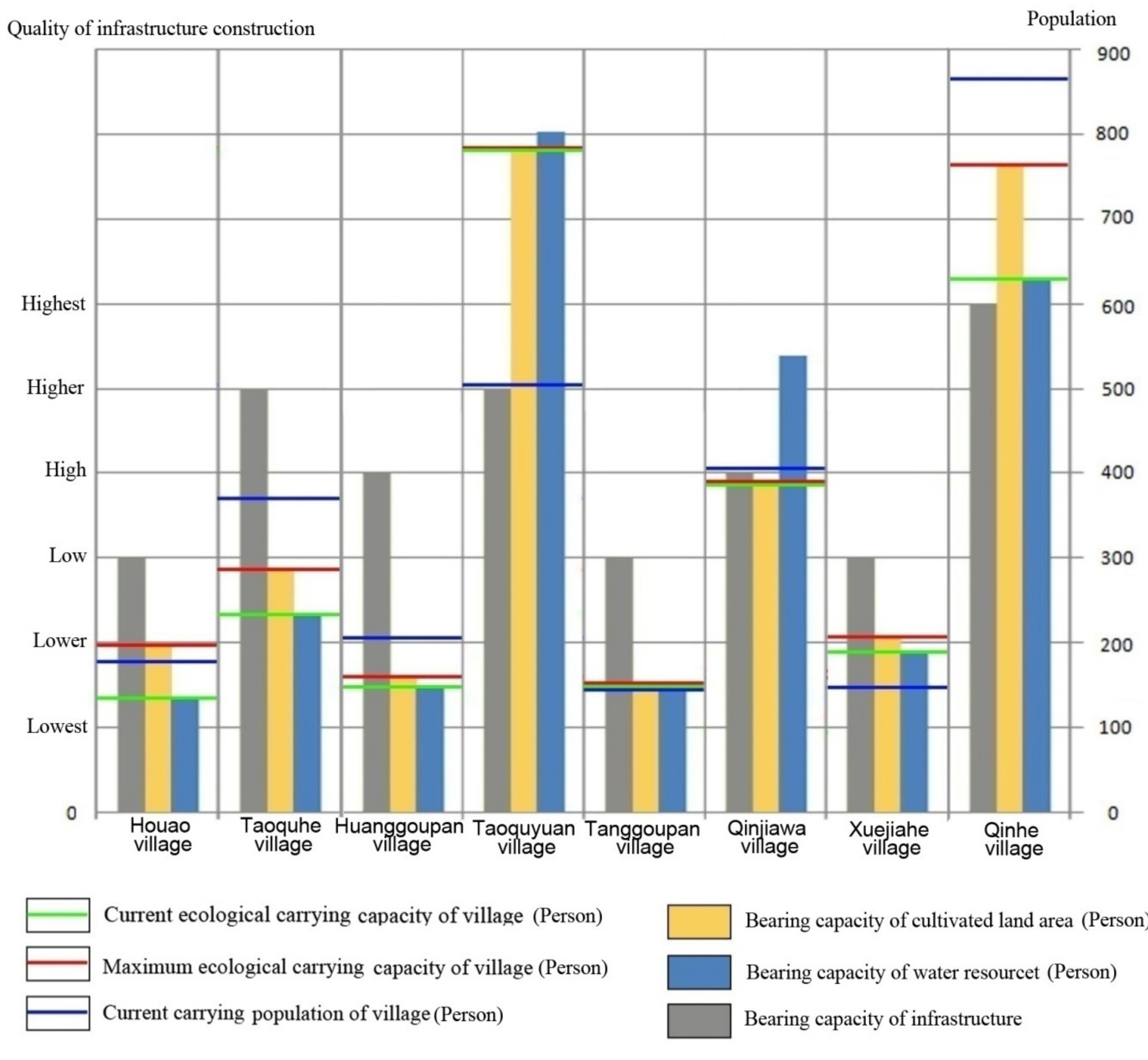


Figure 4.11 Ecological carrying capacity situation based on restrict factors

4.1.4 Rationality analysis of population distribution in typical villages

Through the analysis of ecological carrying capacity, the rationality of each village's ecological carrying capacity and their supporting population is shown in Table 4.9. The population in Qin He village, Huang Gou Pan Village and Tao Qu He village are far over their carrying capacity, thus the population there is not reasonable. The population scale still owns improving space in Tao Qu Yuan village and Xue Jia He village. For Hou Ao village, if it still hopes to keep the current population scale, the current water supply infrastructure should improve to increase its current ecological carrying capacity value. The population in Tang Gou Pan Village is relatively reasonable, but has already reached " saturation.

Table 4.9 Analysis of ecological carrying capacity and population scale

Villages	Relationship among P_{max}、P_c and P_p	Rationality analysis on population
Hou Ao	$P_{max} > P_p > P_c$	Current population is less than the maximum ecological carrying capacity, but the low carrying capacity, if need to increase the population, the current ecological carrying capacity should be improved firstly.
Tao Qu He	$P_p > P_{max} > P_c$	Current population is far over its ecological carrying capacity threshold, too much population
Huang Gou Pan	$P_p > P_{max} > P_c$	Current population is far over its ecological carrying capacity threshold, too much population
Tao Qu Yuan	$P_{max} \approx P_c > P_p$	Current supporting population is much less than current ecological carrying capacity, and current ecological carrying capacity is near the maximum , thus there are big space for enlarge the population.
Tang Gou Pan	$P_{max} \approx P_c > P_p$	Current population is little bit less than current ecological carrying capacity, and current ecological carrying capacity is near the maximum, thus the population is reasonable.
Qin Jia Wa	$P_p \approx P_{max} = P_c$	Current population is little bit over the maximum ecological carrying capacity, and the population has reached "saturation".
Xue Jia He	$P_{max} > P_c > P_p$	Current population is less than current ecological carrying capacity, and current ecological carrying capacity still can be improved, thus the population can be suitably increased.
Qin He	$P_p > P_{max} > P_c$	Current population is far over the maximum ecological carrying capacity, and the population is too much

4.1.5 Village relocation and combination based on the analysis of ecological carrying capacity

The aim of ecological carrying capacity analysis is to give the guideline for the future development of rural human settlement. Firstly, villages should be graded by their maximum ecological carrying capacity, current ecological capacity and current supporting population. Secondly, the suitability of movement or integration should be decided by the villages' grades. Finally, if village movement is necessary, the whole village movement or parts movement, and where to move, all these should be put into consideration Table 4.10.

If the difference between maximum ecological carrying capacity and current supporting population (P_{max}–P_p) is positive value, it means that the population has the possibility to be increased. If it is negative value, it means that the village population should be decreased. The difference between maximum ecological carrying capacity and current carrying capacity (P_{max}–P_c) is positive value, which means that there is possibility for improvement of current ecological carrying capacity. If the value is zero, it means there is no space for improving the current ecological carrying capacity. The difference between current ecological carrying capacity and current population (P_c–P_p) is positive value means there is increasing space of current population. If the value is negative, it means the population must be moved to other villages.

Table 4.10 Analysis of the suitability of village relocation and combination

Villages	Relationship among P_{max}、P_c and P_p	Construction grades	P_{max} - P_p (No.)	P_{max} - P_c (No.)	P_c - P_p (No.)
Hou Ao	$P_{max} > P_p > P_c$	Ⅳ	12	65	-53
Tao Qu He	$P_p > P_{max} > P_c$	Ⅵ	-87	54	-141
Huang Gou Pan	$P_p > P_{max} > P_c$	Ⅵ	-45	14	-59
Tao Qu Yuan	$P_{max} = P_c > P_p$	Ⅱ	275	0	275
Tang Gou Pan	$P_{max} = P_c > P_p$	Ⅱ	2	0	2
Qin Jia Wa	$P_p \approx P_{max} = P_c$	Ⅴ	-13	0	-13
Xue Jia He	$P_{max} > P_c > P_p$	Ⅰ	65	17	48
Hou Ao	$P_p > P_{max} > P_c$	Ⅵ	-113	134	-247

Combining the analysis of villages' suitability for movement or integration with their infrastructure situation, it can give the suggestions for village movement and integration Table 4.11.

After the comprehensive analysis, Tao Qu Yuan village can integrate with other villages to enlarge its population. On the one hand, it can release the pressure of other villages. In the other hand, the centralized society resource can improve local people living conditions, and city level tourist resource should be explored. Parts of population in Tao Qu He village and Huang Gou Pan Village should be moved to improve the village living conditions. Xue Jia He village can ignore the immigrated population that can release the nearby village for their population pressure. Qin He village , Tao Qu He village and Hou Ao village need to establish new water supply infrastructure to increase their water carrying capacity, thus to further improve local peoples' living quality.

Table 4.11 Suggestions about villages' future development

Villages	Analysis of ecological carrying capacity	Evaluation of infrastructure	Marks	Suggestions
Hou Ao	Current population beyond the current ecological carrying capacity. If the carrying capacity can be improved by increasing water resource, it will meet the demand of current population.	3	No	No need to movement; Population cannot be increased; Improve the supply water.
Tao Qu He	Current population is far beyond it ecological carrying capacity threshold value. If the carrying capacity can be improved, it still cannot support current population.	5	No	Appropriately move some parts of population and increase water supply.
Huang Gou Pan	Current population is over ecological carrying capacity threshold value, and the capacity can be improved.	4	No	Appropriately move some parts of population
Tao Qu Yuan	The ecological carrying capacity level is high and near to maximum, the supporting population can be increased.	5	Have city-level tourist resource	Appropriately enlarge population
Tang Gou Pan	Current population is near maximum capacity and current capacity	3	No	No need to move and increase population
Qin Jia Wa	Ecological carrying capacity level is relatively high and a little bit beyond the maximum capacity, that can support large population.	4	No	No need to move and increase population
Xue Jia He	Ecological carrying capacity level is relatively low, but still can support small parts of population	3	No	Increase small parts of population
Qin He	Ecological carrying capacity level is relatively high, but the supporting population is far beyond its capacity threshold. The difference between current ecological carrying capacity and current population can be less by improvement of water resource.	6	Town government is located there, and own part non-agriculture population.	Appropriately move some parts of population, and the water supply infrastructure should be improved.

4.2 Research on planning of human settlement environment of Tao Qu Yuan village in Qin He town

Through the analysis of ecological carrying capacity of each village in the typical research area in Qin He town, the comprehensive ecological carrying capacity of Tao Qu Yuan village is the highest, and the infrastructure is relatively good, there are also plenty travel resource, thus it is suitable to enlarge its population and integrate the surrounding low carrying capacity village. Facing the problem of population enlarge and village extension, how to use the current resources, reduce resources waste and improve human settlement environment by low investment, are the main research contents. The analysis of ecological carrying capacity based on restrict factors and draw the distribution on water resource and infrastructure, which can be used as guideline for future village development and planning.

4.2.1 Present human settlement environment in Tao Qu Yuan village

Tao Qu Yuan village of Qin He town located in the middle of Chun Hua county and 17 km from the town, covers an area about 3900 Mu (260 hm^2) Figure 4.12. In 2014, the agricultural population is about 500 people and average income per capita is about 3500 RMB. Tao Qu Yuan used to be an outguard and logistic base in Shaanxi-Gansu-Ningxia border region and famous for the war "Tao Qu Yuan Battle". During December 1936 to August 1937, the leader of Eighth Route Army, Deng Xiao Ping and the leader of First and Fifteenth Army, Nei Rong Zheng, Xu Hai Dong, and Liu Zhi Dan, Xi Zhong Xun, all lived and commanded the war there.

(a) North side bird's view of Tao Qu Yuan village (b) South side bird's view of Tao Qu Yuan village

Figure 4.12 Ecological carrying capacity situation based on restrict factors

Tao Qu Yuan village is lower from north to south, and the landscape is the typical gully region of Loess Plateau. The village owns very good views with gully and rivers surrounding. This village has the laudatory title of "revolutionary resort", which is good for developing tourism industry. In the report of Shaanxi Daily newspaper on July 5, 2010, Chun Hua County plans to develop it as a county rich in fruits productivity, tourism and ecology, and the original revolutionary place in Tao Qu Yuan village plan to establish a theme park, named "Ye Tai Shan Battle" park. After the site investigation by experts, this area was planned and rebuilt. Three million was invested in the establishment of this scenic spot, not only the old locust tree square, revolutionary museum, some sculptures were built and the original living rooms by the famous revolutionist, Deng Xiaoping, Xu Zhongxun and Yang Shangkun, also be rebuilt. What is more, observation deck, Ye Tai Shan Battle Museum, parking site and round mountain road and other infrastructure were also built. Around the revolutionary resort, green belt gradually finished and the revolutionary tourist area is about 15 km² and owns the functions of revolutionary history education, simulation about real battle and leisure service district, have already carried out Figure 4.13. Three village-scales farmhouse tourist spots were also built around the revolutionary resort, which attack lots of tourists come to there. They can receive revolutionary education at the same time; it will help local villager poverty alleviation. The original revolutionary place has been named "Patriotism education base in Xian Yang city," "Education base of party member in Xian Yang city," and "National defense education base".


(a) Original place of directorate in Ye Tai Shan Battle (b) Tao Qu Yuan Revolutionary museum


(c) Greening landscape in tourist resort (d) Architecture landscape in tourist resort

Figure 4.13 Present situations on revolutionary tourist spot in Tao Qu Yuan village

Most newly built houses are built on the original base. In order to fit the architectural style of tourist area, the facade is all redecorated. The main road owns good green belts and the drainage system is relatively good Figure 4.14.

(a) Main village road (b) Drainage ditch

(c) Road landscape in village (d) Center village landscape

Figure 4.14 Present situation of infrastructure in Tao Qu Yuan village

4.2.2 Analysis of space distribution of ecological carrying capacity

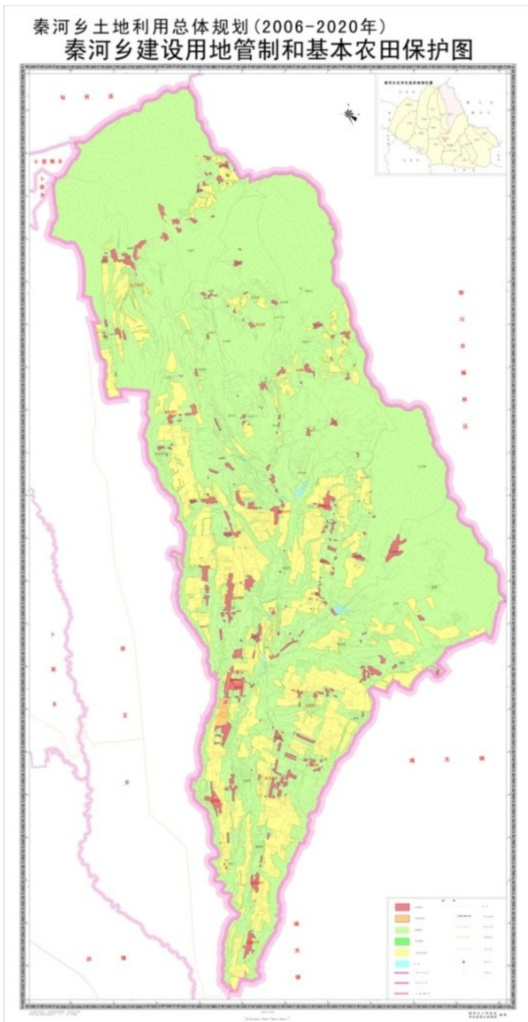
The analysis of ecological carrying capacity in typical villages of Qin He town supplies the basic data for the further analysis of carrying capacity in Tao Qu Yuan village. Further, the investigation on cultivable land, water resource and infrastructure can roughly analyze the space distribution of ecological carrying capacity.

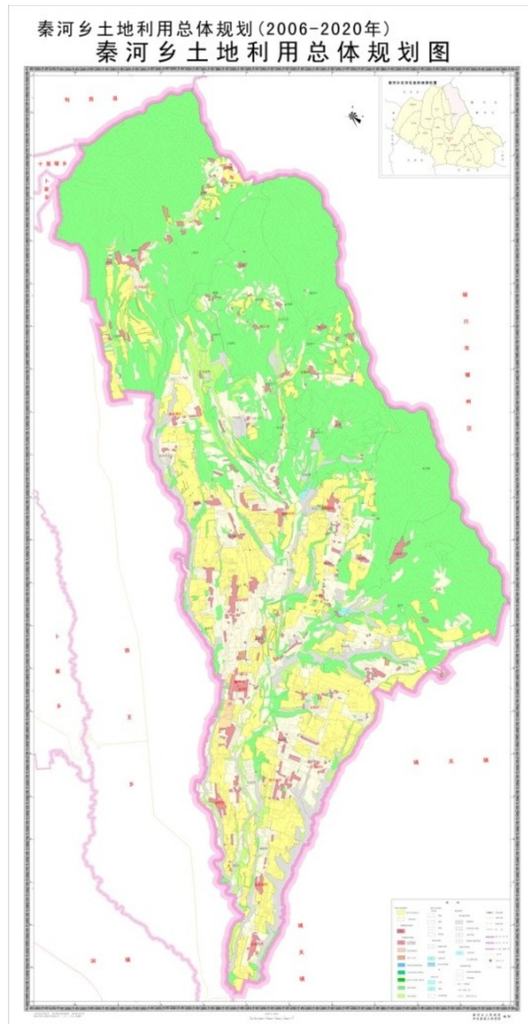
(1) Analysis of population in the future village development

The current residents in Tao Qu Yuan village is 168 families and 508 people, is a small-scale village. According to the ecological carrying capacity, the current carrying capacity is the maximum one, and more than 275 people can be supported. Therefore, the maximum immigrant is about 275 people. The planned maximum population is 783 in 2020, approximation can be 780.

(2) Drawing the distribution map for water resource carrying capacity

Before drawing the water and infrastructure distribution map, the protected cultivable land and unsuitable constructed areas that cannot be used as construction place and those suitable construction places should be figured out. According to "The management of construction land and basic cultivable land distribution map in Qin He town" and "Main planning map for different land usage in Qin He Town" in 2006—2020 Figure 4.15, combining the site investigation, the construction place and village construction the present map can be drawn Figure 4.16.





(a) (b)

Figure 4.15 (a) "The management of construction land and basic cultivable land distribution map in Qin He town" and (b) "Main planning map for different land usage in Qin He Town" in 2006—2020

(Source: Land Resources Bureau of Chun Hua County and Land Resources Office of Qin He Town)

Figure 4.16 Present construction situation and suitable construction places in Tao Qu Yuan village

In order to improve the accuracy, the size of village houses should be put into consideration. The suitable construction area can be divided by 20m X 20m Figure 4.17. The water resource and infrastructure carrying capacity distribution map can be drawn by the investigation of current water resource and infrastructure.

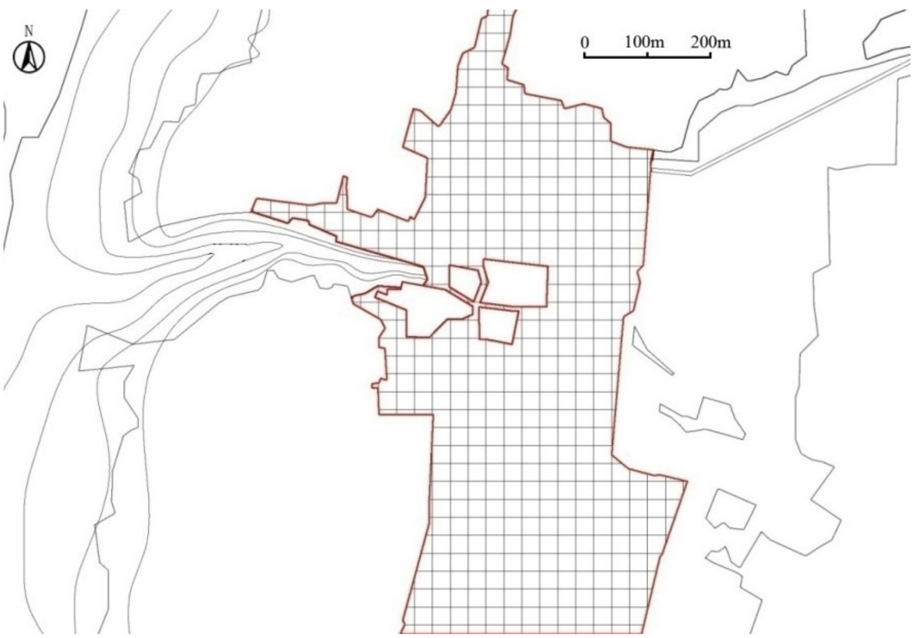


Figure 4.17 Division of suitable construction land

The drawing of water resource distribution map is based on the site investigation on water resource present situation, mainly focus on water supply infrastructure and the distance away from water resource(the distance has direct relationship with future investment). Through the investigation of water resource of each research land, the water supply ability can be roughly graded Figure 4.18.

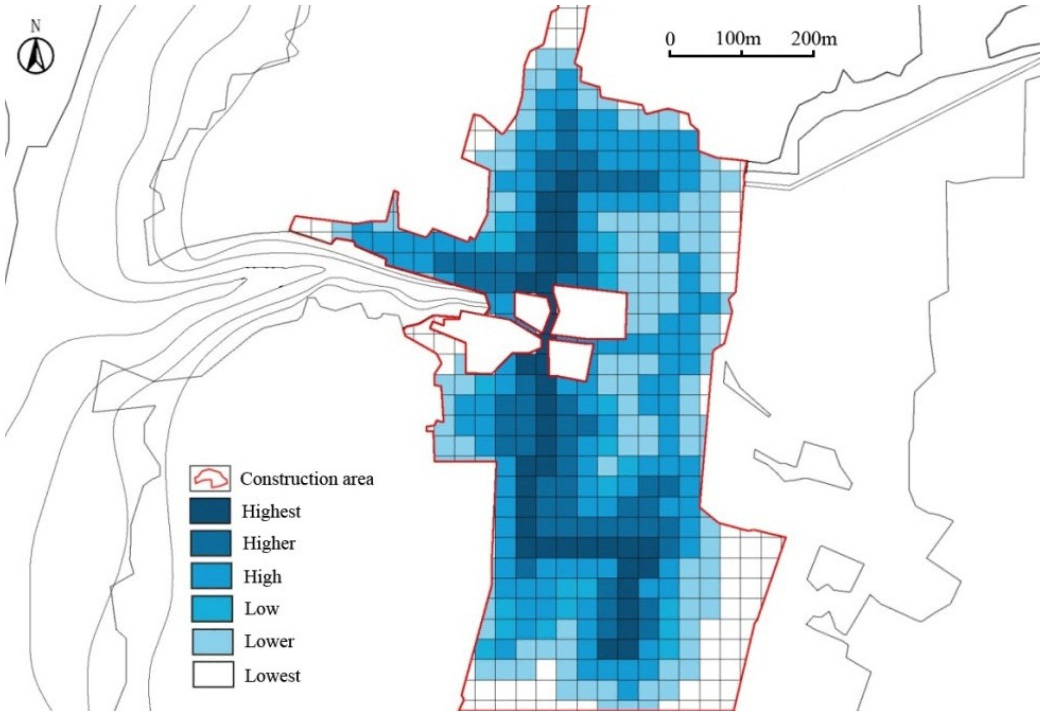


Figure 4.18 Distribution map of water resource carrying capacity in suitable construction areas

In order to know the ecological carrying capacity in more detail, it can be divided into six grades. The higher of water carrying capacity, the color of that area will be darker, which means the water supply facilities are better, the water pressure is higher and can support more population with less investment. The lower of water carrying capacity, the color of that area will be light, which means the water supply facilities are in shortage, and need much more investment to meet the water demand. The current water resource and the cost of improvement should be put into consideration.

The current water supply system is very complex, and there are no systematic indexes to calculate the water carrying capacity in an accurate way. Site investigation and interview are the only way to calculate the situation of water supply facilities in roughly, which cannot show the water carrying capacity accurately, but still can show the space distribution of water carrying capacity. Thus, it can be used as the guideline for the future human settlement planning.

(3) Drawing the distribution map for infrastructure carrying capacity

When do the evaluation of infrastructure in construction area of Tao Qu Yuan village, the productivity, living style, ecological infrastructure and the distance between them, all of these should be researched . Through site investigation, the importance of each infrastructure to the area construction should be investigated and the influence index should be quantitative evaluated.

Table 4.12 Statistics on the investigation of infrastructure importance and their influencing index

First layer	Second layer	Third layer	Statistics of importance	Influencing index
A facility for productivity	A1 Road facility	A11 Road facility	96	0.96
		A12 Parking area	12	0.12
		A13 Station	-	-
		A14 Bridge facility	-	-
		A15 Dock	-	-
	A2 Energy and communication facility	A21 Electricity facility	100	1.00
		A22 Gas facility	-	-
		A23 Coal, wood and straw	-	-
		A24 Fuel facility	-	-
		A25 Clean energy facility	7	0.07
		A26 Post facility	14	0.14
	A3 Industrial supporting facility	A31 Agricultural training facility, technology promote base and agricultural activity service station	4	0.04
		A32 Plant and animal epidemic prevention facility	4	0.04
		A33 Agricultural products quality tested facility	6	0.06
		A34 Storage facility	-	-
		A35 Farmland construction and high quality farmland	-	-
		A36 Buildings for livestock and poultry	-	-
	A4 Farmland water conservancy facility	A41 River, water reservoir, ditches, pumps	-	-
		A42 Soil improving facility	-	-
		A43 Water supply facility	-	-
B Living facility	B1 Safety and disaster prevention facility	B11 Firefighting equipment	13	0.13
		B12 Flood control facility	-	-
		B13 Earthquake proof facility	-	-
	B2 Water supply facility	B21 Centralized water supply facility	-	-
		B22 Dispersed water supply facility	-	-
	B3 Public service facility	B31 Education and culture facility	92	0.92
		B32 Medical facility	98	0.98
		B33 Management facility	65	0.65
		B34 Industrial service facility	100	1.0
		B35 Entertainment facility	21	0.21
		B36 Village landscape facility	42	0.42
C Ecological facility	C1 Drainage facility	C11 Drainage Dutch	71	0.71
		C12 Water resource protection	-	-
		C13 Waste water treatment facility	17	0.17
	C2 Environmental improving facility	C21 Waste collection facility	39	0.39
		C22 Waste treatment facility	21	0.21
		C23 Public toilet	56	0.56
	C3 Ecological improving facility	C31 Yard greening	14	0.14
		C32 Greening belts	2	0.02
		C33 Patch-Corridor-Matrix of landscape	4	0.04

In the investigation of importance of infrastructure, it can be divided into six grades with the score from 0 to 5, 20 pieces of questionnaire were distributed to the local government. The total value of infrastructure importance is 100, and the results can show their influence index Table 4.12. Generally, infrastructures of transportation, electricity supply, small-scale industry and sanitary service have great influence, and the influence of water supply cannot be repeated. At present, there are no systematic evaluations for the ecological carrying capacity of infrastructure, in this case study, the infrastructure value can be got by multiply the evaluation values of each infrastructure with their influencing index, then these values are added together to get the comprehensive evaluation values. It can be divided into six grades according the final evaluation values Figure 4.19.

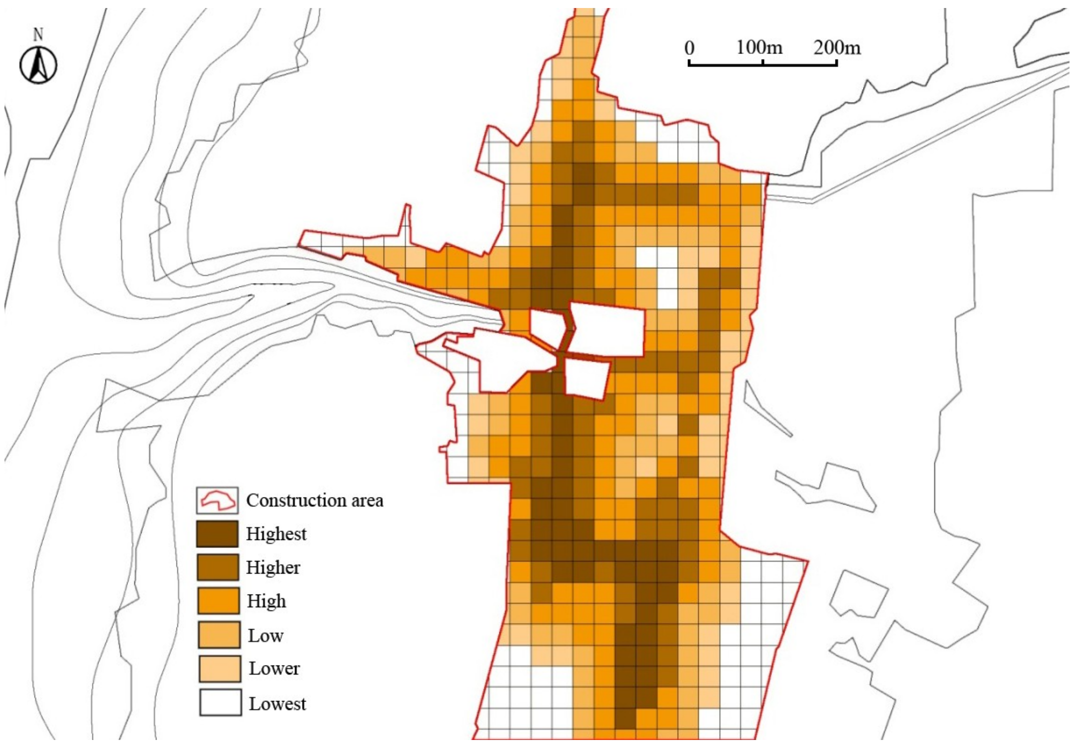


Figure 4.19 Distribution map of infrastructure carrying capacity in suitable construction areas

(4) Analysis of ecological carrying capacity distribution based on restrict factors

By an interview with the person in charge of local planning bureau, it is found that water resource and infrastructure own equal important position in the village planning and the construction investment is almost the same, which can be proved by the 50% transparency of these two maps. Through the overlay of water resource and infrastructure carrying capacity distribution maps in the suitable construction areas in Tao Qu Yuan village, the comprehensive ecological carrying capacity distribution map can be drawn Figure 4.20.

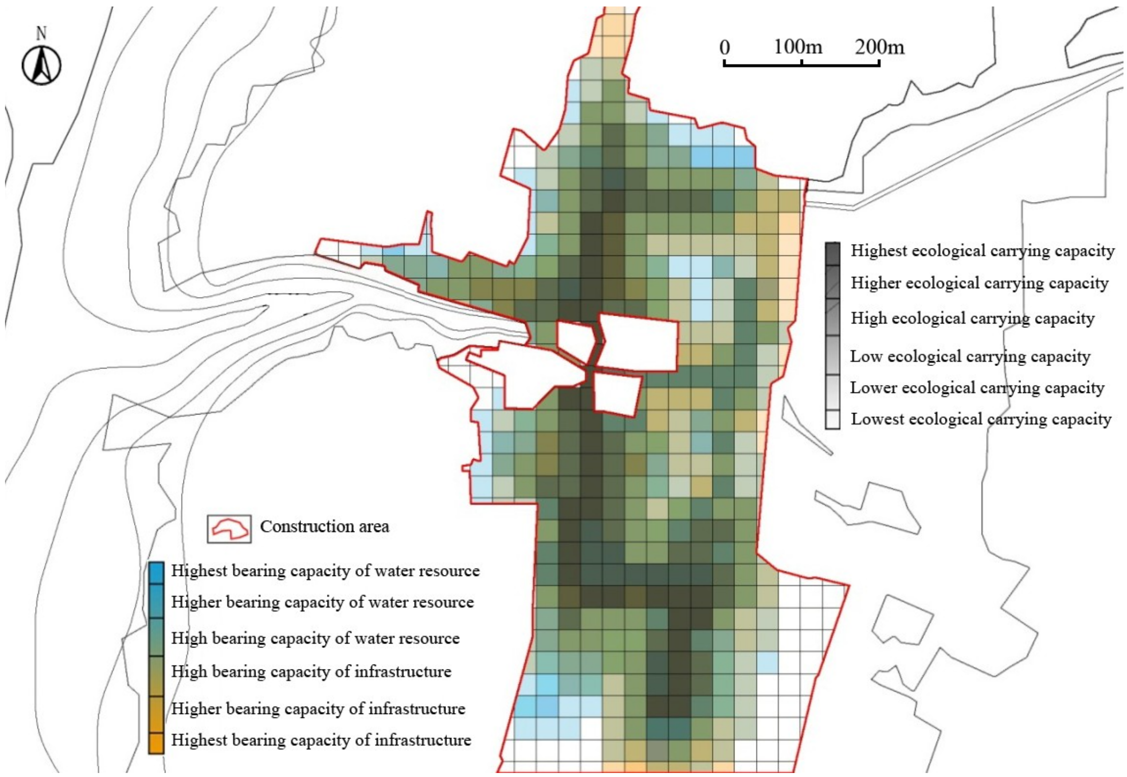


Figure 4.20 Distribution map of water resource and infrastructure carrying capacity

Combined with the previous research, the drawing of distribution of water resource and infrastructure is shown by different colors lightness; the lower of lightness means the ecological carrying capacity is higher. The colors hue shows the main limitation factors for ecological carrying capacity. If the color tends to be blue it means the water resource carrying capacity is higher, and the infrastructure carrying capacity is lower. The color saturation can show the proportionality of ecological carrying capacity of this area, the lower the color saturation means the water resource and infrastructure carrying capacity is almost the same, the higher the saturation means there is great difference between them.

4.2.3 Suggestions on human settlements planning of Tao Qu Yuan village

Based on guarantee the current residents' living quality; the current ecological carrying capacity can support more 275 people. The planned maximum population in 2020 is 783, approximation can be 780. Village construction strategies should be made by the extension planning.

(1) If the extension area is small, the priority construction area can be fixed by the ecological carrying capacity distribution map. When the extension area is small, the best extension way is fully used of current resource and avoids the unnecessary investment based on the current water resource and

infrastructure distribution map. According to the distribution map of water and infrastructure carrying capacity, the suitable construction place can be roughly divided into four grades Figure 4.21. In order to fully use of current resource and reduce the investment of water supply facilities and infrastructure, grade Ⅰ area should be the priority developing place, and after this area come to be sanitation, grade Ⅱ area should be put into consideration, then grade Ⅲ and Ⅳ.

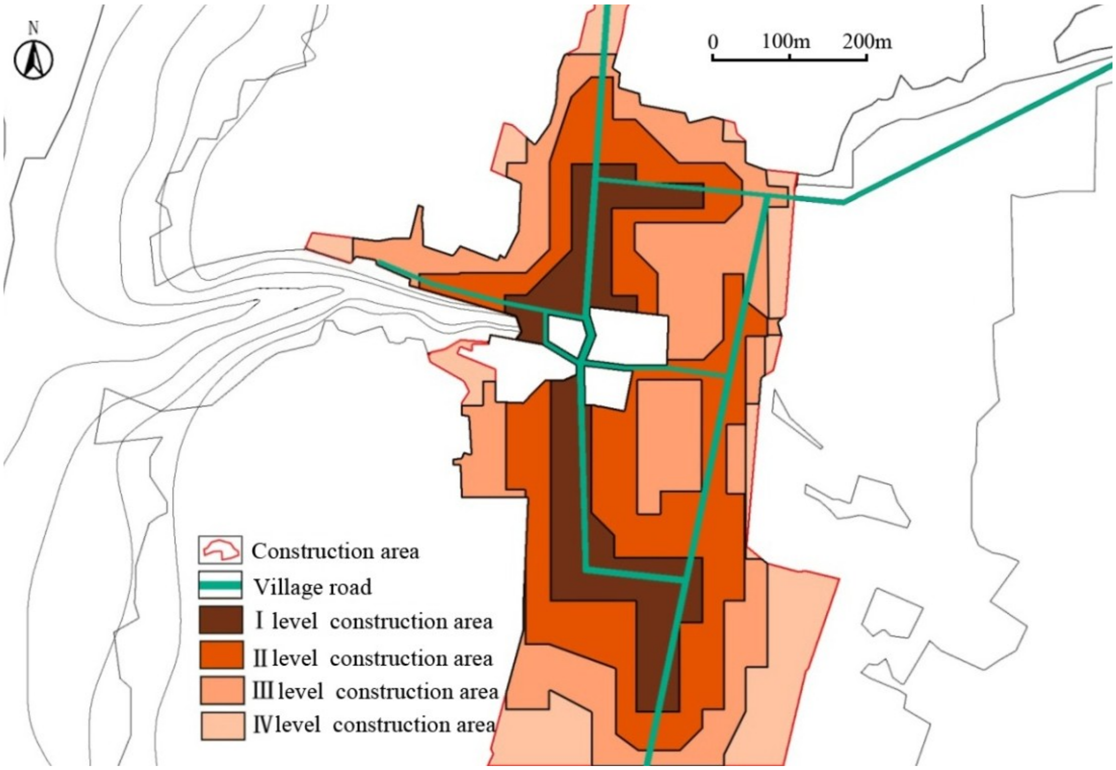


Figure 4.21 Division of priority construction area in Tao Qu Yuan village

(2) If the extension area is large, a certain area can be selected to build some water facilities and other infrastructure to meet the demand for productivity and living after the extension. If 275 people (the limitation of new population growth) are immigrating for once, it means that 91 families will immigrate according to the average 3.02 people in one family in the current village. Such kind of immigration has already over two and half of the current family and large housing land is needed, it must have great influence on the human settlement environment in the current village.

According to the planned priority area to start the construction, there are also some problems. Firstly, the old and new buildings mix together make it in disorder, which is not only hard for keeping the original style and feature, but also not good to improve the outlook of new countryside. Secondly, based on the original infrastructure, the large extension will make the water supply system hard to word normally and the overload work, all of these will reduce human settlement environment.

In order to avoid the above problems happened in the priority developed area, the grades classification for the priority developed areas can be used as reference, to save the social resource and make the decision for future development. The areas with a relatively high level of ecological carrying capacity can be chosen to improve the water facilities and other infrastructure to meet the requirement of village extension and guarantee human settlement quality.

(3) When the extension scale is large, the format of centralized distribution village can be used as reference, the advantages should be used and disadvantages should be avoided. Centralized construction in the areas with high ecological carrying capacity not only saves resources, but it also comes to be the public center for the village and acted as space to do social activities and communication. Taking it as a reference doesn't mean to copy it completely, but the idea should be used by different villages.

(4) The construction should improve the quality of revolutionary tourism. Full use of the local revolutionary tourism resource and build new countryside with special human settlement, which can improve the quality of tourist environment.

(5) Infrastructure should be improved, thus the carrying capacity can be improved and the living quality can be improved. The aims of new socialist countryside construction are "enhanced productive forces, higher living standards, civilized living style, an orderly and clean environment and democratic administration." The infrastructure should be improved, because it is the necessary condition for developing villages' economy and people's living quality.

4.3 The limitations of research

Based on the ecological carrying capacity analysis, the human settlements planning research can solve some current problems happened in the process of human settlement planning in gully regions of Loess Plateau. Firstly, it can avoid the un-planning village movement or integration without think of local natural ecological carrying capacity. Secondly, it can avoid the common phenomenon of the same outlook of all villages because of the lack of space distribution of villages' ecological carrying capacity. Finally, through the analysis of infrastructure, it can be used as a reference for the future infrastructure construction and can solve the problem of backward infrastructure.

The author's major is architecture, so the research on ecological carrying capacity is not very deep. Besides this, this research field is still a gap in related field, thus the analysis of ecological carrying capacity still has many shortages. Based on restrict factors, the analysis of ecological carrying capacity is not perfect currently, which can do the rough evaluation on villages' ecological carrying capacity and used as guideline in villages human settlement planning within research areas. Related research as the influence index of infrastructure should be explored. Thus, future research planning is shown as the following:

(1) The infrastructure carrying capacity analysis in this paper is a kind of qualitative research: the accuracy is not enough. In order to better adopt in the future village planning, it needs to establish a more complete, scientific evaluation system to do the symmetric quantities analysis.

(2) Village planning based on ecological carrying capacity analysis is just at the primary steps, and lacks real case to prove this method. There must be many problems during the usage of this method in reality. It hopes that this method can be improved and be perfect in the future new socialist countryside in gully regions of Loess Plateau.

(3) The results of ecological carrying capacity are mainly used in the process of village movement and integration within the small research areas, which just a small part of new socialist countryside construction. It hopes this ecological carrying capacity method also own important functions in the process of improving human settlement environment.

4.4 Summary

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. This paper focus on the gully regions of Loess Plateau, basically use restrict factors' analysis and ecological carrying capacity analysis to do the research , and the results can be calculated into the following six parts:

(1) Prove that restrict factors' analysis have its feasibility and practicability in the analysis of ecological carrying capacity in gully regions of Loess Plateau.

(2) Base on the restrict factor analysis in the ecological carrying capacity analysis the restrict factors can be divided into two types. One is the unchangeable restrict factor, and another is restricting factors that can be improved according to its requirements. Such kind of division can avoid the one-sidedness of analysis. During the research of human settlement environment, the natural resource, cultural

environment and social and economic development situation should all be analyzed. Among these factors, some can be adjusted, the analysis of ecological carrying capacity is not complete, because of just based on the minimum supporting population based on restricting factors. In order to avoid such kind of one-sidedness, the restrict factors should be further divided into the unchangeable factors and the factors that can be improved for their requirement.

(3) Submitting an efficient and practical analysis method for the cultivable lands analysis. According to the accuracy of villages planning requirement, the national food safety aim and the cultivable land needed by different grain demand in gully regions, can be used to calculate the demand cultivable land areas in certain period of time and certain areas. Thus, the carrying capacity of cultivable land in a certain period can be fixed by current cultivable land areas and support the population.

(4) In the analysis of water resource carrying capacity, because of the region characteristic of water shortage in the gully region of Loess Plateau, water demand volume per capita and the population that water resource can support can be calculated roughly by the water supply volume for high living condition.

(5)Through the analysis of maximum ecological carrying capacity, current carrying capacity and current population, the village that has the potential to support more immigrants and should be integrated with others to improve the human settlement environment. At the same time, villages are graded. Among the six grades, village Ⅰ is suitable for extension and village Ⅵ is suggested to be moved.

(6) Through drawing the restrict factors distribution map, the space distribution of ecological carrying capacity can be easy to know. According to this distribution map, the suitability for constructed and developed can be divided into four grades, the area owns high ecological carrying capacity should be put in the priority developing position, which has significant functions on saving natural resource and social resource, and reduces the cost of constructing water supply infrastructure and other infrastructures.

CHAPTER 5
RESEARCH ON CURRENT CONSTRUCTION SITUATIONS OF VERNACULAR DWELLINGS IN TABLELAND RURAL HABITATS

5 Research on current construction situations of vernacular dwellings in Tableland rural habitats

5.1 Regional characteristics of traditional vernacular dwellings in Tableland rural habitats

Traditionally, the main living resource comes from farming and land, which are the main resource that rural people depend on in gully region of Loess Plateau. Farming economy decides the people's economic model: family is the basic unit, the combination of agriculture and cottage industry, the self-sufficiency natural economic model. Under such kind of economic model, villagers build their houses mainly by artisans in their villages. The economy of construction is the main characteristics in vernacular dwellings construction.

5.1.1 Related definitions

(1) Concept category of villages' vernacular dwellings

Vernacular dwellings can be simply referring to the houses for residents. China owns vast territory, numerous nationalities, different customs, and living habits, thus lots of different vernacular dwellings models. The main characteristics of these vernacular dwellings are convergence and economy. Convergence means that the vernacular dwellings models, construction methods, and outlooks are all tend to be the same. The economy mainly refers to the construction cost. The housing construction is mainly restrained by local people's income situation; low-cost is one of the most important influencing factors. These low-cost vernacular dwellings are very different from big houses and yards constructed by some businessmen, such as Tang Jia Da Yuan in Xun Yi County, Xian Yang city of Shaanxi province.

(2) Definitions of traditional and modern vernacular dwellings

In gully region of Loess Plateau, the traditional vernacular dwellings in rural habitats refer to the houses that built according to the traditional village construction methods, while the modern village vernacular dwellings refer to the houses constructed under the influence of modern urbanization and takes modern urban construction method as reference. There are no architectural designers involved in the traditional vernacular dwellings construction, while the local artisans use their experience, knowledge, and heritage from generation to generation to design and build houses. Usually, these artisans are very familiar with local materials and climate, they can design and build low-cost houses with high suitability. The disadvantage of this kind of construction is that these artisans are all without systematic training just depend on their heritage experience and traditional construction methods; actually, it cannot keep pace with the times and meet the needs of people's modern life. In the gully region of Loess Plateau, the traditional vernacular dwellings can be divided into cave dwellings and adobe vernacular dwellings. Comparing with traditional vernacular dwellings, the modern one has great change in it space distribution, plan layout, building materials and construction. The modern vernacular dwellings in rural habitats refer to those brick-concrete structure vernacular dwellings.

(3) Definitions of caving dwelling and "House" vernacular dwelling

Cave dwellings are special vernacular dwelling form that just exists in Chinese north areas where people dig caves to live. Cave dwellings in the gully region of Loess Plateau can be divided into hillside cave dwellings and underground cave dwellings.

The "House" vernacular dwelling shown in this research refers to the houses on the ground expect cave dwellings. It can be divided into adobe vernacular dwelling and brick-concrete structure vernacular dwelling. Courtyard as the important component is the common characteristic of these vernacular dwellings. Thus, they are also called as "Courtyard type" vernacular dwellings.

5.1.2 Traditional thoughts about land-saving

Since the ancient times, the Loess Plateau has been a place with the contradiction that the population density is very high but the cultivable land is limited. For this reason, ancestors developed construction methods to reduce construction land and maximize the cultivated land. The courtyard dwelling on the Loess Plateau is called the narrow yard dwelling, and the unique place is the proportion of the courtyard. The length-width ratio of the narrow yard dwelling is close to 3:1[60]. It is different from most of the dwellings in northern China, the proportion of which are around 1:1 Figure 5.1.

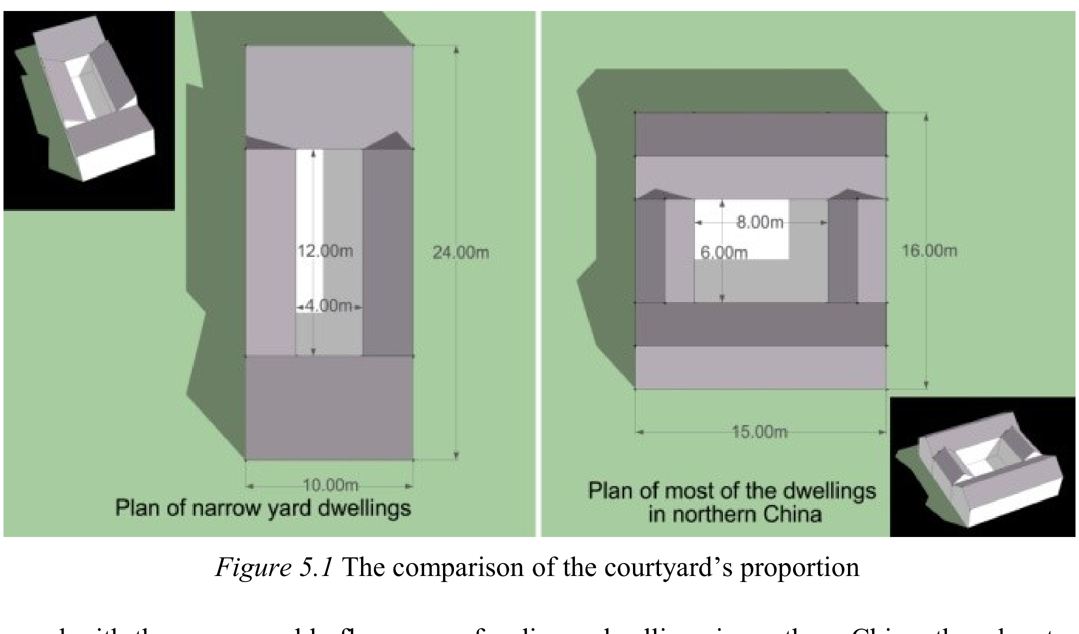


Figure 5.1 The comparison of the courtyard’s proportion

Compared with the same useable floor area of ordinary dwellings in northern China, the advantage of this lies in the fact that, the face width of narrow yard dwellings is narrower; it can take more dwelling units in the certain area Figure 5.2. Thus, the use efficiency of useable area can be increased effectively, the village land for construction can be saved and a large number of fertile farmland can be retained through such initiatives.

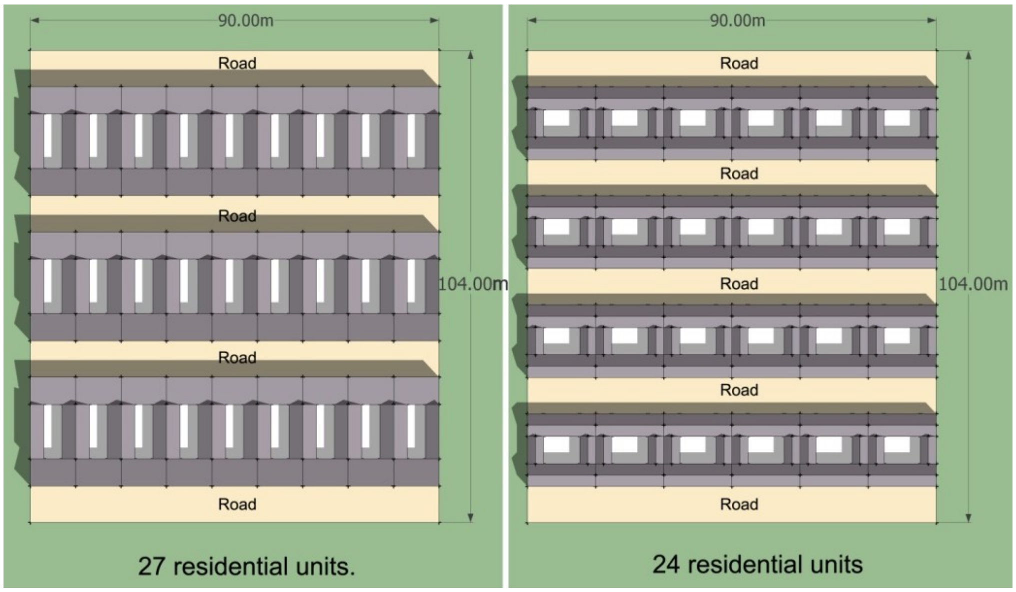


Figure 5.2 Comparison of the number of residential units between narrow yard dwellings and ordinary dwellings in northern China

5.1.3 The application of immature soil

For a long time, as the most common material in the Loess Plateau, immature soil has been widely applied to traditional dwellings. Usually, the local people make it into adobe brick, and fill fiber material such as wheat straw into it to increase the strength of materials Figure 5.3. The advantages of using immature soil as a material as follows:

Figure 5.3 Wall made by immature soil

(1) Economic and environmental

Immature soil can be seen everywhere in the gully region of loess plateau. Because of the low using cost, that makes it become a popular material [61]. For thousands of years, people live on it, grow foods on it, and use it to build house. The adobe house is rooted in the earth, seemed growing from the ground, blending with nature. Through long-term repeated practice by local people, it makes adobe house a kind of mature form of dwellings.

(2) Good physical properties

Climatic conditions in gully region of Loess Plateau decide that the housing constructions have to take the thermal insulation and safety as the main targets. Immature soil has good physical properties such as high breathability, plasticity, and porosity, low water content, high compressive strength, and it will become increasingly strong in a dry environment [62]. What's more, because of its good thermal stability and sound insulation, the building made by it has a good heat preservation, heat insulation, and sound insulation performances. In addition, immature soil can adjust the indoor humidity. The rammed-earth wall can absorb the moisture in the air when it is too wet. On the contrary, when it is too dry, the wall can release excess moisture to the air. Therefore, adobe dwellings are likely to remain relatively pleasant indoor environment.

(3) Simple maintenance

During the process of using, some damage will come out, such as dry shrinkage cracks or cracks in the wall caused by uneven settlement of the foundation. As long as it does not seriously affect the safety of the structure of the overall housing, the process of repair is very simple, the only thing needs to do is pasting the adobe cracks in the wall.

5.1.4 The influence of history and culture on vernacular dwellings

Gully region of Loess Plateau is one of the birthplaces of Chinese civilization and several dynasties were established there. The long historical civilization forms the unique custom and has deep influence on the living, economic, transportation and diet habit, also have the effects on local vernacular dwellings' construction.

(1) Traditional civilization

Gully regions of Loess Plateau located in the center of China, the capital areas for several dynasties in history, also the center of Yellow River civilization. Wei River gets through this region and forms the complex landscape. This region has fertile soil and rich in property. Qin Ling Mountain and Yellow River as the natural protective screens, this region also is an important region for politics, military and economy. At the same time, it is a relative intimate inside and closes from outside area. The traditional self-sufficient farming and living style makes unique civilizations and customs [63]. For a long time, people are engaged in farming and own stable life, which makes the local people' characteristics are exquisite, steady and full of patience. All of these can be reflected in the local dwellings, which are heavy construction, closure, and introversion.

(2) Cultural accumulation

The culture of being harmonious with nature and customs has, for a long time, been integrated into the traditional vernacular dwellings. In ancient China, rituals and ceremonies are used as the base of country management, and they are regarded as the regulations and rules to maintain the different relationship of social classes and social orders [64]. In the past two thousand years, ritual and ceremonies are carried out in the whole Chinese social life and every field, thus having deep influence on architecture. They also have an influence on the traditional vernacular dwellings in gully region of Loess Plateau. The layout of traditional courtyard layout can show it. The main room, as the most important building space, the room located in the middle of it is used to enshrine ancestors and as living room to do the guests' reception; and the rooms that are located on each side of the main room are the bedrooms for elders. On each side of the courtyard, the rooms are used as kitchens, storages, and bedrooms for the younger generations. Generally, the grading of east side rooms is higher than the west. All of these layouts show the traditional Chinese ethical order Figure 5.4, Figure 5.5.

When ancient human beings feel fear and gratitude to nature, they put themselves into the natural and try to live in harmonious with it [65]. During the long time evolution in traditional vernacular dwellings in gully region, they form a systematic evaluation on environment, such as climate, soil conditions, plants, rivers and so on, also some natural elements comes to be their characteristics, such as back on the mountains and face to water and the south sunshine.

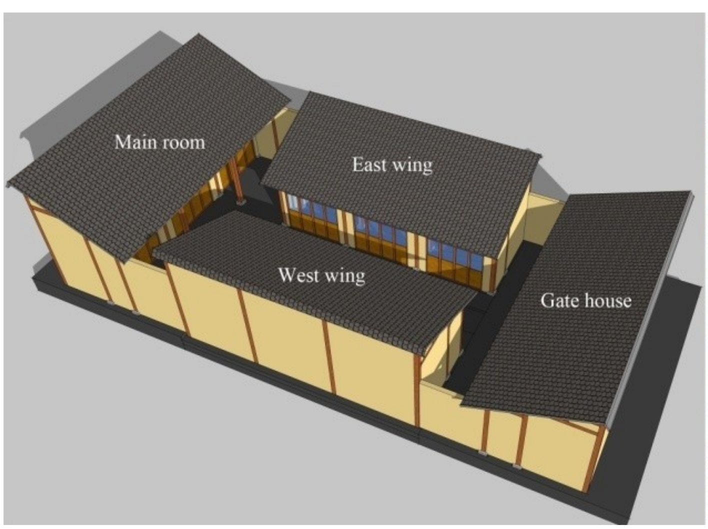


Figure 5.4 Space layout of traditional vernacular dwellings in gully region of Loess Plateau

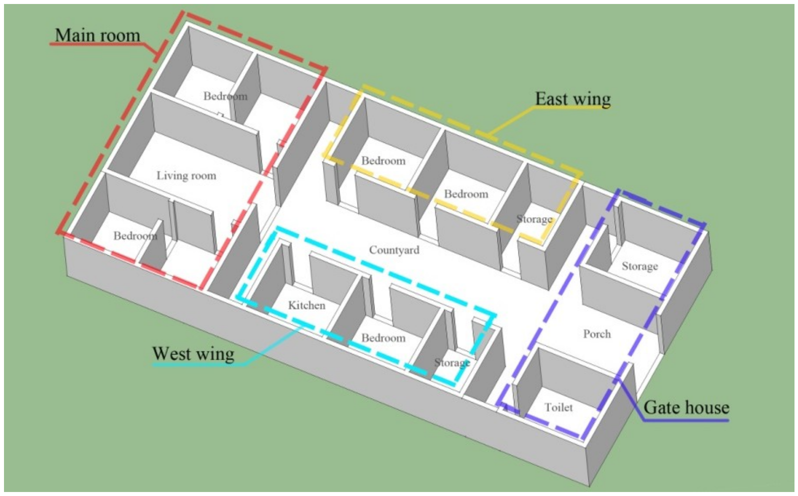


Figure 5.5 Division of spaces in traditional vernacular dwellings in gully region of Loess Plateau

5.1.5 The influence of living habits on vernacular dwellings

(1) Courtyard is an important living space

The courtyard is an important living and production space in the traditional vernacular dwellings of Tableland villages, many daily activities are held there. In good day, villagers like to eat and rest in the courtyard, and women do daily housework there, such as washing, laundry, shoes' making, children also play there. What is more, as an important production assistant space, villagers usually put their farming tools there, and park farming vehicles, also they raise livestock and plant vegetables there Figure 5.6.

(a)South side of courtyard (b)North side of courtyard

Figure 5.6 Typical courtyard in Qianyang County

(2) The design of attic space

Slope roof is commonly used in "House" vernacular dwellings of gully region in Loess Plateau, thus attics are very common there. On the one hand, attics can be used as temperature damping control areas, which has the thermal and insulation functions for the bottom space and indoor climate. On the other hand, the spacious space of attic can be used to store farming tools, grains and family debris, which is an important store space in the whole house Figure 5.7.

(a) Appearance of the attic (b) Attic inside

Figure 5.7 Attic space in typical vernacular dwellings

(3) Water cellars and soil cellars

Water cellars and soil cellars are the wisdom crystal of the people who live in gully region in a long-term adaptation with nature. The climate in Loess Plateau is dry and lack of rain, rainwater is the main living water resource in the time without artificial welling, thus the effective rainwater collection is the important guarantee for living water usage. Water cellars are very important water storage equipment in gully region of Loess Plateau, which can collect and storage rainwater for the daily use Figure 5.8. Currently, there are still lots of water cellars are exiting in Tableland rural habitats.

Figure 5.8 Existing water cellar in residential courtyard

Soil cellar is an important storage space of food in traditional vernacular dwellings Figure 5.9. In the past, there were no refrigerators, so people put food in soil cellars for long time storage. Especially, in cold winter, because of the humid and CO_2 in the relatively stable indoor air, the indoor temperature usually can maintain be between 0℃ and 5℃, which is suitable for storage crops.

Figure 5.9 Existing soil cellar in residential courtyard

5.2 Development situation of vernacular dwellings

In history，in order to adapt to the arid climate and make the best use of limited natural resources, local people in the Tableland rural habitats created unique traditional vernacular dwellings forms: underground cave dwelling and adobe vernacular dwelling. Underground cave dwelling is characterized by low cost, low energy consumption and low pollution. It takes full advantages of the characteristics of loess and merges harmoniously into nature. Adobe vernacular dwelling is "soil and wood" structure, characterized by proven technique, simple construction, cheap and easily available material, energy saving and ecologically environmental protection. It is widespread in the gully region of Loess Plateau. However, they are based on backward productivity and economic conditions. Under such background, construction can only use local materials and simplify the way of building construction.

With the development of the social productivity and industrialization, modern transportation and improvement of construction level easily erase the chasm. Because of the high-speed information flow, the architectural culture in the developed areas shows the influence on the countryside in gully region deeply. Brick and concrete, and those "modern" architectural materials were gradually used in the construction of vernacular dwellings, and then the brick-concrete structure starts to be popular in the Tableland rural habitats in this region. Therefore, from the viewpoint of traditional vernacular dwelling heritage, dwellings can be divided into two kinds: traditional vernacular dwellings and modern vernacular dwellings. In addition, from the types of vernacular dwellings, it can be divided into cave dwellings and "house" vernacular dwelling.

5.2.1 Underground cave dwelling

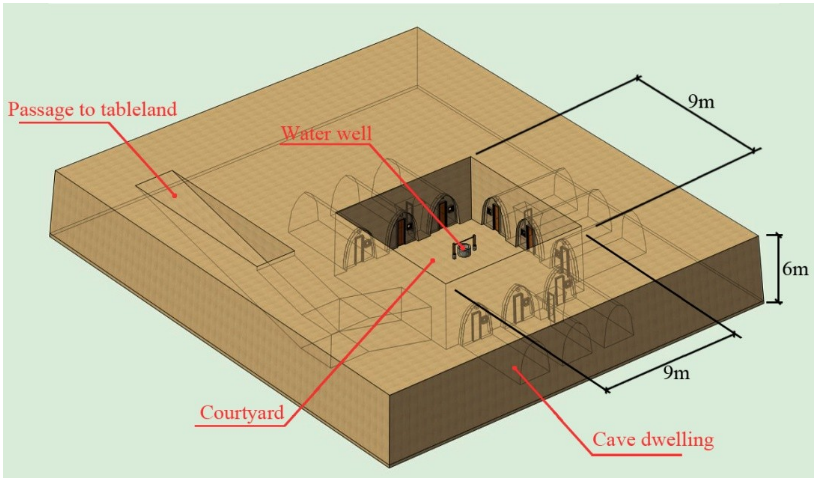


Figure 5.10 Structure diagram of Underground cave dwelling

(a)Courtyard (b)Cave dwelling unit (c)Cave dwelling indoor

Figure 5.11 Underground cave dwelling example in Changwu County

Underground cave dwelling, the primitive and simple vernacular dwelling in Tableland rural habitats, is the result of thousands years' experience about human living and natural environment [66]. Take the advantage of good vertical stability of yellow soil, villagers dig a square underground courtyard on the tableland, then dig horizontally to the four walls. The underground courtyard is usually called silo-cave courtyard, which is generally 9m X 9m, 9m X 12m, smaller one is about 6m X 9m Figure 5.10, Figure 5.11.The size is decided by the consideration of security, there is no relationship with owners' economic and social position[67]. If the size is too big, it will be more difficult to dig and more dangerous. If there are fissures, the original cave has to be abandoned, the new one should be dig again, which will cost time and money. If the size is too small, it will have the impacts on living comfort, thus the best size is generally 9 meters. In the courtyard, enough space should be left for the sewage pit, in some of courtyards, there are facilities, such as water cellars, soil cellars, milling cave, henhouses and so on.

Since the reform and opening up of China in the 1980s, the original closure village opens to the outside world; the architectural culture in the developed areas shows the influence on gully region deeply. For the social improvement, economic development, more and more villagers work in cities, and their living conception and living styles have been changed. The traditional cave dwellings are poor in ventilation and light, humid and dark, and short of water supply equipment, all of which cannot meet modern peoples living requirement. What is more, in people’s traditional conception, cave dwellings are the symbol of poverty. Therefore, along with the development of new countryside construction, lots of cave dwellings are abandoned, even they have many advantages, such as warm in winter and cool in summer, cheap and good for environment Figure 5.12.

（a）Topside of courtyard （b）Interior of courtyard

Figure 5.12 Abandoned underground cave dwelling in Yongshou County

Since 2010, the local government initiated a project named "Three farewells", which made the requirement that all the people live in cave dwellings should be moved out within three years and the cave dwellings should be demolished to be farmland. During the field investigation, just a few people still living in cave dwellings in 2014, almost all the cave dwellings disappeared, especially in Tableland rural habitats. The disappearance also weakens the special characteristics of local architecture.

Figure 5.13 and Figure 5.14 show the change in the number of underground cave dwelling in Liang Jia Zhuang Villiage of Yong Shou County. In 2002, the underground cave dwelling takes over 50% of vernacular dwellings, while the number decreased to less than 30% in 2013. In 2014, almost all the underground cave dwellings were disappeared. Therefore, the traditional cave vernacular dwellings have already out the historical stage and cannot be established in large amount as vernacular dwelling form in the future countryside construction in gully region of Loess Plateau.

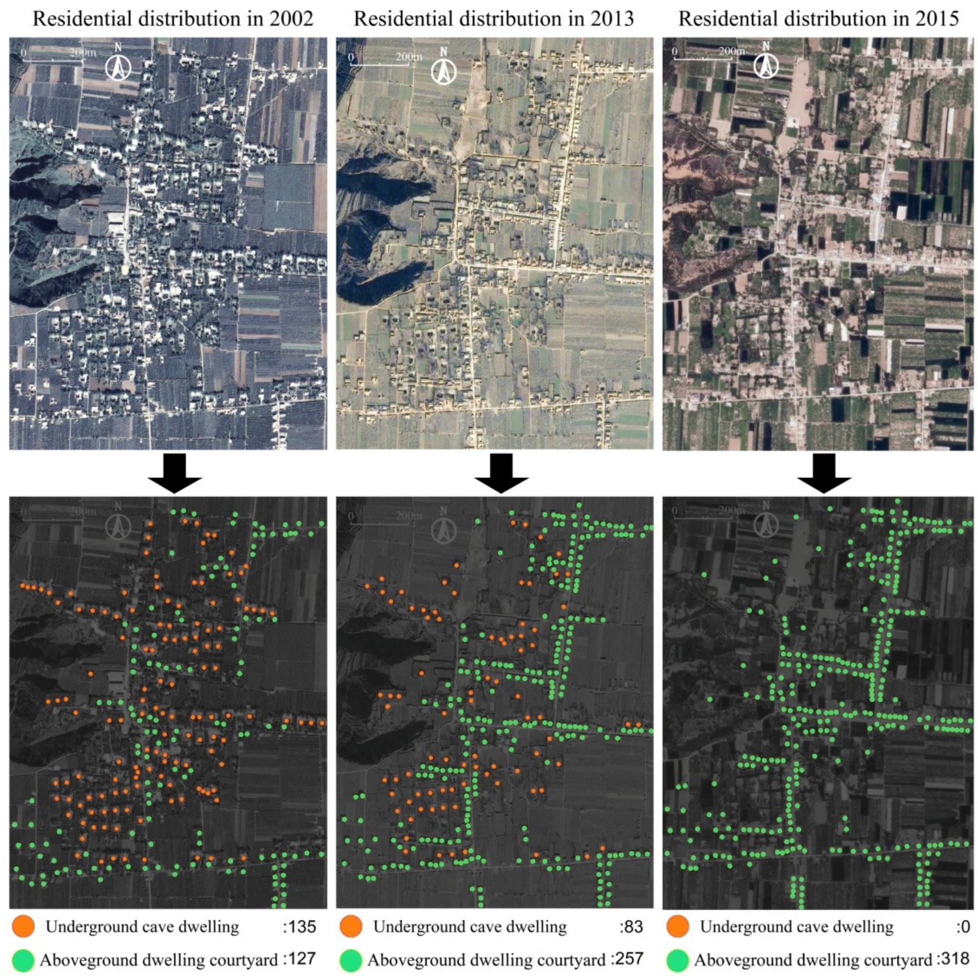


Figure 5.13 The change in the number of underground cave dwellings in Liang Jia Zhuang Village

Figure 5.14 The bird view of vernacular dwellings changing in Liang Jia Zhuang Village

5.2.2 "House" vernacular dwelling

(1) Adobe vernacular dwelling

Adobe vernacular dwelling is the typical green ecological architecture; it is characterized by proven technique, simple construction, cheap and easily available material, energy saving and ecologically environmental protection. It is widespread in the Gully Region of Loess Plateau Figure 5.15.

Figure 5.15 Existing adobe vernacular dwelling in Qianyang County

(a) Interior roof (b) The end of eaves in outdoors

Figure 5.16 Adobe vernacular dwelling roof structure

Adobe vernacular dwelling uses immature soil to make walls and use wooden structure as weight bearing structure. Generally, the lower soil wall is related thick, which is rammed earth wall; the upper wall is thin, which is built with immature adobes. The outside of wall usually uses soil mud with forages to protect the whole wall. The traditional adobe bricks or rammed soil wall can be made by the local people themselves, the requirements of producing methods and techniques are low, and operation is simple, while the wall is very thick about 400mm. The bottom of rammed soil wall is usually made by rubble masonry and bricks about 300mm, which is used to prevent rain. Because of the building depth of adobe vernacular dwelling usually within 6m, the roof is generally single slope roof, which is saving construction time and materials. Column and tie construction is widely used, and raw, grass ashes are used as insulation with small gray tiles Figure 5.16. Windows in the facade are less and window area is small within 1m X 1m. Windows are usually wooden frame with single layer glass, the price is low and production is simple. The building foundation of adobe vernacular dwelling is low about 600mm. The structure is very simple, the bottom uses rammed soil and then rubble masonry, the earthquake resistant actually is very low Figure 5.17.

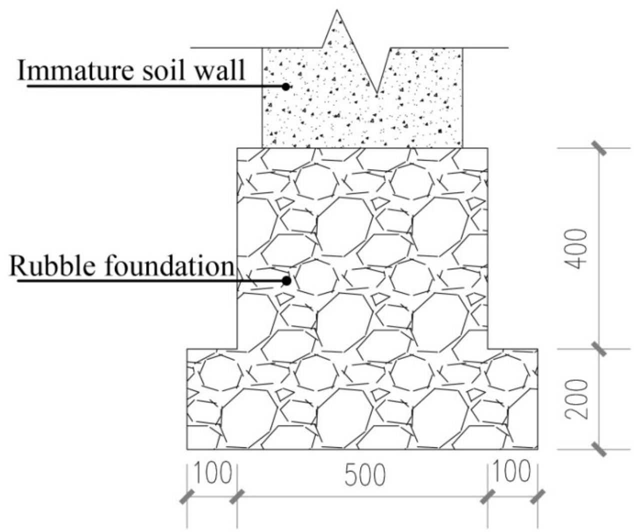


Figure 5.17 Diagram of rubble masonry base structure

However, because of its defects, such as primitive easy to damp, limited ventilation and lighting, inadequate sanitation, the original immature soil houses seems to be the symbol of poverty and backward, few people plan to build new immature soil houses again Figure 5.18. It causes the constant decrease of these environmental protection and ecological houses, especially, during the Construction of New Countryside. Currently, the existing adobe vernacular dwelling are almost built 30 years ago, they still keep the traditional vernacular dwellings characteristic. At that time, because of the backward economy, villagers built their dwelling according to their economic ability and actual demand without unified planning. Therefore, "houses are built along one side" is very common. The doors and windows open to courtyard and distributed in a symmetrical form Figure 5.19. The buildings are usually built in one line facing to the courtyard, more were built when they have enough money, such kind of layout is rather scattered. Through field investigation of more than 50 villages in gully region, it is found that the number of existing adobe vernacular dwellings decreased by 25% compare with 30 years ago， traditional adobe vernacular dwellings, immature soil human settlements, construction techniques are all at the edge of collapse and disappearance.

(a) Bedroom (b) Family's workshop

Figure 5.18 Adobe vernacular dwelling interior

(a) Elevation (b) Interior of courtyard

Figure 5.19 Courtyard layout of adobe vernacular dwelling in Chunhua County

(2) Brick-concrete structure vernacular dwelling

In the promotion of new countryside construction, the reconstruction amount is experiencing rapid increase in Tableland rural habitats of gully region in Loess Plateau. As long as the family economy allows, almost all hope to rebuild new vernacular dwellings. Brick-concrete structure vernacular dwelling is the main vernacular dwelling form developed in the process of new countryside construction. The courtyard space layout and architecture plan are mainly copied from other modern vernacular dwellings in some developed areas in China, which are many different forms and very different from the traditional vernacular dwelling in gully region of Loess Plateau. These modern dwellings can be divided into two kinds: one-storey and two-storey brick-concrete structure vernacular dwelling Figure 5.20. Because of the backward economic conditions, most of local villagers' income is less than 10,000 RMB/Y (1500 USD); thus, the high-cost two-storey dwellings are less. One-storey brick-concrete structure dwelling is the main house style and put as the unified architectural form in the construction of demonstration villages during the new countryside construction.

(a) One-storey brick-concrete dwellings (b) Two-storey brick-concrete dwellings

Figure 5.20 Brick-concrete vernacular dwellings in Qianyang County

Comparing with the traditional adobe dwelling in gully region of Loess Plateau, brick-concrete structure dwellings have the advantages of tense space layout, spacious indoor, sturdy structure, and nice appearance and so on. The construction methods and materials are similar to urban houses' construction, concrete and 240mm bricks are the mainly used materials, outside yards' walls are uncovered, the facade of architecture is generally white ceramic tiles, inside walls use cement mixed with sand, there are no insulation layers for the walls and roof Figure 5.21. The inside space also has great change, the room size is more suitable than before. It is usually is 3.9m X 5.1m. The windows are larger about 1.6m X 1.8m, which provides enough natural lightness and better ventilation. The entrance doors are usually metal frame, and inside doors are made of wood. Some new and cheap passive energy techniques and cleaning energy are gradually used, such as solar power, methane and so on. The base of brick and concrete houses usually use lime-loess foundation, the proportion is 3:7, 30% lime and 70% soil, and bricks are used on the top of it Figure 5.22.

Figure 5.21 Construction site of brick-concrete structure vernacular dwellings in Qianyang County

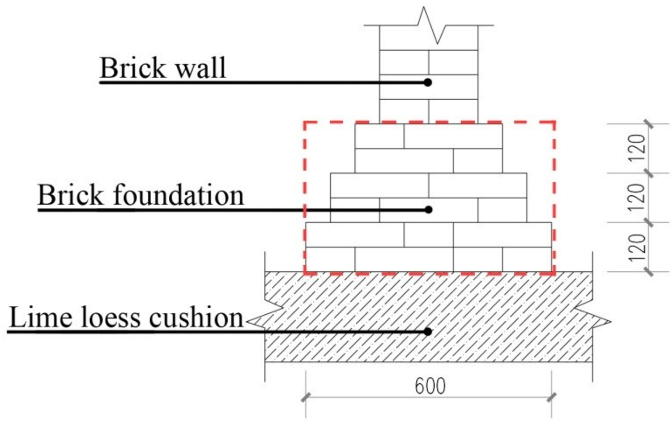


Figure 5.22 Brick made base

However, building the new house takes large amount of land resource, and most of the new houses ignore the relationship between houses and surrounding environment, without scientific design and plan, the style of new residential buildings emphasizes on the unity of village's facial feature excessively leads to architectural form monotonous and rigid, and courtyard layout unreasonable Figure 5.23. Meanwhile, interior space division mainly copies the modern houses, lacking the consideration of regional environment and villagers' living habits.

(a) Planning of Gun village (b) Gun village is under construction

Figure 5.23 Massive replication of brick-concrete structure dwellings

Because of the blind pursuit of the construction speed, ecological design and energy saving measures are completely neglected in the construction, making the heat preservation and insulation effect of house cannot meet the requirements. Thus, people put more money and resources in the winter heating. What is more, the poor construction technique and the lack of relevant technical guidance cause the construction quality is generally poor Figure 5.24. As the main building material, clay brick is used as that is cheap but not environmental protection. Firstly, the production process of clay brick needs to consume a large number of soils, which destroys the vegetation cover of earth surface and increases the soil erosion. Secondly, because the clay bricks cannot be biodegradable, when the house is demolished, it will also pollute the environment. Thirdly, the waste dregs, gas, material and water cannot be treated well, cause serious influence on the surrounding environments.

Figure 5.24 Poor quality of brick-concrete structure vernacular dwellings

5.3 Current construction models in vernacular dwellings in Tableland rural habitats

In the integration of city and countryside, construction of villages and cities are two very different methods. In countryside, artisans take charge of the whole construction, they are very familiar with materials, tools and construction techniques, they know very well about how to build a house with lost cost and high quality [68]. In current vernacular dwelling construction in gully regions of Loess Plateau, the original construction system and urban construction system are mixing, more and more architects enter this new countryside construction, they take part in the vernacular dwellings design. For the building materials and structure, brick-concrete structure is the main trend for the development of vernacular dwellings and almost all the newly built vernacular dwellings use this structure.

The adobe vernacular dwellings and cave dwellings are gradually abandoned. In recent years, almost all the cave dwellings are demolished in the “Three Farewell Project” and changed into farmland. For the existing adobe buildings, most of them just are used as the assistance rooms. In order to save money, some villagers usually keep the original adobe building beside the newly built buildings and use them as kitchen or some other assistance space. In some new built courtyards, the soil and wood structure small rooms are built for park farming vehicles and store farming tools. From the viewpoint of architectural space, villages are pursuing the urbanization life. Thus, the layout tends to be the same as urban centralized space layout, and the indoor functions space tend to be more detailed. The new vernacular dwellings are changed from the original one line layout to more complex layout, the space of the living room, bedrooms, kitchen and bathrooms are all put into consideration.

At present, there are main two kinds of construction models for vernacular dwellings: one is guided by local government, unified planning and constructed by some design institutes. Another is following the thousands year's tradition, depend on local artisans to do the unified planning and self-construction Table 5.1.

Table 5.1 Construction models of vernacular dwellings in Tableland rural habitats

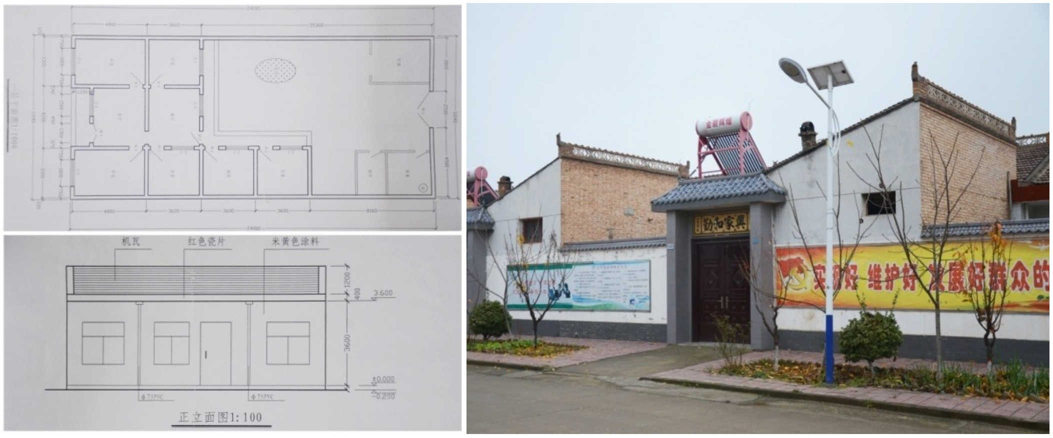
Construction model	Construction methods	Architectural types
Unified planning and construction	Build in new site	Brick-concrete structure dwelling
Unified planning and self-construction	Build in new site	Adobe vernacular dwelling Brick-concrete structure dwelling
	Build in original site	Adobe vernacular dwelling Brick-concrete structure dwelling

5.3.1 Unified planning and construction

Unified planning and construction means vernacular dwellings are unified planned, and designed by some design institutes under the guide of local government, and the exact model should be unified by the government, which is the typical construction model in the process of new countryside construction and started in 2002 Figure 5.25, Figure 5.26.

(a) Village planning drawing of Shi Jia Nian village (b) Present construction situation of Shi Jia Nian village

Figure 5.25 Village planning in the unified planning and construction model



(a) Design drawings of vernacular dwellings   (b) Present situation of vernacular dwellings in Shi Jia Nian village

Figure 5.26 Vernacular dwelling construction in the unified planning and construction model

The newly built houses can meet villagers' modern living requirements for the participation of urban designers. The layout of houses is in good order and space functions are clear. However, the urban designers who do not know and full understand the vernacular dwellings, their design cannot by fully put into the vernacular construction. The gap between design and reality often happens in local residential areas in the process of new countryside construction [68]. The unified planning and construction model is a new construction model for the tableland villages in gully regions, the willingness of local government and architects play a leading role.

5.3.2 The model of self-investment and construction

Unified planning and self-construction is the commonly used model in the vernacular dwelling construction in gully regions. Self-construction means villagers pay themselves to ask the artisans to do the construction [69]. Because of the intermittent adjustment of national policy, unified planning and self-construction can also be divided into two kinds: build in new site and original site.

Build in new site means that government takes back villagers' homestead firstly, and then redistributes a new homestead after whole village planning, villagers build their houses on the new site. Under the guideline of land saving conception, new homestead generally is around 0.4 mu (267 ㎡), the width is between 9m and 13m, the length is about 17m to 22m.

Construction on the original site means that villagers build new houses on the original site. Before the reforming and opening policy, almost no one went outside to work, the permanent population in Tableland rural habitats is large. Usually, there is an average six people in one family and the homestead is relatively large. By the field investigation, it is found that the original homestead is about

0.5 mu (333 ㎡). Along the social development, parts of rich villagers build new houses at the same time keep the original houses. Take Yang Po village in Zhang Jia Yuan town, Qian Yang County as example, most of the villagers are rebuilding houses in the original site, and the old houses are used as storing houses, kitchen or some other assistance houses, while the newly built houses are used as living rooms and bedrooms. The advantage of this model is that the living quality can be guaranteed and can save money, and all the houses can be efficiently used to meet the living requirements Figure 5.27.

Figure 5.27 The dwelling that combination of adobe building and brick-concrete structure building in Yang Po village

5.4 Main problems in the construction of vernacular dwellings during new countryside construction

The research chooses the largest amount and the typical vernacular dwellings in Tableland rural habitats of gully region as research objective to analyze the main problems existed in the construction vernacular dwellings during the new countryside construction.

5.4.1 Poor thermal environment of courtyard in vernacular dwelling

As the development of modern meteorology, Landsbur defined that the temperature and humidity of the area near edge land are influenced by vegetation, soil, and landscape; it is actually a kind of microclimate research, the land microclimate [70]. Courtyard space in the vernacular dwelling of tableland rural habitats belongs to the microclimate research scope; the courtyard should have the functions of adjusting thermal environment, preventing wind and sand, and creating a comfortable living environment. For villagers, courtyard is the important productivity and living space, thus the comfortable of thermal environment own huge influence on people’s living quality.

Therefore, this research selected a typical newly built Brick-concrete house dwelling in Min Feng village in Jian Jun town, Yong Shou County as research object to research the thermal environment conditions of courtyard. According to the field investigation, it is found that in both winter and summer although there is courtyard there, the thermal environment actually is almost the same in and out it. Courtyards actually have no functions for adjusting the thermal environment, there are some problems in the design of courtyard and its thermal environment should be further researched and improved.

5.4.2 Functional disorder for the layout of courtyard in vernacular dwelling

Vernacular dwellings' courtyard in Tableland rural habitats of gully region has the functions for both productivity and living Table 5.2. Inside the courtyard, there are lots of living activities, such as chatting, getting shadow, washing and laundry and so on; also there are some productivity activities, villagers store their farming tools, park farming vehicles, dry grains, or build rooms for livestock there.

Table 5.2 Functions and activities in courtyards

Courtyards' functions	Contents
Living activities	Relaxation
	Laundry
	Parties
Productivity activities	Cultivation
	Drying grain
	Planting
	Vehicle parking
	Storing

Currently, productivity and living, these two different functions are overlain together without good design in most of the newly built vernacular dwellings, which cause the disorder between different functions and inconvenience Figure 5.28.

(a) Vernacular courtyard in Liang Jia Zhuang,Chun Hua County (b)Vernacular courtyard in Yu Jia Gong, Yong Shou County

Figure 5.28 Courtyard layouts in disorder

5.4.3 Indoor thermal environment difference of residential building in vernacular dwelling

During the field investigation, low temperature indoors in the winter is the common problems in both brick-concrete structure house dwellings and adobe vernacular dwellings. For the newly built brick-concrete structure dwellings, the indoor thermal comfort is much worse than adobe vernacular dwellings. This research selected a newly built typical brick-concrete structure dwelling and a typical adobe dwelling in Yu Jia Gong Village of Yong Shou County as research object. The measuring time main divided into two periods of time: days around the coldest in one year without heating system (2005.01.19; 2015.01.20; 2015.01.21) and the days around the hottest (2015.07.22; 2.15.07.23; 2015.7.24). During these days, the indoor temperature was measured, the highest, lowest and average temperature and humidity in one day can be got from the measurement data Table 5.3, Table 5.4, and diagram was made by the average temperature of each measurement time Figure 5.29, Figure 5.30.

Table 5.3 Indoor and outdoor temperature in vernacular dwellings, January 2015

Type	Highest temperature	Lowest temperature	Average temperature	Average humidity
Indoor temperature for brick-concrete structure dwelling	1.9℃	-8.2℃	-3.9℃	50%
Indoor temperature for adobe dwelling	2.3℃	-5.1℃	-3.0℃	53%
Outdoor temperature	2.7℃	-9.2℃	-5.6℃	46%

Table 5.4 Indoor and outdoor temperature in vernacular dwellings, July 2015

Type	Highest temperature	Lowest temperature	Average temperature	Average humidity
Indoor temperature for brick-concrete structure dwelling	31.8℃	17.4℃	24.3℃	58%
Indoor temperature for adobe dwelling	29.1℃	17.6℃	26.5℃	56%
Outdoor temperature	35.2℃	21.3℃	28.0℃	61%

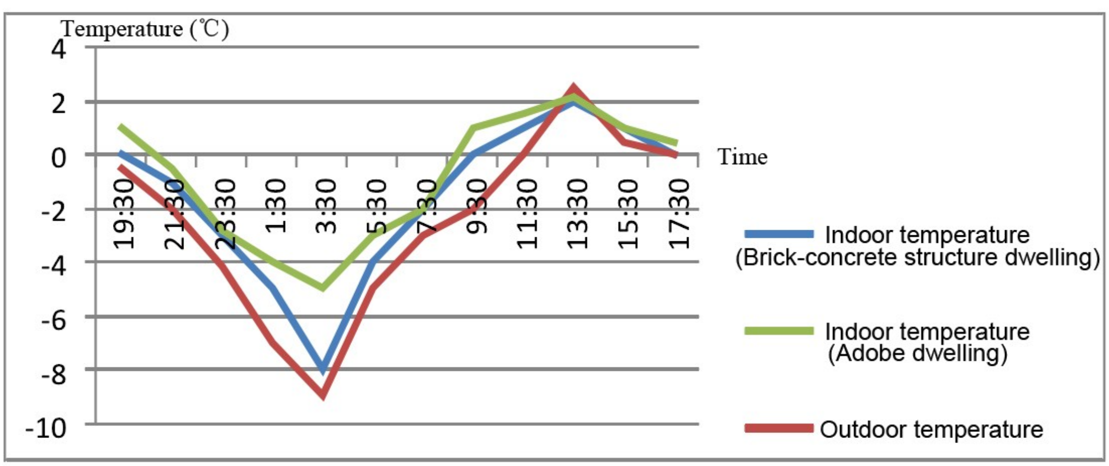


Figure 5.29 Indoor and outdoor temperature graph in vernacular dwellings, July 2015

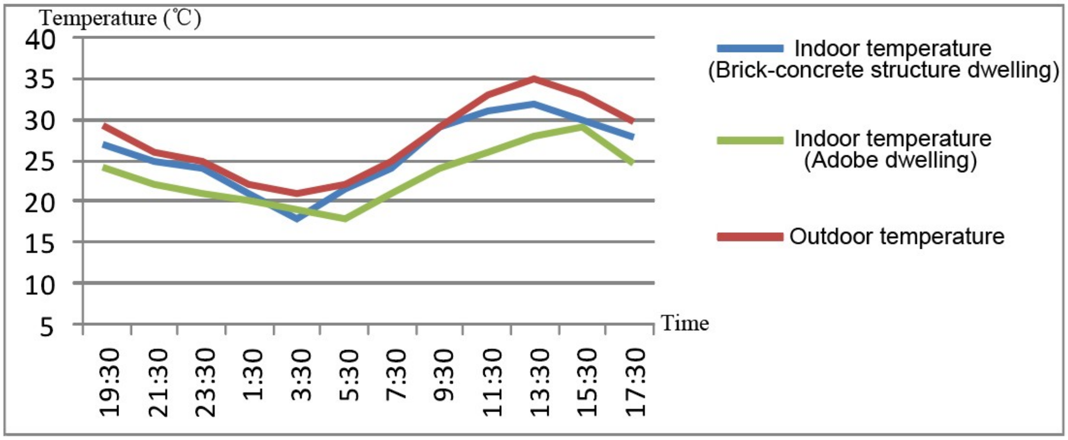


Figure 5.30 Indoor and outdoor temperature graph in vernacular dwellings, July 2015

It is shown that the average outdoor temperature is -5.6°C within the three measurement days, the indoor average temperature and outdoor temperature are not very different in both vernacular dwellings, the adobe dwelling is a little higher than brick-concrete structure dwelling. Overall, the indoor thermal environment is too cold. In July, the average outdoor temperature is 28.0°C. In adobe dwelling, average indoor temperature is 24.3°C, while the brick-concrete structure dwelling is about 26.5°C, the indoor temperature is clearly influenced by the outdoor temperature and the fluctuation is related big. Generally, the thermal comfort in adobe dwelling is better than brick-concrete structure dwelling. For the indoor humidity, adobe dwellings are more stable than brick-concrete structure dwelling. During the field investigation, more than 90% local people think it is very cold indoor without heating facilities. Less than 30% local villagers think it is very hot without any refrigeration facilities, while most villagers think the high temperature in summer just a few days and does not reach the intolerable level. Thus, just a few people install refrigeration facilities in their houses. Therefore, compare with summer, the thermal comfort conditions in winter is worse in vernacular dwellings of Tableland rural habitats.

5.4.4 High energy consumption in vernacular dwellings

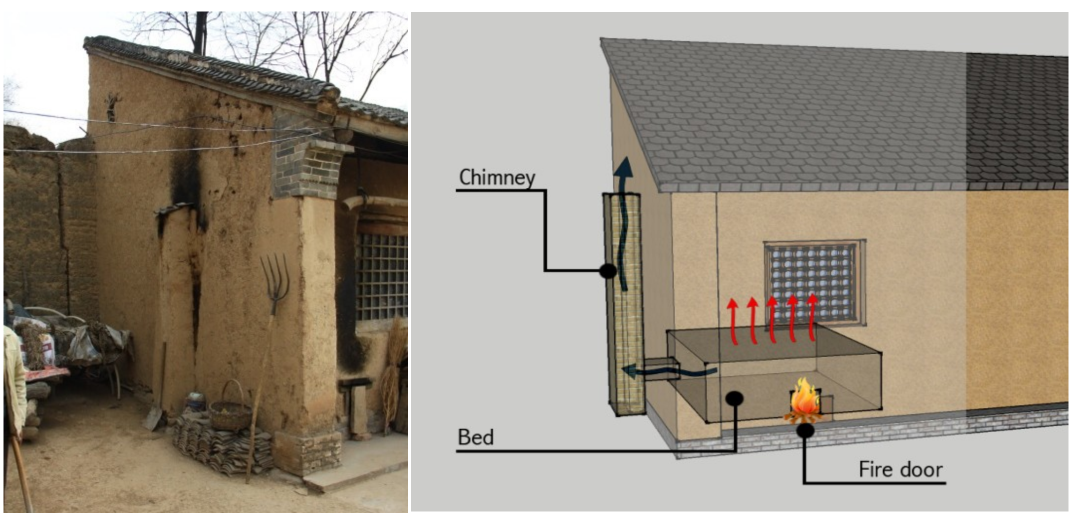
There are many energy types in gully regions of Loess Plateau, including coal, gas, electricity, biomass energy. Heating, cooking and lighting are the main types for daily use. Traditionally, biomass fuels, such as straw and wood, these recyclable fuels are mainly used for cooking and heating in gully regions of Loess Plateau Figure 5.31. Kitchen oven is usually made by soil or bricks. The biomass fuel they use is cheap and recycled, and when the chimney takes out the smoke, the smoke heat can increase the indoor thermal, but its inefficient burning and the ashes happened during burning will affect air quality. Currently, electric cooker and electric frying pan are more and more popular, but the traditional cooking oven are still kept and widely used. Villages are usually combining these two kinds of cooking together Figure 5.32.

(a)Straw stacked outside the courtyard (b) Fuel wood stack inside the courtyard

Figure 5.31 Traditional biomass fuels in gully region of Loess Plateau

(a) Traditional kitchen oven (b) Electric cooker

Figure 5.32 Two cooking modes exist at the same time in a dwelling



(a) Outlook of "Kang" (b) Structure of "Kang"

Figure 5.33 Traditional heating facility "Kang"

The traditional heating system in gully regions is "Kang", a traditional warm bed, used in bedrooms in winter. Currently, about 60% villagers still use this traditional "Kang" for heating in winter, it used as beds indoors with a hole on the outside wall, which is used for filling firewood. In addition, the smoke goes outside by using chimney Figure 5.33, Figure 5.34.

(a) "Kang" in the newly built vernacular dwelling (b)"Kang" entrance for adding fuels outside the room

Figure 5.34 "Kang" is still kept in the newly built vernacular dwellings

For those families without "Kang," coal stove and other modern heating facilities are widely used. Such as electric hot air fans, electric stove. Generally speaking, the thermal comfort in the room with "Kang" is better that using other heating facilities. According to the interview with local residential, the average heating for "Kang" is twice one day in winter, and the coal consumption is about 1.8t with other assistance fuels, such as straw and wood. Recently, the demand for electricity is increased rapidly and comes to be one of the main used energy for local villagers.

5.5 Reasons for existing problems in the construction of vernacular dwellings

5.5.1 Low heat storage capacity in courtyard

Actually, courtyard owns two functions for dwelling in gully regions of Loess Plateau: productivity activities and living activities, but for the newly built vernacular dwellings, the functional space division in most of them are not clear, just put all the functions in courtyard without design, thus cause the courtyard layouts in disorder. Materials used for floor in the courtyard are usually concrete, bricks, which are hard surfacing materials. This kind of floor materials is convenient for human activity, but heat accumulation capacity is low and the temperature increase speed is fast, which cannot supply a stable thermal environment. Wind environment does not put into consideration when construct courtyard there, villagers just build high walls according to their experience without think about the scientific wind preventing methods.

5.5.2 Poor air tightness and no insulation layers in residential buildings

Through the comparative study of traditional indoor temperatures for adobe dwelling and brick-concrete structure dwelling, it is found that the indoor thermal environment comfort in not satisfying in both dwellings, but the insulation capacity of adobe dwelling is better than brick-concrete structure dwelling, and the indoor temperature in adobe dwelling is relatively stable. The reason is that, in brick-concrete structure house, the exterior walls are made from 240mm bricks with cement plaster, roof is covered by tiles, and there are no insulation layers, thus the heat insulating capacity is very low. On contrary, adobe dwelling uses better insulation earth to build walls, while the total air tightness and indoor comfort are seriously affected by the simple construction methods and original structure. The poor insulation capacity actually increases the energy consumption, especially the energy consumption for heating.

5.5.3 Inadequate utilization of energy and the usage of pollution energy

As the development of socialist new countryside construction, people's living standards improved a lot, at the same time, the energy consumption demand is also increased. Currently, the energy usage method is still in its original step, which causes the inefficient energy transforming. For the biomass energy like straw and wood, the burning efficiency is just about 20%, the insufficient burning also causes air pollution and lots waste. Coal and electricity belong to commercial energy, and most of Chinese electricity comes from thermal power generation. The increased use of these two nonrenewable fossil energy, on the one hand, it will cause the dependence on it, on the other hand, will cause the air pollution.

5.5.4 Economic factors and villagers' comparing psychology restrain the ecological construction of vernacular dwellings

At present, the rapid development of gully regions in Loess Plateau makes people over pursue the economy, and gradually they use economic situation to evaluate people. Dwelling's luxury or not is the most direct mark to show the economic situation of the family, this actually largely influence their housing construction requirements. The comparison psychology makes lots people build new dwellings to show their economic situation, also this is the motivation for some people they work and earn money in cities and build new dwellings in countryside. Usually, these new dwellings are just with luxury appearances and the architecture itself might not be put into consideration. Thus, most of them with high-energy consumption, low environmental protection, simple structure, and poor construction appeared in the villages. Meanwhile, many villagers like to follow the tendency and copy others for the format, plan layout, materials and construction methods without thinking their own requirements and reality. The real background of this blindly following trend is the cultural and thought poverty of the local people, even the economic level of them improved [71].

5.6 Summary

This chapter firstly analyzes the influence of culture and regional characteristics of gully region in Loess Plateau on the construction of vernacular dwellings. On the base of this, further research on the characteristics and developing situation of traditional vernacular dwellings. The conclusion can be summarized as:

(1) There are mainly two construction models in the current new vernacular dwelling construction in Tableland rural habitats, they are unified planning, unified construction, unified planning and self-construction. (2) Under the background of socialist new countryside construction, underground cave dwellings have already disappeared, and the number of adobe vernacular dwellings is decreasing year by year. Instead of it, brick–concrete structure vernacular dwellings come to be the main structure in current Tableland rural habitats. (3) There are several main problems exist in the construction of vernacular dwellings, such as the poor thermal environment in the newly built courtyard, disordered functional layout, poor indoor thermal environment, and high energy consumption. (4) Main reasons for these problems are the small heating accumulation in courtyard, and lack of consideration about the design of space functions and wind environment, poor air tightness capacity in houses, in insulation design, the inefficient energy usage and the usage of pollution energy, restrained by economic conditions and villagers' comparing psychology.

CHAPTER 6
RESEARCH ON ECOLOGICAL LAYOUT METHODS OF VERNACULAR DWELLING IN TABLELAND RURAL HABITATS IN GULLY REGIONS OF LOESS PLATEAU

6 Research on ecological layout methods of vernacular dwelling in Tableland rural habitats in gully region of Loess Plateau

Vernacular dwellings in Tableland rural habitats of gully region are usually composed of residential buildings and its courtyard within courtyard walls. The courtyard is the space where the inner space of residential building and outside climate resource can be exchanged. It is the passageway for introducing the climate factors into the inside of vernacular dwellings. Therefore, courtyard space actually owns the functions of ecological energy saving, climate adjustment, and have a positive influence on the light environment, wind environment and thermal environment for the residential buildings, can promote better communication between human beings and nature[72].

Generally, courtyard space can be considered as the surrounding space by top interface, vertical interface and land interface Figure 6.1. Among them, the top interface is the main exchanging channel for the inside air and outside climate resource, the proportion and size are very important for these courtyards and can directly influence on the inside light environment. The vertical interface forms the space of courtyard and decides the closure degree, can influence wind environment inside the courtyard. The land interface is the interface that directly takes sunshine, rainwater and some other natural resource, and the decisive influence on the inside thermal environment for courtyard [73]. This research will propose ecological layout for vernacular dwellings based on the traditional experience of Tableland rural habitats in gully region and combined with the current different characteristics of vernacular dwellings in the new countryside construction.

Figure 6.1 The composition of interfaces in courtyard of vernacular dwelling

6.1 Analyses on courtyard space types and characteristics

Traditionally, the courtyard of vernacular dwelling in Tableland rural habitats of gully region is in the form of narrow courtyard, while it has changed and renewed continuously by the requirements of local villagers with the development and improvement of people's living standards and lifestyles. Under the background of new countryside construction, the courtyards of vernacular dwellings are gradually unified by the form of models. There are mainly two reasons, on the one hand, influenced by the urbanization trend of some other developed areas, more and more modern vernacular dwelling designs start to enter gully regions. On the other hand, peoples' lifestyle, productivity forms are related similar, the functions for the vernacular dwellings' courtyard are almost the same. Although there is some difference in some detailed design, the layout of courtyard space and vernacular dwellings tend to be same.

Under this background, in order to know the current vernacular dwellings situation better, this research did many field investigations on Tableland rural habitats in gully region of Loess Plateau. In the new countryside construction, the general newly built vernacular dwellings cover areas of 0.30mu (200 ㎡) to 0.4mu (267 ㎡), the height of main building is usually 4.5m to 5.4m, and subsidiary rooms are 3.3m to 3.6m, courtyard walls are 2.4m to 2.7m Figure 6.2.

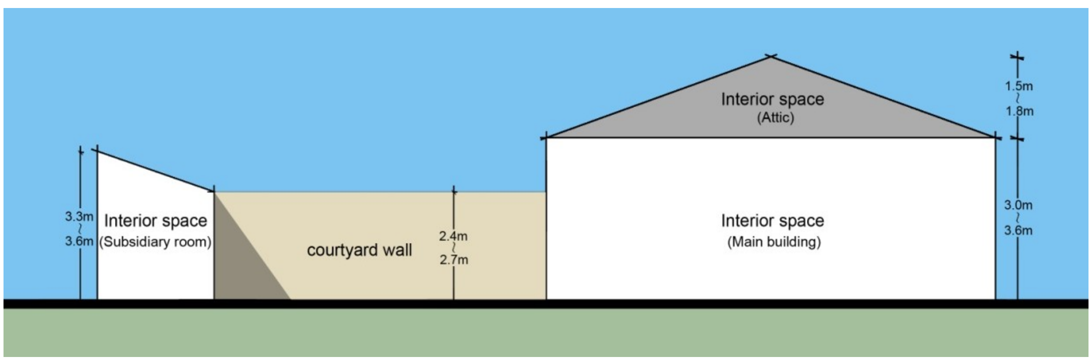


Figure 6.2 Diagram of proportion and scale for the vernacular dwellings

The house bays for most newly built vernacular dwellings are 3.3m or 3.60m with two types: 3 bays and 4 bays. According to the courtyards' location, vernacular dwellings can be further divided into foreyard type, back yard type and both foreyard and back yard type. The courtyard located on the side of main entrance is foreyard and the other side is called backyard. Combining the above two factors, the vernacular dwellings in Tableland rural habitats during the new countryside construction can be divided into the following six types Table 6.1, Figure 6.3.

Table 6.1 Vernacular dwelling types in Tableland rural habitats

Courtyard types	Bay number	Courtyard locations
Type A	3	Foreyard
Type B	3	Back yard
Type C	3	Both foreyard and back yard
Type D	4	Foreyard
Type E	4	Back yard
Type F	4	Both foreyard and back yard

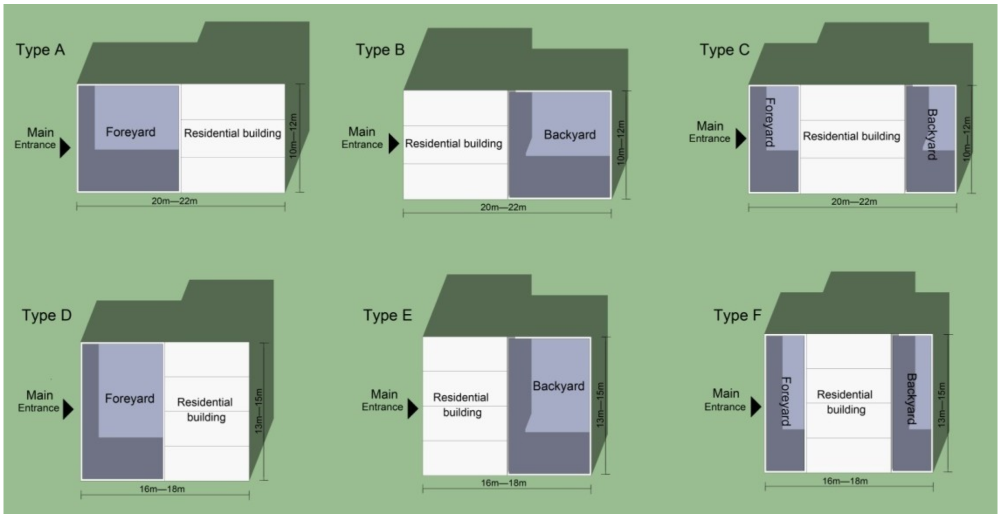


Figure 6.3 Diagram of vernacular dwellings types

According to the classification of different vernacular dwellings, typical dwellings were chosen as case study objectives in different villages during the field investigation, these different types of courtyard will be further analysis of the space division and functions difference.

6.1.1 Type A

(a) Aerial view of the whole village (b) Aerial view of vernacular dwellings

Figure 6.4 Aerial view of village

One of a typical newly built vernacular dwellings were chosen as case study for type A, which located in Gun village, Yu Jia Gong town in Yong Shou County. Gun Village is one of the poverty villages located in the gully originally, 12 km far away from town center. Restrained by the transportation conditions and less cultivable land per capita, villagers' income levels are very low, and living conditions are hard, also the developing speed of village is very slow for a long time. Along with the new countryside construction, Gun Village was chosen to be moved integrally by national governmental financial subsidies and planned by local government. The place for newly built village is located in the nearby tableland, and villagers were moved groups by groups. In November 2015, the whole village movement almost finished and came to be a typical newly constructed Tableland village Figure 6.4, Figure 6.5.

(a) Front facade (b) Side facade

Figure 6.5 Facade of vernacular dwellings

Village and vernacular dwelling are all unified, planned, and designed by local government, and constructed by villagers themselves. Thus, there is a big difference for the materials selection. Because of the fluctuation of materials price, the different movement time can be distinguished by the different material selection. Because of the large scale of movement and the limitation of tableland areas, the scale for each homestead is relatively small, just 0.32mu (204.7 m^2). The standard vernacular dwelling is three bays with foreyard Figure 6.6, each bay is about 3.6m, and the architectural area is about 100 m^2 Figure 6.7, Figure 6.8. During the field investigation, it is found that instead of main buildings, subsidiary rooms were usually prioritized built by the families with poor economic conditions for its low cost, and are usually used as storage room, kitchens, and bathrooms.

(a) South side in the courtyard (b) North side in the courtyard

Figure 6.6 Inside layout in the courtyard

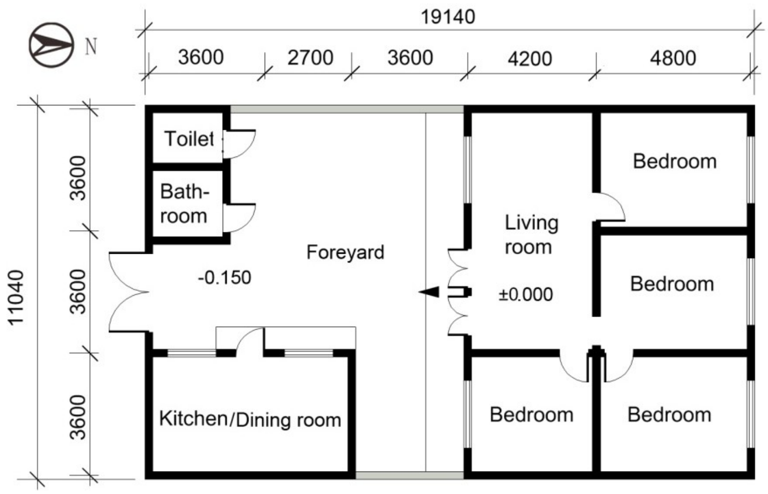
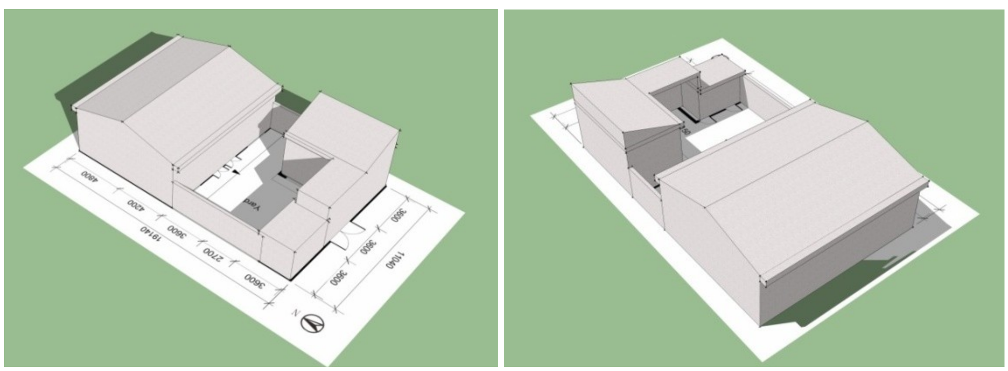


Figure 6.7 Vernacular dwelling plan



(a) Southwest perspective of vernacular dwellings (b) Northeast perspective of vernacular dwellings

Figure 6.8 Perspective of vernacular dwelling

6.1.2 Type B

(a) Aerial view of the whole village (b) Aerial view of vernacular dwellings

Figure 6.9 Aerial view of village

The typical type B vernacular dwelling was selected in the newly built Wu Yi village, Run Town of Chun Hua County. Wu Yi village is one of typical newly-built Tableland village started in 2007, each family can get a certain amount of subsidiaries, planned, designed, and unified by local government. The whole village was completed in 2009, and villagers moved from their original gully villages to the new location. The newly built village has better transportation that near the center of town and national highways Figure 6.9, Figure 6.10.

(a) Front facade along the street (b) Back facade along the street

Figure 6.10 Facade of vernacular dwellings

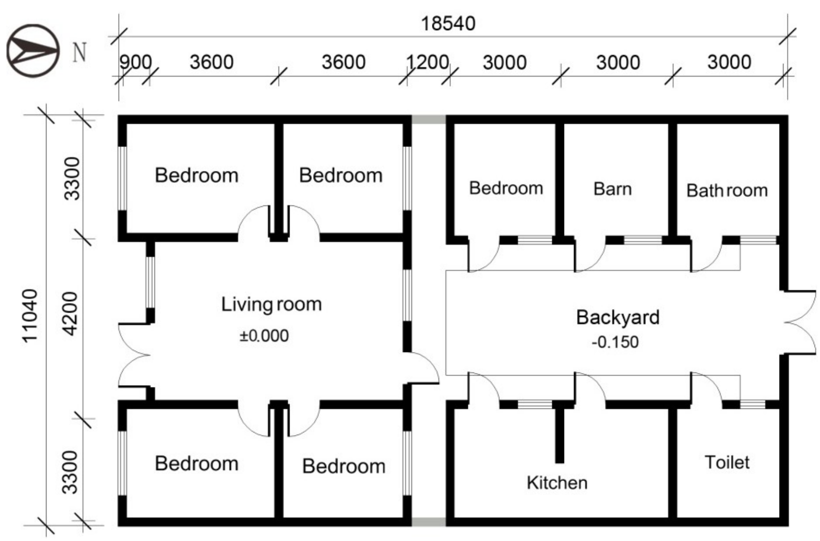
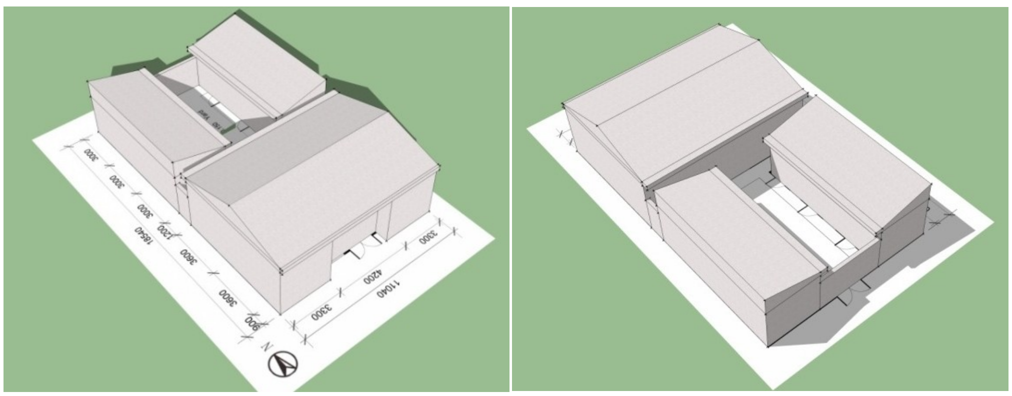


Figure 6.11 Vernacular dwelling plan

This village was unified, planned, and designed with same vernacular dwellings pattern, which is typical three bays with back courtyard. Because of the location is close to the town center, the construction land area is very limited, the homestead for each family is about 0.31mu, and construction area is nearly 140 ㎡ Figure 6.11, Figure 6.12. Therefore, because of the high density of buildings, the courtyard space is small. Therefore, in order to increase the courtyard area for the production needs, some of the people gave up some rooms' construction. Main entrances are along street entrances and on the side of the bedroom and the living room. Because of the lack of the courtyard as a buffer, the main building indoor noise is big, which is not good for residents' normal living and rest. Wu Yi village owns the biogas project that supported by local government, each family will get subsidiaries to install the biogas equipment. However, villagers said that the equipment in the past few years worked very well, but in recent years, because of the shortage of technical support and maintenance system, the cost of using it increases and efficiency is low. All of these make the numbers of users continuously decrease.



(a) Southwest perspective of vernacular dwellings (b) Northeast perspective of vernacular dwellings

Figure 6.12 Perspective of vernacular dwelling

6.1.3 Type C

(a) Aerial view of the whole village (b) Aerial view of vernacular dwellings

Figure 6.13 Aerial view of village

The typical type C vernacular dwelling was selected in the newly built Shi Jia Nian village, Yu Jia Gong Town of Yong Shou County. This village is located in the south 5 km away Yong Shou County center, Fu Yin highway is to the north of it and county level road pass it, thus it owns better transportation conditions and villages' income per capita and living conditions are all higher than other villages. The newly built village now is set as local provincial civilized demonstration village, which is originally located tableland areas with only 101 families and 386 villagers by the end of 2014. Even the population is small there, the original village is short of unified planning, the vernacular dwellings are distributed in disperse, and the total construction area is over 200 mu. After the new construction, local government re-planned the homestead in 2009, the newly built village is in the same place as before, only takes 60 mu lands for village construction and save 140mu lands than before Figure 6.13, Figure 6.14. The saved land was partly kept by the government, and partly distributed to villagers as cultivable land to reclaim.

(a) Front facade along the street (b) Back facade along the street

Figure 6.14 Facade of vernacular dwellings

Comparing with other villages, the construction requirements for the newly built Shi Jia Nian Village is much stricter, the construction period of time and materials are relatively unified. The standard vernacular dwelling is three bays, both foreyard and back yard type Figure 6.15. The floor area for each family is about 0.36mu (241.1 ㎡) and the building area is about 120 ㎡. The proportion of width and length in these newly built vernacular dwelling is close to the traditional vernacular dwelling in this region. At the same time of homestead for each family can be guaranteed, also more vernacular dwellings can be constructed in the same area Figure 6.16, Figure 6.17. Inside vernacular dwelling, the residential building divides courtyard into front and back courtyards, the front one mainly used for daily family life, and back courtyard used as assistance space for storing farming tools, so the whole courtyard can be tidier and in order.

(a) Foreyard of vernacular dwelling (b) Back courtyard of vernacular dwelling

Figure 6.15 Courtyard of vernacular dwelling

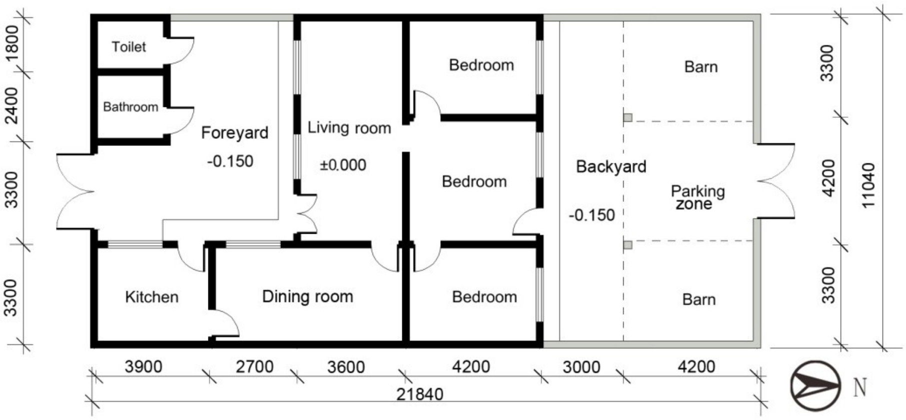
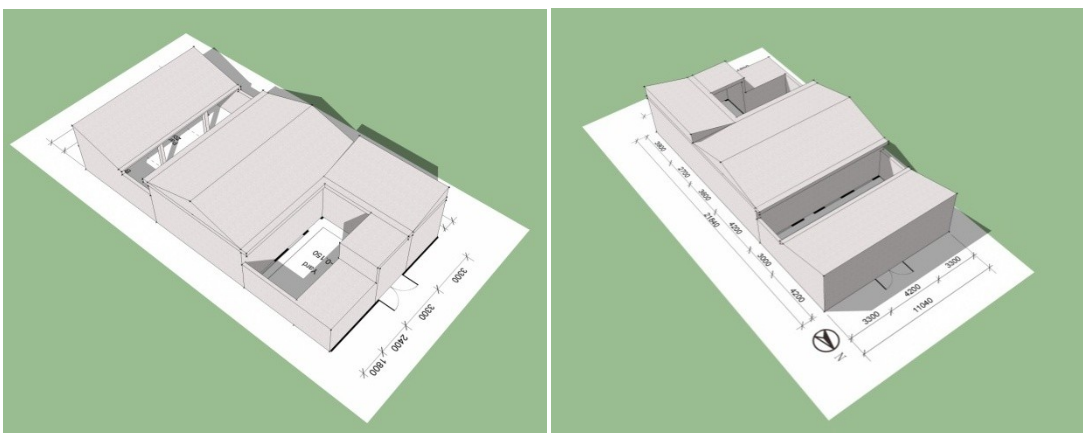


Figure 6.16 Vernacular dwelling plan



(a) Southwest perspective of vernacular dwellings (b) Northeast perspective of vernacular dwellings

Figure 6.17 Perspective of vernacular dwelling

6.1.4 Type D

The typical type D vernacular dwelling was selected in the newly built Wang Jia Zhuang village, Zhang Jia Yuan Town of Qian Yang County. This village is located in the center of Zhang Jia Yuan Town of Qian Yang County. For the good location and convenient transportation, it is always the relatively good developing village in Qian Yang County, and villagers' living standard is higher and is one of the civilized demonstration villages. The construction time for new countryside is earlier, the local government started to do the unified planning and construction since 2000. Until now, all villagers have already moved to the newly built vernacular dwellings, and it also receives some ecological immigrants from other villages. It is a typical extensive construction village Figure 6.18. By the end of 2014, there are total 515 families and 2010 villagers. Due the early construction and big scale of newly built village, each family can get a homestead about 0.36mu (239.0 ㎡) from local government. What is more, according to the different demand, several different vernacular dwelling models were designed, and villagers can select among them according to their demand. The most typical type has four bays and with foreyard Figure 6.19.

(a) Aerial view of the whole village (b) Aerial view of vernacular dwellings

Figure 6.18 Aerial view of village

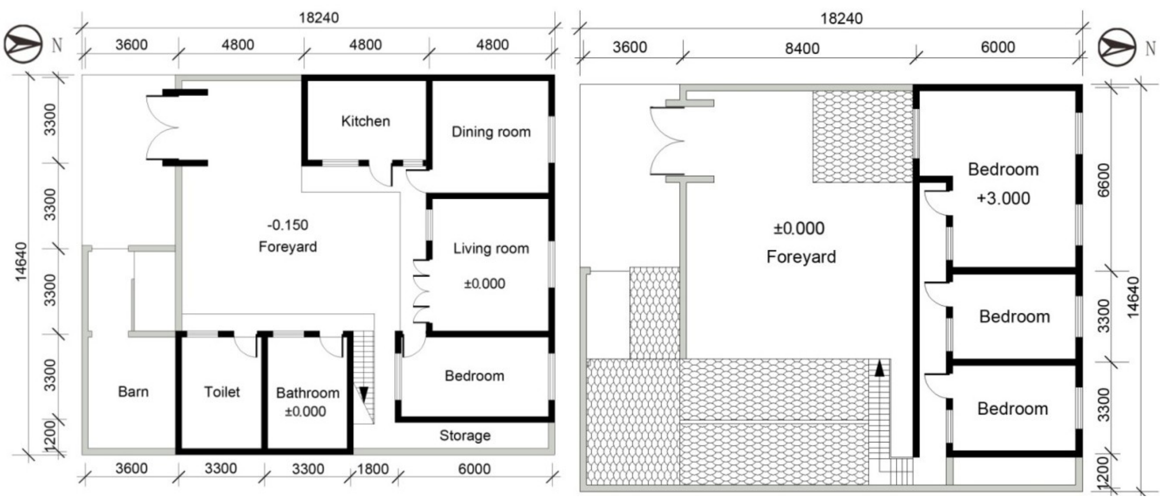
(a) Front facade (b) Side facade

Figure 6.19 Facade of vernacular dwellings

In this kind of vernacular dwelling, there are four bays and usually two floors, thus the total construction area is large about 177 square meters Figure 6.20, Figure 6.21, Figure 6.22. There are no back courtyards, which is the place for feeding livestock and storing straw or farming tools change into the outside place in the south of courtyard. Although it is good for the sanitary and tidiness, there will be strong smell influence people life because of the southeast monsoon in summer. What is more, the functions of this kind vernacular dwelling is similar to villas in cities, the rooms for living functions are too much, which cannot meet villagers' productivity requirements and lack of storage space, thus lots of bedrooms with good lighting and ventilation are used as storing rooms, it is waste of architectural cost and space.

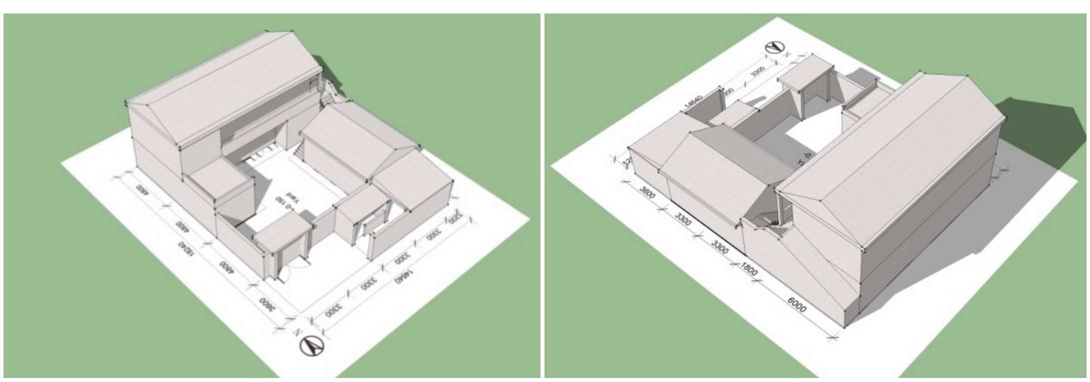
(a) East side of inner courtyard (b) South side of inner courtyard

Figure 6.20 Inner courtyard of vernacular dwelling



(a) First floor (b) Second floor

Figure 6.21 Vernacular dwellings plan



(a) Southwest perspective of vernacular dwellings (b) Northeast perspective of vernacular dwellings

Figure 6.22 Perspective of vernacular dwelling

In the field investigation of one local family, it is found that there is a total of seven family members, but their daughter and son work in the big city. Thus, the grandparents and their grandson now live together in the village. The functions of the second floor in residential buildings cannot be used reasonably, just used as storing room for farming tools or grain Figure 6.23. It is also found that family who choose to build this four bays and foreyard dwelling are usually in good economic conditions. On the one hand, these villagers hope to use this kind of vernacular dwelling type to show their good economic conditions and their pursuit for the modern urban life. On the other hand, the building area is relatively large, that can meet the demand for the future marriage for their children. Because of these two reasons, villagers are willing to spend a lot of money to build these houses. However, during the usage process, the young generation usually choose to live in cities; thus, a lot of space is waste, and this kind of dwelling does not put the requirements of productivity space for consideration and thus, cause lots of convenience.

(a) West side of the second floor (b) East side of the second floor

Figure 6.23 Idle space on the second floor of vernacular dwellings

6.1.5 Type E

The typical type E vernacular dwelling was selected in the newly built Zhu Jie village, Jian Jun Town of Yong Shou County. This village is located in the only 2.5 km west away from Jian Jun Town center, and also close to the county center, thus the village scale is large and people’s living standards are related high. Currently, there are 318 families and 1348 population. Because of the unplanned development of the original village, the distribution of courtyard is in disperse and disorder, still some of the villagers’ living conditions are bad. Since the new countryside construction, in order to improve the village outlook and villagers’ living standards, local government re-planed and constructed the village on the original site Figure 6.24, Figure 6.25. On the one hand, villagers’ homestead was centralized and re-planned for villager's transportation. On the other hand, the vernacular dwellings also are unified designed and constructed.

(a) Aerial view of the whole village (b) Aerial view of vernacular dwellings

Figure 6.24 Aerial view of village

(a) Front facade along the street (b) Front facade

Figure 6.25 Facade of vernacular dwellings

The design of vernacular dwelling in Zhu Jie village is uniform, but the construction time is divided into several steps since 2009. The main reason is the difference among villagers' economic conditions. For the family who has better economic condition, the construction was earlier, and for the family with poor economic conditions, the construction was relatively late. Until now, there are still some villagers do not construct new building. The standard vernacular dwelling has four bays and back courtyard Figure 6.26. The area for each family is about 0.34 mu (230.3 m²), with four bays and the construction area is about 137 m² Figure 6.27, Figure 6.28. The main entrance is connected with the street and side with the bedrooms and living room. Main entrances are along street entrances and on the side of the bedroom and the living room. Because of the lack of the courtyard as a buffer, indoor environment and noise is big, which is not good for residents' normal living and rest. The kitchen and bathroom are located in the back courtyard and take up a large area, which makes the back courtyard wide from the east to west and narrow from the south to north. Villagers usually divided the east and west area of courtyard into productivity area and living area, and the whole courtyard seems crowded and in repression.

(a) East side of inner courtyard (b) South side of inner courtyard

Figure 6.26 Inner courtyard of vernacular dwelling

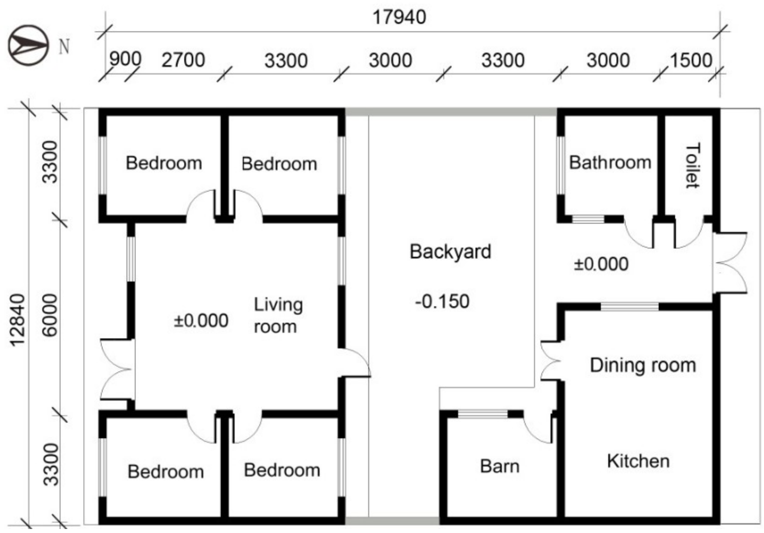
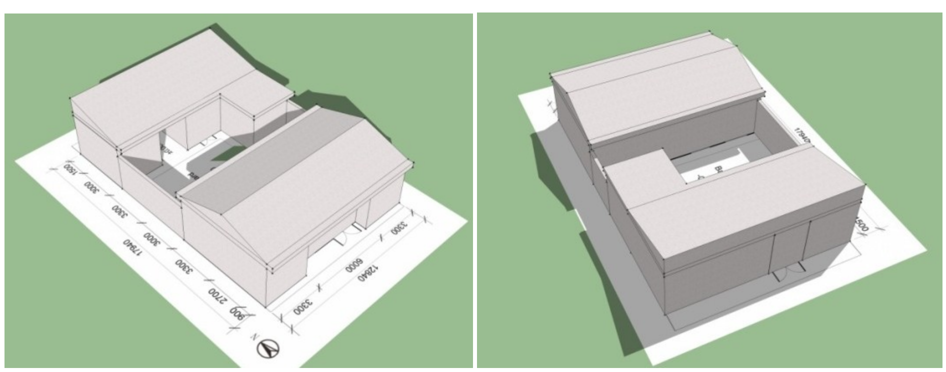


Figure 6.27 Vernacular dwellings plan



(a) Southwest perspective of vernacular dwellings (b) Northeast perspective of vernacular dwellings

Figure 6.28 Perspective of vernacular dwelling

6.1.6 Type F

The typical type F vernacular dwelling was selected in the newly built Long Quan Si Village, Nan Zhai Town of Qian Yang County. This village is located in the 1 km south away from Nan Zhai Town center. The original village is on a gully slope village and with poor infrastructure. Along with the new countryside construction, the local government started the unified planning and construction since 2007, and built a new village in tableland near the original slope area. Villagers were divided into three groups to move into the newly built village separately in 2009, 2010 and 2011. At present, almost all the villages have moved, and the original village has already changed into cultivable land. Because of the Bao Han highway completed in the south of it and the newly built village near the town center, Long Quan Si village experienced a rapid development in recent years. Moreover, because of the unified planning and design and large investment on infrastructure by local government, the outlook of newly built village is tidy and uniform Figure 6.29, Figure 6.30.


(a) Aerial view of the whole village (b) Aerial view of vernacular dwellings

Figure 6.29 Aerial view of village


(a) Front facade along the street (b) Back facade along the street

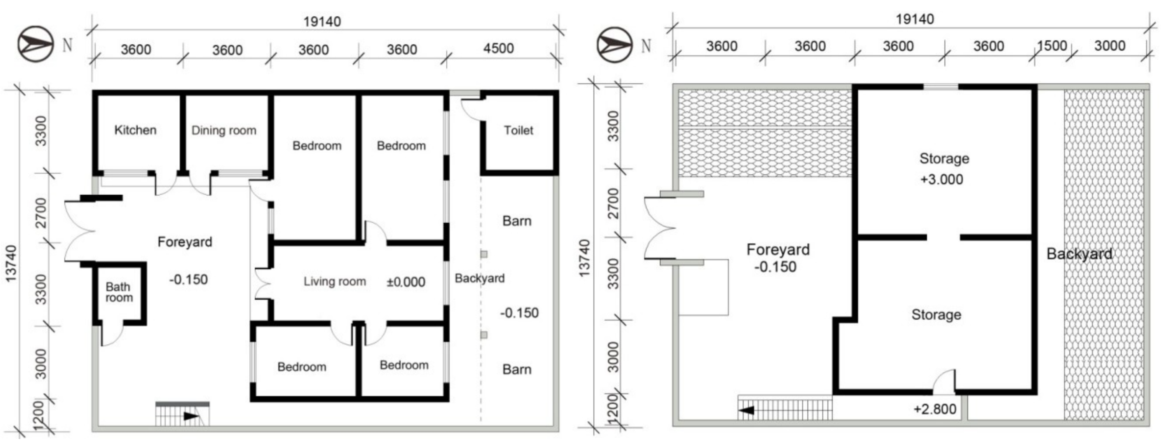
Figure 6.30 Facade of vernacular dwellings

The design and material selection for the vernacular dwelling in Long Quan Si village is uniform. The standard vernacular dwelling has four bays with both foreyard and back yard Figure 6.31. The area for each family is about 0.39mu (263.0 m²), the construction area is about 133 m² Figure 6.32, Figure 6.33

which is relatively large compared with others vernacular dwellings in the gully regions. In the primary design, the area for each family is about 0.34mu without back courtyard. Then after the adjustment according to villagers' opinions, the homestead increased 0.5mu for the back courtyard. The advantage of this design is that there will enough space for storing straw and farming tools, and prevent villagers put these things outside of the courtyard and influence the street sanitary conditions and the whole outlook of the village. What is more, the design of back courtyard can efficiently divide the productivity and living functions by courtyard and make the original courtyard clearer and in better order.

(a) Foreyard of vernacular dwelling (b) Back courtyard of vernacular dwelling

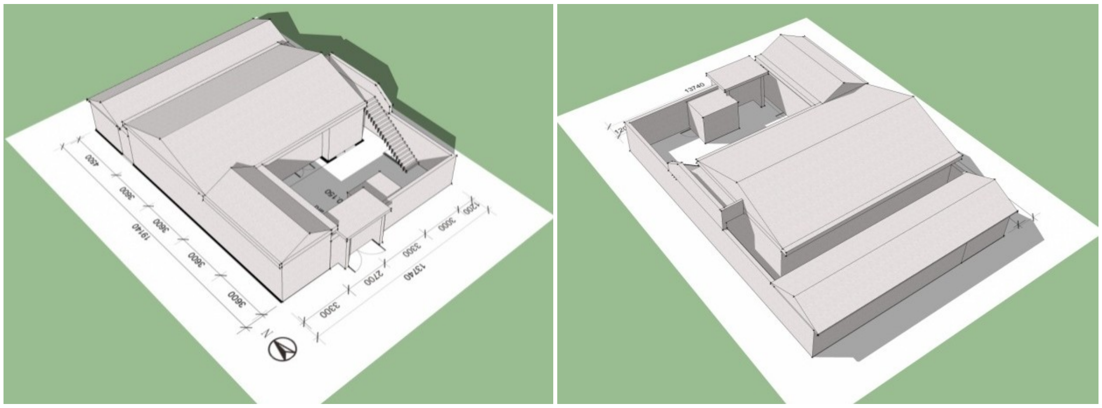
Figure 6.31 Courtyard of vernacular dwelling



(a) First floor (b) Attic floor

Figure 6.32 Vernacular dwellings plan

One of the advantages is more storing space, such as the attic can be used to store grain and the space under stairs can store farming tools and other Figure 6.34. Most of the villagers put up sheds along the wall in back courtyard, and use this "gray area" for storing or feeding livestock. The courtyard also acted as a buffer area for the main bedrooms and living room, making them cleaner and more comfortable.



(a) Southwest perspective of vernacular dwellings (b) Northeast perspective of vernacular dwellings

Figure 6.33 Perspective of vernacular dwelling

(a) Storing space in attic (b) Storing space under stairs

Figure 6.34 Storing space in vernacular dwelling

6.2 Analyses on physical environment in courtyard space

6.2.1 Light environment analyses

The light environment inside the courtyard has the close relationship with the size and proportion of top interface. The suitability of top interface has the directly influence on the light environment. The size of top interface decides the total direct light and reflects on the screen degree by the main buildings. In order to ensure the light in winter, the smallest distance between buildings and the obstacles can be calculated by the local solar altitude in winter Figure 6.35. The proportion of top interface is the same as the proportion of courtyards' width and length. In gully regions of Loess Plateau, because most of the vernacular dwellings are faced south, so comparing to the longer east-west courtyard, the longer north-south courtyard usually has better light environment in winter. Therefore, if the total construction area is same, compared with four bays, the three bays courtyard owns better light environment for the longer south-north courtyard, also for land saving Figure 6.36.

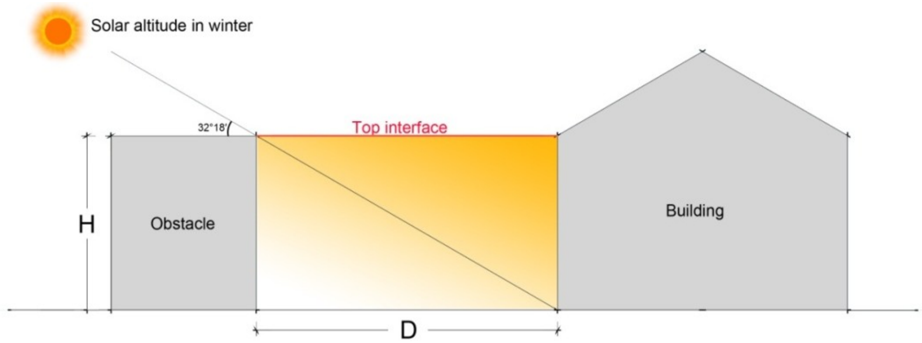


Figure 6.35 Calculation of the distance between main buildings and obstacles inside courtyard

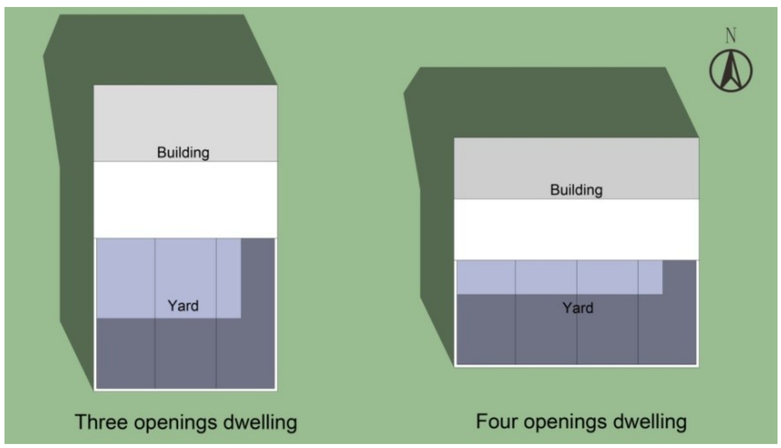


Figure 6.36 Light environment comparison between three bays and four bays

Among the above six types' courtyards, Type A and Type D is foreyard type and the courtyard is large, thus own better light environment. However, in these two types, the subsidiary rooms are usually designed in courtyard. If the design and the size of these rooms are not suitable that will directly influence the south lighting for main buildings Figure 6.37.

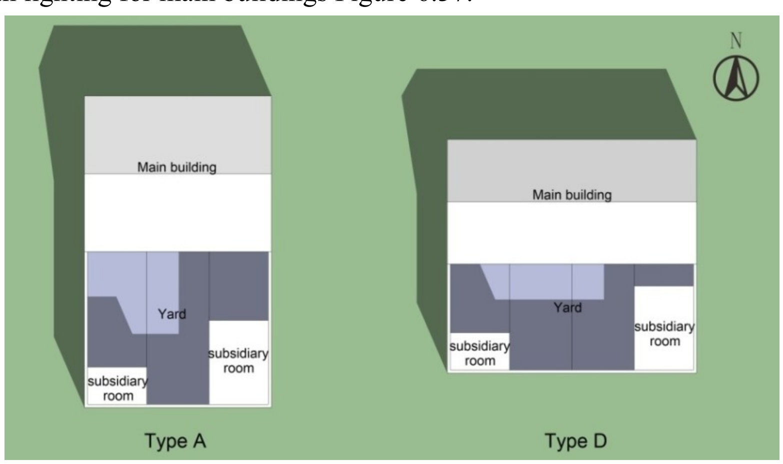


Figure 6.37 Influence of light environment by subsidiary rooms in Type A and D

Type B and E both belong to back courtyard type; the main building is located in the most south part of vernacular dwelling, thus the light requirement for main building can be meet. However, because the courtyard is located in north part of vernacular dwelling, the light is shaded by large size of main building and cannot enter the courtyard directly. Therefore, it causes courtyard space lower temperature in winter and negative psychological influence on the residents Figure 6.38.

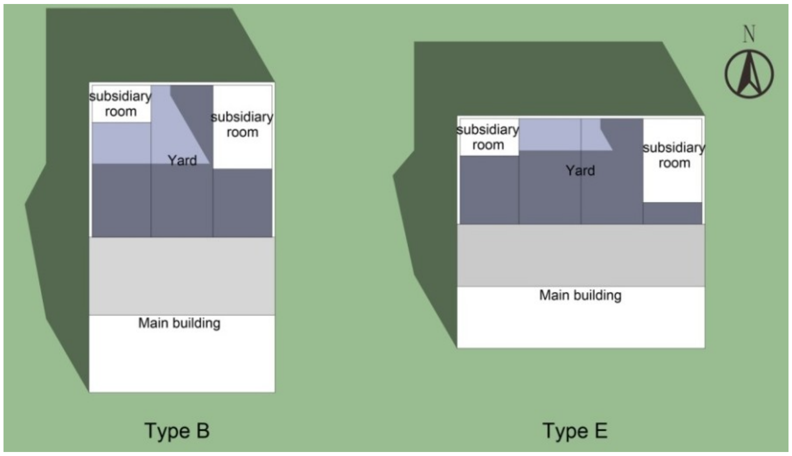


Figure 6.38 Light environment analyses on Type B and E

Both Type C and F vernacular dwellings have front and back courtyard Figure 6.39. With four bays, courtyard of Type F dwelling is usually narrow and long for the south and north side, which makes it hard to meet the requirements for architectural lighting in winter, at the same time gives people strong compression sense. Because there are three bays in Type C courtyard, the south-north side is much wider, thus the light environment is better that type F. However, if there are no scientific calculations, the light environment is also hard to meet the requirements. Therefore, the courtyard space distribution should be designed by scientific calculation, and combined with the area and building size, and the local solar altitude in winter.

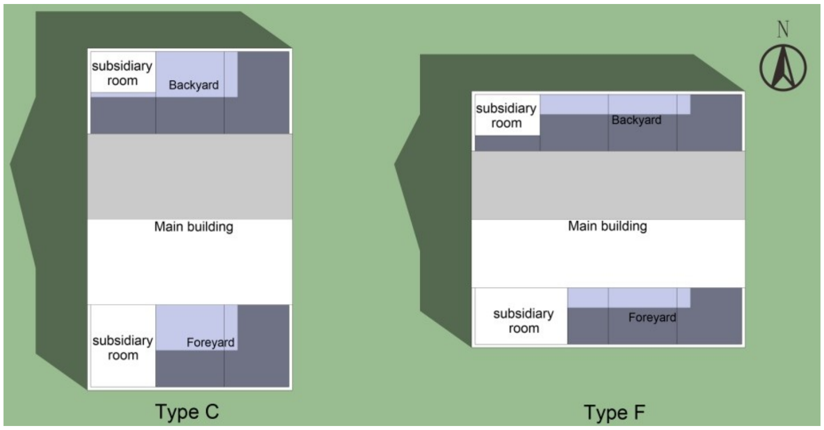
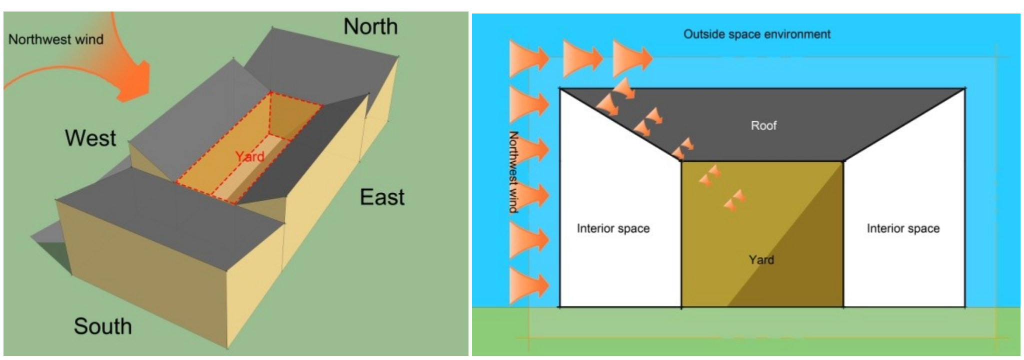


Figure 6.39 Light environment analyses on Type C and F

6.2.2 Wind environment analyses

According to the "Green Building Evaluation Standard" (GB/T 50378-2014), in order not to affect the comfort and ventilation for the outdoor activities in winter, the wind speed around pedestrian areas and at height of 1.5 meters should be less than 5m/s in the typical wind speed and directions in winter. What is more, in order to avoid large wind pressure on the building surface and increase the building energy consumption in winter, it also formulates that the wind pressure difference should less than 5Pa between the frontal and leeward surface, except the first line of buildings[74].

Gully region of Loess Plateau belongs to the cold area in China's climate partition, the winter weather is cold, drought, wind climate is poor, and the dominant wind direction is northwest wind mixed with dust, which often makes outdoor wind environment of the entire region is very poor. However, for other seasonal climate is relatively more appropriate. Therefore, in wind environmental design of traditional vernacular dwelling, the major consideration should be how to resist northwest monsoon impact on the internal courtyard and on the residential building in winter. Courtyard wind environment has a close relationship with the layout and size of vertical interface. In traditional courtyard, there are high courtyard walls, which can efficiently avoid the sand and dust enter the courtyard, thus to establish a better inner environment of courtyard. Meanwhile, there are only a few windows and outside in the resident buildings. Thus, the whole residential building actually is a kind of closed space; it can efficiently prevent the large energy consumption caused by the cold wind in winter Figure 6.40.



(a) Perspective (b) Storing space under stairs

Figure 6.40 Diagram of wind environment analyses on traditional vernacular dwelling

In the design of vernacular dwellings in Tableland rural habitats during the new countryside construction, it usually takes the vernacular dwelling forms in some other developed areas as reference, and adjust them according to the local regulations and governmental requirements, without doing the analyses on wind environment within the courtyards. This research used the software Ecotect Weather Tool to simulate the wind environment in the six different types vernacular dwellings of Tableland rural habitats by dwelling unit and dwelling groups, which mainly show the courtyard inner airflow rate at height of 1.5 meters and in the condition of winter wind in gully region Figure 6.41, Figure 6.42.

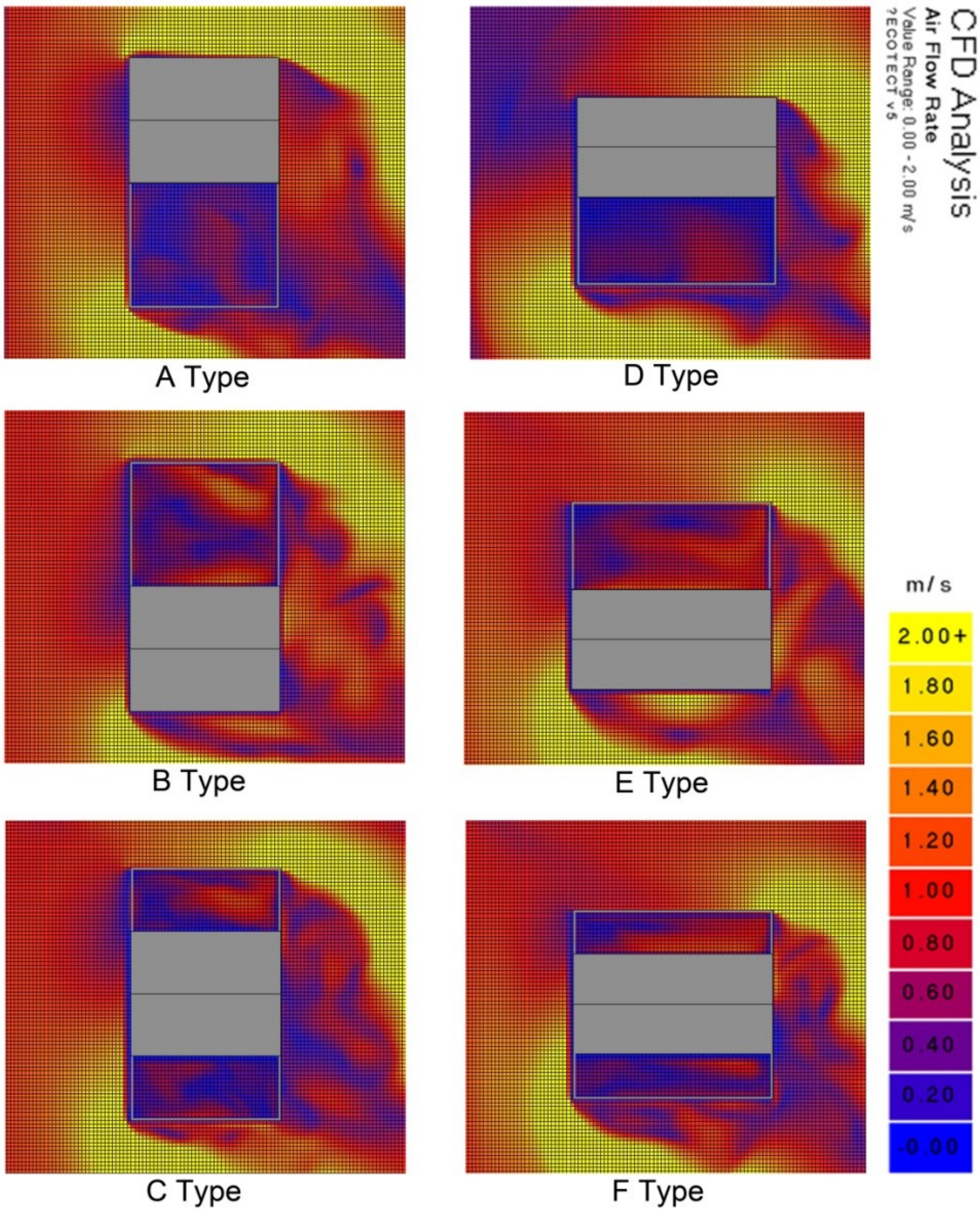


Figure 6.41 Simulation and analyses drawing on air flow rate inside of courtyard in the six types vernacular dwelling units in winter

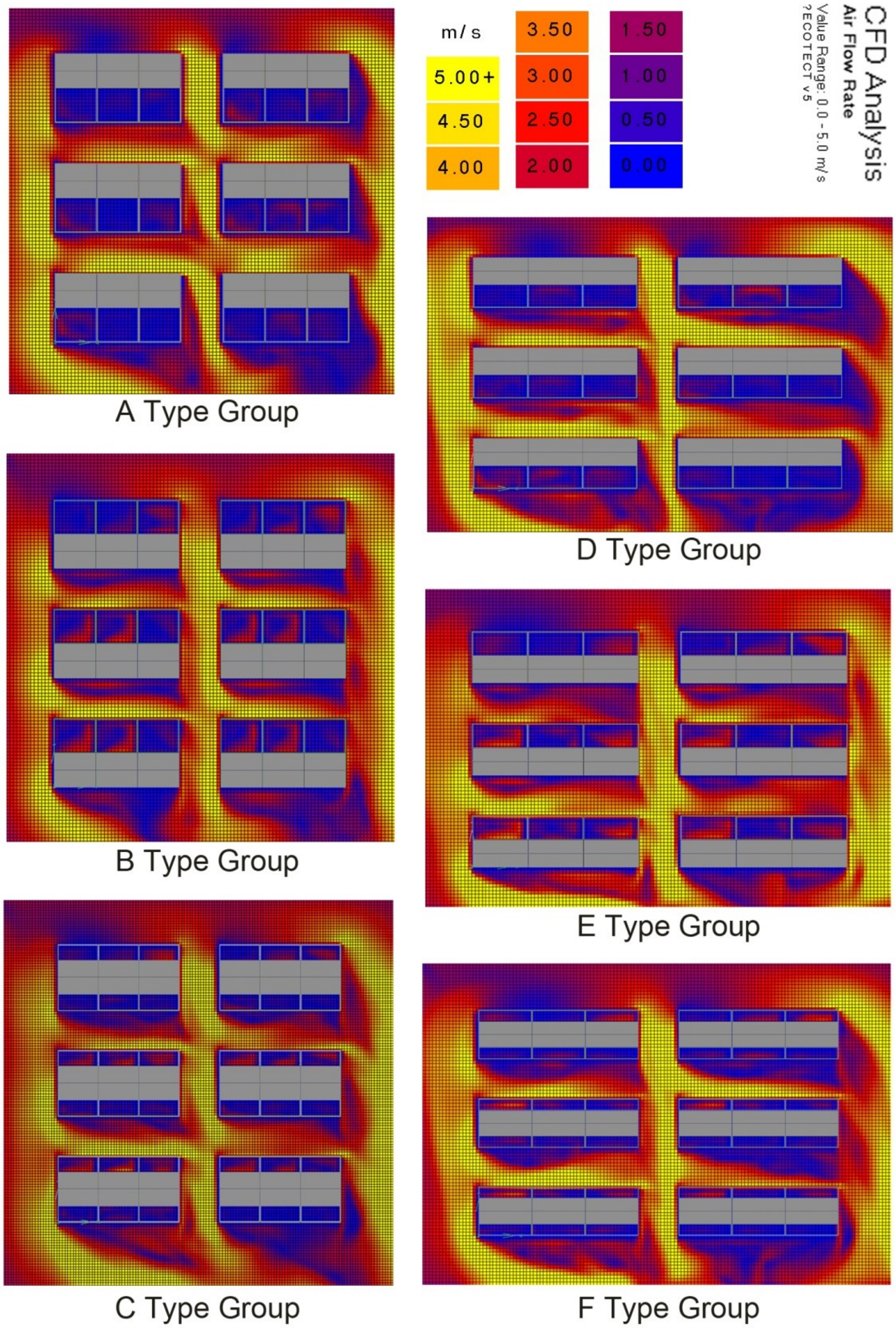


Figure 6.42 Simulation and analyses drawing on air flow rate inside of courtyard in the six types vernacular dwellings groups in winter

(1) Simulating the wind environment by dwelling unit

The results of simulating the wind environment by dwelling unit show that:

1) Comparing Type A and B, Type D and E, the wind speed in the foreyard of Type A is much lower than Type B, and Type D foreyard is lower than Type E backyard. For the Type C and F with foreyard and backyard at the same time, the wind environment in the foreyard is better than the backyard. This shows that the vernacular dwellings with foreyard, the wind environment is better than those with backyards. The main reason for this is that the wind in this region is usually northwest wind in winter, and the main buildings are high and big, which can prevent the wind from entering foreyard, while the backyard walls are relatively lower and the cold wind is easy to enter it and wind environment is relatively worse.

2) Although the wind environment in the foreyard of Type A and D is better, the main building is designed without the backyard as the buffer and faces the cold northwest wind directly, which will cause large amount thermal energy loss and not good for the thermal insulation. Therefore, the design of backyard is very important for insulation and energy saving for the main buildings.

3) In the winter northwest wind, the wind on the surface of buildings can be changed into downwind, and combined with the horizontal wind on ground; it is easy to form high wind speed and vortex near the buildings. It is shown that in Type B, C, E and F, they have backyards, and the wind speed near southeast corner of the backyard is relatively higher and the speed will be faster as the depth of courtyard becomes larger [75]. Therefore, the research of backyards' depth and the height of walls can be playing an important role in improving the wind environment in winter.

4) All in all, the vernacular dwellings in Tableland rural habitats of gully region in Loess Plateau, the wind environment in the foreyard is better than in the backyard for the buffer functions of main building, while the design of backyard is very important for the insulation and energy saving of main buildings. The conclusion is that designing the foreyard and backyard at the same time is good for creating better wind environment in the vernacular dwelling, and is good for the insulation and energy saving for the main building. What is more, the size and proportions of courtyard and the height of walls play an important role for the wind environment in the whole courtyard.

(2) Simulating the wind environment by dwelling groups

Taking into account the actual situation, most of the vernacular dwellings are constructed by groups, this research simulates the wind environment of courtyard by dwelling groups with the same environment conditions in the simulation of dwelling unit. The results of simulating the wind environment by dwelling groups show that:

1) On the whole, the simulation results of wind environment in the courtyard by dwelling groups have the same trends with the results by dwelling unit. Therefore, during the actual construction, for the spatial layout design of the courtyard, it can use the results by simulating of dwelling unit as the reference.

2) The results further analysis that the wind environment of courtyard in each end of dwelling groups is poorer than the middle part of the groups. In addition, because of prevailing northwest monsoons in winter of gully region, the westernmost dwellings in the groups usually have the worst wind environment in courtyard.

6.2.3 Thermal environment analyses

The thermal environment of courtyard has an important relationship with its land interface. The materials used in the land interface will direct take the sunlight radiation and natural rainfall. There are mainly two kinds of materials: flexible floor materials and hard floor materials [76]. The climate in gully regions of Loess Plateau is dry and short of rainfall, flexible and hard floor materials are combined used in traditional courtyard Table 6.2. Hard floor materials are usually used in main activity areas in the courtyard, which easy for people's activities. Because of the dry climate, there is almost no waterscape in the courtyard, people usually plant trees, vegetables, flowers and shrub in some part of courtyard as flexible floor materials. Besides its decoration functions, these flexible floor materials can also improve the temperature and humidity conditions for the courtyard Figure 6.43.

Table 6.2 Floor materials in courtyard of traditional vernacular dwellings in Tableland villages

Characteristics of floor material	Floor materials
Flexible floor materials	Tree Vegetable Flowers and shrubs
Hard floor materials	Concrete Soil Stone

Figure 6.43 Floor materials of courtyard in traditional vernacular dwellings

The current vernacular dwellings in Tableland rural habitats usually do not pay attention to the functions of floor materials. There are mainly two reasons, one is that the courtyard area is usually small in vernacular dwellings of current newly built countryside, the unreasonable floor materials will waste the courtyard space and also cause inconvenience for people's live. Another reason is that the flexible floor materials usually need time for the plants growing and have effects, while the construction speed and effect is very important in the new construction, villagers blindly follow the tendency "a lot in amount, fast speed, better quality and money saving," so most choose to use hard floor materials. On the one hand, it cost a large amount of non-environmental protection materials, on the other hand, it makes the courtyard much hotter in summer, thus reduce the courtyard comfort and people's life quality there. Therefore, it should combine the hard and flexible floor materials together, that will reduce the usage of concrete and brick, other non-environmental materials and improve the microclimate inside the courtyard.

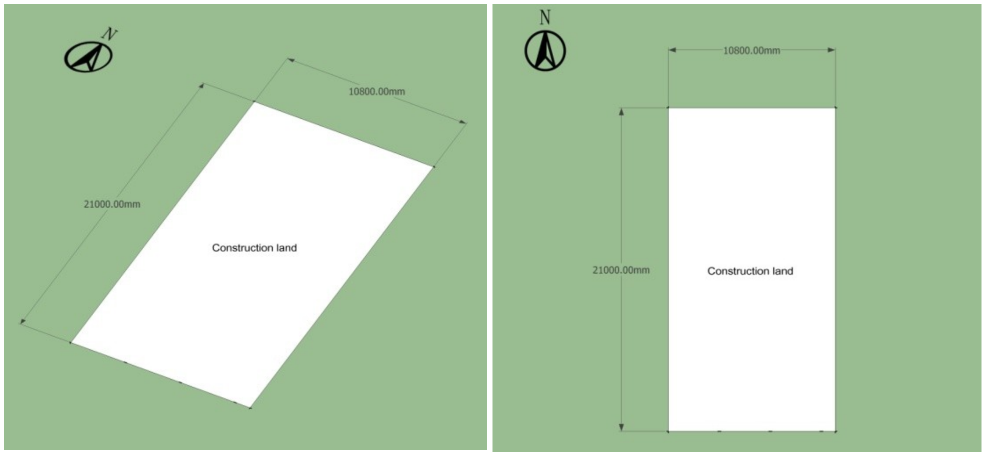
6.3 Ecological spatial layout method of vernacular dwelling

This chapter will be based on section 6.1 and 6.2, analysis of the vernacular dwelling types and their characteristics in the current Tableland rural habitats in gully region of Loess Plateau. Combined with traditional and ecological courtyard layout, this chapter summarized the design methods for ecological layout of vernacular dwellings in Tableland rural habitats. The derivation process about the design methods and the detailed information about these methods will be showed in the following sections.

6.3.1 The layout of bay in vernacular dwelling

The newly built vernacular dwellings are usually having two kinds: the three bays and four bays, the previous chapters have elaborated the characteristics of these two kinds of houses. However, in the current tableland, the land resource is very limited; the area for vernacular dwellings is decreased from the beginning of the household courtyard area 0.4mu (Around 267 m^2) to 0.5mu (Around 333 m^2). Currently, most of the courtyard is about from 0.3mu (200 square meters) to 0.35mu (233 m^2). Therefore, we should learn from traditional courtyards layout to save land, use the current three bays courtyard main forms Figure 6.44. Considering the courtyard area and the practicality of architectural space, the size of the bay should be 3.3m and 3.6m.

Besides land saving, the advantages of three bays courtyard can also be showed: in the same construction land area, comparing with three bays courtyard, the width from south to north is too narrow and east to west side is too long in the four bays courtyard, which is not good for Architectural Lighting of vernacular dwellings. The longer distance from south to north in three bays vernacular dwellings supply more space for courtyard, which is not only good for architectural lighting, but also supply more pleasant scale for the courtyard space.



(a) Perspective (b) Plan drawing

Figure 6.44 Diagram of three bays vernacular dwelling

6.3.2 The layout of courtyard

According to the previous analysis, vernacular dwellings with foreyard are good for the light and wind environment within the courtyard, and good for the lighting in the south part of buildings. However, without backyard, the north surface of the main buildings usually face the cold wind in winter and large amounts of heat will be taken, thus it is not good for the insulation of inner temperature. Vernacular dwellings with backyard can use the yard as buffer space to avoid the cold northwest wind in winter. Meanwhile, the backyard is often sheltered by the main building in south side, the light environment in it is not good. What is more, no matter the foreyard type or the backyard type vernacular dwellings, one side of the main building is connected with street, which will cause the noise inside the buildings. For these two kinds of vernacular dwellings, the productivity and living functions usually are mixed and the space usage is in disorder.

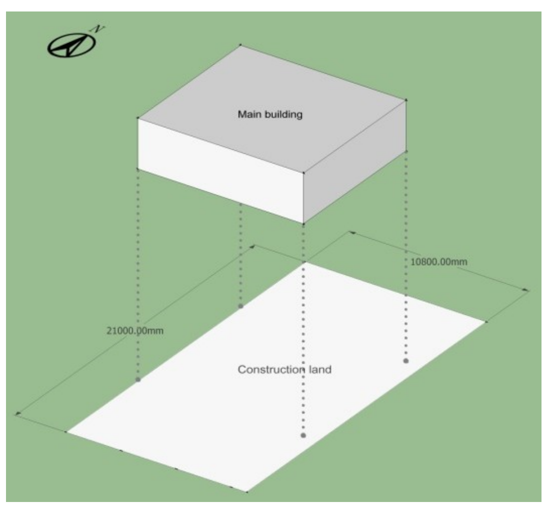
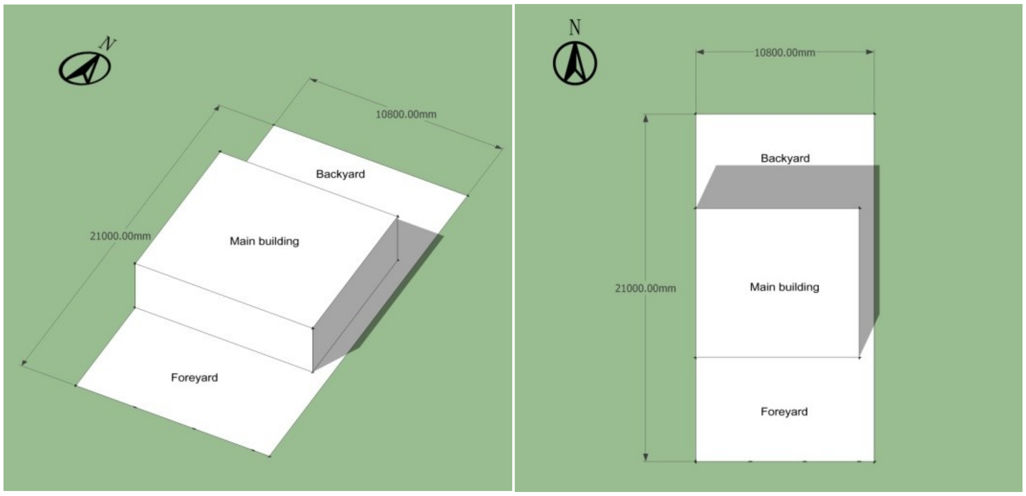


Figure 6.45 Formation of foreyard and backyard in vernacular dwellings



(a) Perspective (b) Plan drawing

Figure 6.46 Diagram of vernacular dwelling with foreyard and backyard

For the vernacular dwellings with both foreyard and backyard, can own the previous advantages and overcome their weakness Figure 6.45. Firstly, backyard can be used as buffer to improve the insulation in winter, and the main building can keep the good wind environment for the foreyard. Secondly, it can efficiently divide the courtyard for the requirements of productivity and living, the foreyard is often used for living activities and backyard used for assisting agricultural productivity, which actually prevent the mixed use of yards and can improve the inner environments for both yards. Lastly, with both foreyard and backyard, it can avoid the connection with street, which can prevent the influence on main buildings by the outside noise. Therefore, no matter from the space usage and energy saving, the design of both yards in vernacular dwelling is the better choice Figure 6.46.

What should be paid attentions to the proportion of foreyard and backyard, which also is the key to design. Theoretically, backyard is used for agricultural production; the usage time and frequency are much lower than foreyard. Therefore, as long as the production requirements can be meet, the backyard should not be too large, and more space should be designed as foreyard.

6.3.3 The layout of attic in vernacular dwelling

Different with urban areas, rural vernacular dwellings need more storage space for its agricultural production needs, on the one hand, it can be used to keep farming tools and straw. On the other hand, these storage spaces can be used to store grains and other crop after harvest. The roof of residential building in vernacular dwellings of Tableland rural habitats often have slope roofs, it has the relationship with the traditional wooden beam structure and good for collecting water in the rainy and snowy days.

Compared with common residence, the storey height is much higher in the newly built vernacular dwellings. The initial altitude of slope roof starts from the ceiling of main building which height is around 3.6 m, most of the ridge is about 5 m. If these attic spaces can be used efficiently as storage space, it does not only save spaces for storing thing, but also can be used as buffer area owns good insulation function between the inside space and outside climate Figure 6.47, Figure 6.48. Generally, the space for people entering should be over 2 m, and most of slope roof height is about 1.5 m, a little bit lower for people to use. Thus under the condition of invariable total building height, it can adjust the initial altitude of slope roof from 3.6m to 3 m. Then, it not only has no influence on space usage of the main building, but also can make an accessible attic which height is over 2m.

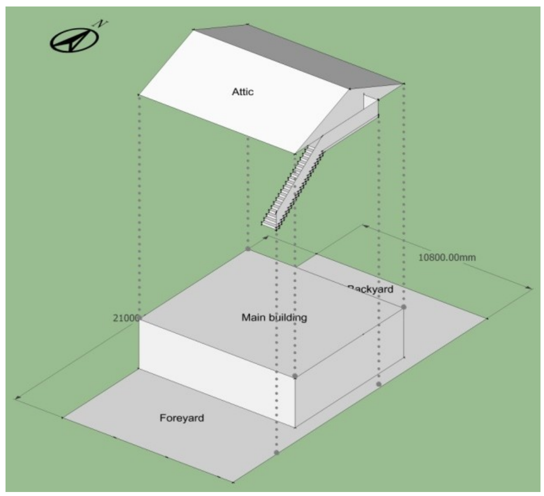
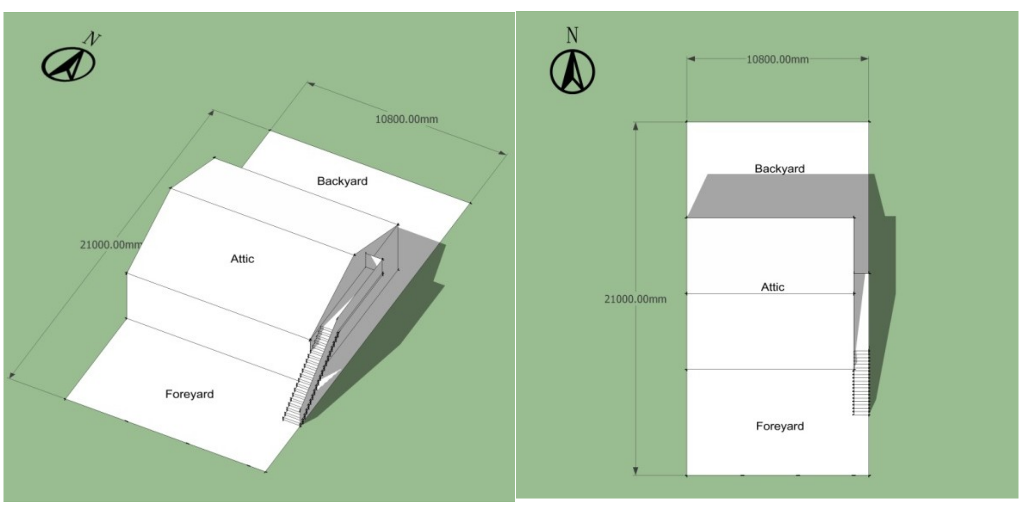


Figure 6.47 Formation of attic in vernacular dwellings



(a) Perspective (b) Plan drawing

Figure 6.48 Diagram of vernacular dwellings with attic

6.3.4 The layout of kitchen and bathroom in vernacular dwelling

As the important subsidiary rooms, the kitchen and bathroom are very important for people. The traditional cooking way in gully region is using firewood, as the main fuel, and a large amount of firewood are often stacked in kitchen. What is more, firewood burning will produce a lot of smoke. Generally, the kitchen is designed in the outside of main building, However，if the distance between kitchen and main building is too far, which will cause the inconvenience to people use, that they have to walk pass the outside from main building to the kitchen.

During the new countryside construction, the local reality and the influence of cooking methods for the inside space should be put into consideration when doing the design and layout for kitchen, which should meet residents' requirements for the modern and convenient life. According to the field investigation and a large amount of interviews with local residents, most of the villagers still keep their traditional stove for cooking, and they usually combine electricity and gas. Therefore, the kitchen should be designed in the south side of main building and connect with the main building. In this way, the kitchen can be relatively independent, and the influence caused by smoke will be less. What is more, it is better for the connection between main building and kitchen, and the villagers do not need to pass the outside space to enter kitchen. The more important point is that the heat from cooking can be transferred to the main building by chimney, thus reduce the energy consumption for inside temperature. Bathroom can be connected with kitchen, this arrangement is more intensive, which can reduce the usage of water pipes and electricity lines, and makes the courtyard in tidiness. The wastewater from bathroom can be used directly to irrigate plants in the foreyard, thus to save water. Because of the summer monsoon in gully regions is usually southeast, in order to increase the inner ventilation, kitchen and bathroom should be designed in the west side of courtyard Figure 6.49, thus the wind can be better enter the courtyard, and the single slope roof can prevent the northwest wind into the courtyard in winter Figure 6.50.

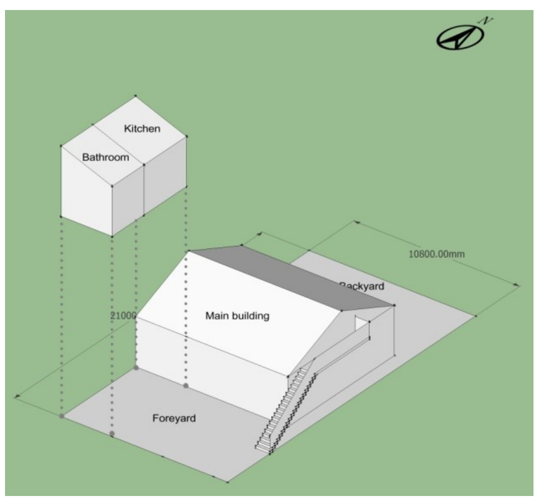
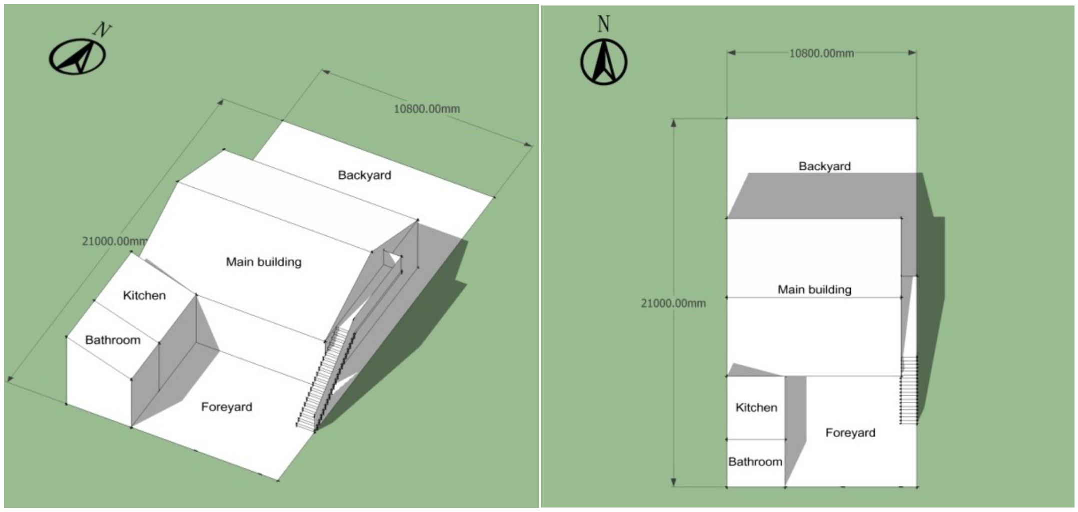


Figure 6.49 Formation of kitchen and bathroom in vernacular dwellings



(a) Perspective (b) Plan drawing

Figure 6.50 Diagram of kitchen and bathroom in vernacular dwelling

6.3.5 The layout of toilet in vernacular dwelling

Toilets in the vernacular dwellings of gully region in Loess Plateau is usually pit toilet, villagers need to clean it time by time, and the feces can be used as the important fertilizer for the land. In order to avoid the smell influence, the layout of toilet is very important. According to the local climate, if there are both foreyard and backyard in the courtyard, is suggests that the toilet should be designed in the northwest corner in the backyard Figure 6.51. In this way, the summer, worse smell cannot be brought into the courtyard by the southeast monsoon, and in winter the single slope roof also can prevent the cold northwest wind enter the courtyard Figure 6.52.

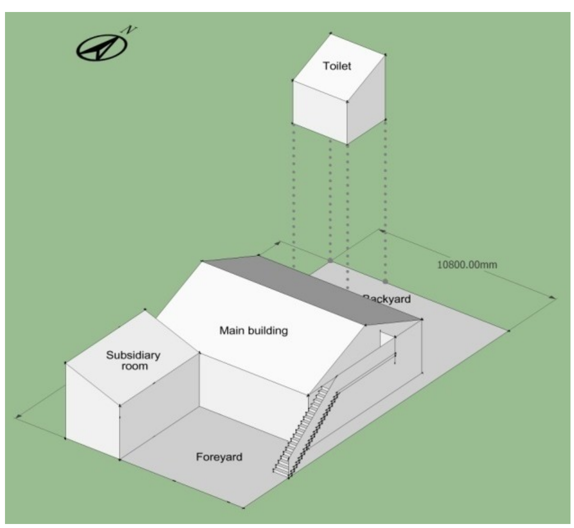
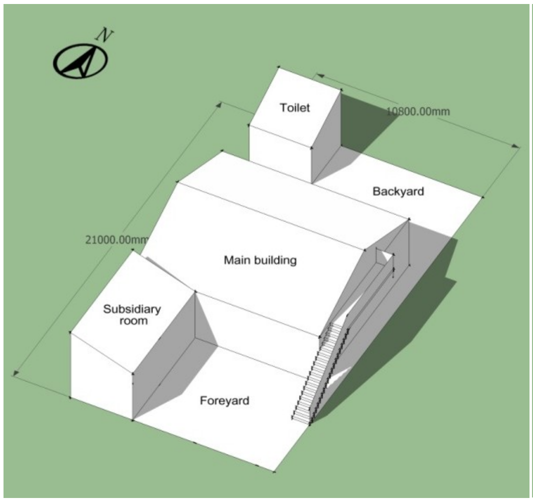
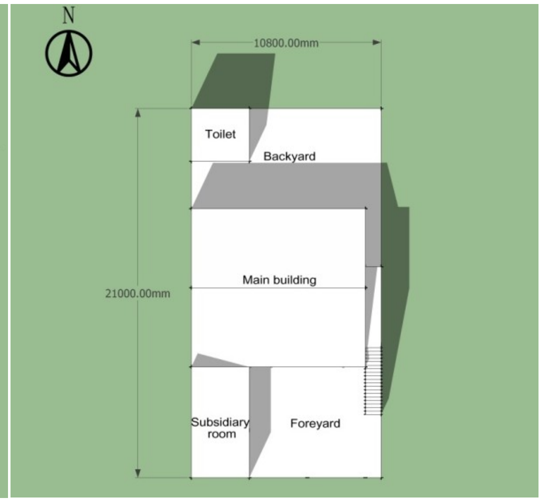


Figure 6.51 Formation of toilet in vernacular dwelling



(a) Perspective



(b) Plan drawing

Figure 6.52 Diagram of toilet in vernacular dwelling

6.3.6 The layout of sunshade in vernacular dwelling

Sunshade space in an important space for the production activities in courtyard of vernacular dwellings in Tableland rural habitats of gully regions, the main functions for the sunshade including: storage, piling debris, drying grains and feeding livestock. In the investigation, it is found that the cost of livestock feeding is much higher than they buy meat from market, and also feeding livestock has the impact on the sanitary conditions, thus at present, there are not many residents feed livestock. Instead of that, residents park their farming vehicles and store farming tools in the sunshade space. Therefore, in the design of sunshade, the storage, piling debris and dry grain, vehicle parking should be put more attentions.

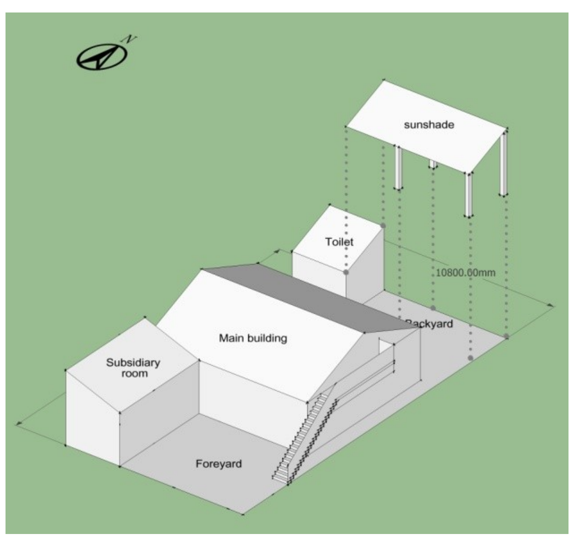
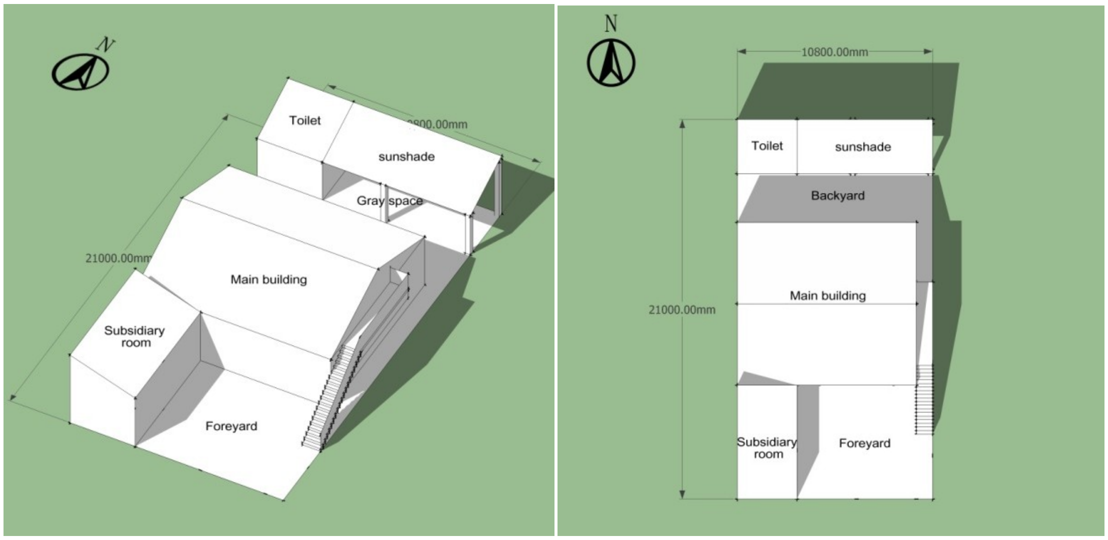


Figure 6.53 Formation of sunshade in vernacular dwelling



(a) Perspective (b) Plan drawing

Figure 6.54 Diagram of sunshade in vernacular dwelling

This research suggests put the sunshade space in the north part of backyard and connect with toilet Figure 6.53. Thus, the backyard will be more in tidiness, and the usage efficiency can be improved. What is more, the wall can be shared by sunshade space and toilet to prevent cold northwest wind enter the courtyard together Figure 6.54.

6.3.7 The layout of yard walls and entrance in vernacular dwelling

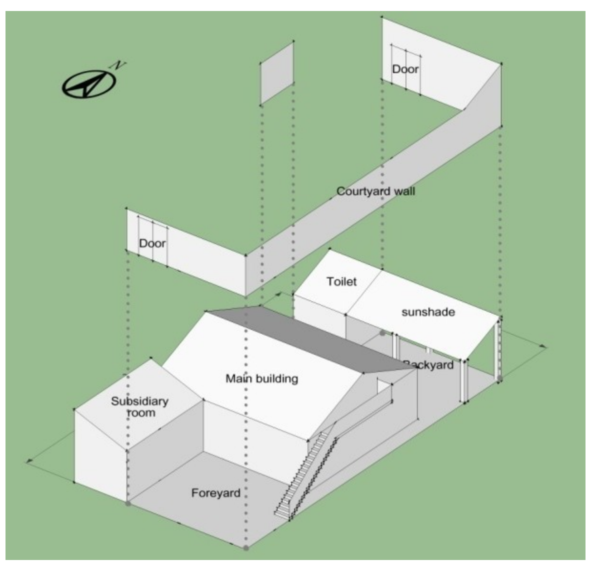
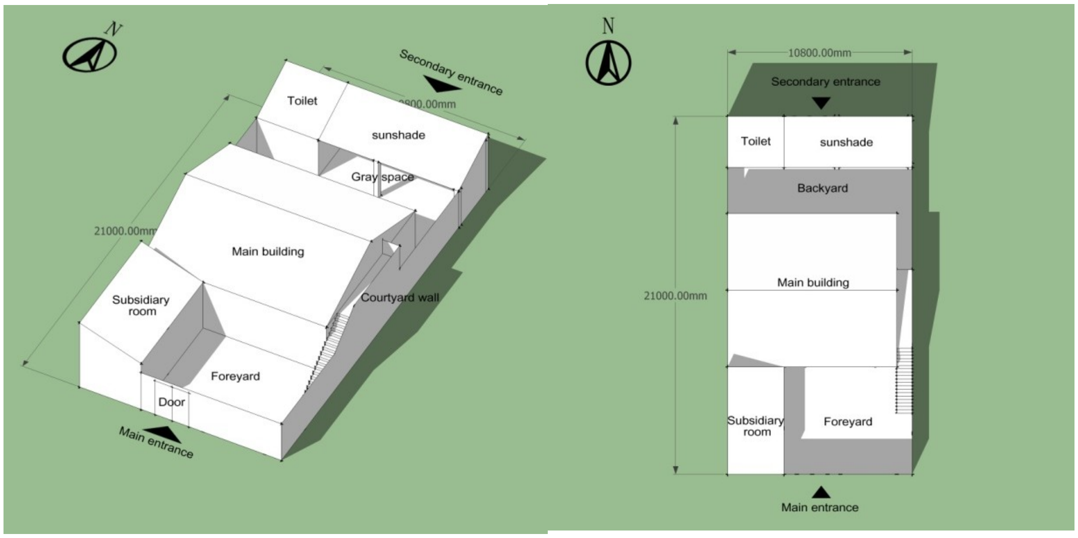


Figure 6.55 Formation of yard wall in vernacular dwelling



(a) Perspective (b) Plan drawing

Figure 6.56 Diagram of yard wall in vernacular dwelling

Yard wall is the main enclosure structure in vernacular dwellings, suitable height can avoid the outside interruption and create better inner environment. However, if the height is too high, it will give the residents the feeling of closure and repression, and not good for light and ventilation. According to the local climate, the south wall should be lower, that is good for the lighting environment and the ventilation in summer. However, the north wall should be higher to avoid the cold winter wind entering the vernacular dwellings Figure 6.55, Figure 6.56.

6.3.8 The layout of flexible floor in vernacular dwelling

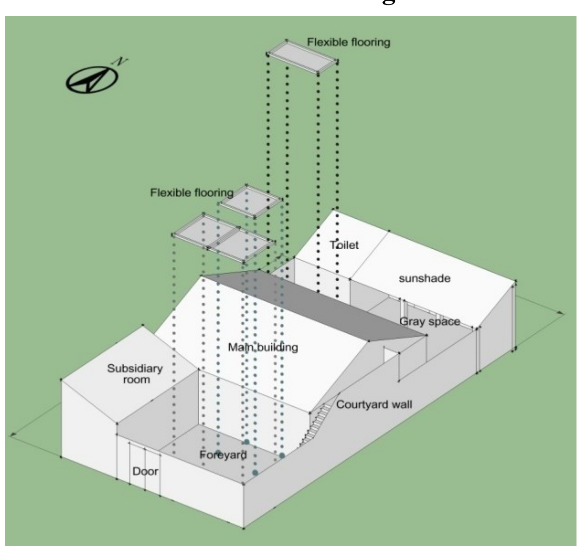
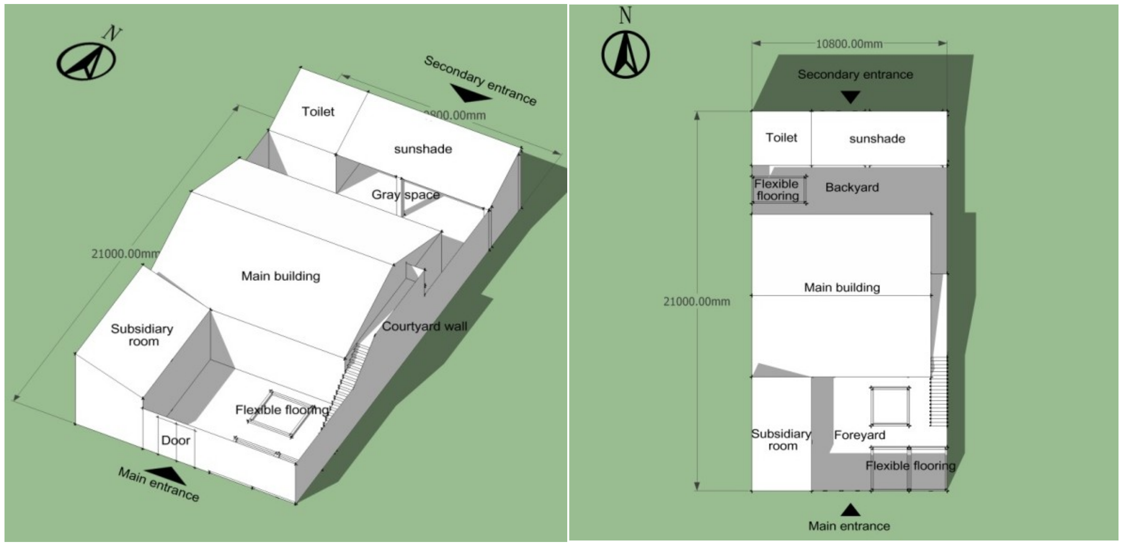


Figure 6.57 Formation of flexible floor in vernacular dwelling



(a) Perspective (b) Plan drawing

Figure 6.58 Diagram of flexible floor in vernacular dwelling

Because of the close relationship between the thermal environment and land interface and the dry and rain shortage climate in gully region, the design of flexible flooring in the courtyard can improve the temperature and humidity conditions, and have important influence on the thermal environment and villagers' production and living. The flexible flooring should be used in Tableland rural habitats in gully region of Loess Plateau; it should be designed by the conditions of newly built vernacular dwellings, and combined with the traditional ecological experience Figure 6.57, Figure 6.58.

(1) The broadleaf and deciduous fruit trees can be planted, such as persimmon trees and walnut trees; they can be planted in the south area of foreyard. In summer, these trees flourish; they can hinder the sunshine and adjust the courtyard climate by evaporating moisture. In winter, all the leaves fall down and the sunshine can enter the courtyard make it warmer.

(2) The garden greening and garden planting can be combined. Some daily consumption vegetables can be planted inside the courtyard, which can be used to increase the humidity by the vegetables' evaporation to stable the courtyard temperature, and further to adjust its micro-climate, and can also save living cost at the same time.

What is more, water cellars are very important water storage equipment in the gully region of the Loess Plateau, which can collect and storage rainwater for the daily use. Nowadays, the modern technology makes the water reuse system gradually perfect, if the traditional water cellars can be combined with this system, it will be a good combination of modern and tradition.

6.4 Summary

The courtyard is the space for the communication and exchange of climatic resource inside and outside the residential building in the vernacular dwellings. Its layout will directly influence on the inner courtyard environment, the insulation and energy saving of residential buildings and the living convenience.

Based on the results of field investigation, this chapter classified the different courtyard types in the newly built vernacular dwellings in Tableland villages of gully regions, and detailed analysis the characteristics of these different type courtyards. Ecotect weather tool was used to simulate and analysis the light, wind and thermal environment in different courtyards, and summarize the advantages and disadvantages for each layout in the different vernacular dwellings. Finally, combining with the local ecological experience in the layout of traditional dwellings, this chapter summarizes and explains the ecological layout of courtyard in Tableland villages of gully regions under the background of new countryside construction. This chapter also lays the foundation for following ecological design research on the residential building of vernacular dwellings.

CHAPTER 7
RESEARCH ON LIFE CYCLE ENERGY CONSUMPTION OF RESIDENTIAL BUILDINGS IN VERNACULAR DWELLING OF TABLELAND RURAL HABITATS

7 Research on life cycle energy consumption of residential buildings in vernacular dwellings of Tableland rural habitats

Along with the accelerating global climate warming and the increasingly tense of energy supply, the architectural energy saving has become a common concern for all walks of life. Nowadays, China's recent construction is estimated to account for half of the global construction [77]. According to the data of department of science and technology, the Ministry of Construction, building energy consumption has accounted for more than 40% of the total energy consumption in China, and the proportion is still growing, thus there are huge potentials for the future architectural energy saving. Chinese agricultural population accounts over 80% of the total population, the number of rural residential buildings is huge. However, it is a common phenomenon that these residential buildings are designed unreasonably with poor insulation and high-energy consumption and huge potential for energy saving. Therefore, the application of energy saving design for these residential buildings has great contributions to the whole society. Through the improvement of indoor light environment and comfort, reduce the energy consumption, the villagers' living qualities can be really improved and people's livelihood can be effectively improved [78].

In the current new countryside construction, because of the lack of ecological design as a theoretical guideline, the construction just pursuit the rapid construction time and convenient operation, thus simple construction methods are used, and simply copy urban houses' models, use "modern" high energy consumption, high pollution building materials. On the surface, the village appearance is improved, while in fact, it cost huge resource waste and energy consumption.

For a long time, the research on the ecological and energy saving of vernacular dwellings in gully region of Loess Plateau had been staying on qualitative or half quantitative level, there are no scientific and systematic research[79]. The quantitative research on vernacular dwellings for the energy consumption in the building materials manufacture, building erection, living, demolition and disposal, are not enough, especially the total energy consumption in architectural full life cycle on the basis of ensuring good thermal functions in vernacular dwellings. The establishment of assessment system on architectural energy consumption and do the analyses on energy consumption in the full life cycle for vernacular dwellings, will act as a basic research for the future "green" assessment. Therefore, comparative analyses and research on the energy consumption in different steps and process for the vernacular dwelling, owns guiding significance for improving and perfecting vernacular dwellings in the future.

7.1 Introduction to Life Cycle Assessment (LCA)

Life Cycle Assessment is an assessment method on a product or an activity from the raw material mining, manufacture to the final disposal. It refers to packaging, production technology, raw materials, energy and other human activities. In detailed, the life cycle includes the raw material mining, manufacture, production, package, transportation, consumption, recycling and final disposal, the energy consumption and the environmental influence in each process should be analyzed and assessed. Assessment of the whole process, systematic and quantitative, focus on the environmental influence, these three are the main characteristics of LCA. Using LCA method in full life cycle energy consumption, will provide more accurate and scientific energy consumption for architecture, and form the carbon emission model in the full life cycle.

In this paper, residential buildings of vernacular dwelling are regarded as products, through the field investigation and calculation of different residential buildings of vernacular dwelling in Tableland rural habitats, five processes were fixed by LCA, they are building material manufacturing, building erecting, building use, building demolition and waste disposal. Using these five steps to establish energy consumption model and add the energy consumption in each steps together, thus get the total energy consumption for vernacular dwellings in the full life cycle. Finally, the comparative analyses should be done for the data in different process of vernacular dwellings construction and used as a basis for the future ecological design of vernacular dwellings.

7.1.1 Basic standards and framework of Life Cycle Assessment (LCA)

(1) Basic guidelines of LCA

For the assessment of the life cycle, there are generally some basic guidelines showed in Table 7.1.

Table 7.1 Basic guidelines for LCA

Guidelines	Detailed explanation
Systematic	Systematically and fully put environmental factors into consideration in full life cycles
Timeliness	Research time and depth are decided by the research aims and scales
Transparency	The research scale, hypothesis, data description, methods and results, all should be in transparency
Accuracy	Data and the resource should be accurate.
Intellectual property	The application of the research on life cycle should be kept in secrecy and the intellectual property should be protected.
Flexibility	There are no unified format, thus the extant application should be carried out according the guidelines and framework of LCA
Comparability	If the hypothesis and research background are same, the results should be studied comparatively.

(2) The general framework of LCA

In the book "Outline and guide for Life Cycle Assessment", it divides the life cycle assessment into four related parts: the research aim and scale, list analyses of life cycle, life cycle assessment and the explanations of life cycle. The research aim and scale are made by the specific research object and hypothesis research intentions and research boundary thus ensure the research aim, breadth and depth. The analysis of life cycle list includes the data collection and calculation and the quantitative of input and output, there are mainly three kinds[80]: list analyses based on the process, list analyses based on the economic input and output, mixes list analyses. In this paper, the list analyses based on the process is adopted. The assessment of the influence in the full life cycle combines the list data and the extant environmental influence together, to do the comprehensive assessment of these influences. The explanations of life cycle use the above analyses results and form conclusions and finally provide suggestions.

7.1.2 Research on the feasibility of the application of Life Cycle Assessment (LCA) in architecture

Architecture is considered as special industrial product. The architectural full life analysis means to use the life cycle in biology and combine with the theory of social organism and system, and regard architecture as a special industrial product, then do the analyses on its full life cycle [81]. The architectural standardization and industrialization provide a good platform for the application of LCA in the architectural full life cycle and the assessment on material conversion. In the previous research on architectural energy saving and emission reduction just stay in the primary process of architectural design and building usage and maintenance, while ignoring the building material manufacturing, building demolition and waste disposal. Life Cycle Assessment (LCA) requires highly efficient energy usage and saving in the full life cycle, including the process of building materials manufacturing, building erecting, building use, building demolition and waste disposal. Among them, the energy and materials input, the solid waste and the emission of waste gas, and they're both positive and negative influence on the environment, all should be put into consideration in each process.

(1) Building materials manufacturing

The manufacturing process of building materials should be effectively save energy and resource as much as possible. By new technology of manufacture, it needs to produce some new building materials that can achieve the energy saving and emission reduction. In China, the energy consumption of indoor heating, air conditioner, ventilation takes more than two-thirds of total energy consumption. If install new walls with better insulation, it will better keep the indoor humidity, isolates the inside and outside heat exchange, thus reduce cooling and heating load and reduce energy consumption. There is close relationship between the energy consumption of building materials invention, transportation, installation, and erecting methods and transportation distance, each part of it should be energy saving and emission reduction. LCA has mature calculation method for the selection and usage of architectural materials, thus the usage of this technology can help designers to select suitable building materials.

(2) Building erecting

Architectural waste, solid waste, and waste gas can destroy the environment, also the water and electricity consumed during construction will cause a large amount of green gas emission. Therefore, scientific and reasonable construction methods, new construction technology and techniques, and the construction management system and resource distribution system, all of these can reduce the energy consumption in the building erecting process.

(3) Building use

Generally, the building use time can be decades even hundreds of years, the energy consumption is huge, and usually takes over 80%-90% [82][83] energy consumption in the full life cycle of the whole building, even for the architecture with high efficient energy consumption, it still can take 50% to 60% [84]. This big part of energy consumption including heating , air conditioner, hot water, lighting, cooking and household appliances. LCA can calculate the about energy consumption and compare and analyze the calculated data thus put forward related improving measurements. In the same time of ensuring good living comfort, the energy saving and emission reduction can be realized.

(4) Building demolition

For different architectures, there are different demolition methods. Generally, the first type is manual demolition in site. This demolition type is usually used for the small-scale architecture. The structure is mainly wooden, brick and concrete structure, brick and wooden structure and small-scale steel structure. The second type is machine demolition, which is mainly used in the steel and concrete structure architecture. The third one is explosion demolition, which is mainly used in the demolitions of high rising architecture, large-scale architecture, or there are special requirements for the surrounding architectures. The energy consumption for different demolition has a difference, and LCA method can do the qualitative calculation for energy consumption.

(5) Waste disposal

It is different among the recycle and disposal for different building materials. For example, glass, steel, aluminum and wood can be recycled and concrete and bricks can also be used to produce other building materials. However, for the architectural glue, painting, these high polymer elements cannot be biodegraded and contain lot of harmful heavy metal elements, which should be treated carefully before disposal. For those recyclable materials or disposal materials, there is also huge energy consumption during the transpiration and treatment and a large amount of greenhouses gas emission. If the building materials can be recycled, this part of energy consumption and emission can be reduced.

All in all, LCA can do the quantitative energy consumption evaluation on the whole process of building materials, from mining, processing and transportation, project planning and construction, maintenance, demolition, recycling or disposal. It can be used as important reference for the designers to design the energy consumption, and good for the controlling work on the energy consumption in the full life cycle, thus to realize the aim of energy saving and emission reduction.

7.1.3 Aims and scales of Life Cycle Assessment (LCA)

(1) Assessment aims

The research object is residential buildings of current vernacular dwellings in Tableland rural habitats in gully regions of Loess Plateau. Combining the field investigation and the previous analyses, the traditional underground cave dwelling has already disappeared and there seems no possibility of developing cave dwellings in the new countryside construction process. "Housing" vernacular dwellings are the main developing trend in recent years. The existed residential building of housing vernacular dwellings can be divided into adobe vernacular dwelling and brick-concrete structure vernacular dwelling. Brick-concrete structure vernacular dwelling can be further divided into two kinds: one-story brick-concrete structure dwelling and two-story brick-concrete structure dwelling. Therefore, the most common residential building: adobe residential, one-story brick-concrete structure residential building and two-story brick-concrete residential building are regarded here as the main research objects, and their energy consumption in full life cycle will be calculated by LCA.

(2) Research scale and the system boarder

In LCA, in order to get the more objective and accurate assessment, the full life cycle refers the time from the raw materials' mining to the time return back to nature by the landfill method. Thus, it is good for assessment the energy consumption situation and waste emission situation for the products or system in their full life cycle. In this research, there are significant difference for the energy consumption of the building materials, methods and building use, even the demolition in the different residential buildings of vernacular dwellings. The solution is establishing a list for each energy consumption, then use LCA to figure out the difference among these residential buildings and their influence on environment. Architecture, as a special and complex industrial product, the assessment should within boundary from macro perspective. In the paper, the architectural full life cycle can be divided into five steps: building material manufacturing, building erecting, building use, building demolition and waste disposal, showed in Figure 7.1. The architectural full life cycle system showed in Figure 7.2, within the frame is the research systematic boarder.

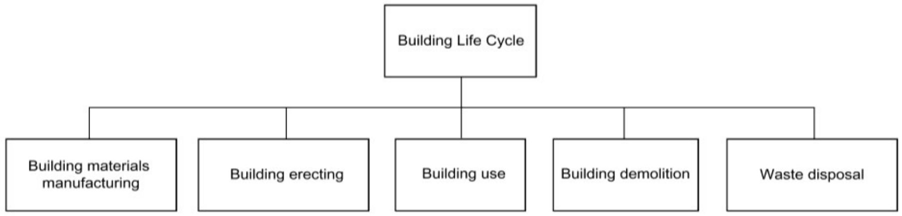


Figure 7.1 Five steps in the architectural full life cycle

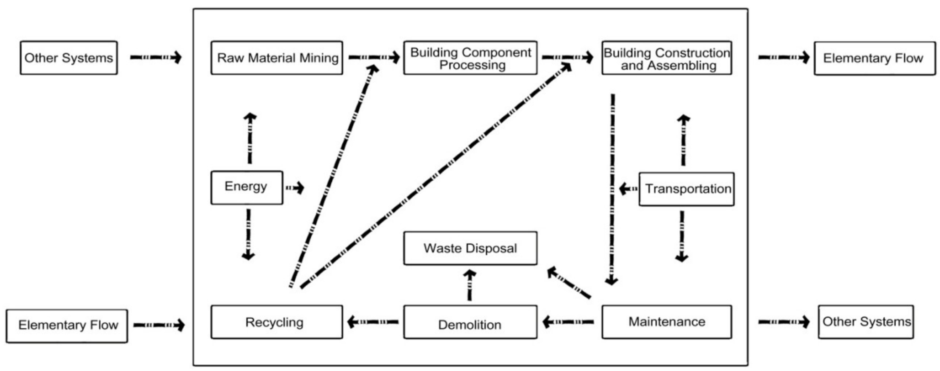


Figure 7.2 System for the architectural full life cycle

In order to further fix the research scale and for the future research, several hypotheses are submitted as following:

1) Even for common architecture, there are hundreds of building materials even more; it is difficult to do the detailed and accurate statistic. Because of the limited conditions and author's limited ability, there just several main building materials' energy consumption is calculated.

2) In the vernacular dwellings' usage period, the calculated energy consumption is the required energy consumption for getting certain comfortable inside environment, but not the real energy consumption for the architecture.

3) This paper focus on the energy consumption in full life cycle of the vernacular dwellings, the resource consumption, such as land, mineral and water resource are not calculated in detailed.

4) In the life cycle, the consumption of human labors, the bio-energy is relatively extreme and hard to be calculated, thus does not put into consideration in this paper.

(3) Fixing functional units

When doing the comparative research on two or more products or systems, the unified functional units are the basic conditions. In the LCA analysis of energy consumption and environmental evaluation of the vernacular dwellings, the functional units used are quality, volume, distance, energy and so on [85] [86]. In this paper, in order to better compare the energy consumption in full life cycle in different architectures, the energy units used as functional units in this paper are energy consumption: MJ, energy consumption per unit area: MJ/ m^2 and energy consumption per unit area per year: MJ/ m^2 · Y .

7.2 Full life circle energy consumption model building for residential buildings

Architecture is a special and complex industrial product. In this paper, there are mainly five steps used for doing the assessments on architectural energy consumption and its influence on environment, these five steps are building materials manufacturing, building erecting, building use, building demolition and waste disposal, the explanation of each steps are showed in Table 7.2. In addition, this method can be also used in the analyses of residential buildings of vernacular dwellings.

Table 7.2 Explanation on the five steps in architectural full life cycle

Steps	Detailed explaination
Building materials manufacturing	Materiasl and other products used in architectural construction, their mining, production and manufacturing process
Building erecting	Construction materials' transportation, the prepareation of building site, basis digging, structureal installation and indoor decoration
Building use	The basic usage and renovation and maintenance for the architectures
Building demolition	The demolition process of physical space of building
Waste disposal	The transportation and treatment for the recyclabel and inrecyclabel waste construction materials

Following above steps, this research is going to establish the energy consumption model, and the total energy consumption of each step will be the final energy consumption for residential building of vernacular dwelling. In this paper, the total energy consumption equation in the architectural full life cycle is [87][88][89]:

$$E_{\mathrm{Tot}} = E_{\mathrm{manu}} + E_{\mathrm{erect}} + E_{\mathrm{ues}} + E_{\mathrm{demo}} + E_{\mathrm{dis}} \qquad \text{Equation 1}$$

Meanings for each character in Equation 1 are showed in Table 7.3

Table 7.3 Meanings for each character in Equation 1 (MJ)

Characters	Meanings
E_{Tot}	The total energy consumption in full life cycle
E_{manu}	The total energy consumption in building materials manufacturing
E_{erect}	The total energy consumption in building erecting
E_{use}	The total energy consumption in building use
E_{demo}	The total energy consumption in building demolition
E_{dis}	The total energy consumption in building waste disposal

7.2.1 Total energy consumption in the process of building materials manufacturing

In the process of building materials manufacturing, the total energy consumption includes the total consumption of materials used in construction and in the later renovation.

$$E_{\text{manu}} = E_{\text{manu, prod}} + E_{\text{manu, renov}} \qquad \text{Equation 2}$$

Meanings for each character in Equation 2 are showed in Table 7.4

Table 7.4 Meanings for each character in Equation2 (MJ)

Characters	Meanings
E_{manu}	The total energy consumption in building materials manufacturing
$E_{manu,prod}$	Total energy consumption for manufacturing building materials used in construction
$E_{manu,renov}$	Total energy consumtpion in the process of renovation

$$E_{\text{manu, prod}} = \sum_{i=1}^{n} m_i \times \left(1 + \frac{w_i}{100}\right) \times M_i \qquad \text{Equation 3}$$

Meanings for each character in Equation 3 are showed in Table 7.5

Table 7.5 Meanings for each character in Equation 3 (MJ)

Characters	Meanings
$E_{manu,prod}$	Total energy consumption for manufacturing building materials used in construction
n	Numbers of different building materials used in the construction (types)
m_i	Usage amount of construction building material "i " (Ton)
w_i	Disposal proportion of building materials "i" in manufacturing (%)
M_i	Unit energy consumption of manufacturing building material "i " (MJ)

Because of the different functions, the lifetime for each building material is different. Suppose a residential building has 30 years' lifetime, the usage times for each construction material is also different. For example, if the floor usage lifetime is 10 years, so it needs to be changed twice, thus the following Equation 4 can be used to calculate the total energy consumption.

$$E_{\text{manu, renov}} = E_{\text{manu, prod}} \times \left[\frac{Y_{\text{bui}}}{Y_{\text{mat}}} - 1\right] \qquad \text{Equation 4}$$

Meanings for each character in Equation 4 are showed in Table 7.6

Table 7.6 Meanings for each character in Equation 4 (MJ)

Characters	Meanings
$E_{manu,renov}$	Total energy consumption in the revenotion
Y_{bui}	Architectural service life (year), refers to the main structure
Y_{mat}	Building material service life (year)

7.2.2 Total energy consumption in the process of building erecting

The total energy consumption in the process of building erecting can be divided into construction energy consumption and building material transportation. Different construction methods have different energy consumption, and the transportation methods and distance have a huge influence on the total energy consumption. It can be calculated by the following equation:

$$E_{\text{erect}} = E_{\text{erect, proces}} + E_{\text{trans, mat}} \qquad \text{Equation 5}$$

Meanings for each character in Equation 5 are showed in Table 7.7

Table 7.7 Meanings for each character in Equation 5 (MJ)

Characters	Meanings
E_{erect}	The total energy consumption in building erecting
$E_{erect,proces}$	Energy consumption in the process of construction
$E_{trans,mat}$	Energy consumption in the transportation of building materials

The equation of energy consumption in the process of construction is:

$$E_{\text{erect, proces}} = \sum_{j=1}^{m} p_j \times P_j \qquad \text{Equation 6}$$

Meanings for each character in Equation 6 are showed in Table 7.8

Table 7.8 Meanings for each character in Equation 6 (MJ)

Characters	Meanings
$E_{erect,proces}$	Energy consumption in the process of consturction
m	Different construction methods (kind)
p_j	Construction areas (m^2) volume (m^3) weight (Ton) for each construction method
P_j	Unit energy consumption in construction mehtod (MJ)

Energy consumption calculation equation for building material transportation:

$$E_{\text{trans, mat}} = \sum_{i=1}^{n} m_i \times \left(1 + \frac{w_i}{100}\right) \times D_i \times T \qquad \text{Equation 7}$$

Meanings for each character in Equation 7 are showed in Table 7.9

Table 7.9 Meanings for each character in Equation 7 (MJ)

Characters	Meanings
$E_{trans,mat}$	Energy consumption in the process of building materials transportation (MJ)
n	Different construction materials (types)
m_i	Materials' usage amount of materials "i" in construction (m^3) ,(Ton)
w_i	Disposal proportion of materials i in construction (%)
D_i	Transportation distance for building material "i" (Km)
T	Energy consumption per units of kilometers by transportation (MJ/unit·Km)

7.2.3 Total energy consumption in the process of building use

This process is the longest process in the full life cycle, and the energy consumption proportion is the largest. In the general steel and concrete architecture, the energy consumption in this process can take about 70%-80% of the total energy consumption [90]. Therefore, lots of researchers put a lot of efforts in research of air conditioner and heating, hope to get a more accurate energy consumption assessment model and the method for energy saving. However, these assessment models are usually limited by local geographical conditions and climate, thus it is hard to get a common assessment model [91]. What is more, the energy consumption of traditional vernacular dwellings has their own characteristics. Comparing with other architectural models, there are mainly influenced by the following conditions: 1) climate, 2) national economic level, 3) family incomes, 4) family structure and vernacular dwellings' culture. In view of these factors is uncertainty, they cannot be described by a uniform rules.

Overall, the aim of this process energy consumption is to create a health and comfortable indoor environment. Based on this, the energy consumption is calculated and used in comparing thermal performance in different architectures. The calculation of energy consumption can also be used in calculating hot and cold load. The calculation of hot and cold load is the base for fixing the thermal insulation properties of enclosure structure and the selection of assistance heat resource. Generally, it can be divided into unstable heat transformation and stable transformation, the unstable one is more suitable for detailed analyses on the moment indoor temperature, but if used in calculation it is too complex. Therefore, this paper uses the simple and practical stable heat transformation to do the calculation [92]. Cooling and heating load of the building corresponding to the energy consumption for heating and cooling, they need to be calculated by the heat and cool load, thus the calculation of energy consumption in building use, is the calculation of building cooling and heating load.

During the field investigation and the research about the local climate, it is found that: compared with local cold load, the energy consumption used for cooling in summer actually is very small that can be neglected. For the local villagers, they do not need to use air conditioners to cool the indoor temperature in summer. Besides, the temperature in gully regions is not too high to endure, and villagers usually choose to use the low energy consumption equipment, electrical fans. Therefore, in this research the cold load energy consumption in summer can be ignored. However, the energy consumption for heating in winter is the most energy usage part in this process, which the important part for calculation architectural energy consumption.

Meanwhile, in gully region of Loess Plateau, inner heat gain by solar radiation in winter is also a very important to residential buildings, so it should put solar radiation heat into consideration when doing the calculations of total heating load. Therefore, the auxiliary energy consumption coefficient can be used, which refers to the energy that should be supplied by some indoor heating equipment in unit time and construction area for keeping the indoor temperature under the average outdoor temperature. The calculation methods are showed as following [93]:

(1) Calculation of the heat load coefficient NLC [94]: heat load coefficient is the sum of heat loss in the enclosure structure and the heat loss in cold wind penetration, the equation is:

$$NLC = 24 \times (3.6 \sum_{i=1}^{j} A_i K_i + nV\rho_a c_p) \qquad \text{Equation 8}$$

Meanings for each character in Equation8 are showed in Table 7.10

Table 7.10 Meanings for each character in Equation 8 (MJ)

Characters	Meanings
NLC	Archtectural heating load coefficient
A_i	Area of enclusure struction i (m^2)
K_i	Heat transfor coefficient in enclusture struction (W/ $m^2 \cdot {}^oC$)
n	House ventiliation times (times/hour)
V	House ventiliation volumn (m^3)
ρ_a	Average outdoor air density, 1.2Kg/m^3
c_p	Air specific heat at constant pressure , 1.008 KJ/$^oC \cdot d$

(2) Calculation for the solar effective heat S_M of directly influence houses, the equation is:

$$S_M = A_g X_m S_{ot} a_a M \qquad \text{Equation 9}$$

Meanings for each character in Equation9 are showed in Table 7.11

Table 7.11 Meanings for each character in Equation 9 (MJ)

Characters	Meanings
S_M	Heat of effective solar heat (KJ)
Ag	Daylight opening area (m^2)
X_m	Effective illuminating area coefficient by glass window
S_{ot}	Month average solar radiation heat absorbed into indoors by unit glass (KJ/ $m^2 \cdot d$)
a_a	Absorbing coefficient for the effective solar heat by collecting system
M	Days for each month (Day)

(3) Calculation for ratio of monthly solar heat load SLR_M, the equation is:

$$SLR_M = \frac{S_M}{NLC \times DD_M} \qquad \text{Equation 10}$$

Meanings for each character in Equation9 are showed in Table 7.12

Table 7.12 Meanings for each character in Equation 10 (MJ)

Characters	Meanings
SLR_M	Ratio of monthly solar heat load
S_M	Total monthly solar radiation through glass windows (KJ)
DD_M	The difference in temperature between indoor standard temperature and outdoor average temperature in heating period, multiply by the heating days ($^oC\cdot d$)

(4) The calculation of monthly solar heating rate SHF_M. According to the above equation, the previous SLR_M can be calculated. Then by check Appendix 1, the SHF-SLR curve chart, the SHF_M can be got.

(5) The calculation of monthly auxiliary energy consumption $Q_{aux,m}$(KJ/M) and the yearly auxiliary energy consumption $Q_{aux,q}$(KJ/Y).
Equation for monthly auxiliary energy consumption is:

$$Q_{aux,M} = (1 - SHF_M) NLC \times DD_M - Q_{in,\mathrm{M}} \qquad \text{Equation 11}$$

Equation for yearly auxiliary energy consumption is:

$$Q_{aux,q} = \sum_{\mathrm{M_K}}^{\mathrm{M_E}} Q_{aux,M} \qquad \text{Equation 12}$$

Meanings for each character in Equation11, Equation12 are showed in Table 7.13

Table 7.13 Meanings for each character in Equation 11, Equation 12 (MJ)

Characters	Meanings
$Q_{aux,m}$	Monthly auxiliary energy consumption (MJ)
$Q_{aux,q}$	Yearly auxiliary energy consumption (MJ)
SHF_M	Heating rate by solar power (MJ)
$Q_{in,M}$	Monthly heat by artificial heating (MJ)
M_E	Month start to do building heating
M_K	Month end to do building heating

7.2.4 Total energy consumption in the process of building demolition

For different constructions, the demolition methods are also different. For both wood and brick structure houses, they can be manual demolished with little machine usage. The steel and concrete structure houses need to be demolished by machines, and for the steel structure, most of them are manual demolished in site. The different demolition methods make the calculated results are also different.

Some scholars in China think the energy consumption in building demolition process besides the demolishment works, the energy used for soil cover and the transportation of fulfill materials also should be included. Energy consumption for demolition account to 90% of construction energy consumption, the energy consumption of transportation of fulfill materials can be calculated by the construction area, the average speed of soil cover, average proportion of fulfill materials and average transportation distance [95]. For the traditional vernacular dwelling, the demolishment methods are usually manual demolishment in site. Because of the difficulty for calculating manual works energy consumption, and there are no related literatures, thus this is not calculated in this paper. Even for the steel and concrete architecture, the energy consumption for demolition takes just 0.18% of the full life cycle [96]. In this research, the energy consumption for demolition is calculated by 90% of energy consumption in construction, add the energy consumption by fulfill soil. The average depth of soil fulfill is 1.5 m, the average proportion of recover material is 2.0 and the unit energy consumption for short distance for transportation is 1.836 MJ/t · Km [95]. Therefore, the energy consumption of this process can be calculated by the following equation.

$$E_{\text{demo}} = 0.9\times E_{\text{erect}}+S\times1.5\times2\times1.836=0.9\times E_{\text{erect}}+5.508S \qquad \text{Equation 13}$$

Meanings for each character in Equation13 are showed in Table 7.14

Table 7.14 Meanings for each character in Equation 13 (MJ)

Characters	Meanings
E_{demo}	Total energy consumption building demolition (MJ)
E_{erect}	Total energy consumption in erecting (MJ)
S	After demolition, the construction area for backfill (m^2)

7.2.5 Total energy consumption in the process of waste disposal

Waste building materials can be divided in to two parts: the recyclable and the unrecyclable. According to the systematic boundary of architectural full life cycle assessment, the transportation energy consumption for unrecyclable building materials is just the energy consumed by the transportation from building site to disposal site. However, for the recyclable materials, the energy consumption includes the energy consumption for the transportation and for the second manufacture. From the energy consumption circular system, when the remanufacture materials reused in buildings, this part of energy consumption should be subtracted from the total energy consumption [97] [98]. Therefore, the energy consumption can be calculated in the following equation:

$$E_{\text{dis}} = E_{\text{trans, recycle}} + E_{\text{trans, was}} + E_{\text{dis, was}} - E_{\text{recycle}} \qquad \text{Equation 14}$$

$$E_{\text{trans, recycle}} = \sum_{i=1}^{n} W_i \times R_i \times D_i \times T \qquad \text{Equation 15}$$

$$E_{\text{trans, was}} = \sum_{i=1}^{n} W_i \times \left(1\text{-}R_i\right) \times d_i \times T \qquad \text{Equation 16}$$

Meanings for each character in Equation14, Equation15, and Equation16 are showed in Table 7.15

Table 7.15 Meanings for each character in Equation 14, Equation 15, Equation 16 (MJ)

Characters	Meanings
E_{dis}	Total energy consumption in waste disposal (MJ)）
$E_{trans,recycle}$	Energy consumption for the transportation of recycable construction materials (MJ)
$E_{trans,was}$	Energy consumption for the transportation of waste construction materials to the final treatment factory (MJ)
$E_{dis,was}$	Energy consumption for the treatment of waste construction materials (MJ)
$E_{recycle}$	Energy saving for the recyclabe construction materials (MJ)
W_i	Total weight of waste construction materials "i", (Ton)
R_i	Recyclable rate for the waste construction materials "i"
D_i	Distance for tranporting waste construction materials back to recycling factory (km)
d_i	Distance for tranporting waste construction materials back to the final recycling factory (km)
T	Energy consumption for per kilometer by a certain kind of transportaion method (MJ/Ton·km)

7.3 Calculation and analyses on energy consumption in each process during the full life cycle of residential buildings

7.3.1 Selection the typical residential buildings

This research selects three typical residential buildings of vernacular dwellings in Tableland rural habitats: Adobe residential building, one-storey brick-concrete structure residential building, and two-storey brick-concrete structure residential building. The LCA method is used to calculate energy consumption. Because the data influenced by several factors and conditions, in order to get relatively accurate to do the comparative analyses, this paper selects three kinds of residential buildings that take similar area, and all located in Nan Zhai Town, Qian Yang County, thus the meteorological geographical information can be ensured to be similar.

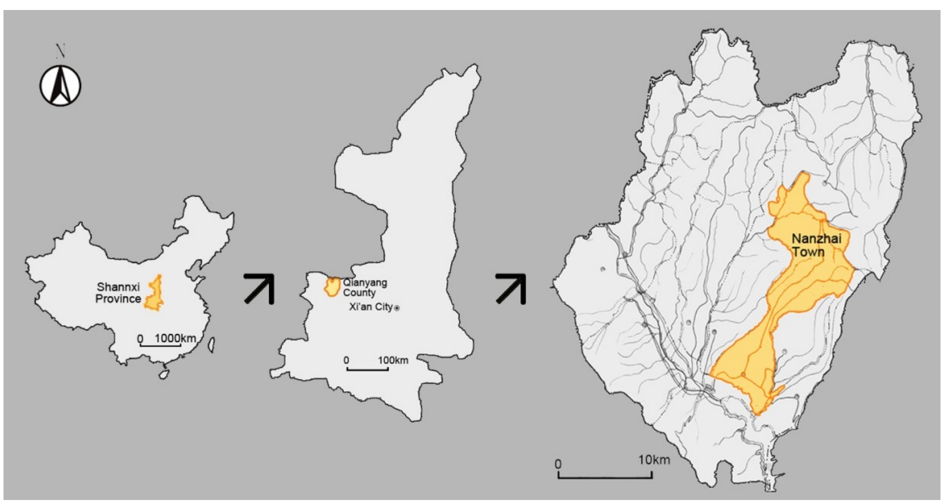


Figure 7.3 Location of Nan Zhai Town

Nan Zhai Town is located in 5.6 km northeast of Qian Yang county center, including 15 villages Figure 7.3. In 2014, there are 5547 families, the total population is 21097 and workforce population is about 8657, land area is about 180,000mu, that contains cultivable land is 41,600 mu [99]. The residential buildings of vernacular dwellings selected in the research are located in Zhao Yang village and Yang Po village in Nan Zhai town and both of them is typical Tableland village, the residential buildings are all used for living. The detailed information about their types, distribution and land taking are showed in Table 7.16.

Table 7.16 Overview of three different kinds of residential buildings

Residential building	Village	Building area (m^2)
Adobe residential building	Yang Po Village	44.10
One-storey brick-concrete structure residential building	Zhao Yang Village	46.21
Two-storey brick-concrete structure residential building	Zhao Yang Village	46.44

(1) Adobe residential building

The Adobe residential building was selected in Nan Po village Figure 7.4, the architectural drawings are shown in Figure 7.5 and Figure 7.6.

Figure 7.4 Present situation of the adobe residential building

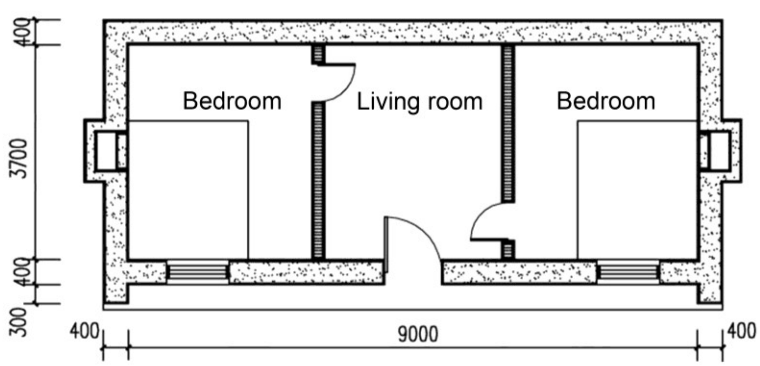


Figure 7.5 Adobe residential building planning drawing

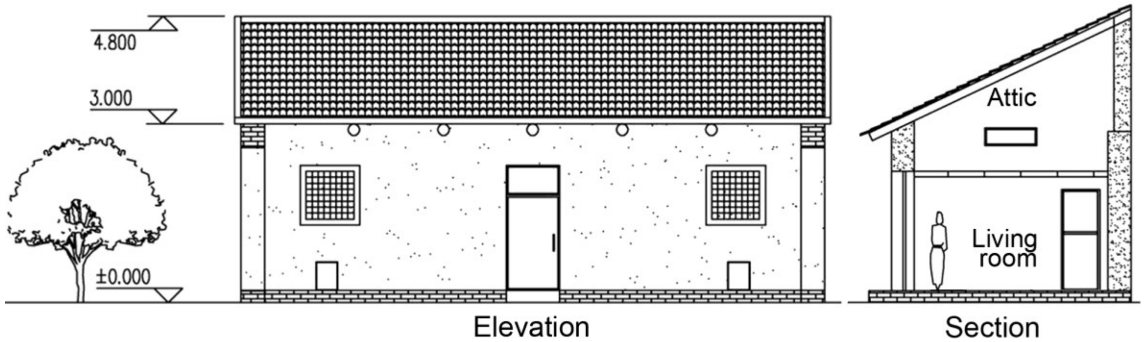


Figure 7.6 Elevation and cross section drawings of adobe residential building

(2) One-storey brick-concrete residential building

The one-storey brick-concrete structure residential building was selected in Zhao Yang Village Figure7.7. The architectural drawings are shown in Figure 7.8 and Figure 7.9.

Figure 7.7 Present situation of one-storey brick-concrete structure building

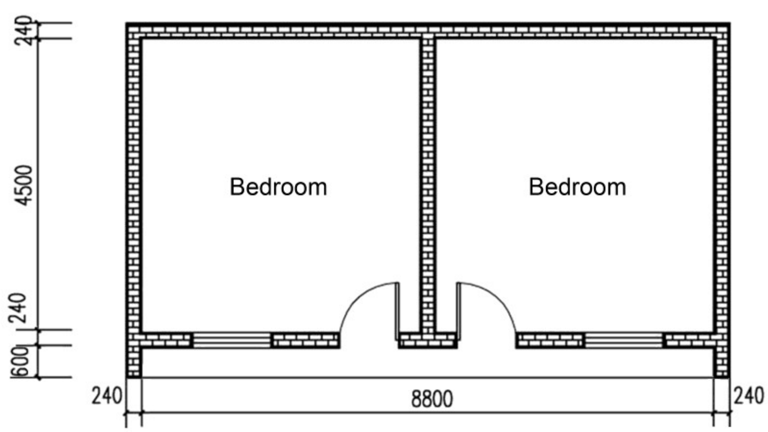


Figure 7.8 Planning drawing of the one-storey brick-concrete structure building

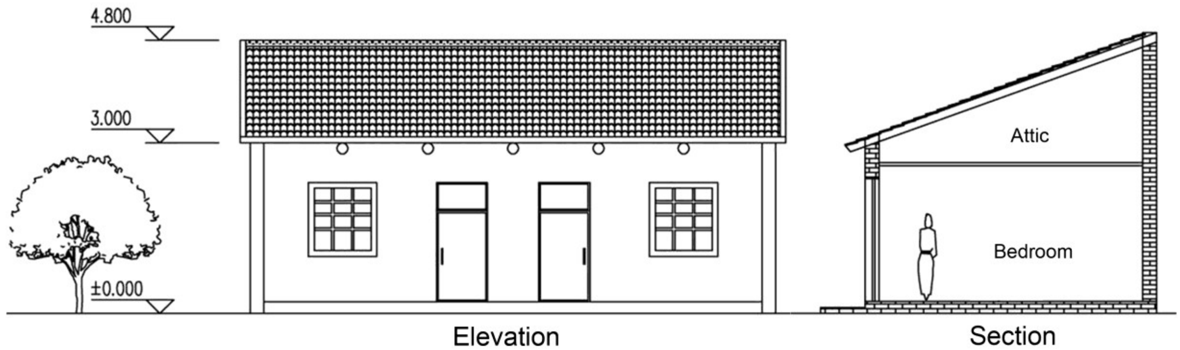
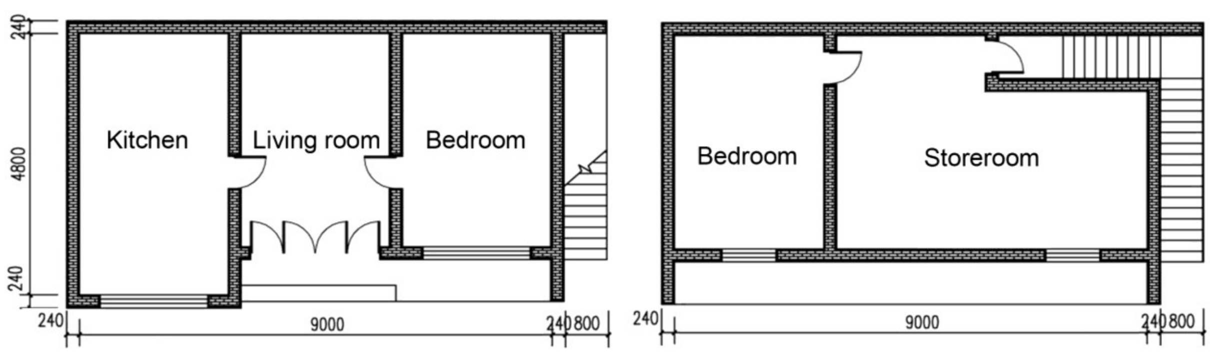


Figure 7.9 Elevation and cross section drawings of one-storey brick-concrete structure building

(3) Two-storey brick-concrete structure house

The two-storey brick-concrete structure house was selected in Zhao Yang Village Figure 7.10, the architectural drawings are showed in Figure 7.11 and Figure 7.12.

Figure 7.10 Present situation of two-storey brick-concrete structure building



(1)The first floor (2) The second floor

Figure 7.11 Planning drawing of the two-storey brick-concrete structure building

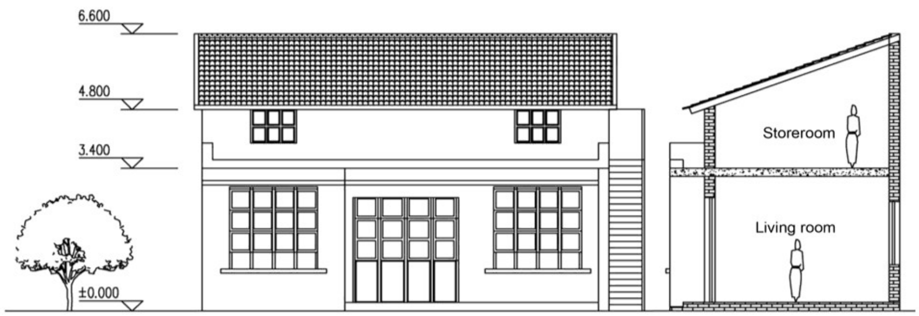


Figure 7.12 Elevation and cross section drawings of two-storey brick-concrete building

7.3.2 Calculation of the energy consumption in building materials manufacturing

Table 7.17 Energy consumption of manufacturing unit building materials and the waste proportion

Material (Unit)	Energy consumption(MJ/Unit)	Waste proportion (%)
Clay brick (block)	13.45	5
Stone (m^3)	5.78	5
Wood ($m^{3)}$	540	0
Steel (Ton)	16387	10
Cement (Ton)	2302.32	5
Glass (Kg)	24.5	5
Ceramic materials (Ton)	843.12	10
Preproduced concrete (Ton)	1600	10
Sand (m^3)	4.97	5
Tile (block)	4.46	5
Paint (Kg)	4.46	5

(Data source: [100] [101] [102] [103])

Table 7.18 List of building materials in different residential buildings

Name (Unit)	Adobe residential building	One-storey brick-concrete structure building	Two-storey brick-concrete structure building
Clay brick (block)	2654	14053	20076
Stone (m^3)	5.16	9.45	10.50
Wood ($m^{3)}$	18.9	9.66	19.4
Steel (Ton)	0.01	0.13	0.18
Cement (Ton)	0.23	1.53	1.74
Glass (Kg)	—	110.7	230.7
Ceramic materials (Ton)	—	0.53	1.58
Preproduced concrete (Ton)	—	2.35	6.79
Sand (m^3)	3.87	7.56	10.64
Tile (block)	1973	2004	2092
Paint (Kg）	—	53	76
Total construction area (m^2)	44.10	46.21	86.61

In this process, the energy consumption for manufacturing unit construction material is the measurement criteria, which refers to calculate about the consumed fossil oil and electrical energy for manufacturing unit building materials respectively. Then it combines the product of heat energy by unit fossil fuel and electrical energy, the total energy consumption for building materials of each residential building can be calculated, which can shown in Table 7.17. Besides, the waste proportion of building materials also has influence on the final calculated results (P.S.32.5 cement is the commonest one used in residential houses, and it is used in this research). Table 7.18 shows the construction material list for these three residential buildings and their energy consumption. According to the data in Table 7.17, Table 7.18, Equation 3 can be used to calculate the energy consumption in materials manufacture process, the results showed in Table 7.19, Figure 7.13 and Figure 7.14.

Table 7.19 Energy consumption in manufacture process of different residential buildings (MJ)

Name (Unit)	Adobe residential building	One-storey brick-concrete structure building	Two-storey brick-concrete structurebuilding
Clay brick (block)	37481.11	198463.49	283523.31
Stone (m^3)	31.32	57.35	63.72
Wood (m^3)	10206	5216.4	10476
Steel (Ton)	180.26	2343.34	3244.63
Cement (Ton)	556.01	3698.68	4206.34
Glass (Kg)	—	2847.76	5934.76
Ceramic materials (Ton)	—	486.29	1449.70
Preproduced concrete (Ton)	—	4136	11950.4
Sand (m^3)	20.20	39.45	55.52
Tile (block)	9239.56	9384.73	9796.84
Paint (Kg)	—	248.20	355.91
Total energy consumption (MJ)	57714.46	226921.69	331057.13
Total construction area (m^2)	44.10	46.21	86.61
Energy consumption in unit construction area (MJ/m^2)	1308.72	4910.66	3822.39

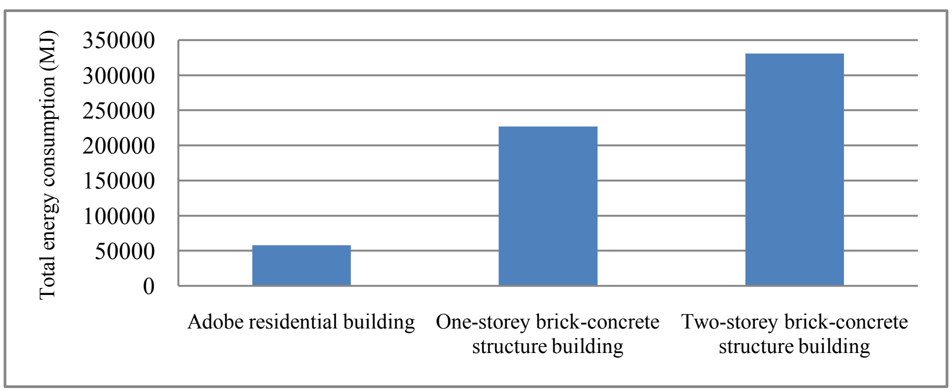


Figure 7.13 Total energy consumption in building materials manufacturing (MJ)

According to the analyses results, both of the lowest energy consumption for unit construction area and total energy consumption in process of building material manufacturing is adobe residential building. The highest total energy consumption is two-storey brick-concrete structure residential building and the highest energy consumption for unit construction area is one-storey brick-concrete structure residential building. For the brick-concrete houses, the high-energy consumption construction materials are widely used, such as tiles, clay bricks, cement and concrete. Among them, clay bricks are the largest used construction materials, which cause the energy consumption is more than three times higher than traditional immature soil houses. Therefore, in the design of low carbon vernacular dwellings, it is better to reduce the usage of these high-energy consumption building materials.

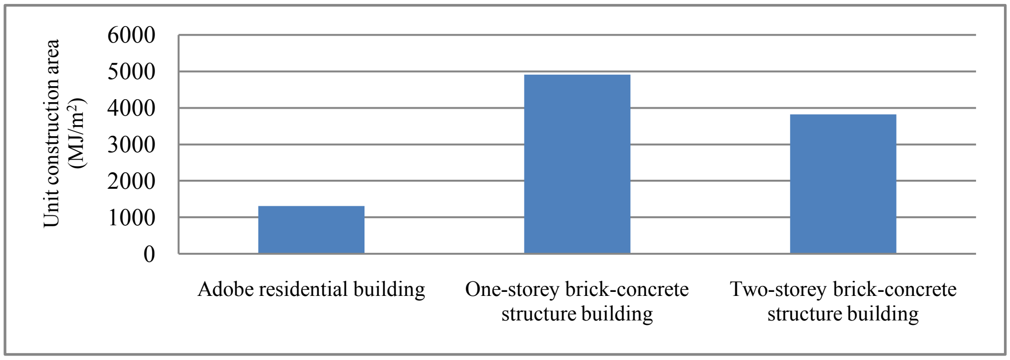


Figure 7.14 Energy consumption of building materials manufacturing in unit construction area (MJ)

7.3.3 Calculation of the energy consumption in building erecting

Because of the limitation of site conditions, building use, scales and some other conditions, different residential buildings should use different construction methods. According to the investigation, the materials used in adobe residential building and brick-concrete residential building, such as clay bricks, cement, steel and some other material can be bought within Qian Yang County, the average transportation distance is 10.6km.

According to Equation 6 and Equation 7, the construction and transportation energy consumption can be calculated respectively. Then by usage of Equation 5, the total energy consumption of construction and transportation can be calculated. The construction steps and methods should be classified and calculated the energy consumption list in unit area Table 7.20. The needed construction steps, methods and construction energy consumption list of different residential buildings are showed in Table 7.21. The calculated energy consumption for building materials' transportation shown in Table 7.22. T value in equation can be seen in Table 7.23.

Table 7.20 Unit energy consumption in some common construction methods (MJ/m^2)

Constrcution method	Unit construction area energy consumption	Constrcution method	Unit construction areaenergy consumption
Site cleaning	10.00 (MJ/ m^2)	Material transportation in site	198.74 (MJ/ m^2)
Floor layout	52.24 (MJ/ m^2)	Foundation excavation	27.26 (MJ/ m^2)
Material stacking	52.00 (MJ/ m^2)	Transportaion for workers	459.93 (MJ/ p)
Site leveling	17.03 (MJ/ m^2)	Temporary power supply	22.65 (MJ/ m^2)

(Data source: [104] [105])

Table 7.21 Energy consumption list in building erecting process for different residential buildings (MJ)

Constrcution method	Adobe residential building	One-storey brick-concrete structure building	Two-storey brick-concrete structure building
Site cleaning	441.00	462.10	866.10
Floor layout	2303.78	2414.01	4524.51
Material stacking	2293.20	2402.92	4503.72
Site leveling	751.02	786.96	1474.97
Materisl transportation in site	8764.43	9183.78	17212.87
Foundation excavation	1202.17	1259.68	2360.99
Transportaion for workers	20282.91	21253.37	39834.54
Temporary power supply	—	1046.66	1961.72
Total energy consumption	36038.51	38809.48	72739.42
Total construction area（m^2）	44.10	46.21	86.61
Unit construction area energy consumption（MJ/m^2）	817.20	839.85	839.85

Table 7.22 Energy consumption for transportation of building materials in residential buildings (MJ)

Construction materials	Adobe residential building	One-storey brick-concrete structure building	Two-storey brick-concrete structure building
Soil brick (block)	6.64	35.34	50.19
Stone (m^3)	15.48	28.35	31.50
Wood (m^3)	18.9	9.66	19.4
Steel (Ton)	0.01	0.13	0.18
Cement (Ton)	0.23	1.53	1.74
Glass (Kg)	—	0.111	0.231
Ceramic materials (Ton)	—	0.53	1.58
Preproduced concrete (Ton)	—	2.35	6.79
Sand (m^3)	5.23	10.21	14.35
Tile (block)	1.973	2.004	2.092
Paint (Kg)	—	0.053	0.076
Total energy consumption (MJ)	1456.36	2712.64	3850.41
Total construction area (m^2)	44.10	46.21	86.61
Unit construction area energy consumption (MJ/m^2)	33.02	58.90	44.46

Table 7.23 The option value for T in Equation 7

Transportation methods	Energy consumption for tranporting unit construction material (MJ/unit·Km)
Long distance land transportation (≥50Km)	1.008
Thort distance land transportation (≤50Km)	2.7
Shipping	0.468

(Data source: [104] [105])

Values in Table 7.23 are just suitable for the transportation energy consumption in plain regions. According to the field investigation, these values should be multiplied by weighted coefficient 1.15 when the transportation is in gully region, and thus the results can be more accurate. The total energy consumption for three different residential buildings in this process can by calculated by adding the energy consumption of construction erecting and construction materials transportation, and the unit energy consumption can also be calculated, the results showed in Table 7.24, Figure 7.15, Figure 7.16.

Table 7.24 Energy consumption in building erecting of different residential buildings (MJ)

Energy consumption	Adobe residential building	One-storey brick-concrete structure building	Two-storey brick-concrete structure building
Energy consumption in erecting process (MJ)	36038.51	38809.48	72739.42
Energy consumption in the material transportaion process (MJ)	1456.36	2712.64	3850.41
Total Energy consumption (M)	37494.87	41531.12	76589.83
Total construction area (m^2)	44.10	46.21	86.61
Unit energy consumption (MJ/m^2)	850.22	898.75	884.31

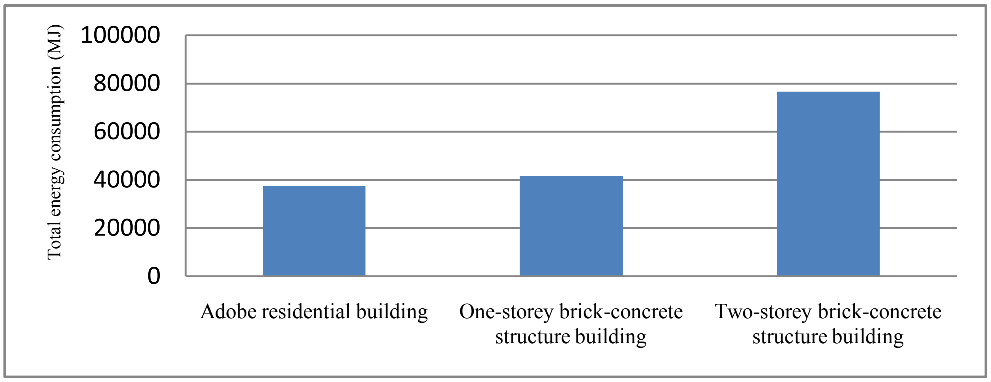


Figure 7.15 Energy consumption of building erecting (MJ)

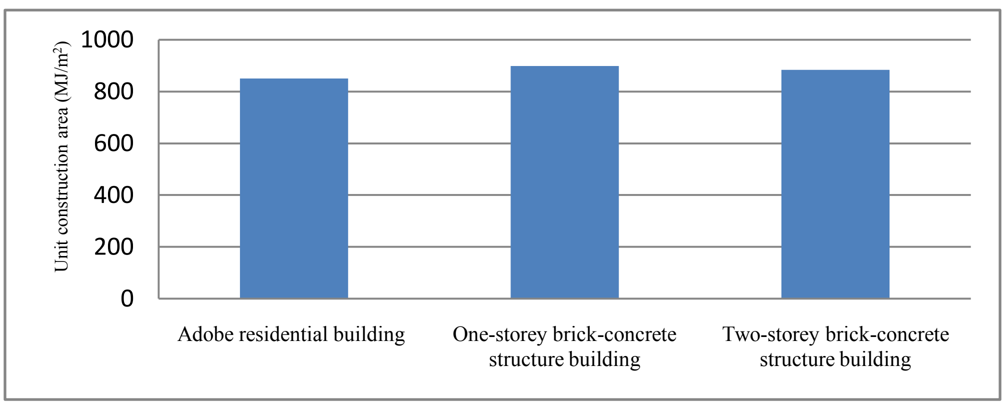


Figure 7.16 Energy consumption of building erecting in unit construction area (MJ)

According to the calculated results, the building areas and total energy consumption are both similar for adobe residential building and one-storey brick-concrete structure building, while for the two-storey brick-concrete structure residential building, the building area is twice bigger and the total energy consumption is also twice bigger than others. Thus the building area has direction influence on the calculation of energy consumption in this process, the larger the building area, the energy consumption for building erecting is larger. Therefore, in low carbon vernacular dwelling design, reasonable design functional space and avoid unnecessary building area is very important for energy saving. Beside the building area, construction method and the distance for construction materials transportation also important factors have impact on energy consumption. The design principle of simple construction methods and the usage of local construction materials can reduce energy consumption largely.

7.3.4 Calculation of the energy consumption in building use

The equations and calculation method of energy consumption in building use have already been explained in the previous sections. The energy consumption used for cooling in summer is almost zero, and the energy consumption for heating is just calculated in this paper. Energy consumption used for heating can be calculated by the auxiliary energy consumption coefficient, which has direct relationship with indoor temperature. Besides winter, the residential buildings in this region, there are no requirement for indoor temperature in other seasons and the auxiliary heating is zero. In this paper, in order to better compare the three different residential building, when calculating Q_{aux} , there need a basic indoor temperature and it is 14°C[92][106]. This basic indoor temperature means the lowest temperature by the design of heating standard, once the temperature lower than this basic temperature, the auxiliary energy for heating should be used. The detailed calculation method and results are showed in the following:

(1) Model simplification

In order to make the calculation simpler and easy for the following data calculation and comparative study, the model simplification data for the three residential buildings are showed in Table 7.25:

Table 7.25 Model simplification data for different residential buildings (m)

Types	Building bay	Building depth	Storey height	Volume (m^3)
Adobe residential building	9.00	3.70	3.00	99.90
One-storey brick-concrete structure building	8.80	4.50	3.00	118.80
Two-storey brick-concrete structure building	9.00	3.90	4.80	168.48

(2) The calculation of heat load coefficient NLC for three different residential buildings

The calculation results of heat load coefficient of cold wind penetration showed in Table 7.26:

Table 7.26 The calculation results of heat load coefficient of cold wind penetration

Types	N: Ventilation frequency (Times/ hour)	V:Ventilation volume (m^3)	P_a: Average density for outdoor air (Kg/ m^3)	C_p: Specific heat capacity in fixed air pressure (KJ/°C • d)	nVp_ac_p: Heat load coefficient of cold wind penetration
Adobe residential building	0.5	99.90	1.2	1.008	60.42
One-storey brick-concrete structure building	0.5	118.80	1.2	1.008	71.85
Two-storey brick-concrete structure building	0.5	168.48	1.2	1.008	101.90

(Data source: [93])

Closure structure areas for three different residential buildings showed in Table 7.27:

Table 7.27 Closure structure area A_i for three different residential buildings (m^2)

Types	East wall	West wall	South wall	North wall	Roof
Adobe residential building	11.10	11.10	27.00	27.00	56.93
One-storey brick-concrete structure building	13.50	13.50	26.4	26.4	56.83
Two-storey brick-concrete structure building	18.72	18.72	43.20	43.20	53.98

Equation for thermal conductivity coefficient K_i is：

$$K = \frac{1}{R_0} = \frac{1}{R_i + R + R_e} = \frac{1}{R_i + R_e + R_1 + R_2} = \frac{1}{R_i + R_e + \frac{\delta_1}{\lambda_1} + \frac{\delta_2}{\lambda_2}} \quad \text{Equation 17}$$

Table 7.28 Meanings for each character in Equation 17

Character	Unit	Meanings
R_0	$m^2 \cdot K/℃$	Heat transfer resistance in closure structure
R_i	$m^2 \cdot K/℃$	Heat changing resistance in inside surface, general is 0.11
R_e	$m^2 \cdot K/℃$	Heat changing resistance in outside surface, general is 0.04
δ_1	m	Thickness of material "i"
λ_1	W/m • K	Thermal conductivity coefficient of material "i"

Calculation results of thermal conductivity coefficient K_i in three different residential buildings showed in Table 7.29, Table 7.30, and Table 7.31.

Table 7.29 Thermal conductivity coefficient K_i of immature soil houses

Adobe residential building	Construction materials	δ (m)	λ (W/ m2· ^oC)	K:Thermal conductivity coefficient(W/ $m^2 \cdot {}^oC$)
East wall	Immature soil	0.4	0.76	1.479
West wall	Immature soil	0.4	0.76	1.479
South wall	Immature soil	0.4	0.76	1.479
North wall	Immature soil	0.4	0.76	1.479
Roof	Tile	0.03	0.76	3.380
	Grass mud	0.05	0.47	
Floor	Clay brick	0.12	0.76	3.248
Window	Wood frame and single glass window			5.800
Door	single wooden door			4.650

(Data source: [107])

Table 7.30 Thermal conductivity coefficient Ki of one-storey brick-concrete structure house

One-storey brick-concrete structure building	Construction materials	δ (m)	λ (W/ m2· °C)	Thermal conductivity coefficient (W/ m^2· °C)
East wall	Clay brick	0.24	0.76	2.052
	Cement plastering	0.02	0.93	
West wall	Clay brick	0.24	0.76	2.052
	Cement plastering	0.02	0.93	
South wall	Clay brick	0.24	0.76	2.052
	Cement plastering	0.02	0.93	
North wall	Clay brick	0.24	0.76	2.052
	Cement plastering	0.02	0.93	
Roof	Tile	0.03	0.76	3.380
	Grass mud	0.05	0.47	
Floor	Clay brick	0.12	0.76	2.668
	Cement plastering	0.03	0.93	
Window	Steel frame and single glass window			6.400
Door	Steel frame and single glass door			6.400

(Data source: [107])

Table 7.31 Thermal conductivity coefficient Ki of two-storey brick-concrete structure house

Two-storey brick-concrete structure building	Construction materials	δ (m)	λ (W/ m2· °C)	Thermal conductivity coefficient (W/ m^2· °C)
East wall	Clay brick	0.24	0.76	2.052
	Cement plastering	0.02	0.93	
West wall	Clay brick	0.24	0.76	2.052
	Cement plastering	0.02	0.93	
South wall	Clay brick	0.24	0.76	2.052
	Cement plastering	0.02	0.93	
North wall	Clay brick	0.24	0.76	2.052
	Cement plastering	0.02	0.93	
Roof	Tile	0.03	0.76	3.380
	Grass mud	0.05	0.47	
Floor	Clay brick	0.12	0.76	2.668
	Cement plastering	0.03	0.93	
Window	Steel frame and single glass window			6.400
Door	Steel frame and single glass door			6.400

(Data source: [107])

According to above data, the A_iK_i in three residential buildings can be calculated, showed in Table 7.32:

Table 7.32 The calculated AiKi value of closure structure in three residential buildings

Adobe residential building	East wall	West wall	South wall	North wall	Roof	Floor	Windows	Doors	Total
A_i	11.10	11.10	23.11	27.00	56.93	44.10	2.00	1.89	
K_i	1.479	1.479	1.479	1.479	3.380	3.238	5.800	4.650	
$A_i K_i$	16.42	16.42	34.18	39.93	192.42	142.80	11.60	8.79	462.56
One-storey brick-concrete structure building									
A_i	13.5	13.5	19.50	26.40	56.83	46.21	3.12	3.78	
K_i	2.052	2.052	2.052	2.052	3.380	2.668	6.400	6.400	
$A_i K_i$	27.70	27.70	40.01	54.17	192.09	123.29	19.97	24.19	509.12
Two-storey brick-concrete structure building									
A_i	18.72	18.72	27.74	43.20	53.98	46.44	9.46	6.00	
K_i	2.052	2.052	2.052	2.052	3.380	2.668	6.400	6.400	
$A_i K_i$	38.41	38.41	56.92	88.65	182.45	123.90	60.54	38.40	627.68

NLC value of each vernacular dwelling can be calculated by Equation 8, and showed in Table 7.33.

Table 7.33 NLC value of three residential buildings

Types	Adobe residential building	One-storey brick-concrete structure building	Two-storey brick-concrete structure building
NLC	41415.26	45712.37	56677.15

(3) Calculation of annual auxiliary energy consumption

By the Equation 9: $S_M = A_g X_m S_{ot} a_a M$ to calculate the value S_M for each residential building. According to the field investigation, the heating period in gully regions starts in November and end in the following March. The value S_{ot} in the equation is showed in Table 7.34.

Table 7.34 The average daily radiation in south vertical surface of buildings in Qian Yang, and its total radiation quantity for glass window (KJ/ $m^2 \cdot d$)

Average daily radiation	November	December	January	February	March
South vertical surface	13151	15635	15358	13289	11610
Single glass window	11207	13379	12943	11003	8166
Double glass window	10143	12283	12078	10129	6558

(Data source: [107])

Simplified formulae of monthly solar efficient heat S_M for each residential building, showed in Table 7.35.

Table 7.35 Simplified formulae of monthly solar efficient heat S_M for each residential buildings

Types	A_g (m^2)	X_m	a_a	S_M
Adobe residential building	2.00	0.7	0.98	1.3720 $S_{ot}M$
One-storey brick-concrete structure building	3.12	0.75	0.98	2.2932 $S_{ot}M$
Two-storey brick-concrete structure building	9.46	0.75	0.98	6.9531 $S_{ot}M$

Combining the above two tables, the value of S_M within five months for three residential buildings can be calculated, and showed in Table 7.36, Table 7.37 and Table 7.38. Put NLC and S_M in Equation 10, the specific months and days DD_M can be figured out in reference [93]. Solar heating rate SHF_M can also be figured out in Appendix 1.

According to Equation 11and Equation 12, the monthly and yearly auxiliary energy consumption can be calculated respectively. Q_{in} refers to the heating got by manmade, including the heat radiation of people movement indoor and the heat from electrical applicants. Suppose there are four people live in one house, when do the daily indoor movement, the average heat radiation is about 500KJ per person per day, the time for people stay indoor is about 12 hours, the indoor heating from human body radiation is about 500x4x12=24000 KJ. According to the local living conditions, the domestic electrical appliances are light, television, washing machine and refrigerator, the average power for theses appliances in 600w. If using these appliances 12 hours, the average heating should be 600x60x60x12=25920KJ, thus the total indoor manmade heat is 49920KJ. All these parameters should be put into the equation to calculate auxiliary energy consumption for each month in the heating period, and it shows in Table 7.36, Table 7.37 and Table 7.38.

Table 7.36 Calculation for the yearly auxiliary energy consumption in adobe residential building

Character	Unit	November	December	January	February	March
M	d	30	31	31	28	31
DD_M	$^oC\cdot d$	360	558	620	462	310
S_{ot}	$KJ/m^2\cdot d$	13151	15635	15358	13289	11610
S_M	KJ	541295	664988	653206	510510	375839
SLR_M	—	0.036	0.029	0.026	0.027	0.030
SHF_M	—	—	—	—	—	—
$Q_{aux,m}$	10^3MJ	13.41	21.56	24.13	17.74	11.29
$Q_{aux,q}$	10^3MJ			88.13		

Table 7.37 Calculation for the yearly auxiliary energy consumption in One-storey brick-concrete structure building

Character	Unit	November	December	January	February	March
M	d	30	31	31	28	31
DD_M	$^oC·d$	360	558	620	462	310
S_{ot}	$KJ/ m^2·d$	11207	13379	12943	11003	8166
S_M	KJ	770997	951102	920108	706498	580514
SLR_M	—	0.046	0.037	0.032	0.033	0.041
SHF_M	—	—	—	—	—	—
$Q_{aux,m}$	10^3MJ	14.96	23.96	26.79	19.72	12.62
$Q_{aux,q}$	10^3MJ			98.05		

Table 7.38 Calculation for the yearly auxiliary energy consumption in Two-storey brick-concrete structure building

Character	Unit	November	December	January	February	March
M	d	30	31	31	28	31
DD_M	$^oC·d$	360	558	620	462	310
S_{ot}	$KJ/ m^2·d$	11207	13379	12943	11003	8166
S_M	KJ	2337702	2883791	2789813	2142139	1760149
SLR_M	—	0.114	0.091	0.080	0.081	0.100
SHF_M	—	0.03	—	—	—	0.03
$Q_{aux,m}$	10^3MJ	18.29	30.08	33.59	24.79	15.50
$Q_{aux,q}$	10^3MJ			122.25		

The above calculation is for the yearly energy consumption in building use process for the three different residential buildings, the ratio of this calculated value and construction area is the yearly energy consumption of unit construction area for the building use process, the detailed list showed in Table 7.39, Figure 7.17 and Figure 7.18.

Table 7.39 Energy consumption of building erecting in unit construction area (MJ)

Types	Adobe residential building	One-storey brick-concrete structure building	Two-storey brick-concrete structure building
Yearly auxiliary energy consumption (MJ)	88130	98050	122250
Total construction area (m^2)	44.10	46.21	86.61
Yearly auxiliary energy consumption of unit construction area (MJ/m^2)	1998.41	2121.84	1411.50

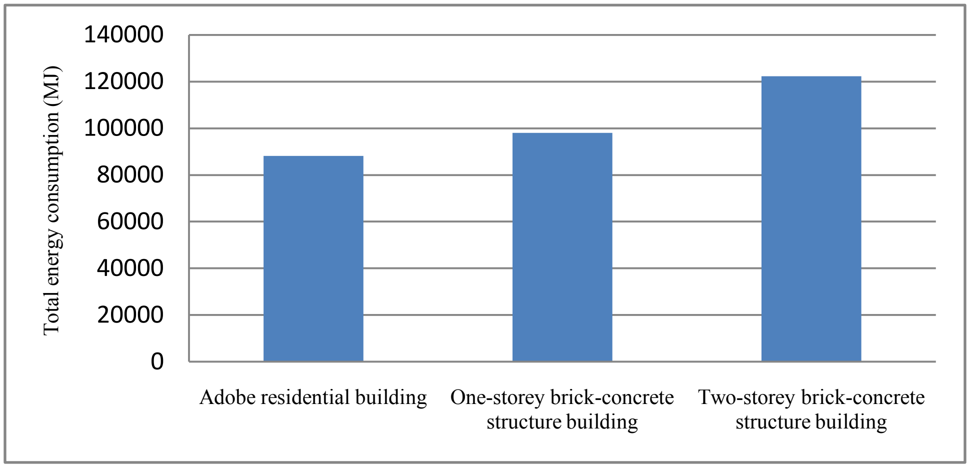


Figure 7.17 Total energy consumption in the process of building using

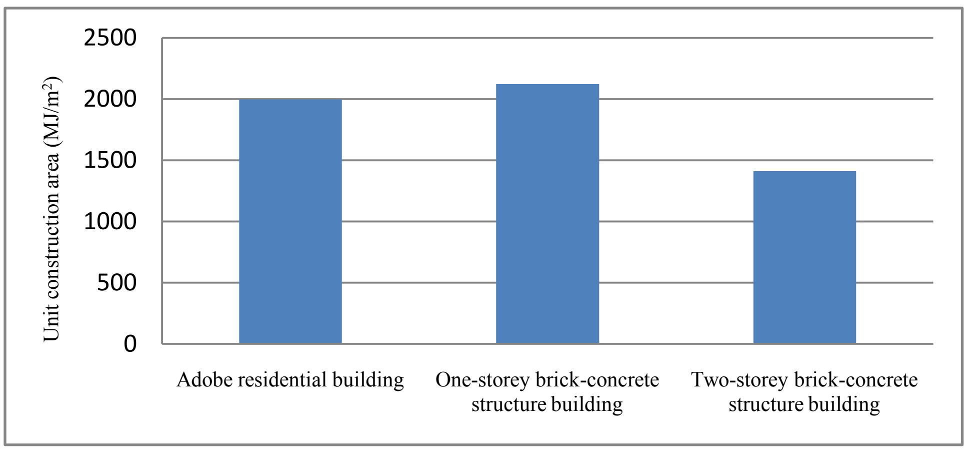


Figure 7.18 Energy consumption of unit construction area in the process of building using

The calculated result shows that the energy consumption in the process of building using of adobe residential building and One-storey brick-concrete structure building are almost the same, the unit energy consumption for Two-storey brick-concrete structure building is 30% lower than the other two, but the total energy consumption is 25% higher than them. All in all, the energy consumption for these three residential buildings in the using process are all high, the main reason is that there is no thermal insulation , the windows and doors' insulation and air tightness are bad, which cause a large amount of energy consumption. Therefore, how to improve the thermal insulation for each part of residential buildings is the key for to saving energy and reducing emission.

7.3.5 Calculation of the energy consumption in building demolition

From the previous research, the energy consumption in the process of demolition can be calculated by Equation 13. Put all the parameters into equation and calculate the demolition energy consumption for each part in this process. Among them, the recovering area for flatting land should be calculated by the excavation boundary. Energy consumption for demolition takes 90% of construction Table 7.40, Figure 7.19 and Figure 7.20.

Table 7.40 Energy consumption for building demolition in different residential buildings (MJ)

Terms	Adobe residential building	One-storey brick-concrete structure building	Two-storey brick-concrete structure building
Foundation excavation area (m^2)	44.10	46.21	46.44
Energy consumption for demolishing building (MJ）	33745.38	37378.01	68930.85
Energy consumption for soil refilling(MJ)	242.90	254.52	255.79
Total energy consumption for building demolition(MJ)	33988.28	37632.53	69186.64
Total areas (m^2)	44.10	46.21	86.61
consumption for unit construction area(MJ/m^2)	770.71	809.13	798.83

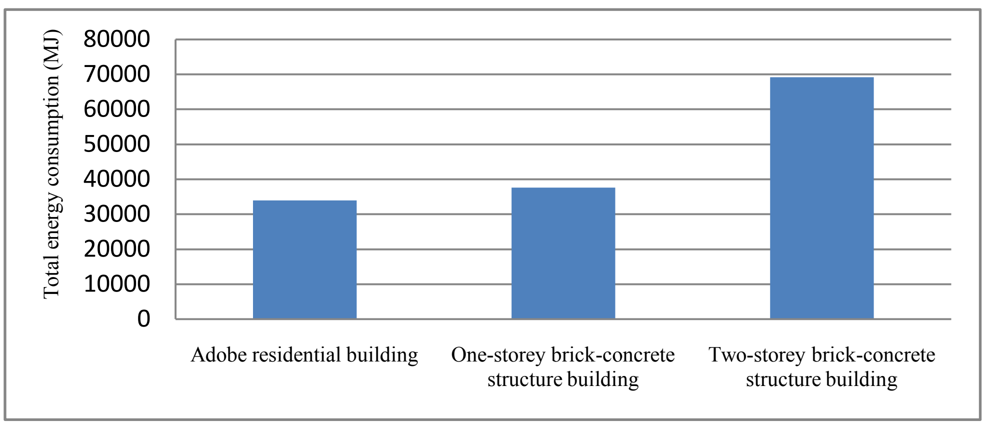


Figure 7.19 Total energy consumption in the process of building demolition

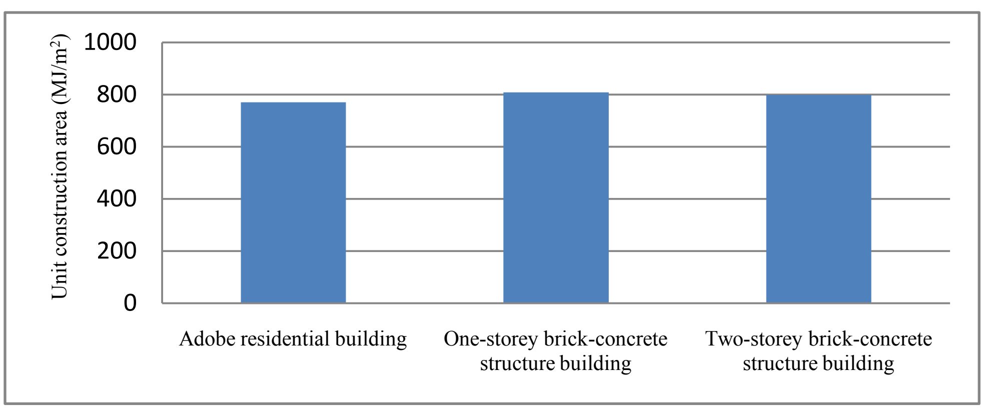


Figure 7.20 Energy consumption of unit construction area in the process of building demolition

The calculated results show that unit area energy consumption are almost same for the demolition of the three residential buildings. While for the total energy consumption, adobe residential building and one-storey brick-concrete structure building are almost the same, but two-storey brick-concrete structure building is twice higher than the other two, the main reason is the large area of two-storey brick-concrete structure building. By comparative research on energy consumption, the demolition energy consumption of residential building is lower than energy consumption of building erecting, the main reason is the similar construction and demolition process. Therefore, design reasonable construction area and select demolition method can reduce the energy consumption in this process.

7.3.6 Calculation of the energy consumption in the waste disposal

Among the researched materials in this paper, glass, wood, steel belongs to common recyclable materials, and the recyclable rate showed in Table 7.41[108]. For the demolished bricks, stones, local residents directly reuse them after recovery such as fulfilling the road base. In this process, the disposal of non-constructional material is open and loop recyclable treatment. According to the boundary of full life cycle in construction, the energy consumption for unrecyclable materials is the transportation energy consumption from construction site to the treatment place, and for the recyclable materials, the energy consumption the transportation energy consumption from site to the treatment place and remanufacturing energy consumption. The three construction materials researched in this paper, the glass, wood and steel are all the recovery and recyclable materials. However, the glass cannot be used in architecture after recycled and the wood is hard to use directly in architecture, and the energy consumption for remanufacturing different products is very different. In this paper, these materials are regarded as recyclable materials, but these are no contribution for the energy saving. Among the three materials, only steel is the open and loop materials and the energy consumption for remanufacturing is 20%-50% of the manufacture energy consumption, in this paper it is calculated by 40% and the recovery coefficient is 0.50[100] [104].

Table 7.41 Recovery rates for different construction materials

Construction materials	Steel	Clay brick	Stone	Glass	Wood
Recovery rate %	0.5	0.6	0.6	0.8	0.1

According to Equation 14, Equation 15 and Equation 16, the energy consumption in each process in three residential buildings can be calculated. For the recyclable materials, the average distance from construction site to the treatment place is about 56.6 km, and for the unrecyclable material, the average distance is 10.6 km. The unit transportation energy consumption is 1.836 MJ/tank [104]. For the recyclable steel, the energy saving form reused in other architecture showed in Table 7.42, Figure 7.21 and Figure 7.22.

Table 7.42 Energy consumption in the recyclable process for construction materials in different residential buildings (MJ)

Demoliation terms	Adobe residential building	One-storey brick-concrete structure building	Two-storey brick-concrete structure building
Energy consumption for the transportaion of recycalbe construction materials(MJ)	1499.12	46.21	5385.48
Energy consumption for the transportaion of unrecycalbe construction materials (MJ)	590.83	1539.48	2221.42
Energy consumption for the second manufacture of recyclable material (MJ)	72.10	426.06	1297.85
Total energy consumption for waste material treatment (MJ)	2162.05	6103.77	9828.32
Total energy consumption for energy saving of the recyclabel material (MJ)	54.08	703.00	973.39
Total construction area (m^2)	44.10	46.21	86.61
Energy consumption for water materials treatment in unit construction area (MJ/m^2)	49.03	131.44	113.78

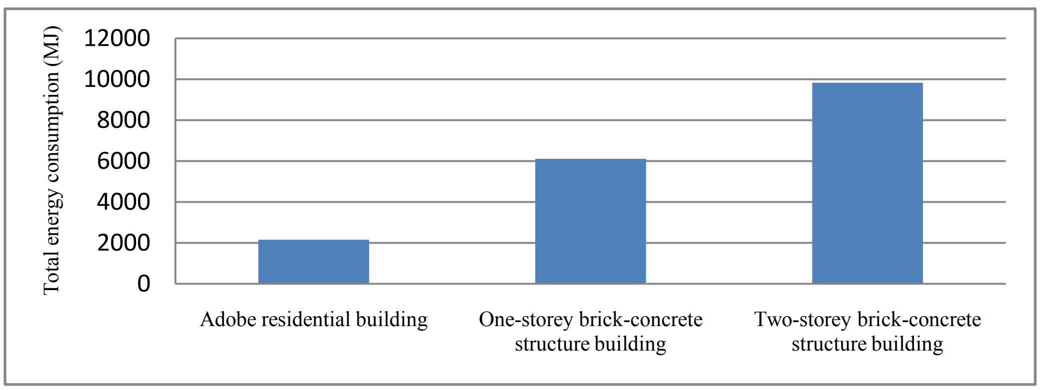


Figure 7.21 Total energy consumption in the process of waste disposal

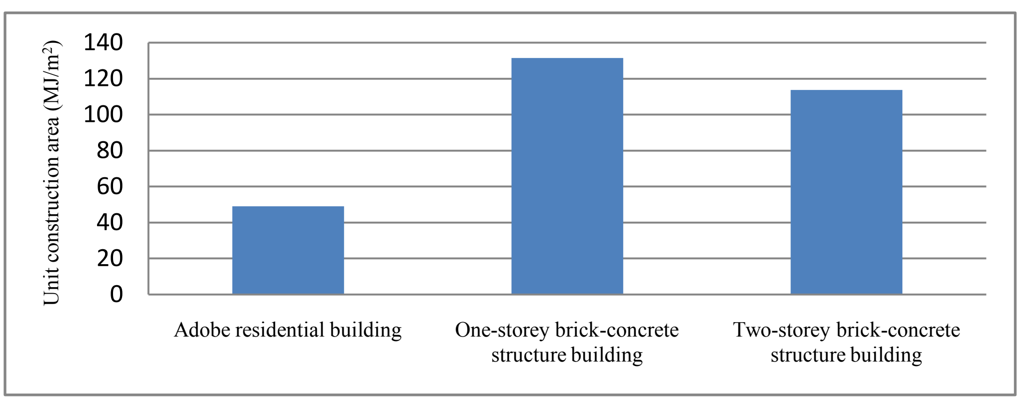


Figure 7.22 Energy consumption of unit construction area in the process of waste disposal

The calculated result show that total energy consumption and unit construction area energy consumption for waste disposal in adobe residential building is the lowest, the construction area of two-storey brick-concrete structure building is twice higher that one-storey brick-concrete structure building, and the total energy consumption is 1.5 times higher than one-storey brick-concrete structure house. And in general, the complex architecture structure need more types of materials, thus the more complex the architecture is and the more types of construction materials it uses, and the energy consumption of waste disposal will be more. Therefore, in the construction of residential building, it is better to use some simpler and easier structures and high-energy efficient materials, especially the use of reusable and recyclable construction materials.

7.4 Calculation and analyses on the total energy consumption during the full life cycle of residential buildings

For all architectures, energy consumption in full life cycle can be changed along the time. In each different process of full life cycle, the proportion in total energy consumption is different. According to the field investigation, life of the most of the local residential buildings in Tableland rural habitats is about 30 years. The energy consumption in each process is showed in Table 7.43.

Table 7.43 Energy consumption in each process of full life cycle for the three residential buildings (MJ)

Calculation terms	Immature soil house	One-storey brick-concrete structure house	Two-storey brick-concrete structure house
Building materials manufcture(MJ)	57714.46	226921.69	331057.13
Buidling erecting(MJ)	37494.87	41531.12	76589.83
Building using (MJ)	2643900.00	2941500.00	3667500.00
Building demoliation(MJ)	33988.28	37632.53	69186.64
waste disposal (MJ)	2162.05	6103.77	9828.32
Total energy consumption in full life cycle(MJ)	2775259.66	3253689.11	4154161.92
Total construction area(m^2)	44.10	46.21	86.61
Energy consumption in unit construction area (MJ/m^2)	62931.06	70410.93	47964.00

7.4.1 Analyses of total energy consumption in the full life cycle of three kinds of residential buildings

According to the results in Table 7.43, the total energy consumption in three vernacular dwellings and total energy consumption in unit area in full life cycle can be showed in Figure 7.23 and Figure 7.24.

The site area for the three different residential buildings is almost the same. The calculation shows that: 1) For energy consumption: from both energy consumption in the each process of full life cycle and the final total energy consumption, the lowest is adobe residential building, then one-storey brick-concrete structure building and the highest is two-storey brick-concrete structure building. No matter from the analyses of material selection and residential building use, it seems the lifestyle is getting more and more energy consumption. 2) Although the two-storey brick-concrete structure building supplies larger living space with small unit energy consumption, and also can save land, because the total energy consumption in unit area has close relationship with construction area, the energy consumption for two-storey brick-concrete structure building is much higher than the other two residential buildings.

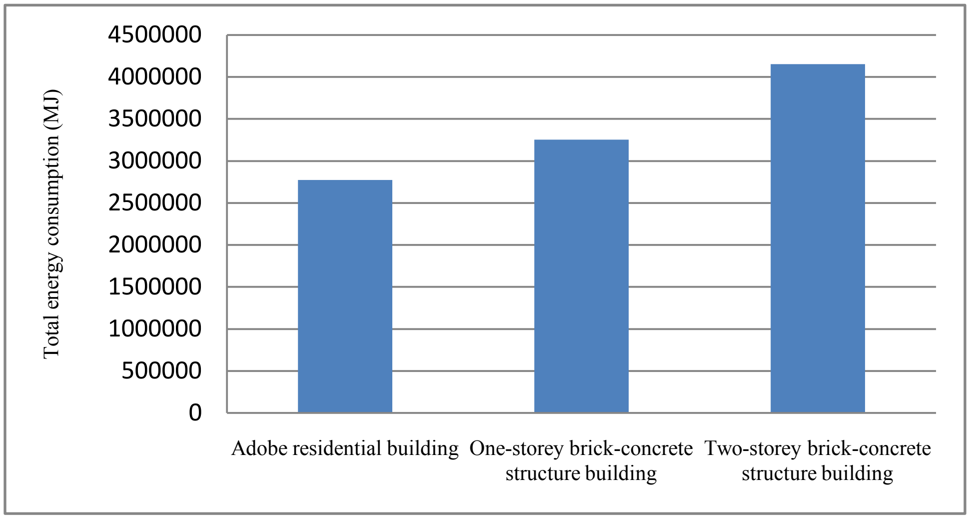


Figure 7.23 Total energy consumption in full life cycle

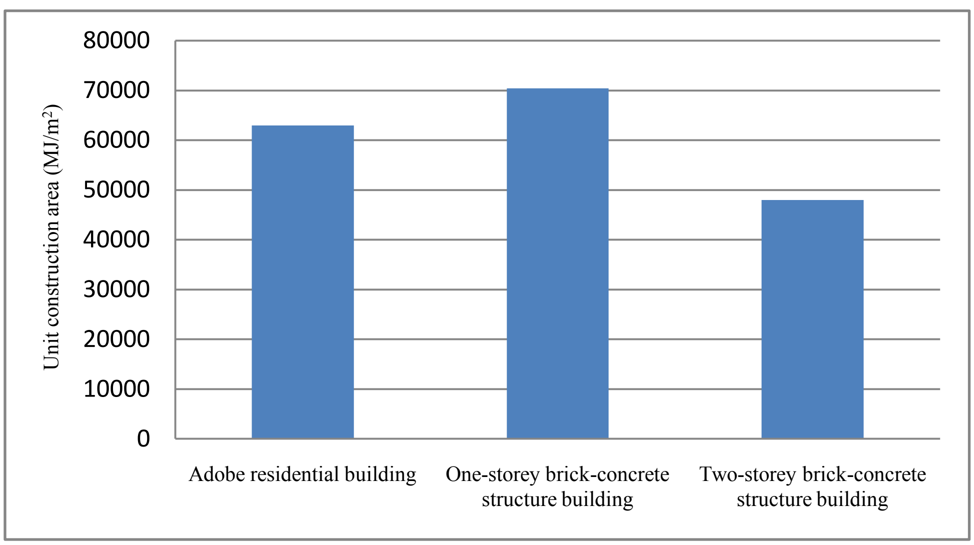


Figure 7.24 Total energy consumption of unit construction area in full life cycle

7.4.2 Comparative study on the total energy consumption in the full life cycle of three kinds of residential buildings

According to the Table 7.43, the energy consumption in each process of full life cycle of three residential buildings can be showed in Figure 7.25. The calculated results show that:

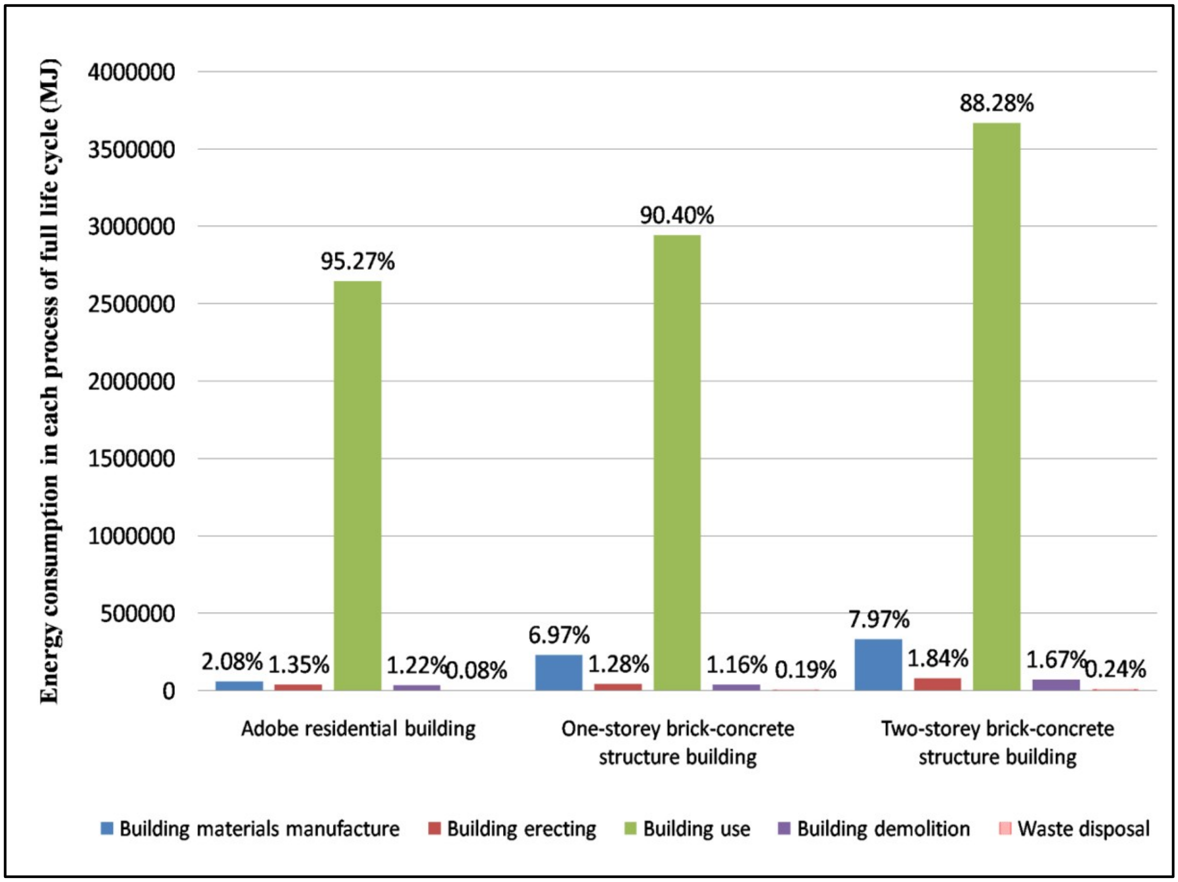


Figure 7.25 Energy consumption in each process of full life cycle of three residential buildings (%)

(1) The proportion for energy consumption in usage process is big

In the three residential buildings, the energy consumption for building use is the most, also 90% of the total energy consumption. Because of the 30 years' usage time, the proportion for energy consumption in this process is high and it will be much higher as time passed. Thus, for the whole architectural energy saving, the energy consumption in this process should be the key, and the reduction of energy consumption is the key process for realizing energy saving and emission reduction.

(2) Energy consumption in demolition is litter lower than building erecting process

In the full life cycle, energy consumption for demolition is always a little bit lower than erecting process, thus these two processes can seem reversible. If the energy consumption in erecting process can be reduced, which means the energy consumption for demolition also is reduced. Therefore, when do the architectural design, the low carbon design and management of erecting technology and its process should be put into consideration, the energy saving should be macro monitored in the full life cycle.

(3) The proportion for the energy consumption of waste construction materials disposal is the smallest

The energy consumption in this process for each residential building is far less than 1%, but it does not mean this process can be neglected. From the equations in above paper, if most construction materials come from local recyclable materials, the transportation cost will be reduced. Theoretically, the energy consumption in this process can be negative, thus have the influence on the full life cycle emission reduction.

7.5 The limitations of research

Because of the limitation by several factors, LCA in this paper still have some limitations and needed to be improved.

7.5.1 Short of database resource and date statistics

Energy consumption in full life cycle is a complex project, and need to do data collection and investigation. For the energy consumption, there are lots of processes and very complex, have relationship with people's lifestyle and living activities. Take the manufacture process of construction materials as an example, there are many different manufacturing technologies for thousands of materials. The domestic statistic and data cannot supply detailed basic data; thus, the energy consumption of some main construction materials should take foreign related research as reference. Therefore, it is very important, necessary to do the energy relatively statistics work, and to establish a complete database for the energy consumption in full life cycle in the field of architecture.

7.5.2 Defects of accuracy

There are certain defects in the statistics in this paper, the hypothesis are made for the shortage of current resource and data. At the same time of establishment of simply assessment model, the calculated results are not accurate. If conditions allow, the model should reduce the process of hypothesis, thus to increase its accuracy. Because of the limited conditions, in the process of full life cycle model calculation, some calculations for the total energy consumption are not accurate. If there are detailed data, which should be calculated respectively and then get the total energy consumption, thus get the more accurate influence on environment by assessment of energy consumption in full life cycle.

7.6 Summary

This chapter takes the energy consumption calculation method: architectural full life cycle (LCA) researched by foreign experts as reference. It takes residential buildings as special products, and divides the full life cycle into five processes: building materials manufacture, building erecting, building use, building demolition and waste disposal, and then sum each process data together to get the total energy consumption for the full life cycle.

According to the domestic architectural situation and characteristics, this paper collects data and does some data correction for the previous data, and then establishes and carbon emission model for current Chinese architecture, and used it as measurement. Based on large field investigations on typical residential buildings of vernacular dwellings in Tableland rural habitats in gully regions, fully understand and collect data about the five process of full life. Then do the calculation of the energy consumption of these five processes in full life cycle and get the unit energy consumption for each residential building. Through the comparative analyses and study on the energy consumption in each process for the full life cycle, this paper summarizes the reasons for these differences and supplies some improving suggestions.

The design is good or not has the direct influence on the total energy consumption in architectural full life cycle. Thus in the primary design process, it should foresee the influence by energy consumption in each process on the full life cycle. If by the renovation to improve living environment after the accomplishment, it will cause large amount of unnecessary energy waste. Therefore, although there are some defects in this paper, the statistic and calculated data in this chapter, still can reflect current situation of energy consumption. Therefore, it can be used as basic data to guide future research analyses and methods, and it is a great attempting for the use of energy consumption in architectural full life cycle.

CHAPTER 8
RESEARCH ON RESIDENTIAL BUILDING ECOLOGICAL DESIGN BY PROPOSING THE IDEAL MODEL IN VERNACULAR DWELLINGS OF TABLELAND RURAL HABITATS

8 Research on residential building ecological design by proposing the ideal model in vernacular dwellings of Tableland rural habitats

In the previous chapter, the energy consumption in three different residential buildings of vernacular dwellings in Tableland rural habitats of gully regions, are compared and analyzed. This chapter puts forward some improved design and innovation methods in several processes of architectural full life cycle to ensure good physical properties for the residential buildings, at the same time, inherit traditional energy saving and living culture. Finally, it summarizes ecological design rules and methods for the future construction of residential buildings in vernacular dwellings of Tableland rural habitats in gully region of Loess Plateau.

8.1 Residential building ecological design system framework

Ecological design system framework for residential buildings is an organizational structure includes human being development, material energy exchange and ecological balance, which can be improved by suitability technical methods and participants' efforts, and finally realize a harmonious relationship between residential buildings and the environment. In this framework, there are mainly three factors, and they are life cycle, suitability technology and human factors. These three aspects are indispensable. Ecological and low carbon design system framework for residential buildings in Tableland rural habitats use the life cycle as their theoretical guide, suitable low carbon technology as methods, and human factors as the basis, thus realize the full low carbon design and construction aim Figure 8.1.

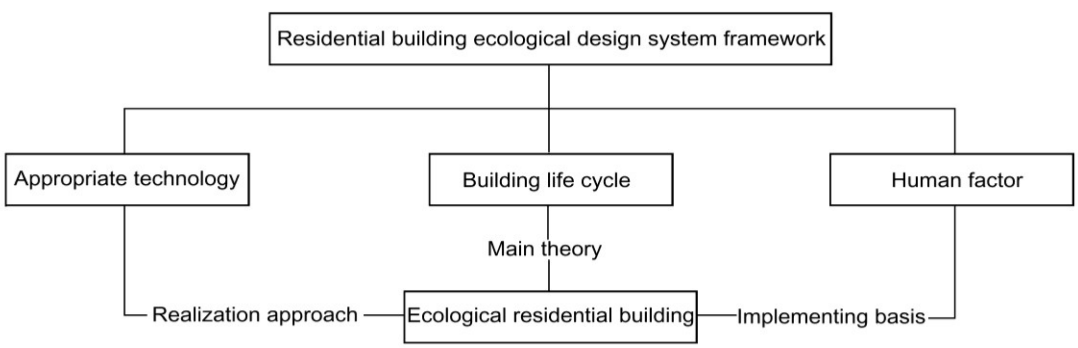


Figure 8.1 Residential building ecological design system framework of Tableland rural habitats

8.1.1 Building life cycle——Main theory

Only the realization of energy saving and emission reduction in architectural full life cycle, will the ecological architecture come true. Thus it should establish the design ideas for full life cycle, realize ecological design framework in the whole process of the manufacture and transportation of raw materials, building erecting and installation, building usage and maintenance, demolition and waste disposal. Any actions in these processes can have the influence on energy consumption for full life cycle, and has the relationship with the assessment and location for the residential buildings. Therefore, the principle of full life cycle is the main line for low carbon residential buildings' design, and should be put into every process for residential buildings from "cradle" to "grave", which have relationship with industrial production, machine manufacture, transportation, environmental protection and people's daily life.

8.1.2 Appropriate technology——Realization approach

Energy consumption cannot be avoided, and it has to use necessary technologies to improve the efficiency of current resource, even to create new resources. When technologies are adopted in architecture, local climate, economic conditions, cultural factor and environmental carrying capacity, all should be put into consideration. Only when the selection of architectural technologies and improving designs are suited to local conditions, the complete ecological construction on economy, society, environment and human culture can be truly realized. Appropriate technologies can be adopted in the usage of recyclable resource, the design of energy saving structure and integration of building, the extraction, inheritance and development of traditional construction model and living culture. Appropriate technologies can ensure the ecological conceptions used in architecture, it is also the base for ecological architecture and the realization way for design framework of ecological vernacular dwellings.

8.1.3 Human factor——Implementing basis

Architecture is designed and built by people and for people, thus the huge influence of human factors on the ecological design for vernacular dwellings cannot be neglected. In the full life cycle, most energy consumption is consumed by human. Therefore, in order to realize a comprehensive ecology, it has to realize the ecological entire process for manufacture, erecting, demolition, improve manufacture and construction methods, use suitable construction technology, and design low carbon spaces for living and production, thus to reduce energy consumption. Because the energy consumption in building use and maintenance process takes over 90% energy consumption in full life cycle, it has to promote low carbon living and production and then realize comprehensive energy saving and emission reduction. Human factors have direct relationship with the realization of low carbon conception and technology, which is the basic in the design framework for ecological vernacular dwellings.

8.2 Residential building ecological design principle

Under the previous guide of ecological design framework for residential buildings, in this section, some design principles will be summarized. The design principles for low carbon residential buildings includes the principle of full life cycle, suitability, integration, low carbon materials, low cost, reasonable implementation and public participation Figure 8.2.

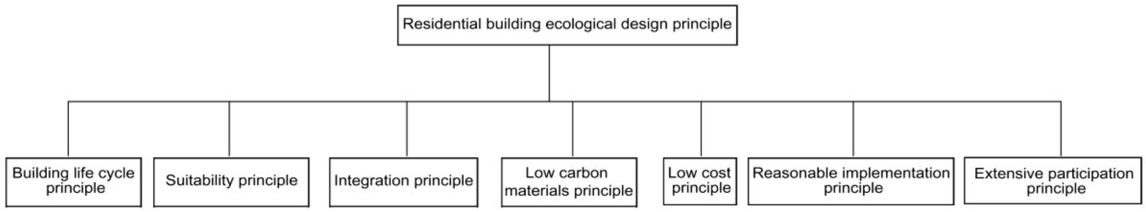


Figure 8.2 Ecological design principles for residential buildings in Tableland rural habitats

8.2.1 Building life cycle principle

Ecological buildings are not just a space, but similar to a living body, from born to return back to nature, it needs to realize low carbon even zero carbon emission, thus the influence on the environment can be reduced. Architecture can be regarded as an industrial product, factors in the full life cycle should be put into consideration, and final realize the ecological development of it. In architectural full life cycle, there are several key processes, which are construction manufacture and transportation, building erecting and installation, building usage and maintenance, renovation and demolition, waste recycled and disposal. Among these processes, factors about energy consumption and emission are a lot and they are complex, it requires reducing the unnecessary loss caused by negligence.

8.2.2 Suitability principle

Ecological conception is a macro conception that can change people's current production and living way, exits in every process of human development. Regions with different geographic and cultural characteristics, the methods to realize ecological development are different and own their own characteristics. Thus at the same time of achieving ecological vernacular dwellings, the design and construction should be suited to local conditions, and some special low carbon measurements should be adopted in certain regions. The suitability principle refers to the suitability of both technology and culture.

Technology suitability does not only mean the adoption of current ecological energy saving technologies, but also means use new energy saving and emission reduction technologies, which are suitable to local resource supply, climate and economic conditions. There should be some targeted technologies, which can meet local requirements. For example, the adoption of some new resource should put local natural conditions into consideration, otherwise, it will cost more and the results will be not good.

Cultural suitability means to meet local cultural requirements. Ecological conception in traditional vernacular dwellings of Tableland rural habitats in gully region of Loess Plateau is simple and suitable to local conditions, thus they should be inherited and further developed in newly ecological residential buildings and local living culture and regional characteristics should be protected. Ecological vernacular dwellings, do not mean to design a completely new living model, but means to review and evaluate the original vernacular dwellings by the rules of energy saving and emission reduction. Without changing thousands years' culture of original villages, at the same time, to design and construct new low carbon vernacular dwellings, which is a process of development and also an heritance for historical culture.

8.2.3 Integration principle

In the primary design process of ecological vernacular dwelling, energy saving and emission reduction in full life cycle should be put into consideration, thus integrative design should be adopted. Optimizing design should be adopted to solve problems, such construction materials selection, natural ventilation, thermal insulation, sound insulation of floor and wall, and there should be no renovation work by artificial equipment after construction completed. Because renovation work by artificial equipment will cause energy waste and waste emission. Architectural integration can be seen as a passive adaptive to the natural environment.

In the previous chapter, the calculation results show that the longer time the building is used, the less of yearly energy consumption of unit construction area. Therefore, integration design should also be predictability and forward, thus it can meet living requirements for a long time, also design some possibilities for future renovation.

8.2.4 Low carbon materials principle

Construction materials are used in full life cycle in residential building, thus the low carbon of construction materials is very important, which mainly includes the heritage and development of traditional construction materials, material disposal and recyclable use, the adoption of new and local materials.

Traditional low carbon materials include stone, wood, immature soil and so on, these materials are usually easy to get manufacture, and are recyclable with small energy consumption in full life cycle, and they can also keep the special regional characteristics. For some local old construction materials, some of them can be reused by industrial waste treatment and biomaterial usage technologies, and some of them, such as clay soil bricks, wood and concrete can be reused directly in construction. With the development of construction material technologies, if conditions allow, some polyethylene pipes, fly ash blocks, strut channels, polyethylene foam board and gypsum blocks can also be used. No matter what kind of construction materials, the principle should be using local materials, on the one hand, it will reduce the energy consumption and pollution caused by manufacture and transportation, and on the other hand, it can ensure the unified and harmonious architectural style.

8.2.5 Low cost principle

Ecological vernacular dwelling does not mean the construction cost will be increased, on the converse, combining low carbon technologies and integrating design conception into the architectural full life cycle, in the long run, the cost will be lower compared to the same standard and same scale building. Low carbon vernacular dwellings own suitable ecological technologies, the cost of construction, usage and maintenance can be reduced and will not cause economic burdens for residents.

8.2.6 Reasonable implementation principle

Reasonable implementation principle means in the process of architectural construction, maintenance and demolition, the operation should be based on low carbon principle, which is saving the "grey energy". "Grey energy" refers to the indirect energy consumption in full life cycle, including raw material manufacture, building material transportation, construction methods, and disposal and so on. Comparing with other direct energy consumption, this "grey energy" takes a large proportion, thus in order to realize complete low carbon vernacular dwellings, "grey energy" should be reduced.

When the implementation of low carbon structure and measurements, dominant energy consumption will be reduced, there must be some invisible "grey energy" consumption increased. Therefore, it should grasp the overall situation and comprehensive considering the energy consumption in each process in full life cycle, to balance them all and finally realize the aim of energy saving and emission reduction.

8.2.7 Extensive participation principle

Ecological conception is an effective measurement for global climatic crisis, and it is not a difficult theory. The low carbon design method is easy to know and master. Residential buildings in vernacular buildings are usually constructed by local people themselves, thus the extensive participation by villagers is very important. Only by extensive participation, ecological residential buildings can be promoted and developed, and the low carbon conception can be known by more people. The construction of ecological residential buildings is just one part of ecological economy, and the extensive participation by residents can improve their knowledge about low carbon life and production, and better realize the construction of ecological villages.

8.3 Residential building ecological design strategy

Residential building is the most typical architecture that can reflect regional characteristics among all architectures, which is the carrier for local culture, history, economy, culture, technologies and other factors. Residential building in different regions are very different, the uniqueness decides the design and construction should be different. According to lots of field investigation of residential buildings in Tableland villages and data calculation and analyses, this paper research on the design methods, that is suitable for the low carbon construction for local residential building. This design method will be explained in detailed from the following five parts: ecological improvement, selection of low carbon construction materials, and ecological improvement of architectural construction, low carbon construction engineering, and low carbon energy consumption Figure 8.3.

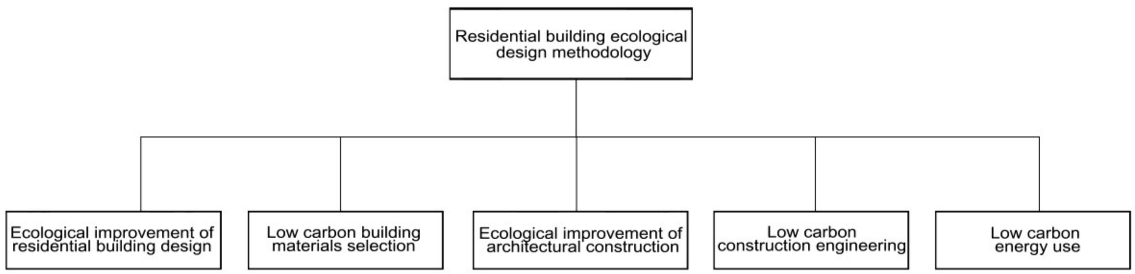


Figure 8.3 Residential building ecological design strategy in Tableland villages

8.3.1 Ecological improvement of residential building design

Architectural design is good or not has decisive influence on the amount of energy consumption. In the primary design process of ecological residential building, energy saving and emission reduction of each process in its full life cycle should be put into consideration, thus the design should have prospective to the future. Because renovation works will cause the loss of energy consumption and waste.

(1) Land saving and reasonable construction area allocation

Architectural land use has huge influence on energy consumption in its full life cycle, the larger area it takes means larger closure structure, higher maintenance cost, more energy consumption for foundation digging and site cleaning, and more energy consumption for construction and demolition. Therefore, based on meeting residents' requirements for living now and future, the land should be reduced, which will save energy consumption at the same time of saving land resource.

(2) Optimization of shape coefficient of building

Shape coefficient of building is the most important influence factor for energy consumption, which refers to the proportion of outside surface area and the volume enclosed by the outside surface. Because energy consumption in heat transfers in closure structure is proportional to its heat transfer area. Thus the shape coefficient of building is smaller means energy saving is much better. Generally, in order to reduce energy consumption, the coefficients should be controlled in a certain level. In this research, the typical one-storey brick-concrete residential building in Tableland rural habitats in gully region is researched, and the shape coefficient of building is calculated, it is about 0.57, while for adobe residential building, the shape coefficient of building is about 0.60. The reason why adobe residential building has higher coefficients is that the singly slope roof in immature soil house is related steep and need higher roof, thus the outside area is increased.

Generally, residential buildings in Tableland rural habitats have relatively even and neat facade, which is good for reducing shape coefficient of building [109]. Therefore, in the ecological design, it is better to reduce shape coefficient of building by increasing its depth, and makes the plan functions much more even and more compact, and can reduce storey height to reduce its outside wall area.

(3) Reasonable partition for different architectural functions

Different with modern urban architectural functions, residential building in rural area usually have two functional areas, one is for living and another is for agricultural production, and these two functions are also included in the construction of vernacular dwellings in Tableland rural habitats in gully region of Loess Plateau. As the improvement of people's living conditions and their pursuit for modern life, the functional partition in residential buildings of traditional vernacular dwellings cannot meet their demand. However, in the newly built vernacular dwellings in Tableland rural habitats, most of residential buildings just copy the architecture forms from other developed rural areas, even copy urban villa, which are not suitable for local conditions and cannot meet residents' practical demands. The unreasonable design causes the mix and chaos between production and living in newly built vernacular dwellings, and inconvenience for residents' life.

The main functions of living space in vernacular dwellings of Tableland rural habitats are used for sleeping, meeting guests, cooking, eating, entertainment and toilet, the main functions of agricultural functions include grain drying, storing, farm vehicle parking. Because of the backward economy and low productivity, in traditional residential buildings, different functions are usually mixed together, for example, the traditional main building is use for meeting guest, eating and entertainment. As the improvement of people's living conditions and their knowledge about modern living, residents in gully region tend to design independent space for different functions. According to the field investigation and interviews, in current newly built residential buildings, the main rooms that residents need are bedrooms, living room, kitchen, dining room, shower room, toilet and storing room. Therefore, how to reasonable design the space partition to meet residents' requirements for modern life and better service for agricultural production is important for the ecological design.

(4) Fully use of "grey space"

The gully region of Loess Plateau has a harsh climate, drought in summer, winter is cold and spring has sandstorm [110]. In order to suitable to this climate, local traditional dwellings also have evolved corresponding counter measures.

1) Attic space under slope roof

The typical form of traditional residential building owns a single slope roof directed to the courtyard. Inside the building, suspended ceilings are widely used, and the space between the suspended ceilings and the sloped roof is an air interlayer between the indoor and outdoor environment Figure 8.4. In summer, air in the attic can block heat penetrating into the indoor area, and, in the winter, it can be used as air thermal insulation. Thus it has significant ecological meanings.

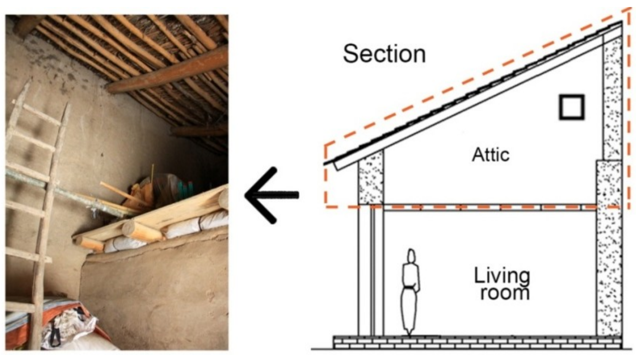


Figure 8.4 Air interlayer formed a grey space in the roof of residential buildings

On both sides of the sloped roof, there are window holes used for ventilation Figure 8.5. In summer, it can take excess heat, and in winter it will be closed and form a thermal insulator. However, in current newly built buildings, these window holes just act as decoration without practical functions. Residents use bricks, concrete and some other materials block up them and make different figures as a decoration for the building.

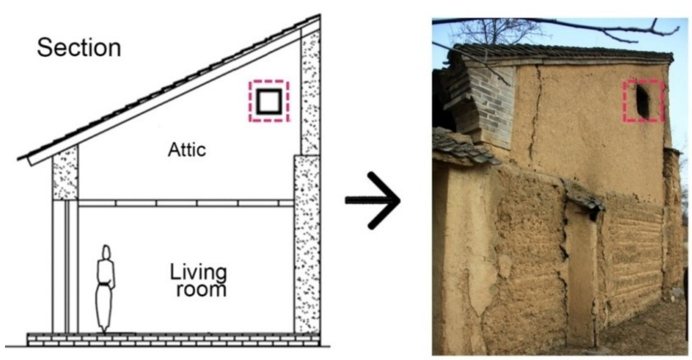


Figure 8.5 Diagram of ventilation window

2) Eaves gallery space

Compared with double pitched roofs, the pent-roof, tilting inward, has advantages such as saving wood and part of the construction spending, guiding the rainwater into the courtyard Figure 8.6, resisting sandstorms, and maintaining a relatively clean and safe interior environment of the courtyard.

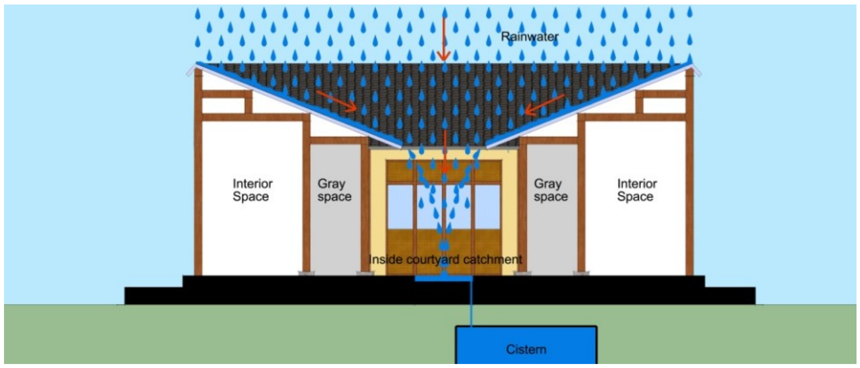


Figure 8.6 Analysis of catchment in traditional courtyard

On the side of the inner courtyard, the pent-roof commonly singled out to form cornice, which function s not only for shelter, but also for blocking directing sunshine to interior. The space under the cornice is similar to the transitional space between the indoor and outdoor, to maintain a relatively comfortable indoor environment in the hot summer Figure 8.7.

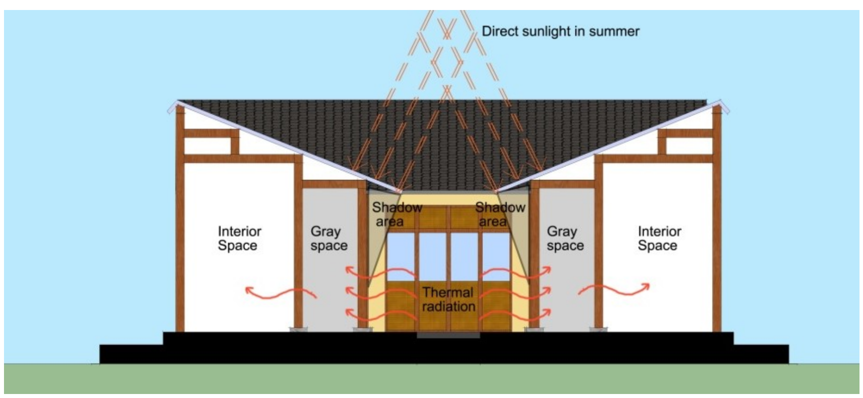


Figure 8.7 Analysis of building shading in summer

Equation $H = 90° - [\varphi - \delta]$, can be used to calculated the solar elevation angle in winter and summer solstice, in which φ stands for the local latitude and δ stands for the latitude of direct solar radiation point. According to the solar altitude of in winter solstice, the slope's starting angle on north slope of south architecture should be less than 32° 18′, thus avoiding south facade winter lighting being sheltered by the south side building. What is more, the structure of gentle slope is simple and easy for drainage, also architectural height, roof truss should be put into consideration, and the roof slope is suggested to be about 30°.

In addition, according to the solar altitude of summer solstice, the optimal length of architectural south façade is around 0.7 Figure 8.8.Thus in summer, the sunshine can be effectively barrier, and in winter enough sunshine can enter the residential building[111]. Besides, the space under cornice can be changed into passive sunshine room, which can improve the indoor thermal environment. The larger of this passive sunshine room, the faster the indoor temperature can be increased.

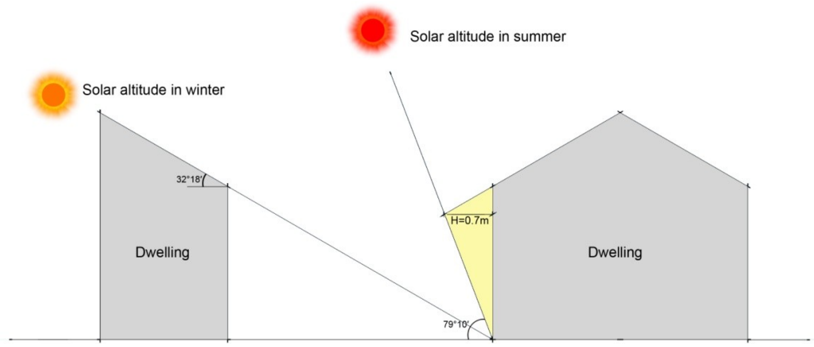


Figure 8.8 Diagram of the solar elevation angle in gully region of Loess Plateau

8.3.2 Low carbon building materials selection

From the calculation of energy consumption in full life cycle in Chapter 7, although the energy consumption from building material takes less than 10% of total energy consumption, there are some indirect energy consumption, including the energy consumption for maintenance, demolition and materials disposal and recycled. When designed, it is better to select low energy consumption materials and the materials with high potential for recycling [112]. Therefore, in order to realize the ecological residential buildings, construction materials should be firstly realized to be low carbon from the very beginning of construction, which means recyclable construction materials should be selected in full life cycle, and try to reduce their influence on the environment for materials' manufacture, usage and recycled process. New environmental protection materials should be selected to ensure good qualities indoors at the same time protecting environment. Waste material is better used again, which will reduce the cost of old material treatment and the green gas emission. The principle of using local materials and architectural culture protection should be kept, and the energy consumption for transportation can be reduced, the detailed explanations showed in following:

(1) Renewable materials

Residential building is relatively small and does not need big structure support system. In the previous calculation for the three kinds of residential buildings, the original local structure can meet the requirements of energy saving and emission reduction. Therefore, in the design, the local construction materials should be selected, especially those renewable materials.

1) Wood

Wood is a good renewable material, which come from the natural and can return to it, owns good reproducibility, humidity adjustment, and is the natural carbon sequestration container. In Chinese north residential buildings, most of them use wood as main material, which should be inherited and further developed, thus residential building can have regional characteristics. However, in gully region of Loess Plateau, the vegetation resource is scarcity, thus when select wood as construction materials, which should be used reasonable and recycled.

2) Natural stone

Natural stone is one of the most common construction materials in the gully region of Loess Plateau, the manufacture and mining process are simple and the influence on environment is small. The physical characteristics of stone can realize good physical thermal environment for architectures.

3) Immature soil

Immature soil is the most widely used material in gully region, its good physical characteristics, suitability and recyclable make it largely used in local residential buildings. However, in recent years, the natural materials are regarded as the symbol of backward and are abandoned. However, in recent 30 and 40 years, some European developed countries start to do research on these natural materials, the inherent defects for immature soil have already be overcame and form some optimization theories and application technologies for using immature soil. Modern immature soil and construction technologies can be the effective way for green architectures. Immature soil has already been used in lots of modern high-level architectures, thus it should be put more attentions in the design of low carbon residential building in gully region. For example, use immature soil adobe, which made by immature soil and grass mud, and adopt advanced ramming method to improve its firmness.

(2) New low carbon building material

Low carbon building materials refers to the materials that can ensure its use performance and the use of unrecyclable raw materials should be reduced. The manufacture process should be low energy consumption, low pollution and low emission. These materials can be used in long time without producing harmful substances, and can be reused and recycled [113]. The manufacturing and using process of low carbon materials should be energy saving and emission reduction, and sustainable material. In the residential building design, some new low carbon materials can be used, such as new pipe materials: copper pipe, polyethylene and polypropylene pipes; new ceramic materials, such as thermal ceramic materials and bathroom ceramic made from industrial waste; new paint, which can reduce of volatile organic compounds .

(3) Waste material recycling

Waste material recycling is the key to realizing building materials recycled and reused. On the one hand, at the very beginning of architectural design, the final waste material in full life cycle should be foresighted. On the other hand, the reuse of waste materials should be put into consideration during building erecting process. Waste materials include reusable wood, stone, metallic materials, glass, concrete and so on, there are some new building materials made from waste materials by secondary processing, such as powder cinder blocks made from cinders, immature soil, grass and mud bricks and so on.

(4) Using local materials and reduce the energy consumption for transportation

Using local building materials can protect architectures' regional characteristics, make the residents have self-identity, and also can reduce the energy consumption and pollution in material manufacture process, especially the energy consumption and pollution in transportation, also can avoid unnecessary time waste for waiting building materials.

8.3.3 Ecological improvement of architectural construction

As the calculation and analyses in previous sections, energy consumption in architectural usage process takes more than 80% in total energy consumption in the full life cycle. Architectural structure has decisive functions on ventilation, thermal insulation, and sound insulation. Therefore, in the very beginning, the architectural structure should be improved to be low carbon and meet the requirements of energy saving and emission reduction in maintenance process [114]. The low carbon measurements are showed in following:

(1) Wall structure

Residential building wall structure is the closure structure, by using suitable technologies, the cost of thermal insulation will be increased 3%-6%, while the energy saving rate can be 20%-40% [115]. There are many methods for low carbon wall structure, this paper mainly researches on the methods for low carbon wall in gully region of Loess Plateau. Natural stone can be used in the base of wall or the whole wall in residential buildings in tableland villages, thus realize the win-win for good physical functions and low carbon of building materials. Besides, for the immature soil residential buildings, grass mud layer can be put between immature soil bricks, or use polystyrene board and grass mud bricks to make a mixed insulation wall, which improve thermal insulation for the external closure structure in whole buildings.

(2) Doors and windows system

Doors and windows system is the cold and hot bridge in external closure structure, which has close relationship with ventilation and insulation. In this region, the design of energy saving for doors and windows is usually neglected. Aluminum alloys and plastic steel window, or low-E middle empty glass doors and windows can be used in this region for local climate. At the same time, reasonable proportion for doors and windows also has huge influence on energy consumption.

(3) Roof system

Roof is important component in external closure structure, which can be design as flat stage people can go, or design as a stage on second floor, thus the thermal performance of insulation is very important. In gully region of Loess Plateau, the most suitable design for roof is suspended insulated composite roof, which can guarantee good ventilation in summer, and own good thermal performance in winter.

8.3.4 Low carbon construction engineering

According to the theory of LCA, energy and resource consumption in building erecting process are a lot, the unnecessary energy consumption in this process can be reduced by reasonable design and construction methods. Low carbon construction engineering mainly includes architectural structure, decoration and construction.

For architectural structure system, the traditional wood structure should be used, and in some parts, the steel structure made in prefabricated factory can also be used. Percentage of usable house area of these two structures are all higher than traditional brick mixing structure, the performance for earthquake resistant is better, and building materials are easy to be reused and recycled. Wood structure system has been used in Chinese architecture for thousands years and has mature construction technology, which is easy to be promoted and developed. Building decoration need to be designed integration, unnecessary decoration should be avoided, and it is better do dry operation in process of decoration, so the materials saving can be over 10% [116]. In building construction, the use of recyclable materials, suitable construction technologies and advanced operations on sit, the energy consumption can be reduced, and the efficiency and security will be improved.

8.3.5 Low carbon energy use

There is energy consumption in both processes: the use and maintenance in residential buildings, but the selection of different energy, the consumption will be very different. Low carbon energy consumption means that reasonable use of current energy and recyclable new energy. Residents' living activities can produce certain heat, reasonably use this part of energy can reduce energy consumption. For example, smoke and heat from cooking can be used to heat in winter, thus the suitable design for chimney can improve the usage of this kind of energy. The adoption of clean and renewable energy can largely reduce energy consumption in residential buildings. Biogas and solar energy have already developed to be mature clean energy. In low carbon residential buildings, the reasonable design can help the energy recycle in bathroom, livestock room, digester and kitchen. The good sunshine condition in gully region makes it possible for the development of passive solar energy. Passive solar building and solar energy collector is the advanced new energy carrier, which can be used in ecological residential building.

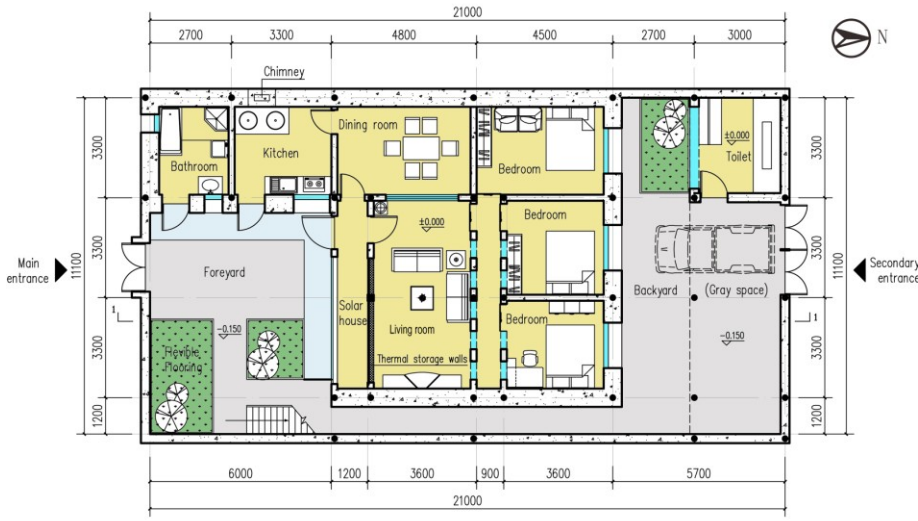
8.4 Proposing the ideal model of ecological residential building

On the base of section 8.1, 8.2 and 8.3, and combined with chapter six research results about courtyard ecological layout, by establishing idealized model for residential buildings in Tableland rural habitats, the ecological design methods for residential buildings are explored in this section. The residential building model established here is the direct description and analyses of ecological design methods. The aim of this model is establishing a complete model for vernacular dwellings, including courtyard and residential buildings, thus can be used as reference in the future vernacular dwelling construction for different families of different land conditions in Tableland rural habitats in gully region of Loess Plateau.

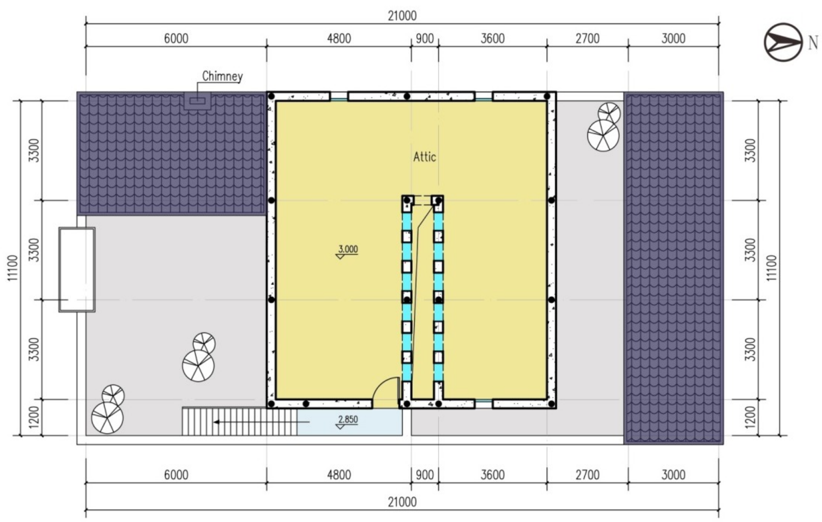
8.4.1 Layout of space functions in residential building

In the past, because of the limitation of construction technologies, traditional residential buildings in Tableland rural habitats are small with one bay, which causes architectures are dispersed. This is not good for energy saving and hard to combine with modern space functions, thus it cannot meet people's requirements for modern lifestyle. Therefore, from the consideration of energy saving and usage, newly built vernacular dwellings should make main buildings larger. Through the previous research, the design of second floor space can improve construction areas and saving land, also can reduce unit energy consumption in full life cycle, but most of residents do not have requirements for so large area. The constructions of second floor not only increase their economic burden, but also cause space waste. Therefore, this research use newly built one floor residential building as case study.

The most needed space in residential building in Tableland villages in gully region of Loess Plateau are bedroom, living room, kitchen, dining room, toilet, bathroom and storing room. Among them, bedroom, living room and dining room are used by most residents and the most used space, they are main rooms, while kitchen, bathroom, toilet, and storing room, the use frequency is less, and they are secondary rooms. In Chapter 6, about the courtyard layout research, kitchen, bathroom and shower room have already been designed outside main building, storing room can use attic space on top of the main building, and this space distribution has already been explained in the previous chapter. Therefore, how to do the reasonable layout for main building, which is the most frequency used in the whole residential building, should be the key point for space layout in residential building Figure 8.9.



(a) First floor



(b) Attic floor plan

Figure 8.9 Floor plan of residential building

(1) The design of Living room

For a long time, living rooms have been the most important space in residential buildings, sleeping, entertainment, meeting guests are happen there, and the space requirements are relatively high, orientation, lighting , space and thermal comfort are all high. According to the habits for living room design and current residential living requirements, it suggests to establish sunshine room in the south of main building, to ensure there is enough ventilation and lighting, at the same time, the use of sunshine room can improve indoor thermal comfort in winter Figure 8.10.

(2) The design of bedroom

Bedrooms in residential building are the space for resting and sleeping, good space layout and indoor environment is the premise for basic living quality. In traditional residential building in gully region, bedrooms are usually designed in both sides of main buildings in the deepest place of courtyard, which can ensure the privacy of bedrooms and avoid the disturbing from outside environment by maximum. Family members in traditional family in gully region are a lot, the average number is 5-6, the proportion of three generations living together is big. Thus, they need many bedrooms, usually more than four. However, by the implementation of Chinese family planning policy and the later opening and reforming, the population birth rate reduced and lots of young people leave villages go to work in cities, which cause large amount of population lost in gully region of Loess Plateau, the average family number in each family is 3-4. In field investigation, it is found that just old people and kids now live in villages and for young generations they work in cities just come back during the holidays and the harvest days.

Therefore, some bedrooms are long time unused and cause resource waste. In new residential building design, it should combine with family composition and the actual needs to design bedrooms. Generally speaking, three bedrooms are suitable, which can ensure the requirements for current few residents, and can keep some space for future development Figure 8.9.

(3) The design of dining room

Dining room usually is not separated design in the traditional residential buildings in gully region of Loess Plateau, and residents usually eat in living room or in the courtyard. As the improvement of people's living standards, modern lifestyle and conception gradually spread in gully region, and residents start realize the importance of dining environment, independently eating not only avoid the mix of space functions and benefit for the usage of other spaces, but also good for keep house clean and tidy. Therefore, in this paper, it suggests putting dining room separated from main building and connect to kitchen, thus it will be convenient for eating and the cleaning housework after eating Figure 8.9.

8.4.2 Optimization design for the architectural construction

(1) Foundation and floor

This research suggests that foundation should keep using rubble and block stone. Stone resource is a kind of local materials that is easy to be mined, manufactured and constructed. Local people are familiar with these traditional material construction methods; thus, it is good for the future promotion.

Indoor floor can use lime to make it; the construction method is easy. Based on this, residents can select more decorative materials according with their like and economic conditions Figure 8.10.

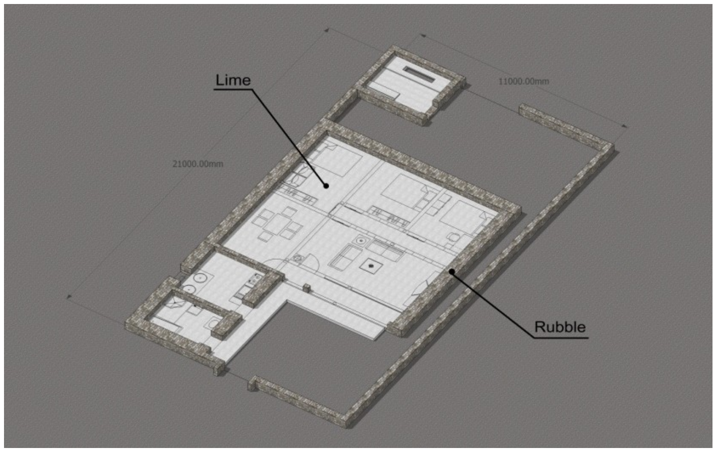


Figure 8.10 Foundation and floor of residential building

(2) Support structure

For the support structure, wood frame structure is suggested to use, which is an environmental friendly material for this region after years of development. Wood is a natural carbon sequestration material, which is good for earthquake resistance, easy to be manufactured, renewable and recyclable; all of them make it the first choice for low-carbon residential buildings. Besides, wood has lighter weight, and easy to be transported, assembled and disassembled, and can be used multiple times. In recent years, plywood timber is widely used in residential building, which has the advantages of short time construction, easy construction methods, low cost, thus is suitable to be selected in low carbon residential building Figure 8.11.

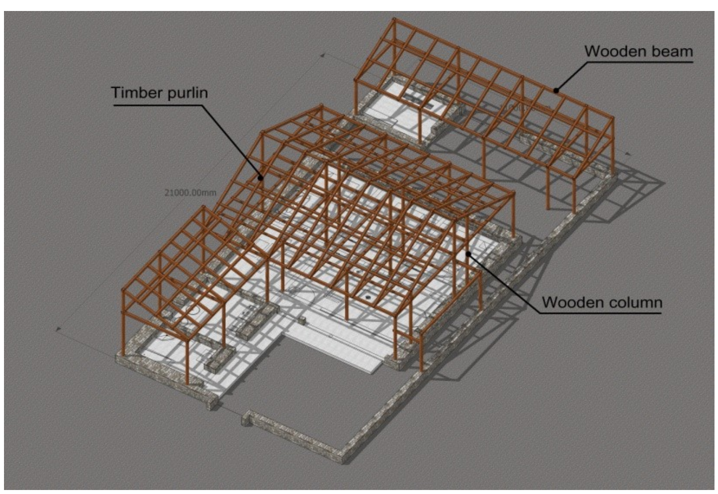


Figure 8.11 Support structure of residential building

(3) Wall structure

At present, brick is widely used in the construction of architectural extent closure wall in gully region of Loess Plateau, and this model is largely copy in the whole region without consideration. The manufacture of clay bricks consumes large amounts of unrecyclable resource, and dig large amount of clay will disrupt vegetation and make soil and water loss much more serious. What is more, clay bricks cannot be degraded, the disposal will cause the second solid pollution. Adobe residential building owns a lot of ecological construction experience. When build the extent enclosure structure, immature soil wall is made by formwork and tamped loess in it, the thickness in 400-500mm. Heat transfer coefficient of immature soil is very small, which is also a poor conductor for heat transfer, thus own good thermal performance and insulation compared with brick wall. Besides, the immature soil wall is good at moisture absorption, which can keep a relatively stable indoor temperature and humidity environment and owns significant ecological meanings.

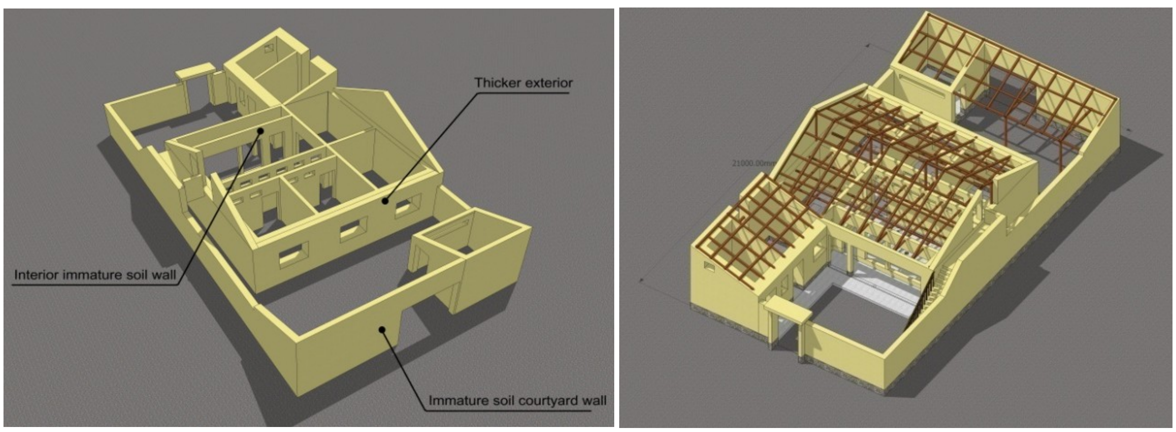


Figure 8.12 Support structure of residential building Wall structure of residential building

However, immature soil wall is afraid of water, and the overall structural performance will be changed in humid environment, the time for using will be short. In the field investigation, it is found that the average life expectancy for rammed earth wall is about 30 years. Besides, it is not good at earthquake resistance, easy to be cracked and not beautiful, and need maintenance time to time; thus, it needs further improvement, and then can be promoted to the new countryside construction. At present, ecological environment in gully region of Loess Plateau is fragile and resource carrying capacity is weak, how to improve these traditional immature soil wall by modern technologies to meet the requirements of modern rural life and own its ecological and environmental protection meanings, is very important and have its reality meanings. For the defects of immature soil wall, the suitable improvement method is using ecological composite wall structure, which means to compositely use immature soil and concrete together, use concrete as main support for the wall, and immature soil adobes in the middle of it. In this method, concrete can improve the structural performance and immature soil bricks can improve thermal performance. In order to make it much more beautiful, the outside surface can be painted by waterproof materials, which can improve the outside appearance, also can strength its waterproof performance, thus extend is service life. In gully region of Loess Plateau, the thermal insulation performance of exterior wall is very important for the climate. In order to improve the thermal performance more, it suggests thickening the exterior wall for the main building. For the family, if their economic conditions allow, they can use polystyrene foam board, this relatively economic and good insulation performance material Figure 8.12.

(4) Floorboard

Because of attic, floorboard not only acts as the ceiling for the first floor, but also support attic as a storing room. Attic, as a buffer is between the indoor and outdoor in residential building, the thermal insulation of floorboard has great influence on the whole building. In this research, it suggests using wood as frame floor, and putting a layer of grass mud in certain thickness as surface, which can effectively control the noise transmission, and the thermal performance of grass mud can get good thermal insulation effects Figure 8.13.

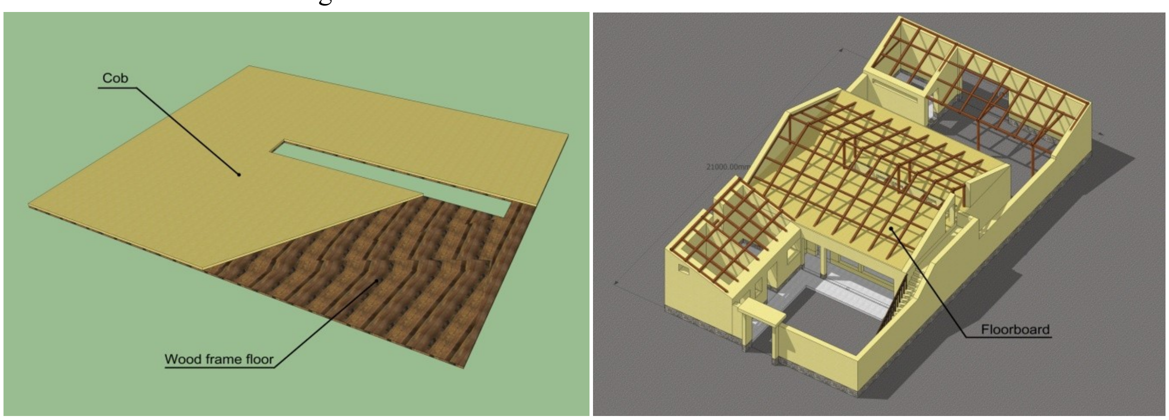


Figure 8.13 Floorboard of residential building

(5) Building roof

Building roof in traditional residential building of tableland villages in gully region of Loess Plateau is mainly composed by supporting structure and roof. Supporting structure is composed by timber pruline and wooden beam, and the roof is composed mainly by straw, cob and clay tile Figure 8.14. Traditional roofing uses local materials, the construction method is easy, the cost is low and have can protect environment, thus it widely used in gully region of Loess Plateau for thousands of years. As time goes, the defects come out, such as simple, short life, poor insulation and earthquake resistance performance, poor indoor environment caused by dust. Therefore, how to do the modernization improvement on the base of inherit for roof, is the key point for realizing ecological residential building.

This research compares the heat transfer coefficients, price, and thermal insulation for several common used building materials for roof, and showed in Table 8.1. Currently, clay tile is the most common used material in roof, the main materials is clay soil, which cause large destroy on land resource and belongs to unfriendly environmental material, should not be promoted in large area and can be replaced by glass tile and color steel tile. The heat transfer coefficient for color steel tile is bigger than glass tile, but the thermal insulation is worse than glass tile. For the requirements of roof insulation, a thermal insulation layer should be added, thus color steel tile can be good selection for replacing clay tile.

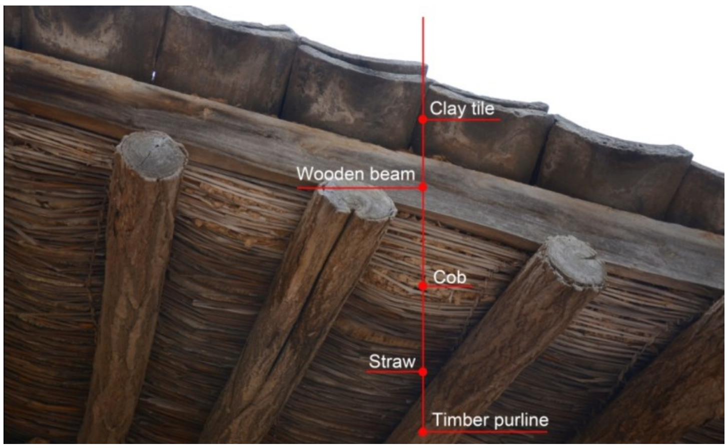
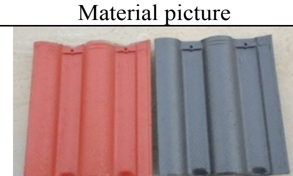


Figure 8.14 Roof construction of traditional residential building

Table 8.1 Different building materials in roof

Materials	Price	ecological character	Heat transfer coefficient	Material picture
Cement tile	40-50 RMB/m^2	It made from cement, and cause pollution during manufacture	0.7—0.9W/(㎡·K)	
fiberglass asphalt shingles	32-42 RMB/m^2	It made of asphalt, glass fibers and other elements, the raw materials are relatively environmental friendly.	0.6—0.8W/(㎡·K)	
Color steel tile	22-30 RMB/m^2	It made form steel broad, is a kind of environmental friendly material.	There are no exact numbers. The heat transfer coefficient for metallic materials is relatively high.	
Clay tile	18-30 RMB/m^2	It made form soil, causes land resource destroy, and is not environmental friendly material.	There are no exact numbers. The raw material for clay tile is clay soil, similar to solid clay bricks, The heat transfer coefficient is 0.81W/(㎡·K)	

For roof insulation, take traditional insulation methods in traditional residential buildings as reference, the insulation layer should be further improved by put thermal insulation materials cob between composite Figure 8.15 and Figure 8.16. The thermal insulation materials can avoid exterior influence, thus extend the usage years and strength it thermal insulation capacity. At the same time, the thermal insulation performance can be improved by increasing the thickness. At present, the common used roof thermal insulation materials are EPS, XPS, which have small heat transfer coefficients and low price, are very suitable to be used in residential building in gully region of Loess Plateau.

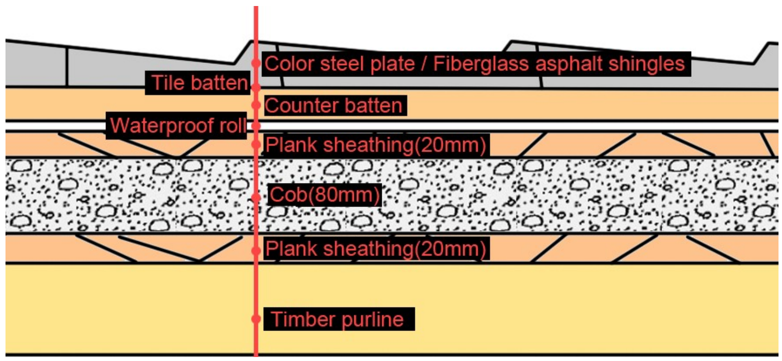


Figure 8.15 Sectional view of the improved residential building roof

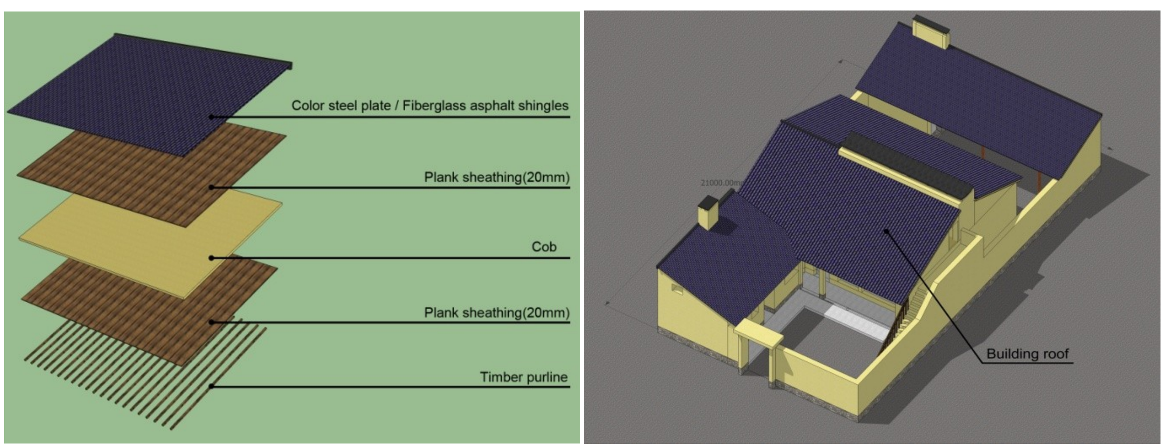


Figure 8.16 Building roof of residential building

(6) Doors and windows

Doors and windows, as part of exterior enclosure structure, have direct influence on architectural thermal insulation performance. The thermal performance can be improved by improving air tightness, preventing cold wind penetration, using energy saving glass, strengthen insulation performance and so on Figure 8.17.

1) Choosing the exterior doors and windows with good thermal insulation performance

Materials and section form are important factor that can influence thermal insulation performance. The material selection for window framework is very important, which can be made by metallic materials, non-metallic materials and composite materials. Generally, the heat transfer coefficients of wood and plastic materials are much smaller that metallic materials. Currently, PVC plastic window and glass fiber reinforced window adapt to use in rural areas, which have good thermal insulation performance and relatively low price. The heat transfer coefficients for PVC double glass window is 2.8 W/ (m^2•K). Comparing with traditional single glass, the heat transfer coefficients of it is 6.03/ (m^2•K), double glass window can efficiently reduce the heat lost in winter. What is more, the air tightness of casement window is better than sliding window, and it is better to use it in cold area. In current residential buildings, casement windows fell into disrepair and the crack on window is big. Besides replacing the broken windows by PVC double glass casement windows, it can also be solved by put sealing strips.

2) Using insulation curtain

There are lots of important energy saving functions by insulation curtain, for example it can improve windows' thermal insulation performance, reduction of heat lost, sheltering the cold radiation caused by low temperature in window, reducing indoor ventilation. It is calculated that the insulation curtain by materials with functions of light reflection and insulation, can make heat load for residential buildings in winter reduced by 10%-15% [117].

3) Design foyer space

Design foyer spaces in entrance, which can prevent wind and cold air, and efficiently reduce cold wind penetration by residents' entrance or departure. At the same, the foyer space can be connected with sunshine room, thus increase indoor space.

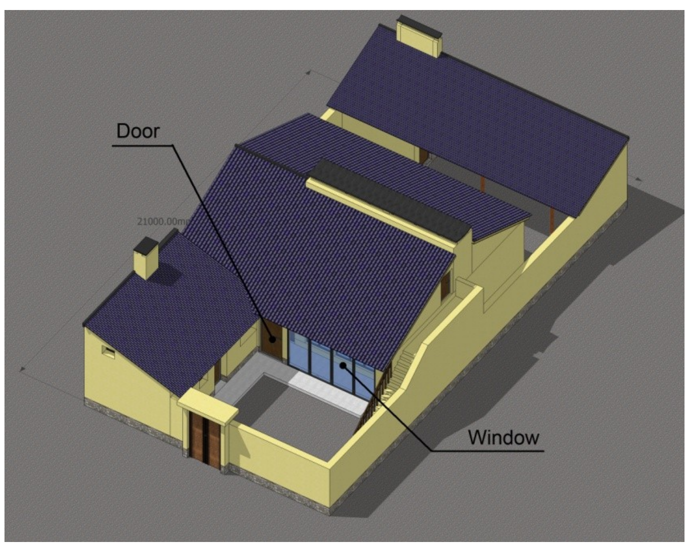


Figure 8.17 Doors and windows of residential building

8.4.3 Whole outlooks of vernacular dwelling

In the courtyard, hard paving and flexible flooring should be paving respectively Figure 8.18 and the whole outlooks of vernacular dwelling is showed in Figure 8.19, Figure 8.20, Figure 8.21, Figure 8.22.

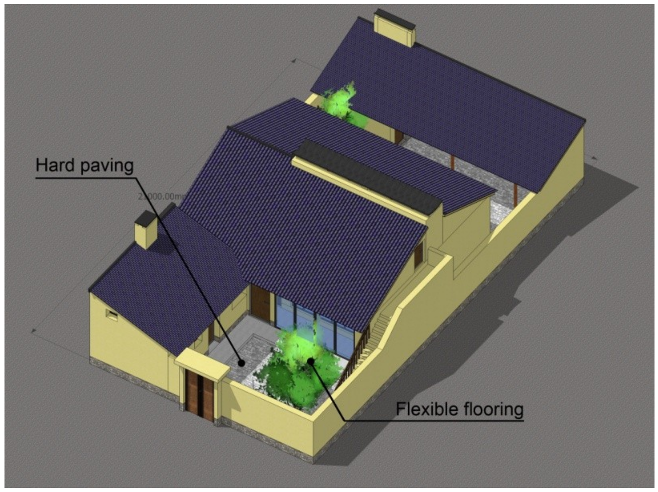
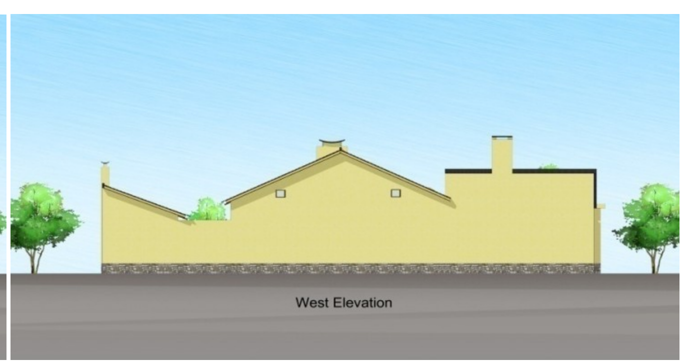


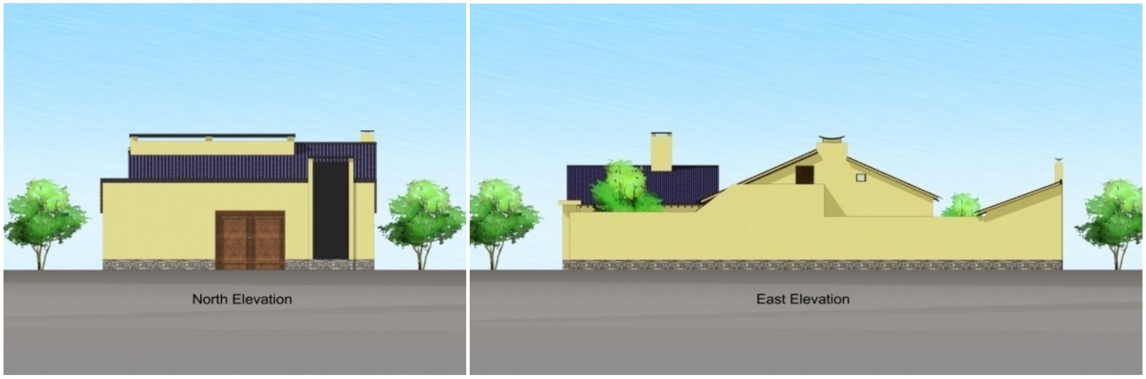
Figure 8.18 Pavement of courtyard in vernacular dwelling

Figure 8.19 Site plan

(a) South elevation



(b)West elevation



(a) South elevation (b)West elevation

Figure 8.20 Elevation

Figure 8.21 Section

(a) Southeast side perspective drawing (b) Northwest side perspective drawing

Figure 8.22 Section

8.4.4 Analyses on the energy saving design in vernacular dwelling

(1) Ventilation design for vernacular dwelling in summer

The main wind in gully region of Loess Plateau in summer is southeast monsoon. Good indoor ventilation is effective methods for improving indoor thermal comfort. In this research, it suggests to design an airshaft in the middle of main building, outside of this airshaft should be painted with dark endothermic waterproof paint. In this way, the temperature in the top of chimney is higher than the bottom, the temperature difference can create chimney effect, and thus indoor air can flow, the hot air in first floor can be took out. Design of ventilation window in attic is also good for bring hot air outside. What is more, the design of ventilation shaft between living room and bedroom, can act as a barrier, thus the noise influence on bedroom from living room can be reduced Figure 8.23.

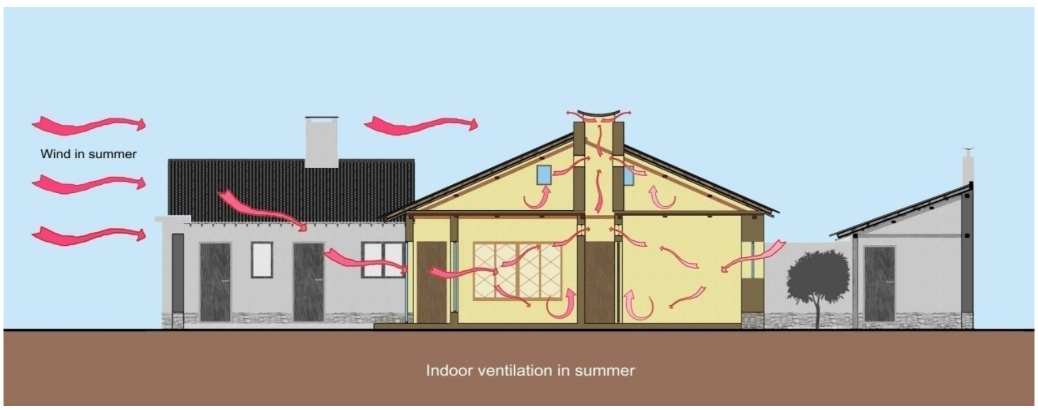


Figure 8.23 Analysis drawing for summer thermal ventilation in vernacular dwelling

(2) Design of thermal insulation in vernacular dwelling

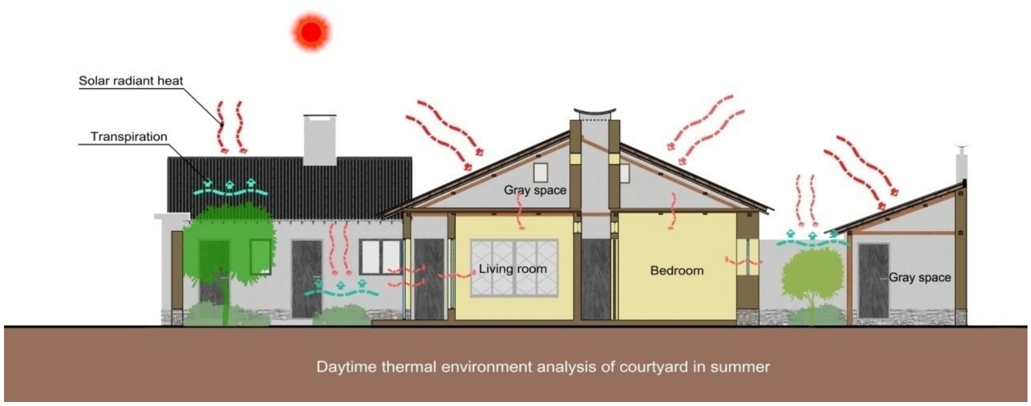


Figure 8.24 Analysis drawing for summer thermal insulation in vernacular dwelling

Residential building connects with outside environment directly, the influence comes from solar radiation cannot be avoided. At the same time, improving architectural thermal insulation performance, avoid solar radiation in living space by maximum, can ensure indoor thermal comfort in summer. In this research, vegetation planted in courtyard and its evaporation function used to take parts of solar radiation heat away. Architectural top is the strongest area for solar radiation, attic space is designed to be buffer area to prevent heat radiation enter the first floor of main building. In the south side of main building, use sunshine room as buffer area to avoid heat radiation enter living room. In the north side, solar radiation heat is prevented to enter bedroom by thicken outside wall Figure 8.24.In winter, attic and sunshine room can also be used as buffer, and north wall can be thickened, thus gets better thermal insulation effects and prevents the loss of indoor heat Figure 8.25.

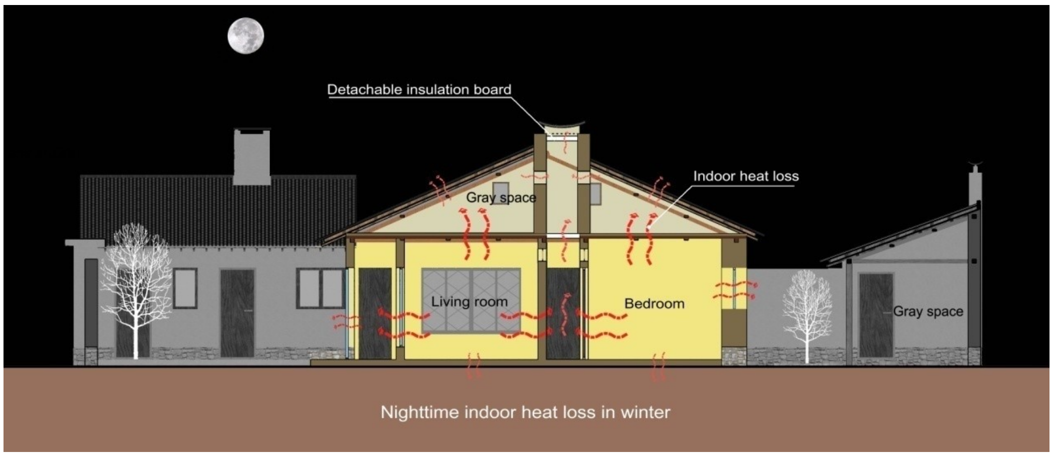


Figure 8.25 Analysis drawing for summer thermal insulation in vernacular dwelling

(3) Sun-shading design for vernacular dwelling in summer

In summer, reducing direct sunlight enter courtyard and indoor rooms is the important way to improve indoor thermal comfort. According to the solar height angle in summer in gully region of Loess Plateau, the design method about eave space in Section 8.3.1 can be used and combining the method of planting deciduous trees in courtyard, it avoids direct sunshine to enter courtyard by maximum and indoor space in summer Figure 8.26.

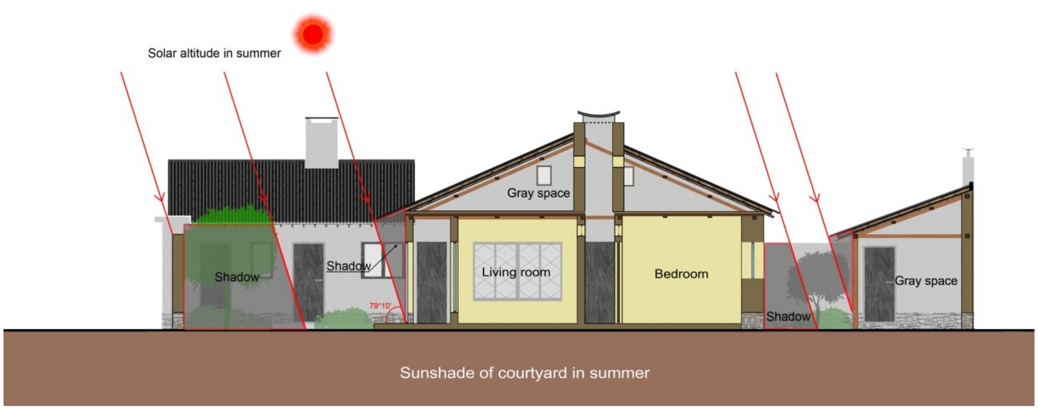


Figure 8.26 Analysis drawing for summer shading in vernacular dwelling

(4) Winter lighting design in vernacular dwelling

According to the solar height angle in winter in gully region of Loess Plateau, the design method about eave space in section 8.3.1, maximizing sunshine enter indoor space in winter, and the sunshine room in south of main building can be used to improve indoor temperature. What is more, heat collection and storage wall can be used to store the heat in days and use them in night Figure 8.27.

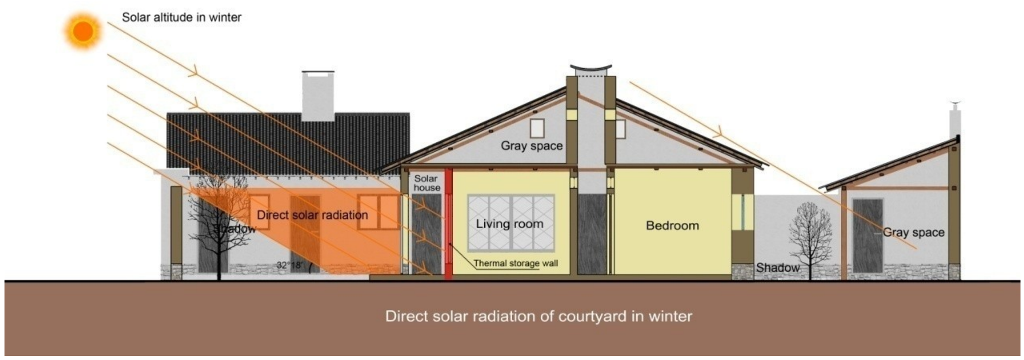


Figure 8.27 Analysis drawing for winter lighting in vernacular dwelling

(5) Water saving design in the courtyard of vernacular dwelling

The climate in gully region of Loess Plateau is drought and few rains. In the years without running water, roof is usually designed to guide rainwater in traditional vernacular dwellings, and cistern was used to collect rainwater, thus to solve the problem about water use in production and living. As the improvement of technologies, almost all families have running water in their home and people's drinking water almost solved. However, for the dry climate, water shortage and continuous declined underground water level, the efficient rainwater collection and scientific usage is benefit to water saving, and even have the functions on the ecological balance in the whole gully region of Loess Plateau. Therefore, in this research, traditional cistern is suggested to be kept and the rainwater usage efficiency should be improved by modern equipment, which can be used to do wash clothes, clean and irrigation Figure 8.28.

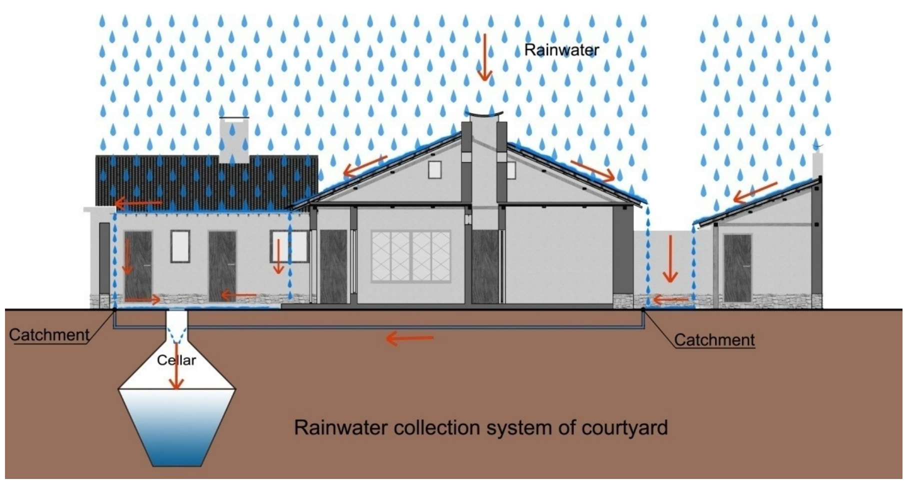


Figure 8.28 Analysis drawing for the design of water saving in vernacular dwelling

(6) Ecological toilet design

The pit toilet is the most common toilet in gully region of Loess Plateau, because human and animal feces can be used as organic fertilizer in agricultural production and this tradition toilet has continued to today. However, for pit toilets, the sanitary condition is worse with strong smell, especially in summer, if do not clean in time, the strong smell will have negative influence on daily life. Thus, this paper researches on ecological design for toilet in courtyard. The areas for stool and urine should be separated, thus to ensure the clean environment for toilet. Urinal is designed in south side; the waste can be used directly as fertilizer for courtyard soil by collecting equipment. Cesspool is designed in the north part, the high wall is designed in the south, and ventilation shaft is designed in north wall. By chimney effect, smell in toilet can be taken out, thus avoid the influence on courtyard by the smell from toilet Figure 8.29.

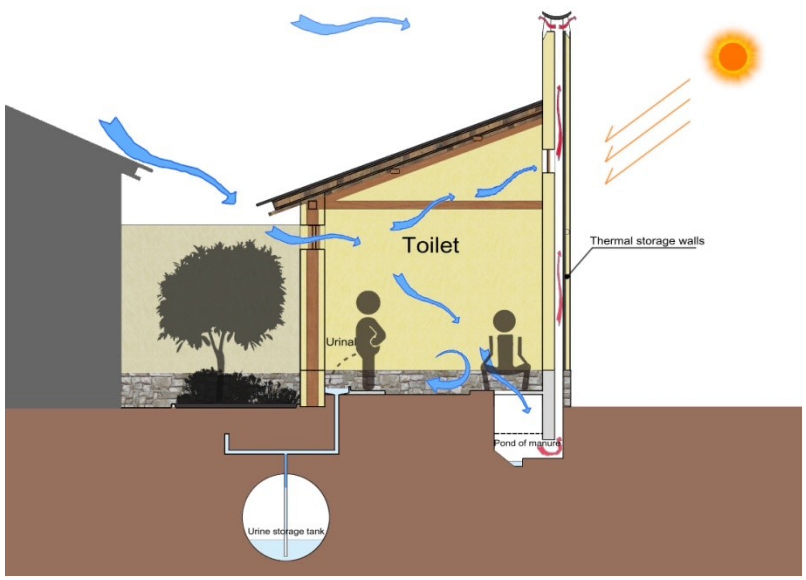


Figure 8.29 Analysis drawing for the design of ecological toilet in vernacular dwelling

8.5 Summary

Living culture in Loess Plateau is Loess culture. The designs of ecological vernacular dwelling are the inheritance for this culture, which mainly consist of two parts: the inheritance to traditional architectural technologies and living culture. Using immature soil to build immature soil house is the improvement and development of the special traditional cave dwellings, wood frame structure is the traditional Chinese architecture followed for thousands years. Combined with modern low carbon suitability building materials and the measurements of energy saving and emission reduction, these two traditional architectural structure can be the good inheritance and development of Chinese traditional architectural technologies. The development of scientific technologies brings the revolution for lots of new building materials and construction structures and makes them tend to be unified, while the traditional construction technologies can keep villages' unique regional characteristics, and benefits for the sustainable development of ecological environment and culture in this region.

In this chapter, firstly, we summarized the design frame for low carbon residential buildings, which including three factors: its full life cycle, suitability technologies and human factors. Then combined with the previous calculation and analyses on carbon emission in residential buildings in Tableland rural habitats of gully region in Loess Plateau, forms some design principles for low carbon residential buildings, which consist of full life cycle principle, suitability principle, integration principle, low carbon materials principle, low cost principle, reasonable implementation principle, extensive participation principle, these principles can be used as a guide in the future low carbon residential building design. Secondly, this chapter analyzed and summarized design strategies for residential buildings, such as improvement by ecological design, the application of low carbon materials, ecological improvement by architectural structure, and low carbon construction, low carbon energy consumption. Finally, using these research results as guideline, from functional space layout, optimization design on structure, the overall image of building, energy saving design, this chapter explores the design methods for ecological vernacular dwellings in Tableland villages.

CHAPTER 9
CONCLUSION AND PROSPECT BUILDING

9 Conclusion and prospect

9.1 Main research conclusion

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. Because of the improvement of traffic and information conditions, modern rural building and residential pattern in the developed regions of China challenge the traditional dwellings through various ways. It has a profound impact on the rural habitats in gully region of Loess Plateau. Human settlement environment in Tableland rural habitats in gully regions of Loess Plateau is the research object, this research deeply discusses the sustainable developing methods of Tableland rural habitats in gully region, and mainly completed in three parts: research on the planning methods in Tableland villages; research on the ecological layout of vernacular dwellings in Tableland rural habitats; and research on the ecological design methods for residential buildings in Tableland rural habitats. The research pays attention to the notion that the research should be more scientific and the results should be more operability. The main research conclusions show as follows:

(1) Based on field research of Tableland villages in Yong Shou County of Shaanxi Province, the research combines the present spatial distribution, land utilizing mode with the requirements of new rural construction, and divides Tableland villages' construction model into rectification construction type, expansion construction type and newly-built construction type.

(2) In the gully region of Loess Plateau, the ecological environment is fragile and economic development situation is lag back forward. It is very important to use the analysis of ecological carrying capacity to forecast and planning the future human settlement places. This research focuses on the Tableland villages in gully region of Loess Plateau, proving that restricting factors' analysis has its feasibility and practicability in the analysis of ecological carrying capacity in gully region of Loess Plateau, dividing the restricting factors into the unchangeable restricting factors and the restricting factors. Using restricting factors by model forecast method can simplify the calculation process of ecological carrying capacity, and the results can be used as a rapid and efficient reference for the future human settlement environmental planning.

(3) Because of the influence of the landscape of gully region in Loess Plateau on the construction of vernacular dwellings, and under the background of new countryside construction, the proportion of different kinds of vernacular dwellings in Tableland rural habitats are constantly changing. Underground cave dwellings have already disappeared, and the number of adobe vernacular dwelling is decreasing year by year. Instead of it, brick–concrete structure dwelling come to be the main structure in current Tableland rural habitats. The main problems exist in the construction of vernacular dwellings

are the poor thermal environment in the newly built courtyard, disordered functional layout, poor indoor thermal environment and high-energy consumption. In addition, the main reasons for these problems are the small heating accumulation in courtyard, and lack of consideration about the design of space functions and wind environment, poor air tightness capacity in houses, no insulation design, the inefficient energy usage and the usage of pollution energy, restrained by economic conditions and local people's comparing psychology.

(4) Based on the results of field investigation, this research classified the different courtyard types in the newly built vernacular dwellings in Tableland rural habitats of gully regions, and detailed analysis the characteristics of these different type courtyards. Ecotect weather tool was used to simulate and analyze the light, wind and thermal environment in different courtyards, and summarize the advantages and disadvantages for each layout in the different vernacular dwellings. Finally, combining with the local ecological experience in the layout of traditional dwellings, the research summarizes and explains the ecological layout of courtyard in Tableland rural habitats of gully regions under the background of new countryside construction.

(5) According to the domestic architectural situation and characteristics, this paper collects data and does data correction for the previous data, and then established carbon emission model for current Chinese architecture, and used it as measurement. Large field investigations on typical residential buildings of vernacular dwellings in Tableland rural habitats in gully region help to fully understand and collect data about the five processes of life. Then do the calculation of the energy consumption of these five processes in full life cycle and get the unit energy consumption for each residential building. Through the comparative analyses and study of the energy consumption in each process for the full life cycle, this paper summarizes the reasons for these differences and supplies some improving suggestions.

(6) This research summarized the three main factors for the design framework of low carbon vernacular dwellings, including the life cycle, appropriate technology and human; proposed the design principles, including the full cycle principle, suitability principle, whole principle, low-carbon materials principle, low cost principle, reasonable implementation principles and the principles of public participation. Then this paper analyzed and summarized eco-design strategies by the eco-design and usage of low-carbon materials, and suitable building construction, to create low-carbon energy consumption. Finally, these theories can be used as a guide for discussing ecological design of vernacular dwellings in Tableland rural habitats, from their layout, the optimized structure design, the overall image of the building, as well as energy-efficient building design aspects.

9.2 Prospect of the research

Time and geography are the two main factors of civilization evaluation, and the main factors for the evaluation of vernacular dwellings. The long history and the unique natural geographical environment shaped the special local characteristics of human settlement. During the rapid development of current Chinese urbanization, how and where these rapid developing gully villages should go in their future developing ways? Generally, villagers are facing a series of challenges in the new countryside construction, and they cannot overcome many of these challenges, the traditional life style in these villages is in the danger of disappearing. Currently, the model of cities helps villages to develop, that cannot find back the ability of self-renew and benign development that villages owned before. What is more, because of the abandonment of vernacular dwellings, many professional craftsmen disappear, and very good traditional construction methods disappear at the same time. When people start to complain some phenomena in the new countryside construction, as researchers, what can we supply to the local people?

The research of ecological theory and planning on human settlements in gully regions of Loess Plateau need to use the sustainable developing theory and modern human settlement theory as research background and framework; the core of it is using ecological methods to explain the direction and whole developing framework in a long developing period. The contents should include the theory about city and town system, the space structure, ecological functional areas, and the developing aims of the natural, economy, social culture and so on. The traditional ecological technologies used in the vernacular dwellings is the most efficient, wisest ways to solve some living problems after thousands of years' living experience under the local climate and resources. Although it seems that there are many defects in traditional vernacular dwellings, which cannot meet the requirements of modern lifestyle, as a researcher of new rural construction , what we should do is learn from local farmers and craftsmen about their traditional techniques, and then to find ways to improve it and finally return to the villages. In fact, to discovering the traditional construction techniques can only be made by simple improvement and correctly guiding and teaching the villagers to use these traditional ecological technologies, this is the technology strategy that we need in the new countryside construction in these regions of Loess Plateau.

During the theoretical exploration and practice of the ecological construction of human settlements in gully regions of Loess Plateau, there are still many problems to explore. However, due the limited time and energy, there are still many things to supplied and perfected. In addition, because of various reasons, the conclusions of this paper have not yet been applied in the design of the project. The paper hopes that by the results of this research, more researchers in the field of environment, ecology, urban planning and other related fields can be stimulated to do more research on human settlement planning in gully region of Loess Plateau. In addition, to speed up the process of urban and rural integration in this region, this research hopes to contribute to the construction of ecological civilization and economic construction.

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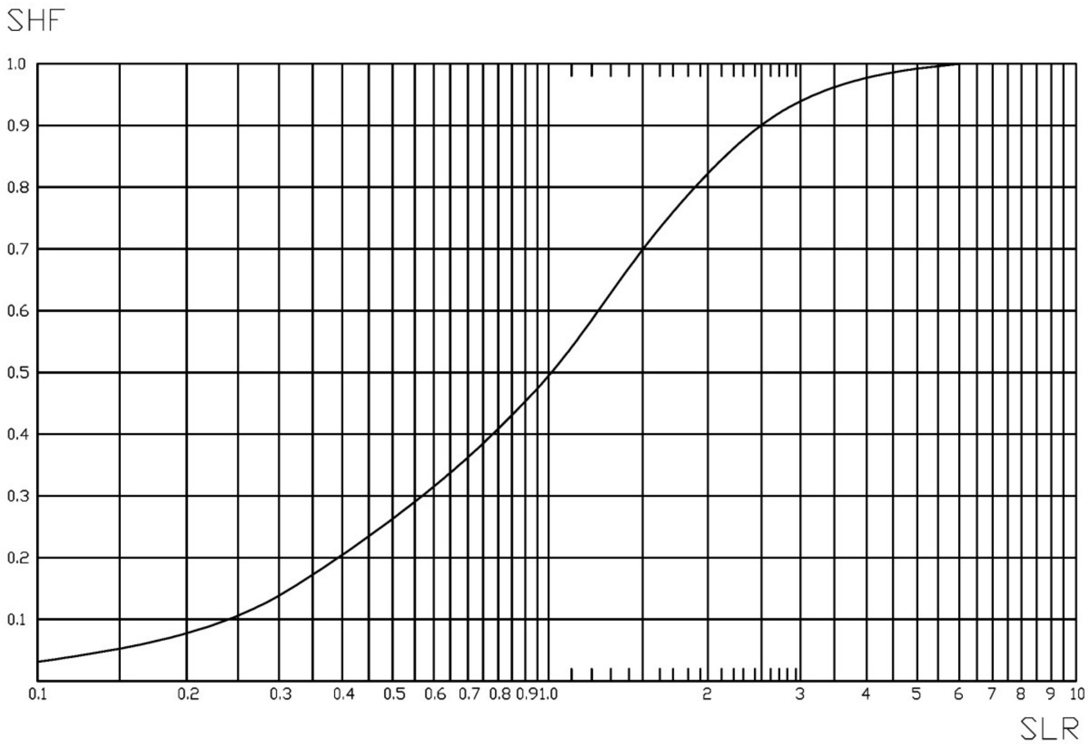
Appendix 1 Functional relationships between solar heating rate SHF and solar heat load



Source: 95 J G J. Standard for energy conservation design of new heating residential buildings [S][D]., 1995.

Appendix 2 Questionnaire on new countryside construction for local county and town governments in gully region of Loess Plateau (Chinese Version)

县政府访谈提纲

县名称：		
政府部门：	调查者：	调研时间： 月 日
全县总人口____人，其中农业人口____人；全县总面积____平方公里，耕地____亩；全县经济收入主要来源为__________________，农民人均纯收入达到______元/年。		
1. 县整体经济发展及新农村建设在全市及全国中的水平？		
2. 自然环境近年来的变化，例如水土流失加剧，雾霾天气情况。		
3. 各类型村落构成比例，塬面村，沟坡村，沟谷村，以及各自的发展情况（人口与经济）。		
4. 村镇人口的变化，空心村情况，人口塬面化情况。		
5. 村镇新农村建设发展中存在的主要问题及遇到的新问题。		
6. 村落规划的依据是什么和新政策实施情况。		
7. 县地图及新农村示范工程及相关区域规划图纸。		
8. 塬面村落发展评级，示范村。调研村落选型指导建议。（经济发展最好及最差的村落。）		
9. 塬面型村落新农村建设与原有文化的结合情况。		
10. 新农村建设住宅的变化，砖瓦房建设情况及户型平面；生土房的变化，消亡还是改进？窑洞在当地和塬面的存量。对于生土方和窑洞环保而砖瓦房高碳的知识是否了解。		
11. 人们普遍愿意接受住哪种类型的房子：砖瓦房，生土房，窑洞，以及当前的建房成本如何。		
12. 新农村建设搬迁后，农民宅基地面积大小的变化情况如何，以及新建民居的户型情况。		
13. 当地民居建筑主要采暖与耗能设备情况。		
14. 村落基础设施建设情况，交通及公共交通体系，医院，学校情况。		

乡政府访谈提纲

乡镇名称：		
政府部门：	调查者：	调研时间： 月 日
全镇总人口____人，其中农业人口____人；全镇总面积____平方公里，耕地____亩；全镇经济收入主要来源为____________________，农民人均纯收入达到______元/年。		
1. 乡整体经济发展及新农村建设在全县各乡镇中所处的水平？		
2. 各村落人口及家庭人口的变化，空心村情况，人口塬面化情况。		
3. 农户在村镇新农村建设发展中存在的主要问题及遇到的新问题。		
4. 各村新农村建设的规设和设计图纸。		
5. 各村新农村建设发展中存在的主要问题及遇到的新问题。		
6. 塬面型村落新农村建设与原有村落民居建设的结合情况。		
7. 各村落在新农村建设中的类型，例如新建型，扩建型，搬迁型。		
8. 各村新农村建设中有无考虑当地生态承载力水平。		
9. 村落中当地人民对于新农村建设的态度？赞同和反对的比例和意见。		
10. 主要民居的种类以及在各村落新农村建设中民居类型及数量的变化情况。		
11. 人们普遍愿意接受住哪种类型的房子：砖瓦房，生土房，窑洞，以及当前的建房成本如何。		
12. 新农村建设搬迁后，农民宅基地面积大小的变化情况如何，以及新建民居的户型情况。		
13. 各村落中的主要道路，水源，耕地位置及其其他与承载力相关的情况。		
14. 村落基础设施建设情况，交通及公共交通体系，医院，学校情况。		

Appendix 3 Questionnaire on courtyard environment and residential buildings in vernacular dwellings in tableland villages in gully region of Loess Plateau (Chinese Version)

村落名称：________________　　　　　　　　　调研时间：

姓名：　　　　　　　　　　　年龄：　　　　　　　　　　　性别：

1.居住条件现状

（1）现居住房屋：1）土坯　2）砖瓦房　3）其他：

（2）建造年代：_______________　　　　　　　使用时间：

（3）建房花费：_______________　　层数：_______________　　朝向：

（4）宅基地面积：_______________㎡　　长：_______m　　宽：_______m

（5）建筑开间数：

（6）常住人口：_______________人　　家庭人员组成：

（7）房间设置与数量：1)客厅____间　2）卧室____间　3）厨房　4）卫生间　5）储藏间

（8）厨房位置：_________________　　面积：______________㎡　　灶具类型：

（9）卫生间位置：_________________　　类型：1）旱厕 2）水厕

（10）院落数量：_________________　　　院落布局：

（11）太阳能热水器的安装：　1）有　2）无

（12）门窗材料：_________________　　　门窗尺寸：

（13）自来水：1）有　2）无

（14）水窖：1）有　2）无　　　　　使用情况：

（15）炕的设置：1）有　2）无　数量：__________　位置：__________　尺寸：

（16）现住房条件是否满意：

（17）改进意见：

（18）民居院落及建筑平面布局图：

2.对新建房屋的规划

（1）是否打算近期新建住房：1）是　　2）否　　拟定建造时间：

（2）新房建造材料：1）生土　　2）黏土砖　　3）其他：

（3）层数：______层　　造价：______元　　朝向：_______　　门窗材料：

（4）宅基地面积：_______________㎡　　长：_______m　　宽：_______m

（5）住宅面积：_______________㎡　　长：_______m　　宽：_______m　　高：
m

（6）房间设置与数量：房间总数______间

1）客厅____间　2）卧室____间　3）厨房

4）卫生间　5）储藏空间　6）其他：

（7）厨房位置：______________　面积：______________㎡　灶具类型：

（8）卫生间设施：

（9）院内是否有种植：1）是　2）否

3）种植原因　4）种植品种

（10）院落中是否设置水窖：1）是　2）否

（11）是否设置太阳能热水器：1）是　2）否

其他：

3.民居建筑空间物理环境

（1）冬季体感最冷房间：______________　夏季体感最热房间：

（2）哪个房间是家人最喜欢呆的房间：____________　此房间的主要功能：

（3）各房间的采暖方式：____________　各房间的制冷方式：

（4）门窗开闭时间：____________　主要目的：

（5）开门窗是否担心尘土：____________　空气质量：

（6）开门窗后室内通风情况：1）好　2）中　3）差

（7）房间采光情况：

客厅：1）好　2）中　3）差

（8）房间是否受外界噪声干扰： 1）是　2）否　受噪声影响房间：

（9）房间之间是否有噪声干扰情况： 1）有　2）无　受噪声影响房间：

其他：

4.民居院落中能源使用

（1）炊事用能源：______________　采暖用能源：

（2）炊事方式：______________　采暖方式：

（3）采暖能源使用量：______________　采暖时间（每年）：

（4）制冷能源使用量：______________　制冷时间（每年）：

5.村落公共空间

（1）村落道路情况： 1）柏油路　2）水泥路　3）石子路　4）土路

（2）村民出行主要交通工具：

（3）村落中是否有中学：1）是　2）否　村落中是否有小学：1）是 2）否

（4）村落是否有集中垃圾收集点：1）是　2）否

（5）村落是否有商店：1）是　2）否

（6）村民就医情况：1）小病去哪就医____________　2）大病去哪就医

（7）是否经常在村落公共空间与其他村民进行交流：1）是　2）否

（8）是否经常到邻家串门：1）是　2）否

（9）村落中室外公共活动空间的设置情况

（10）室外公共活动有哪些内容__________________　活动的时间段

（11）对村落建设的意见与希望：

Appendix 4 Interview report on the carrying capacity of tableland villages in gully region of Loess Plateau (Chinese Version)

1.访谈调研对象：黄土高原沟壑区农村发展、城乡建设相关部门工作人员；基层政府、国土资源管理所工作人员

2.访谈目的

1）初步了解现行的村落拆迁、合并的决策方式；

2）初步了解秦河乡各村落的生态环状况及生态承载力水平；

3）精略确定生态承载力限制因子；

4）了解黄土高原沟壑区村落人居环境规划现状及未来发展方向。

3.访谈时间及方式：访谈时间为25-45分钟不等；主要访谈方式为现场访谈，个别采用电话访谈方式。

4.访谈提纲及结论

访谈提纲	访谈结论
您是如果理解“城乡一体化”与“新农村建设”的	城乡一体化并不是合为一体，而是城乡之间的交流无碍化，差距缩小化。适当地“合村并点”，不是完全合并，要综合实际情况、农民意愿，而不是政策强制，要注意适当。作为建筑专业来讲，我们的工作重点是改善农村的生活环境，提高农民生活质量，缩小城乡间的生活水平差距。 我国将长期处于初会主义初级阶段，100年不变，因而在今后相当长的一段时间内，“城乡分治”带来的城乡差别还将继续存在，我们仍然需要解决农村问题，而不是认为农村就要消失，没必要去考虑它。
目前秦河乡村落拆迁、合并的决策方式是怎样的，您如何看待现在的决策方式	关于秦河乡村落拆迁、合并，目前的决策方式主要依据村落人口规模和基础设施的建设成本，由政府部门会议讨论决定。
谈谈您对“生态承载力”的理解	生态承载力是大自然能够承载养活人口的能力，也就是在一定的生态环境、自然资源限制下，能够正常生活的人口总数量。
请您说说秦河乡各村落的生态承载力水平状况，与各村落地形地势关系如何	地势平坦的村落由于耕地面积多，因而生态承载力水平较高，当然也需要综合考虑基础设施建设，例如道路设施、自来水供应、用电供应等方面。秦河、北坡、桃源、前白甫这些村落人均耕地面积大，分布在淳一安道路附近，生态承载力水平相对较高。东源村生态承载力水平相对较差。
您认为影响各村落生态承载力水平的因素主要有哪些	耕地面积、水资源、基础设施建设水平等
当前秦河乡新农村规划是如何进行的	由淳化县农村发展建设办公室指导，乡政府配合城乡规划部门实际操作进行。
您认为未来新农村规划是否应当重点考虑生态承载力水平	生态承载力水平决定了村落的人口总量上限，理论上讲应该是在新农村规划前考虑好生态承载力水平。
您认为村落人居环境规划应该注意哪些方面	村落人居环境规划主要考虑宅基地、耕地与水资源和基础设施的空间关系，在此基础上，尽可能做到经济、节约、生态。

Appendix 5 Questionnaire on the infrastructures in Qin He county (Chinese Version)

村落名称：
调查对象：　　　　　　　　　　　调查者：　　　　　　　　　　　调研时间：　　月　　日
全村总人口____人，其中农业人口____人；全村总面积____平方公里，耕地____亩；全村经济收入主要来源为________________，农民人均纯收入达到______元/年。
一、道路桥梁工程： 1. 村内主要道路宽度是____米；路面面层厚度为____厘米。 2. 主要道路的路面形式是下列哪种： （1）沥青混凝土路面；（2）水泥混凝土路面；（3）块石路面；（4）土路。 3. 村内次要道路宽度是____米。 4. 次要道路是单车道还是双车道。 5. 次要道路的路面形式是下列哪种： （1）沥青混凝土路面；（2）水泥混凝土路面；（3）块石路面；（4）预制混凝土块路面。 6. 街巷道路的宽度是____米，街巷道路的路面形式是下列哪种： （1）水泥混凝土路面；（2）石材路面；（3）无机结合料稳定路面；（4）预制混凝土方砖路面；（5）其它。 7. 现有村内道路能否满足当地居民的需要？ 8. 村内是否划有停车位或建有集中停车场？ 9. 村内道路及桥梁由谁出资建设？ 10. 村内道路及桥梁建设于何年？ 11. 村内是否有桥梁通过？如果有桥梁，桥梁跨度为____米，是下列哪种形式的桥梁： （1）简支桥；（2）拱桥；（3）其它。
二、给排水工程： 1. 目前本村水量、水压是否能够满足当地居民用水需求？ 2. 当地水质是否达标？ 3. 给水方式是集中式给水，还是分散式给水？ 1）如果属集中式给水，是下列哪种方式： （1）城市或集镇的配水管网延伸供水；（2）联村供水；（3）联片供水；（4）单村供水。 2）如果属分散式给水，是下列哪种方式： （1）手动泵；（2）筒井；（3）引泉池；（4）雨水收集。 4. 现有水源地保护范围内有无污染源； 5. 水源形式是哪种： （1）地下水；（2）地表水；（3）收集雨（雪）水。 6. 雨水收集方式属哪种： （1）屋顶集水式雨水收集系统；（2）地面集水式雨水收集系统。 7. 村内是否建有水塔？ 8. 村内是否有污水处理站？

9.是否采用分散式排水方式？ 10.村内采用下列哪种方式： （1）雨污合流；（2）雨污分流。 11.雨水排放是明沟，还是暗渠？ 12.雨水排水沟渠选用的材料是哪种： （1）混凝土；（2）砖石；（3）条石。 13.是否采用管道收集生活污水，管材是哪种： （1）混凝土；（2）陶土；（3）塑料。
三、垃圾处理： 1.生活垃圾是否分类收集； 2.垃圾收集点是否能满足每 30 户设置一个点； 3.垃圾收集频次：（1）每周 1-2 次；（2）每 2 周 1 次或以上。 4.是否有简易填埋处理； 5.是否建有垃圾棚； 6.垃圾处理采用哪种形式：（1）填埋；（2）焚烧；（3）堆肥。 7.是否采用集中收集，集中处理的方式。
四、粪便处理： 1.厕所在室内还是室外？ 2.厕所的类型：（1）水冲式厕所；（2）旱厕。 3.粪便污水是否经化粪池、生活污水净化沼气池进行处理？ 4.是否建有化粪池，简单叙述化粪池的材料、规格等？ 5.粪便如何处理
五、生活用能： 1.当地主要生活用能是哪种：（1）液化气、（2）电、（3）沼气、（4）太阳能、（5）其它。 2.新型用能的推广主要由谁出资。
六、坑塘河道： 是否存在坑塘河道？现状如何？
七、文化遗产： 是否存在文化遗产？现状如何？
八、其它： 1.你觉得与当地村民生活息息相关的基础设施还有哪些？ 2.你认为如何才能快速、经济地改善当地村民生活条件？ 3.当前农民心目中的基础设施是什么样的？哪些基础设施已经可以满足当前的使用需求，哪些尚需要改进，哪些目前还需要新增？

Appendix 6 Questionnaire on the importance of infrastructures in Tao Qu Yuan village (Chinese Version)

您好，感谢您对本次调研的支持，请根据您认为村落各项基础设施的重要程度，对各个项目进行评分，重要度较高的项目评分较高，在您认为应该给的分值对应的方格内打“√”，谢谢合作。

基础设施项目			项目评分					
层次一	层次二	层次三	0	1	2	3	4	5
A 生产设施	A1 道路交通设施	A11 道路设施						
		A12 停车场						
		A13 车站						
		A14 桥梁设施						
		A15 码头						
	A2 能源通讯设施	A21 电力设施						
		A22 燃气设施						
		A23 煤炭、柴薪、秸秆						
		A24 燃油设施						
		A25 清洁能源设施						
		A26 邮电设施						
	A3 产业配套设施	A31 农业技术培训设施、科技开发						
		推广基地、农资服务站						
		A32 动植物防疫设施						
		A33 农产品质量检验检测设施						
		A34 农业仓储设施						
		A35 基本农田建设、高质量耕地						
		A36 畜禽圈所建设						

	A4 农田水利设施	A41 河流、水库、沟渠、泵站						
		A42 土壤改良设施						
		A43 生产供水设施						
B 生活设施	B1 安全防灾设施	B11 消防设施						
		B12 防洪设施						
		B13 防震设施						
	B2 供水配套设施	B11 集中型农村供水配套设施						
		B12 分散型供水设施						
	B3 公共服务设施	B31 教育文化设施						
		B32 医疗设施						
		B33 管理设施						
		B34 商业服务设施						
		B35 文化娱乐设施						
		B36 农村景观设施						
C 生态设施	C1 排水配套设施	C31 排水沟渠						
		C32 水源地保护						
		C33 污水处理设施						
	C2 环境改善设施	C21 垃圾收集设施						
		C22 垃圾处理设施						
		C23 公厕						
	C3 生态保育设施	C31 庭院绿化						
		C32 整体林带						
		C33 景观的斑块、基质、廊道						

该问卷被应用两次。一次是桃渠塬村各类基础设施重要性分析，填写对象为村民；另一次是对于各地块基础设施承载力的评估打分，由调研者根据实地观察和评估填写。

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