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Research on the Ecological Wisdom of Traditional Dwellings of the Liangshan Yi Nationality Based on Regional Climate

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Abstract

Abstract: As a typical building with ethnic and regional characteristics in southwest China, its construction skills contain rich local ecological wisdom. The detailed analysis of the climatic and geomorphological features of the Liangshan Yi nationality area shows that the thermal mass effect is the first choice for the passive adjustment strategy of residential dwellings. This study focuses on the typical representatives of traditional dwellings in Meigu County, analyzing the wisdom of ecological construction to improve the thermal mass effects of residential buildings at the macro (village), moderate (courtyard), and micro (building unit) levels. Based on this analysis, the study summarizes the "genetic factor library" of the ecological construction mode of traditional Yi residential dwellings. Finally, the measured data of the residential thermal environment and the simulation data of Ecotect software are used to study and judge the logic behind its ecological construction wisdom. The results show that the traditional dwellings of the Yi nationality in Liangshan have six aspects of local environmental knowledge to improve the thermal mass effects performance of buildings. The winter thermal environment of the house is comfortable, and the heat is sufficient; Rammed earth materials in residential buildings have more potent, powerful, and robust thermal mass effects performance than stone slabs and wooden boards.

Keywords

Climate Adaptability, Liangshan Yi Nationality, Traditional Dwelling, Ecological Intelligence

1. Introduction

Liangshan Yi traditional residence, located in Liangshan Yi Autonomous Prefecture, Sichuan Province, is a characteristic national building with a history and culture of more than 1000 years in China. The local climate belongs to the subtropical plateau monsoon climate, and climate factors such as temperature and precipitation change regularly with altitude increase. The landform is complex and diverse; the terrain is rugged, and the height difference is significant. The unique climate and landform form characteristics different from those in other areas, and traditional dwellings show simple local wisdom to adapt to the climate.

At present, significant progress has been made in the study of architectural ecological strategies. [1]. On the one hand, starting from building materials, some scholars have proposed that using concrete and steel, reused ceramics, and low-energy insulation materials can reduce the energy consumption of residential buildings [2]. Scholars have analyzed the thermal properties of a composite material made of gypsum and peanut shells, proving that it can reduce energy consumption and increase thermal comfort [3]. Others have studied bamboo's potential as a sustainable building material [4]. On the other hand, starting from the planning layout of the building, some scholars believe that the two determining factors determining the orientation of the building are the protection from prevailing winds and the maximum utilization of solar energy [5]. Some scholars believe that the height and depth of the room are appropriately designed, and both unilateral ventilation and cross ventilation can play a good role in cooling and improving air quality [6]. In addition, there are interdisciplinary research methods. For example, some scholars have proposed a bionic design method that imitates and gets creative inspiration from natural mechanisms and uses local resources and behavior patterns as integration and adaptation mechanisms [7].

Studies on traditional folk dwellings of the Yi nationality in Liangshan with regional characteristics are mostly qualitative summaries of the construction culture and features of the buildings [8]. For example, some scholars have proposed measures for optimizing the structure design of traditional dwellings of the Yi nationality [9]. Some scholars have analyzed the spatial form, internal organizational structure, and general construction rules of the architectural style and format of Yi settlements [10]. Some scholars have studied and elaborated on the formation background, architectural culture, architectural types and characteristics, and structure and construction technology of Liangshan Yi dwellings [11] [12]. Some scholars have studied the roof construction technology of Yi rural residents based on indoor thermal environment optimization [13]. In general, there is a lack of scientific research and judgment on the logic behind the strategy of ecological architecture and a lack of quantitative analysis on the environmental wisdom of the traditional dwellings of the Yi nationality in Liangshan.

This paper starts with the regional climate characteristics of Liangshan. At the level of the village (macro), courtyard (meso), and architecture (micro), the construction mode in the construction mode, spatial form, interface structure, and other aspects are summarized, and the ecological wisdom of heat storage in the Yi traditional residential buildings is condensed. At the same time, it analyzed the logic of "building heat storage" behind its ecological construction strategy deeply by using the thermal environment measured data and Ecotect environmental analysis software simulation data. The scientific wisdom of the ecological construction mode of Liangshan Yi traditional dwellings provides a theoretical basis for environmental building design. Moreover, it has important practical significance for protecting and inheriting national cultural heritage and promoting the construction of ecological civilization.

2. Materials

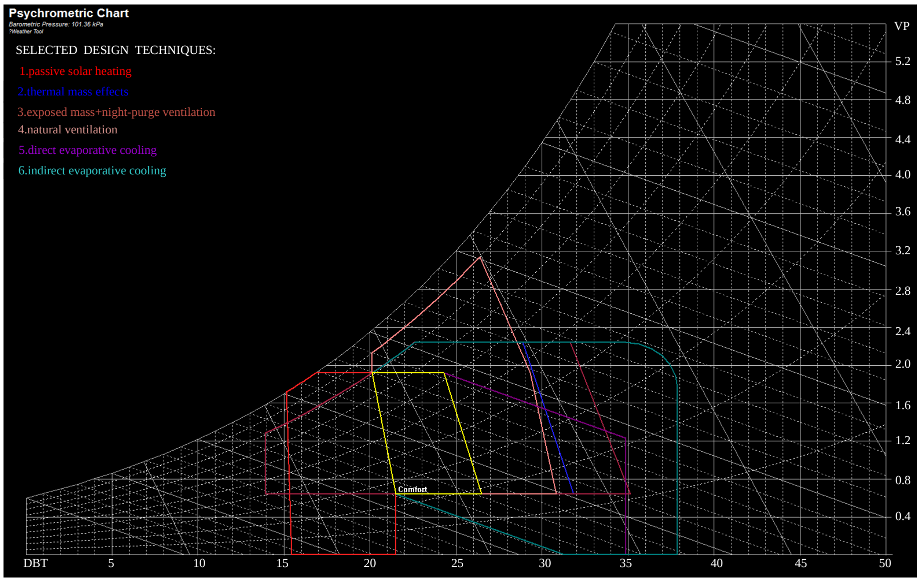
Regional climate includes the relationship between region and climate, and they are interactive. The climate feature provides a design basis for building ecological design; The response of architecture to the characteristics of climate also constitutes the architectural characteristics of territory [14]. The following is an analysis of the climatic and geomorphological features of the Liangshan Yi nationality area.

2.1. Meteorological Parameters—Building Climate

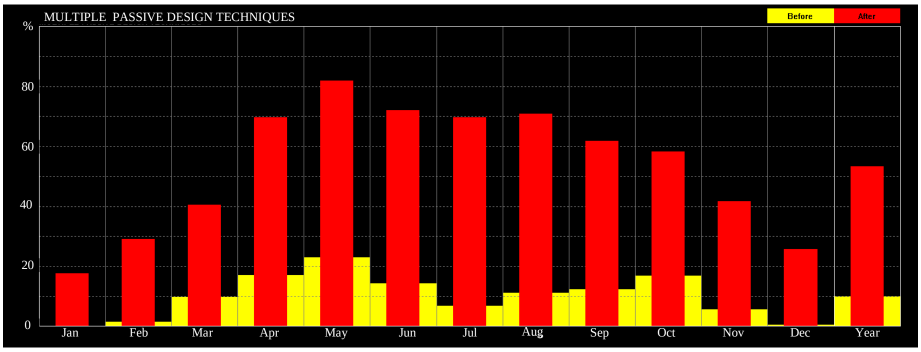
The climate of Liangshan Yi Autonomous Prefecture has solid radiation, abundant sunshine, low temperature, frost, and snow, and the four seasons of weather are not distinct, with no summer in higher altitude areas and no winter in lower altitude areas. The vertical difference in climate is significantly more significant than the horizontal difference, with abrupt temperature changes of more than six ˚C per kilometer. The Weather Tool climate analysis tool was used to conduct a climate analysis of Liangshan Yi Autonomous Prefecture. The psychrometric chart shows that when the passive technology strategy is applied, the improvement effect of thermal comfort is obvious (**Figure 1(a)**). And passive strategy map showed that the comfortable time ratio without any climate adjustment measures is about 10% throughout the year, mainly concentrated in May and June (**Figure 1(b)**), totaling 36 days. Passive adjustment technology has the potential to increase the proportion of relaxing time, with the effectiveness ranking of the following passive strategies: exposed thermal mass and night-purge ventilation being the most effective, followed by the influence of thermal mass; passive solar heating, natural ventilation, and indirect evaporative cooling being moderately effective; and direct evaporative cooling being the least effective (**Figure 1(c)**). Therefore, building thermal mass effects is an essential passive energy-saving measure for traditional dwellings of the Liangshan Yi nationality to adapt to the local climate. The thermal mass effects of buildings should be considered in residential construction so local houses can withstand the invasion of cold winds in winter.

2.2. Geomorphological Features and Elements

Liangshan Yi Autonomous Prefecture is located between 26˚03' to 29˚18' north latitude and 100˚03' to 103˚52' east longitude. The geology is complex and diverse, and the surface is undulating. Among them, there are more than 20 peaks with an altitude of more than 4000 meters, and mountains, deep valleys, plains,



(a)



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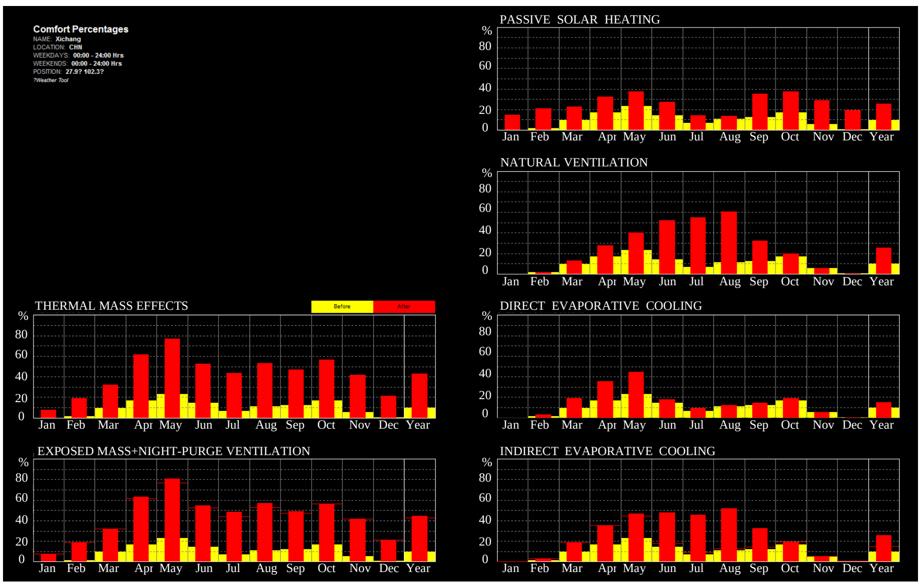


(c)

Figure 1. Climate analysis of buildings. (a) Psychrometric chart; (b) Multiple passive design techniques; (c) Comfort petcentages.

basins, and hills are intertwined. The tectonic landforms in the state are fully developed, fault zones are crisscrossed, and there are many fault mountains and valleys. Puge, Butuo, Zhaojue, Meigu, Jinyang, Leibo, Xide, Yuexi, and Ganluo are known as Liangshan old nine County, located in the northeast part of Liangshan Yi Autonomous Prefecture, and most of the dwellings are located on high mountains (**Figure 2**).

This paper takes an example of Meigu County in the northeast and central part of Liangshan Yi Autonomous Prefecture. The area has a low-latitude plateau climate, with significant three-dimensional weather, four distinct seasons, sufficient sunshine throughout the year, 1790.7 h of sun per year, and abundant rainfall. Geographically, the region is located at the intersection of the crossing mountains in the southeast of the Qinghai-Tibet Plateau and the southwest edge of the Sichuan Basin, with undulating mountains and dense rivers and streams. The terrain is high in the north and low in the south, with the highest point in the northeast being 4042 m and the lowest point in the southeast being 640 m. In the area of Liangshan Yi Autonomous Prefecture, the climate and landforms of Meigu County are very representative and typical.

3. Methodology

This paper uses the field research method and Ecotect software analysis method to research the ecological wisdom of Yi traditional dwellings. Mainly divided into the following two steps:

1) Through field research, the ecological construction mode of Yi traditional dwellings is summarized. The environmental construction of traditional Yi ethnic dwellings is based on local wisdom, which is the subjective cognition and technical response of the Yi people to their natural and human environment [15] [16]. The micro-climate created from the effects of climate in the natural environment directly impacts the indoor and outdoor climate of buildings at the micro level. This difference in temperature also forms a unique regional dwelling, which is precipitated into a kind of dwelling "prototype" related to regional ethnic groups, that is, the original characteristics of the traditional homes of the Liangshan Yi nationality [17] The following article will summarize the localized wisdom of ecological construction for traditional Yi nationality dwellings, which is based on the characteristics of the plateau climate and aims to improve thermal storage performance. This will be done from three levels—architectural villages (macro level), courtyard form (Meso level), and unique construction (micro level)—to provide a comprehensive understanding. Establish a "genetic factor library" of ecological building construction mode in the Liangshan Yi nationality area to support the construction of environmental building construction strategies adapted to the climate in the region. The genetic factor library of ecological construction mode refers to a collection of technologies, methods, and concepts accumulated in ecological construction, screened and verified, replicable, and can be used for reference from experience. These factors can be used as

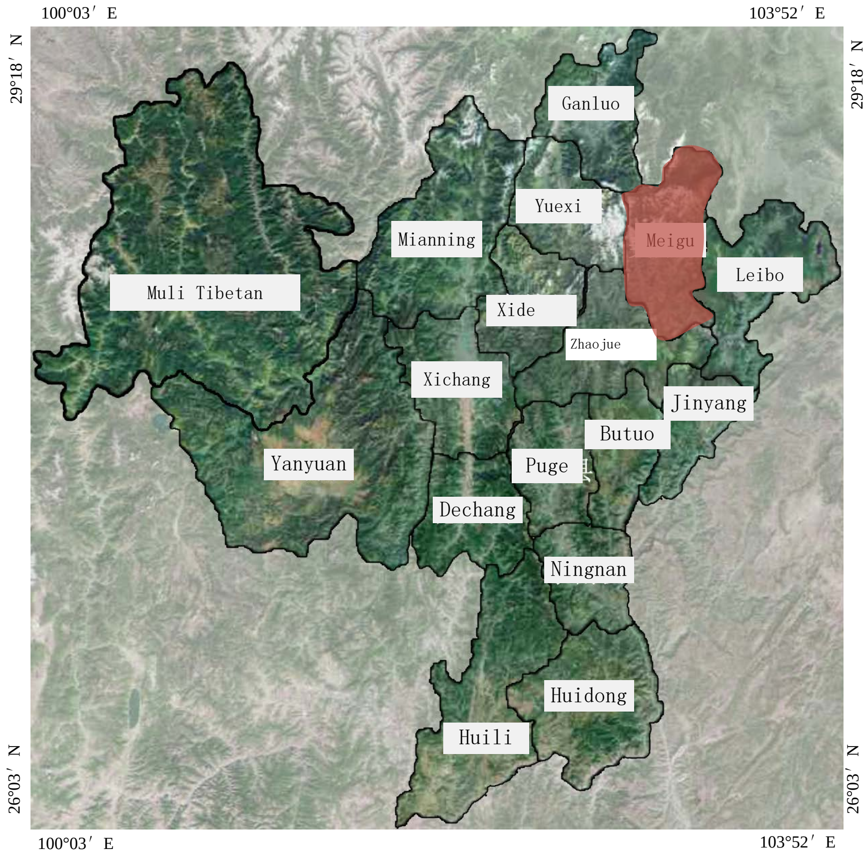


Figure 2. Overall geomorphic pattern of Liangshan Yi Autonomous Prefecture.

"seeds" for the replication and promotion of the ecological construction mode, which is of great significance for the inheritance and development of the ecological construction mode.

2) The scientific analysis of the ecological construction mode is carried out by combining the method of measured and simulated thermal environment. The thermal environment is an essential factor affecting the overall comfort of the environment [18]. It is also an indicator to judge a building's thermal mass effects and materials. This paper analyzed the thermal environmental characteristics of traditional Yi dwellings by combining the measured data with the simulation analysis results established based on the construction mode, spatial form, and interface structure. Modern technologies such as black ball thermometer measurement and Ecotect software simulation are used to quantify the physical properties of traditional dwellings and quantify the physical properties of conventional houses. Scientific data is used to analyze the scientific characteristics of strong thermal mass effects characteristics of Yi traditional dwellings.

4. Results

4.1. The Village Location Layout of "Back Mountain and Face Water"

In Meigu County, the Yi people choose their village locations based on the terrain (**Figure 3**). They have developed the principle of "raising livestock on higher ground, living in the middle, and growing crops at the bottom." This principle means that the mountaintops are suitable for grazing cattle and sheep, the mountainsides are ideal for building dwellings, and the mountain bottoms are suitable for planting crops. This principle embodies the wisdom of human settlements that cleverly combines ways of living, production, and natural conditions [19]. In village layout, dwellings are built according to the terrain, parallel or perpendicular to the mountainside, with layers arranged in a staggered pattern (**Table 1**). This site selection layout results in abundant green and water resources in the village. The dwellings use these natural resources, with their backs against the mountain to withstand the cold winter winds, facing the sun for ample sunshine, and with water in front to buffer the high summer temperatures. The "backing the mountain facing the water" village site layout creates a natural air conditioning system for the dwellings. Utilizing natural landscapes to increase the overall thermal mass effects of the village is ecological wisdom adapted to the high mountain climate.

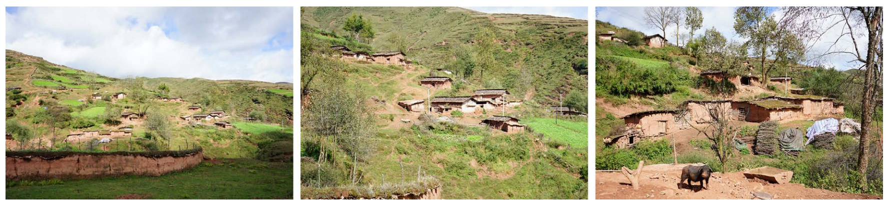
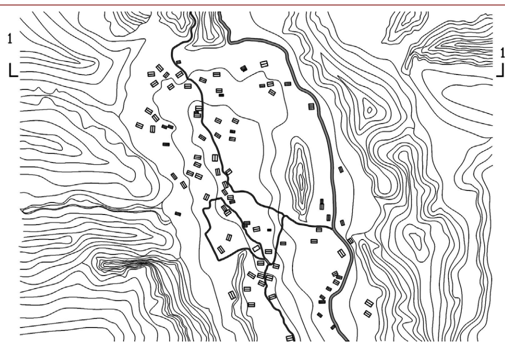
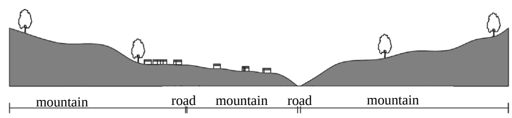
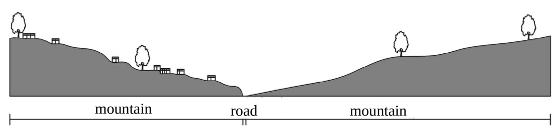


Figure 3. Site selection of the following terrain.

Table 1. Village representative layout in Yiguojue Township, Meigu County.

Village	Schematic of the general plane	The relationship between dwellings and hillsides
Gutuo village		
Shijiji village		

4.2. "Daylighting and Ventilation" Courtyard Shape

Traditional dwellings are designed to withstand the cold winter winds and hot summer sun and, therefore, typically do not have external windows. As a result, such buildings may be limited in terms of natural lighting, ventilation, and other aspects. The setting of the courtyard space weakens this problem, and the courtyard shape system is divided into two types: courtyard dam type and courtyard type. The courtyard dam type of traditional Yi-style dwellings typically consists of flat land enclosed by low walls or unenclosed flat land, combined with residential buildings to form an open space. Using height differences and texture contrasts helps define the courtyard space. The courtyard-style courtyard is enclosed by the main body of the dwellings and the courtyard wall into a closed space form, with the triad courtyard as the mainstay. The yard is between the primary homes and the side buildings and is connected to the hall. This design allows air circulation to promote heat dissipation in summer and block cold winter winds, creating favorable thermal ventilation conditions [20] (see A1 in **Table 2**). This practice of arranging "lighting and ventilation" courtyards improves the thermal mass effects of residential buildings, a kind of local ecological wisdom that creates indoor and outdoor microclimates of buildings.

4.3. "Adaptive Regulation" of Building Construction

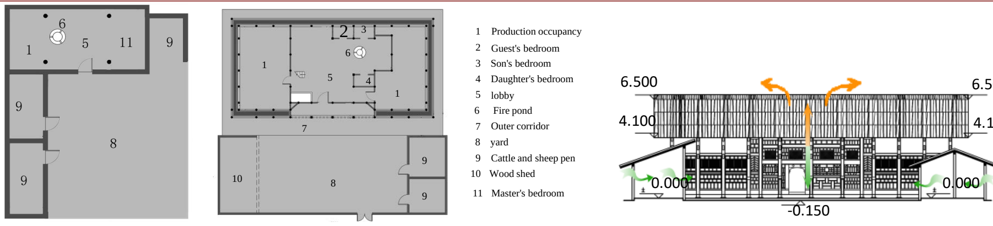
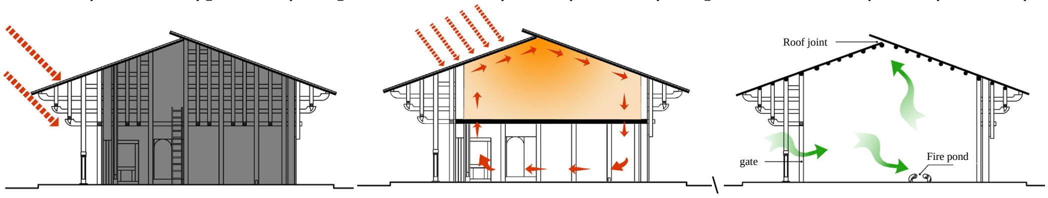
4.3.1. Regular and Energy-Efficient Building form Factor

The perimeter wall of the Yi traditional dwellings in Meigu County is built directly by the plane texture and internal structural form, and the building is regular. A few large households will recess the foyer's entrance into a gray space; there is no practice of dividing or protruding the size of the available dwellings. Traditional residences are built with a design that reflects their inherent characteristics, where the unit volume of the Residence is distributed over a smaller exterior surface area. This results in a small building form factor and less heat dissipation surface area, ensuring that the Residence's thermal mass effects. This design represents a sustainable and energy-saving ecological wisdom that is locally based.

4.3.2. Cushioned Regulated Building Cavities

The cushioning and adjustment effect of the Yi traditional residential cavity is reflected in two dimensions: horizontal and vertical: first, in the horizontal aspect, there is a gray space selected by the frame under the outdoor eaves, and the setting of the horizontal cavity increases the flat level of the room and reduces it The influence of adverse outdoor climate on indoor comfort makes the heat gain in summer and heat loss in winter in the interior of the dwellings to a certain extent. Secondly, in vertical cavities, the Yi usually use wooden floor slabs to separate the attic space at the height of the roof gable roof's eaves to divide the space's upper and lower floors. The central entrance hall is a high-height space, and the interior forms a cooling and heating chamber that can pre-cool and preheat the air in the room. In addition, to cope with the cold climate environment, each household has set up a fire pit. Still, there is no particular flue, but

Table 2. "Genetic factor library" of ecological construction model.

Pattern type	Schematic diagram of the building
A1 A courtyard with natural light and ventilation	 A1-1 Courtyard dam type courtyard plan A1-2 Courtyard-style courtyard plan A1-3 Courtyard-style courtyard
A2 Cushioned regulated building cavities	 A2-1 Transverse climate buffer chamber A2-2 Vertical cooling and heat gain chamber A2-3 Air flow chamber
A3 Building materials adapted to local conditions	 A3-1 Rammed earth A3-2 Wood A3-3 Stone
A4 Climate-adapted roof interface	 A4-1 Double-slope roof A4-2 Single-slope green roof

through the staggered gap between the slopes on the front and back of the roof, the carbon dioxide and smoke produced by the fire pit can be discharged to the dwellings in time Outside. The gate is the air intake, and the roof staggered is the air outlet, forming the indoor airflow layout of the gate-fire pit-roof staggered seam (A2 in **Table 2**). These buffer adjustment chambers set up to adapt to the local climate are a kind of local ecological wisdom that reduces the heat dissipation of winter dwellings and increases thermal mass effects.

4.3.3. Building Materials Adapted to Local Conditions

Meigu County is primarily mountainous and rich in natural resources. When the Yi people build their houses, they use local materials, and the building materials are mainly rammed earth, wood, and stone (A3 in **Table 2**). The most common material used in the construction of residential buildings is rammed earth, which is usually presented in the form of rammed earth walls and rammed earth roofs. The temperature of rammed earth is affected by solar radiation, atmospheric temperature, and soil thermal inertia, resulting in fluctuations from surface to layer by layer. Therefore, the exterior wall of the Yi traditional dwellings built with rammed earth has good thermal insulation performance, so the interior of the building has less heat in summer and less heat loss in winter. Wood is mainly used in the structure, roof, and door of traditional Yi dwellings, and using natural wood has the ecological balance value of the material cycle. Stone is less used in residential materials, and a few residential pillars and roofs will use stone. Regional materials themselves are the product of adapting to the climate and survival of the fittest, and using them makes the characteristics of the interior of the house better adapted to the local climate environment. This method of selecting local conditions materials is a local ecological wisdom to ensure the stability of residential thermal mass effects.

4.3.4. Interface Structure Adapted to Climate

The roof interface of traditional Yi dwellings is mainly in the form of a double-slope roof and a single-slope roof, a climate adaptation construction strategy with heavy rainfall and intense solar radiation. A sloping roof enables rainwater and snow to slide down to the ground through gravity, effectively reducing water intrusion into the building. At the same time, when the summer sunlight hits the sloping roof, the heat can be isolated through the insulated tiles and roof space, ensuring the stability of the indoor temperature (A4 in **Table 2**) [21]. This climate-adapted interface construction is a local ecological wisdom to protect residential thermal mass effects in winter and ventilation in summer.

In summary, under the influence of local climate and environment, the Yi nationality has developed an ecologically-oriented construction model with distinct regional characteristics to adapt to nature and create a suitable living environment. This model is reflected in construction methods, spatial forms, and interface structures. Through these, the Yi people have developed local ecological wisdom that enhances residential thermal mass effects, as seen in six aspects: village layout, courtyard design, building form factor, building cavity, building materials, and rooftop interface. These aspects protect, guarantee, and improve the standard heat retention features of Yi homes, meeting the passive regulation strategy of heat retention priority in the architecture of Meigu County.

5. Discussion

5.1. Data Analysis of Residential Thermal Environment Measurement

Siganpu Village and Gutuo Village in Meigu County are representative villages with more traditional Yi dwellings. During the field research from October 16, 2021, to October 22, 2021, it was selected as the measurement site; both villages are located on high mountains, more than 2000 above sea level. The village's indoor and outdoor temperature and humidity were measured using a black ball thermometer as an average over three days (Figure 4). The average outdoor temperature of the dwellings in Siganpu Village and Gutuo Village was 7.6˚C and 7.0˚C, and the average indoor temperature was 8.1˚C and 7.6˚C respectively. The average outdoor humidity of Siganpu Village and Gutuo Village was 78.4% and 80.6%, and the average indoor humidity was 75.1% and 63.6%, respectively. The indoor temperature of the two villages' traditional dwellings is higher than that of the outdoor temperature, while the humidity is lower. This finding confirms that the traditional homes of the Yi nationality in Liangshan have better insulation performance and exhibit practical adequate thermal mass effects.

5.2. Analysis of Residential Thermal Performance

According to the results of field research, the ground of the traditional Yi dwellings comprises 300 mm of rammed soil. The walls are compacted with 400 mm of bare earth. The roof has three different materials of roofing form: wood, stone, and rammed earth. The structure of the wooden roof is 15 mm wooden rafters and purlins, 20 mm wooden boards, and 30 mm tile boards from bottom to top; The slate roof is made of 35 mm wooden rafters and purlins, 40 mm slates, and the rammed earth roof is made of 35 mm wooden rafters and purlins, 30 mm rammed earth covering. The doors are made of 45 mm wood (Table 3).

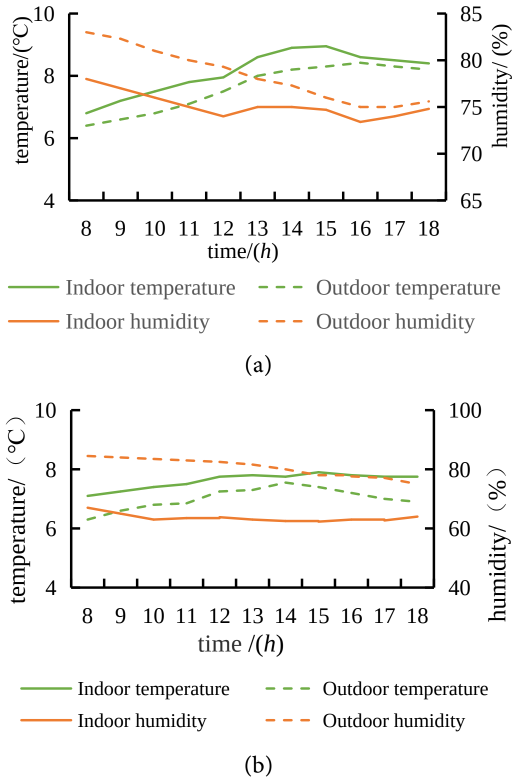


Figure 4. Thermal environment analysis of residential dwellings in Siganpu Village and Gutuo Village. (a) Siganpu Village; (b) Gutuo Village.

According to the calculation parameters of physical properties of building materials according to GB 50176-2016 "Code for Thermal Design of Civil Buildings", the thermal conductivity of the wall made of plain soil compaction is concluded at 1.16 W·(m·k)$^{-1}$. The thermal mass effects coefficient is 12.99 W·(m^2·k)$^{-1}$. Compared with today's concrete materials, its thermal conductivity is smaller and more insulating; its thermal mass effects coefficient is low, and its thermal stability is better. These scientific data confirm that the rammed earth materials of Yi traditional dwellings have sound thermal mass effects performance and the local ecological wisdom of selecting building materials according to local conditions.

Based on the "Rural Residential Building Energy-saving Design Standard" GB/T 50824-2013, rural areas are divided into climate zones for energy-saving building design. Meigu County belongs to a hot summer and cold winter climate zone. For hot summer and cold winter regions, the standards for the heat transfer coefficient of the enclosure structure and thermal inertia index are as follows [22]: for exterior walls, when the thermal inertia index D is greater than or equal to 2.5, K is less than or equal to 1.8 W·(m·k)$^{-1}$; for roofs, when the thermal inertia index D is less than 2.5, K is less than or equal to 0.8 W·(m·k)$^{-1}$. When calculating the D value of the traditional Yi ethnic dwelling's walls to be ≥2.5, the K value is >1.8 W·(m·k)$^{-1}$. When the D value of the roof is <2.5, the K value is >0.8 W·(m·k)$^{-1}$. Hence, the walls and roof fail to meet rural residential buildings' energy conservation design standards. However, the value of the wall is close to meeting the energy conservation design standards, which indicates that the localized ecological wisdom of selecting appropriate building materials has an energy-saving effect.

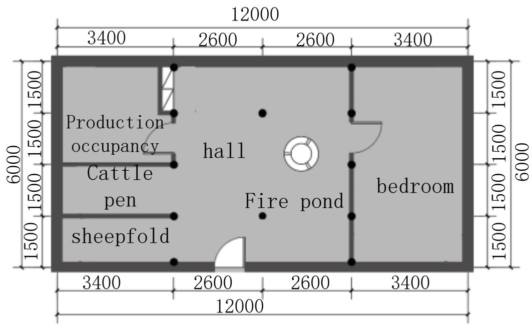
5.3. Simulation Analysis of Residential Thermal Environment Based on Ecotec Software

5.3.1. Model Establishment

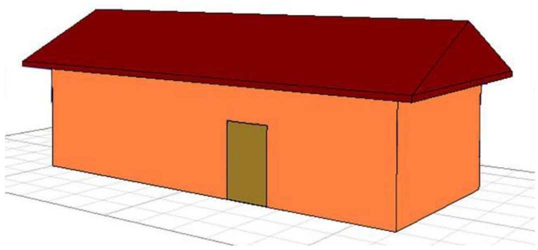
Taking the temperature and heat gain changes of traditional Yi dwellings as the starting point, the ecological performance of residential buildings is intuitively analyzed by Ecotect 2010 software. Using the climate data of Meigu County as the calculation background, the model adopts a three-room structure for traditional Yi nationality dwellings. The exterior of the house only has one door and no windows, with a floor size of 12.0 m (length) × 6.0 m (width) (see **Figure 5**). The construction and thermal calculation parameters of the dwelling are determined based on the results of field research and following the data specified in GB 50176-2016 "Thermal Design Standards for Civil Buildings" [23] (see **Table 3**).

5.3.2. Thermal Environment Simulation Analysis

Firstly, the temperature frequency and indoor heat gain of traditional rammed earth walls and plank roof dwellings of the Yi nationality were analyzed. The simulation produces a temperature frequency distribution plot showing that the outdoor temperature frequency peak is 18˚C, the coldest temperature reaches 0˚C, and the maximum temperature reaches 34˚C. The temperature frequency in the room (**Figure 6(a)**) peaks at 24˚C, with a minimum temperature of 4˚C and a maximum temperature of 32˚C. The peak temperature frequency of indoor and outdoor Yi traditional dwellings is within the range of 18˚C to 26˚C, which meets the needs of human comfort. It has the performance of thermal mass effects in winter and ventilation in summer. In addition, the average monthly indoor hourly heat map of the maintenance structure was simulated (**Figure 6(b)**), showing that the indoor heat gain state was continuous throughout the whole day from April to October. The available indoor heat is sufficient, which further indicates that the thermal mass effects of the house are vital.



(a)



(b)

Figure 5. Floor plan and model of a typical plank house of Yi nationality traditional dwellings. (a) Floor plan; (b) Elevation plan.

Table 3. Thermal parameters of residential materials in accurate-real-state simulation.

Structural form	Constructed form	Specific heat capacity C/KJ·(kg·k)$^{-1}$	Thermal resistance R/m^2·k·W^{-1}	Heat transfer coefficient K/W·(m·k)$^{-1}$	Thermal inertia indicator *D*
Ground	300 mm Tamp soil	1.01	-	-	-
Walls	400 mm Plain soil is compacted	1.01	0.35	1.96	4.55
Roof	Wood panel roofing: 15 mm Wooden rafters, wooden purlins, 20 plank, 30-mile plates	2.51	0.46	1.61	1.771
	Rammed earth roofing: 35 mm Wooden rafters, wooden purlins, 30 rammed earth	2.51 1.01	0.14	3.36	1.16
	Slate roofing: 35 mm Wooden rafters, wooden purlins, 40 flagstone	2.51 0.92	0.13	3.39	1.11
Door	45 mm Timber	2.51	-	-	-

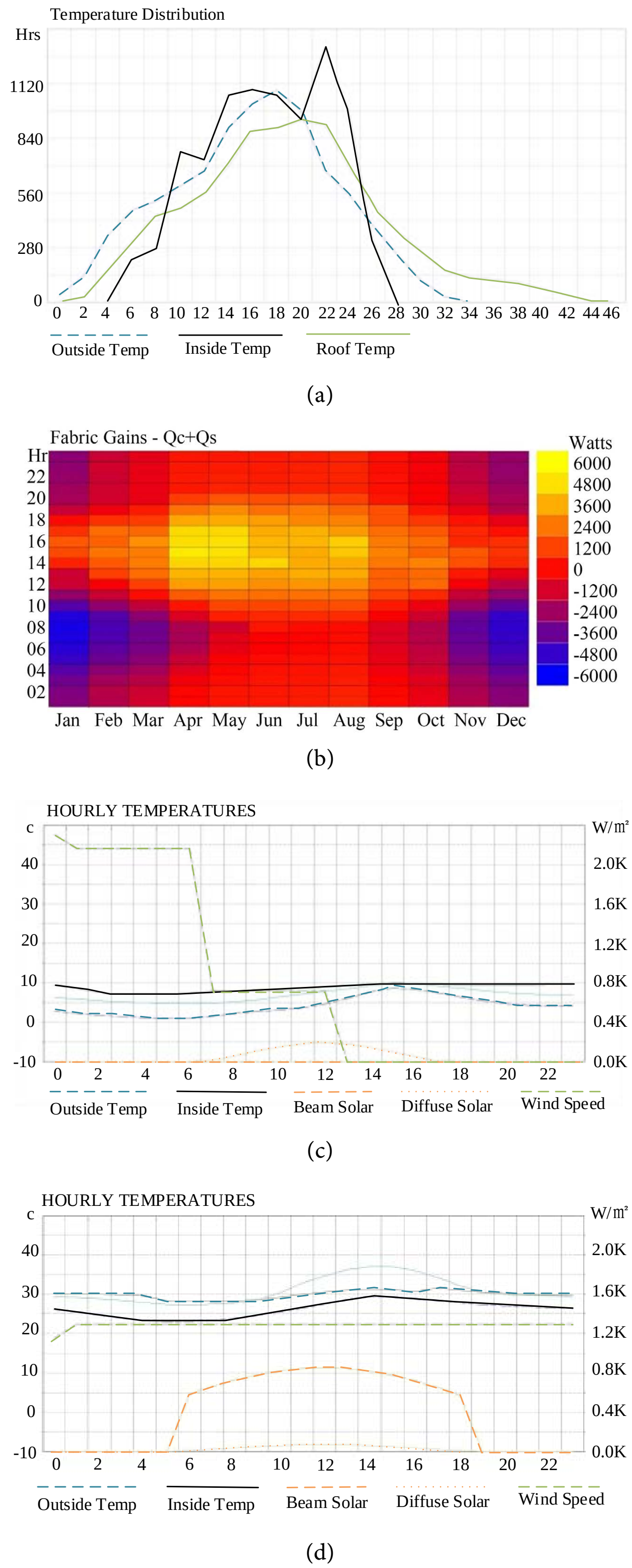
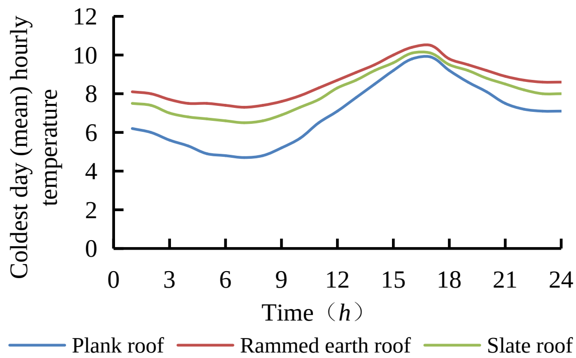


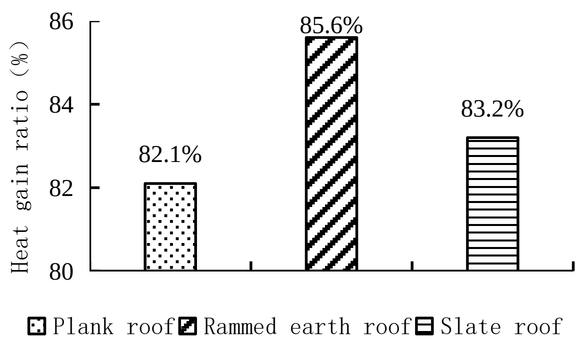
Figure 6. Simulation and analysis results of the thermal environment of Yi traditional dwellings. (a) Temperature frequency distribution diagram; (b) Monthly average indoor hourly heat map; (c) Hourly temperature graph of the coldest day; (d) Hourly temperature graph of the hottest day.

Secondly, the indoor and outdoor temperatures of typical Yi traditional rammed earth wall and plank roof dwellings were analyzed. The data show that the hourly air temperature indicators on the coldest day of the year are (**Figure 6(c)**): outdoor all day 1˚C to 9˚C, indoor all day 8˚C to 10˚C, the indoor temperature is higher than outdoor hourly temperature to 0.5˚C to 7˚C, The temperature inside is more elevated than outside all day. The indoor hourly air temperature indicators on the hottest day of the year are (**Figure 6(d)**): outdoor all day 27˚C to 32˚C, indoor all day 23˚C to 29˚C, and indoor temperature 2 to 8 lower than outdoor temperature ˚C. It shows that the traditional dwellings of the Yi nationality have robust thermal mass effects in winter and strong heat insulation in summer.

Finally, the dwellings with Yi wood, slate, and rammed earth roofs are simulated, and the hourly indoor temperature and heat gain performance of the coldest (average) roof are compared. Importing the results of the Ecotec analysis into the Oxcel, the results show the hourly temperature is highest for rammed earth roofs, followed by slate roofs, and lowest for plank roofs. The chart in **Figure 7(a)** shows that rammed earth material has the best thermal insulation performance compared to wooden boards and slate materials during winter. Meanwhile, **Figure 7(b)** compares the heat gain ratio of three roof materials in



(a)



(b)

Figure 7. Simulation and analysis results of different forms of thermal roof environment. (a) Hourly indoor temperature graph of the coldest day (average) (b) The coldest day (average) passive component gets a heat.

the exterior envelope structure. The heat gain ratio is 82.1% for a wooden board roof, 85.6% for a rammed earth roof, and 83.2% for a slate roof. In the heat gain of the outer envelope structure, the heat effect of rammed earth material is the best compared with that of wood and stone. The building materials of the traditional dwellings of the Yi nationality in Liangshan are mainly rammed earth, which adapts to the needs of winter heat preservation in the climate of the Liangshan Plateau.

In summary, the measured data of traditional dwellings in mid-October showed that the indoor temperature was higher than the outdoor temperature, and the indoor humidity was lower than the outdoor humidity. The simulation results show that the indoor temperature frequency of Yi traditional dwellings is between 18˚C to 26˚C, the indoor heat gain is sufficient, and the indoor temperature is more stable than the outdoor temperature in winter. It shows that the traditional dwellings of the Yi ethnic group have solid hold solid, strong thermal mass effects characteristics, resulting from the combined effect of ecological wisdom in construction mode, spatial form, and interface structure. In addition, through the simulation of three different roof materials, compared with wood and stone materials, rammed earth has thermal inertness and time lag for temperature induction so that the interior can resist external temperature changes well. It plays a vital role in the thermal mass effects of residential buildings in the choice of building materials.

5.4. Challenges and Coping Strategies of Implementing Ecological Construction Practice in the Contemporary Environment

Although the above confirmed the yi traditional folk back mountain water village site layout, lighting ventilation courtyard shape, neat energy-saving building size, buffer regulation of building cavity, adjust measures to local conditions of building materials, to adapt to the climate interface structure, the ecological construction mode has the characteristics of improving regenerative, but in the current environment to implement the ecological construction practice is also facing the following challenges.

1) Restrictions of building codes and land use codes: The current building codes and land use codes may limit the village site selection and layout and the practice of courtyard shape and system. The normative requirements in some areas may prefer large-scale urbanization and high-density development rather than traditional ecological construction models. The government and relevant departments should encourage and provide policy support for sustainable urban planning and the development of corresponding building codes to ensure that the traditional building model is reasonably considered in the norms and planning.

2) Technical and educational challenges: practice standardized and energy-saving building size, buffer, and adjusted building cavity and require the architect to have relevant technical knowledge skills. However, nowadays, many architects may lack professional training and education related to ecological

construction. Schools and research institutions can add relevant disciplines and majors, strengthen education and training opportunities pertaining to environmental building, and cultivate architects' environmental awareness and technical ability.

3) Material supply and cost restrictions: building materials tailored to local conditions are not easy to obtain in the current market, or the cost is high, the supply of traditional materials is limited, and the research and development and production of alternative materials need to invest more resources. Governments can provide incentives to support the ecological and supply chain development of ecological construction materials, thereby reducing their costs and improving availability. Researchers are encouraged to study and develop more environmentally friendly and sustainable building materials to replace traditional materials.

4) Challenges of climate change and adaptability: Due to the influence of climate change, the Yi region may face new climatic conditions and extreme weather events, and the traditional interface structure of climate adaptation may need to be adjusted and improved. We can promote research and collaboration in disciplines to integrate expertise in the fields of climate science, architecture, and engineering to update and enhance traditional interface structures to adapt to new climatic conditions.

6. Conclusion

This paper analyzes the ecological construction mode of traditional dwellings of the Yi ethnic group in Liangshan, starting from the regional climatic characteristics, and condenses its local environmental wisdom. On this basis, combined with the thermal environment measurement data and the simulation data of Ecotec software, the ecological knowledge of improving the thermal mass effects of buildings is studied. The following conclusions can be obtained: First, the wisdom of ecological construction in Liangshan Yi traditional dwellings to improve the thermal mass effects of buildings is manifested in six aspects: the site layout of villages with mountains and waters, the courtyard shape of lighting and ventilation, the regular and energy-saving building shape, the buffer and adjustment of building cavities, the building materials adapted to local conditions, and the interface structure adapted to the climate. Second, the indoor temperature of the traditional Yi dwellings in winter is significantly higher than the outdoor temperature, which has the ecological characteristics of solid thermal mass effects and sufficient heat gain. Third, roof using rammed earth materials has more heat than slate and wood roofs and has better thermal mass effects performance. This ecological construction wisdom can provide a reference for modern ecological building design. Fourth, the implementation of the traditional ecological construction model in the current environment will face challenges from building codes and land use norms, technology and education, material supply and cost, climate change and adaptability, and require policy support, professional education, material innovation, and climate adaptability.

Data Availability

The data used to support the study are available from the corresponding author upon request. The charts in the article are all taken and made by myself.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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