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Source: Mountain Research and Development, 36(1) : 4-14

Published By: International Mountain Society

URL: https://doi.org/10.1659/MRD-JOURNAL-D-14-00067.1

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Mountain Research and Development (MRD)
An international, peer-reviewed open access journal
published by the International Mountain Society (IMS)
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Assessing the Sustainability of the Built Environment in Mountainous Rural Villages in Southwest China

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Mountainous rural areas such as those in southwest China are developing rapidly. This requires scientific understanding and a framework for assessing the sustainability of the built environment that is suitable to such areas. At present, no such framework exists. This lack of assessment options has contributed to the unsustainable development of these areas, which has caused a series of environmental, social, and economic problems. This article analyzes existing assessment frameworks, reviews the theory on sustainable rural development as it applies to rural southwest China, and proposes a new assessment framework that is more suitable to this region and others like it. This framework is based on a sustainable development model for rural areas that emphasizes endogenous development; addresses the environmental, social, and economic dimensions of sustainability; and takes the natural and social conditions of mountainous rural areas into account. Our study tested its applicability to rural southwest China and its sensitivity to local conditions and found them to be better than those of existing assessment frameworks.

Keywords: *Rural sustainable development; endogenous development; social sustainability; economic sustainability.*

Peer-reviewed: *August 2015* ***Accepted:*** *November 2015*

Introduction

After the application of the sustainability principle in architecture in the 1990s (Gauzin-Müller and Favet 2002), several countries and regions established built environment assessment methods to provide a systematic approach to evaluate building design, construction, and management (Wan 2013). However, most of these assessment methods were established for urban areas and are based on the development model of modernization—that is, they are aimed at transforming markets, and criteria are based on quantifiable and comparable technical measures with a linear approach toward conserving resources (Cole 2012). Some mountainous rural areas, such as those in southwest China, are undergoing major construction and development without adherence to appropriate guidelines and assessment methods (Zhang 2013). Rural construction and development adopt urban approaches that are not appropriate for rural areas. This practice results in serious problems such as environmental damage, abandonment of natural and local renewable energy, and lack of public engagement (Qiu 2009). This study proposes a framework for assessing the sustainability of the built environment for mountainous rural areas, based on a sustainable rural development model. It considers a larger scale than conventional built environment assessment methods do, including buildings, infrastructure, and production facilities.

Challenges to assessing the sustainability of the built environment

Development-related challenges

The geographical characteristics of mountainous rural areas impose limitations that result in an inconvenient transportation system, which seriously restricts rural development. In rural southwest China, villagers experience difficulties in accessing education, health care, and markets. Moreover, conventional infrastructure and brick and concrete buildings are difficult to build because of high transportation costs. Although this reality has helped to preserve several unique minority cultures by limiting outside access to their living environment, it has also contributed to their geographical and psychological marginalization (Chen et al 2007).

The level of social development has always been lower in mountainous rural areas than in other areas. For example, rural southwest China is one of the poorest regions in China (NBS 2014). Almost half of the villagers have no more than 9 years of education. Unsafe water, poor sanitation, and inadequate health awareness

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threaten human health in this region (Chen et al 2007). Moreover, southwest China is frequently affected by natural disasters and has limited capacity for disaster prevention and recovery, another factor contributing to poverty in this region (An 1999).

China implemented the New Countryside Construction policy in 2005 to solve these problems (Qu et al 2006), providing increased funding, mainly for rural infrastructure construction. The policy was rapidly implemented in a top-down and large-scale manner. However, it followed an approach that emphasized urban–rural integration, and practice has proven that this is only suitable for 5% of rural areas that are near urban areas (Qiu 2009) and is unsuitable to mountainous rural areas. Thus, serious problems have emerged in the process of implementing rural development (Li et al 2008; Lv 2008; Zhang and Chang 2010). A considerable number of rural residents have moved to urban areas seeking work, leaving behind the elderly and children (Li et al 2008). These mountainous rural areas have lost a strong and cohesive force and have become a symbol of "backwardness."

Assessment-related challenges

Several studies related to rural building performance assessment have been conducted in China and other countries. Wang and Cai (2006), who applied the theory of sustainable development to the rural built environment in Yunnan, found that the embodied energy (the total energy required for the extraction, processing, manufacture, and delivery of building materials to the building site) of vernacular buildings using local materials and traditional technology is much lower than that of modern buildings. Murakami and Ikaga (2008) evaluated vernacular buildings in different countries through the Comprehensive Assessment System for Built Environment Efficiency (CASBEE) and argued that the performance of such buildings, as exemplified by indoor environmental quality, is inconsistent with sustainability despite their relatively low environmental load, that is, negative environmental impacts. Charles Newman, an architect working in Africa who has Leadership in Energy and Environmental Design (LEED) accreditation, found that LEED does not work in rural Africa because almost half of its requirements "are simply irrelevant or financially irresponsible" there. He argued that "sustainable building in disadvantaged, rural communities cannot be limited to architecture. Project success must be considered at a larger scale to include community involvement, building techniques, financial relationships, and development." Therefore, he suggested considering more social and economic factors when assessing building sustainability in Africa (Newman 2013).

These findings highlight the different conclusions derived from the use of different assessment methods. Such varied conclusions increase the difficulty in achieving an objective and comprehensive assessment of the sustainability of rural buildings. To further investigate this problem, this study tested existing built environment assessment methods by applying them to 3 villages in rural southwest China (Figure 1):

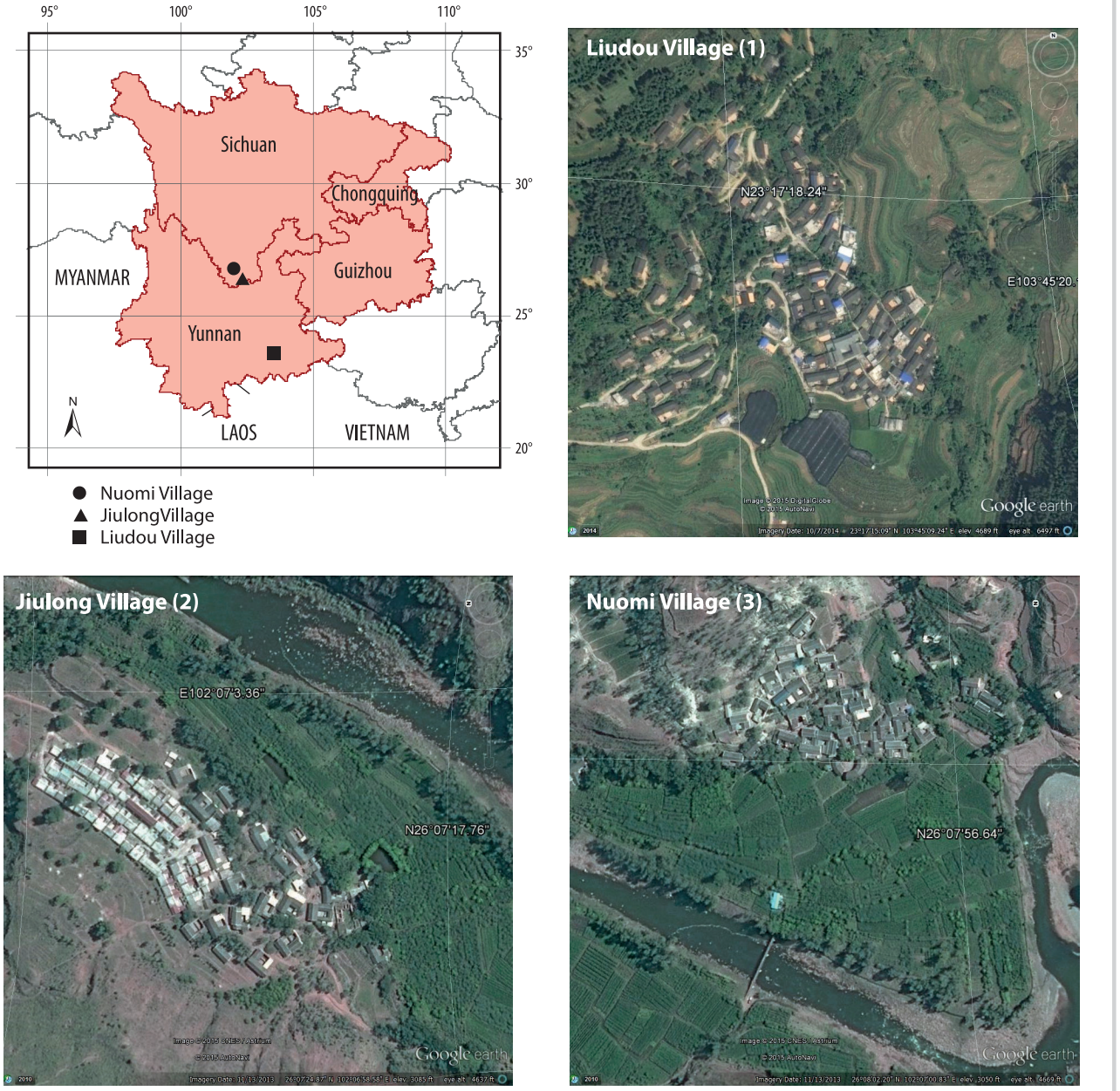
- Village 1, Liudou (Figure 2), is a typical traditional village that faces many common rural challenges, such as low income, poor infrastructure, and uncomfortable living conditions. The villagers rely heavily on local resources, and development has been slow.
- Village 2, Jiulong (Figure 3), was rebuilt in typical top-down fashion after the Sichuan earthquake of 2008. Reconstruction followed the modernization model that emphasizes rapid reconstruction, using industrialized building materials and construction methods, and aiming at concentrated use of space to create a greater number of apartments on little land. Although the infrastructure has been improved, construction costs became an additional burden to the villagers. The brick and concrete houses are not energy efficient owing to the use of materials with high-embodied energy and the lack of passive design strategies that respect the local climate and utilize natural resources. Their unsuitability for rural life is a result of inadequate public engagement.
- Village 3, Nuomi (Figure 4), is a post-earthquake reconstruction demonstration project that adhered to the concept of sustainable development. Innovations based on local traditional building technology included improved seismic performance, indoor environmental quality, energy maintenance, and cost efficiency. Infrastructure has also been improved. Villagers were fully engaged and empowered, and their cooperation was evident during the reconstruction. This project won several national and international awards (Wan et al 2011).

The following assessment methods were applied to the 3 villages:

1. LEED for Neighborhood Development (LEED-ND) is one of the LEED rating tools that were developed for neighborhood-scale projects with more community-level indicators (CNU et al 2014).
2. CASBEE for Homes (Detached Houses), one of the CASBEE tools that evaluates the built environment efficiency of detached houses in Japan, calculates a built environment's efficiency as its environmental quality divided by its environmental load (JSBC 2014).
3. The Sustainable Building Assessment Tool (SBAT) from South Africa, the first framework established for developing countries, assesses environmental, social, and economic sustainability (Gibberd 2003).
4. The Evaluation Standard for Green Building (ESGB) (MOHURD and AQSIQ 2006) and the National Eco-village Creating Standard (NECS) (MEP 2006) are the major standards used in China.

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FIGURE 1 Location and overview of the 3 study villages. (Map by Li Wan; source of images: Google Maps)



In the analysis, the indicators of each built environment assessment method were analyzed one by one to see if they were applicable to the 3 cases. Limitations of applicability included the following:

- Indicators based on urban community structure (eg in terms of scale, density, infrastructure, and building function).
- Lack of assessment method for the materials and technologies of vernacular buildings.
- Lack of indoor environmental quality standards for rural vernacular buildings.
- Reliance on standards, regulations, or guidelines that were established for other countries.
- Reliance on hardware or software that is not available in rural China.

The analysis yielded mixed results in terms of the applicability of the indicators. The applicability of the assessment methods was relatively low (Figure 5), with

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FIGURE 2 Liudou Village. (Photos by Xinan Chi)



that of LEED-ND being the lowest because it was mainly established for urban areas in developed countries. The applicability of CASBEE and ESGB was also low, because they were established for urban buildings using industrial materials and systems. SBAT, which was designed for developing countries, and NECS, which was designed specifically for Chinese rural regions, showed greater applicability. However, even for these 2 standards, more than 20% of the indicators were not applicable to the study villages because they attached great importance to urban issues and to rural areas that follow the modernization model.

In addition to applicability, the indicators were tested for sensitivity. In this analysis, NECS assessed Village 2 as more sustainable than Village 1. However, this conclusion was inconsistent across the built environment assessment methods, which underscores the inability of NESC to recognize some of the advantages of vernacular buildings. The other assessment methods assessed the sustainability of Village 2 as lower than that of Village 1 and the sustainability of Village 3 as the highest. However, the difference between the 3 villages was not significant, which means that none of these assessment methods can effectively distinguish between the different features of the 3 villages. All of the villages scored poorly on more than 50% of the indicators, possibly because these assessment methods do not consider the real sustainability of mountainous rural areas. (Details are provided in *Supplemental material*, Appendix S1, (http://dx.doi.org/10.1659/MRD-JOURNAL-D-15-00067.S1.)

The major problems with applying existing built environment assessment methods to mountainous rural areas are as follows:

FIGURE 3 Jiulong Village. (Photos by Li Wan)



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FIGURE 4 Nuomi Village. (Photos by Li Wan)



- *Scale of assessed object:* Most focus on building scale. However, the building scale is significantly smaller in mountainous rural areas than in urban areas. The sustainability of rural settlements is strongly connected to the community and the surrounding environment.
- *Applicability:* Most were established for urban areas, which are quite different from mountainous rural areas in terms of building form, construction materials, construction technology, management system, and other aspects.
- *Assessment criteria:* Most are based on the urban context and the modernization model, which is not suitable for mountainous rural areas. The majority of their indicators also focus on the environmental dimension of sustainability; consideration of social and economic sustainability is weak or missing.

Because existing assessments have such limited applicability to mountainous rural areas, there is a need for a comprehensive framework for realistically assessing the sustainability of the built environment in such areas.

Improving assessment: conceptual framework and methodology

To support rural development and help meet the need for adequate assessment of built environments in mountainous rural areas, a new assessment framework, the Rural Built Environment Sustainability Assessment System (RBESAS), was established. It combined the concept of rural sustainable development and Maslow's (1943) theory of the hierarchy of needs.

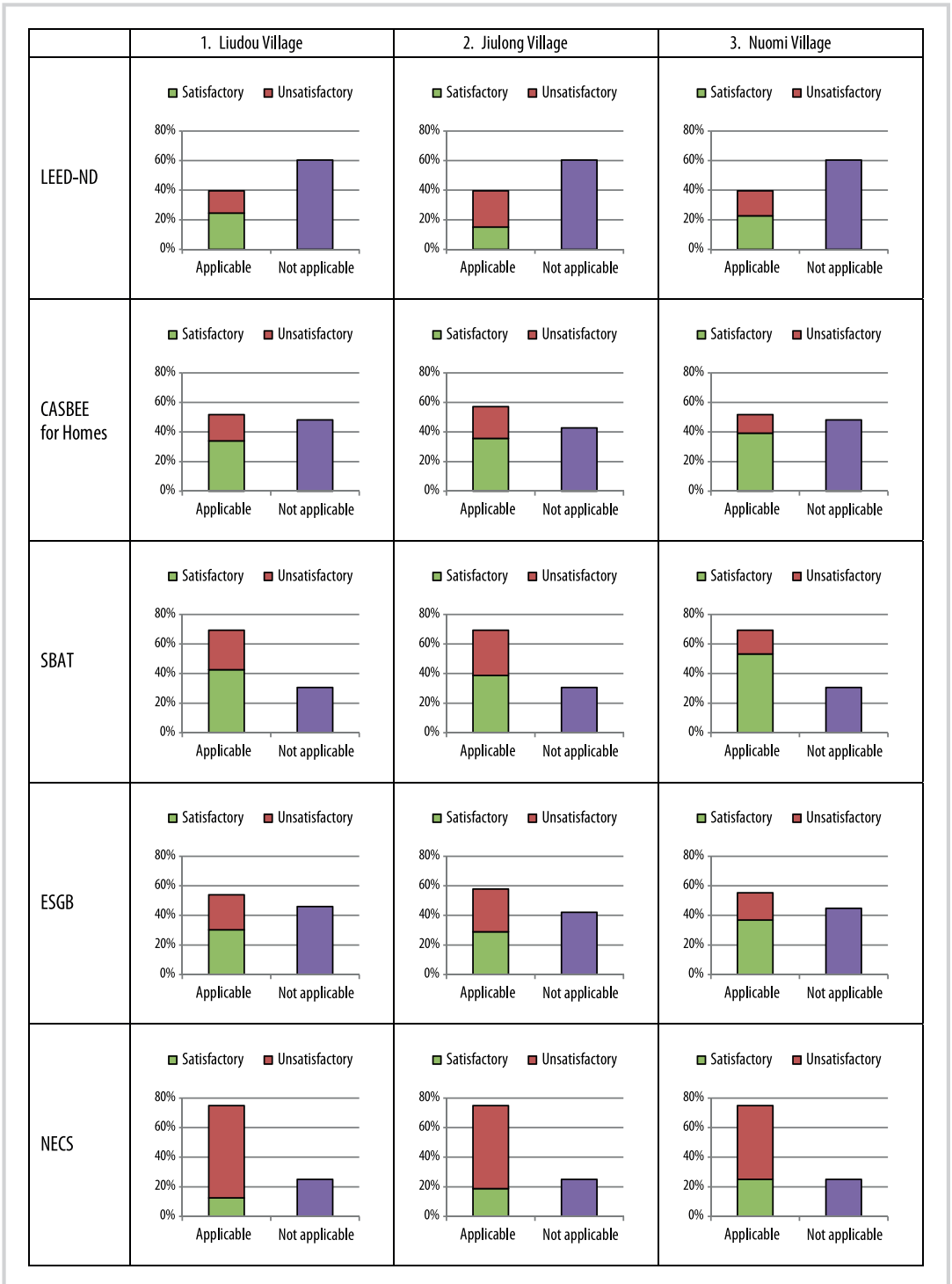
A new approach to rural development

In rural areas of Europe and other developed regions, the modernization model that emphasizes scale enlargement, intensification, specialization, and industrialization once dominated policy, practice, and theory (Van der Ploeg et al 2000). Critique of the rural modernization model that focuses on the problems of overproduction, environmental degradation, and spatial inequality was proposed as early as the 1970s. This led to the conceptualization of a rural sustainable development model. Different from the modernization model, it emphasizes endogenous development with a bottom-up approach (Woods 2011). Table 1 compares the 2 models. Local biocapacity and cultural context serve as basis of the rural sustainable development model, which focuses on food localization, revitalization of traditional crafts, sustainable exploitation of resources, and improvement of social capital (Van der Ploeg and van Dijk 1995). Unlike the older modernization model, it compensates for inconvenient transportation and insufficient financial capital, maximizes local resources, limits environmental impact, respects local culture, and benefits human development. Clearly, this model is appropriate for mountainous rural areas, which suffer from limited transportation options and low levels of development. It is suitable to the aims of improving the quality of rural life, maintaining the vigor and cohesive force of mountainous rural areas, and increasing rural residents' control over their lives (Thomas 2001; Caraveli 2006).

Social and economic sustainability is significant in this rural sustainable development model. Similar to Newman's (2013) argument, endogenous development emphasizes social and economic well-being (Ray 2000a: 447). Ray (2000b: 166) summarized endogenous rural development as having 3 aspects: "development activity within a territorial rather than sectoral framework," "valorizing and exploiting local physical and human resources," and "focusing on the needs, capacities and perspectives of local people."

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FIGURE 5 Applicability of existing sustainability assessment frameworks to the study villages.



Similarly, of the 35 factors considered in the Global Ecovillage Network's (2014) Community Sustainability Assessment tool, 19 focus on the social dimension—including participatory design, social practices, and cultural practices—implying that social sustainability is crucial to rural community sustainability.

Furthermore, sustainable development has been defined as "development that meets the needs of the

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TABLE 1 Features of the old and new rural development models (based on Van der Ploeg et al 2000; Woods 2011).

Modernization model	Rural sustainable development model
Attracting investment from external sources to support development	Endogenous development
Top-down planning approach	Bottom-up innovation approach
Separation of agricultural modernization and rural development as different policy arenas	Integrated approach that combines economic, social, and environmental goals
Financial capital	Social capital
Exploitation and control of nature	Environmentally sustainable development
Transport infrastructure	Information infrastructure
Focus on agricultural production	Focus on meeting new needs, perspectives, and interests
Large-scale and intensive industries	Small-scale niche industries
Urbanized modern society	Traditional society
Spatially and culturally convergent development	Locally embedded development

present without compromising the ability of future generations to meet their own needs" (WCED 1987: 8). It contains 2 key concepts: "the concept of 'needs,' in particular the essential needs of the world's poor, to which overriding priority must be given," and "the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future needs" (WCED 1987: 43).

Thus, while the older modernization model emphasizes scale enlargement, intensification, specialization, and industrialization, the newer rural sustainable development model could be described as an endogenous-based development model that puts more emphasis on social and economic sustainability, and on the simultaneous respect of human needs and environmental limitations.

Maslow's hierarchy of needs

Human needs can be classified according to Maslow's (1943) 5-level hierarchy:

1. *Physiological:* requirements for survival, such as air, water, food, clothing, shelter, and sex;
2. *Safety:* an orderly, stable, and predictable world, including personal security, financial security, secure access to resources, and health;
3. *Love and belonging:* affection and intimate relationships with others that foster a sense of belonging and acceptance by friends, intimate partners, family members, and others;
4. *Esteem:* respect from others and from oneself, including recognition, acceptance, a sense of competence, and independence;
5. *Self-actualization:* realizing one's full potential by exercising one's talents and capabilities.

The first 2 could be considered necessary for survival, and the last 3 for well-being.

Addressing environmental and human needs together

RBESAS is rooted in the concept of maintaining a balance between meeting human needs and protecting the environment. This requires a layered approach that takes multiple factors into account. Complementing the 5 levels of human needs, sustainability efforts can be categorized in 2 levels: *conservation*, minimizing harm by reducing resource use, pollution, and waste; and *regeneration*, going beyond this to improve the health of the system (Cole 2012).

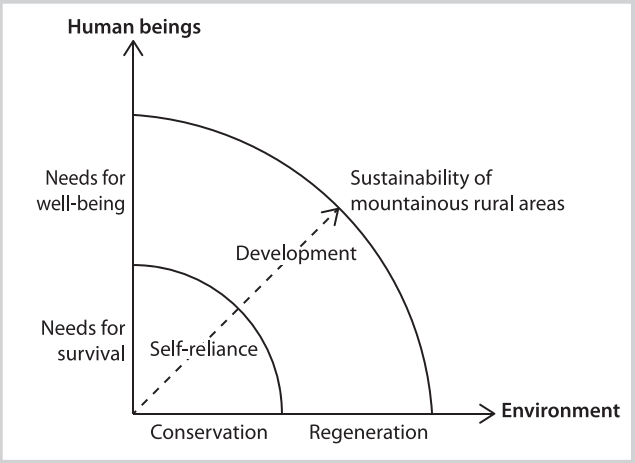
Next, success at meeting human needs in an environmentally sustainable way can also be divided into 2 levels: *self-reliance*: meeting the first 2 human needs, which are related to survival and using local resources, while promoting environmental conservation; and *development*: promoting environmental regeneration and meeting other human needs, related to well-being for the long term. Together, these needs and efforts form the core sustainability issues addressed in this paper; they are summarized in Figure 6.

Focusing on specific elements of the rural built environment

Finally, efforts to meet these needs can be seen as unfolding in 3 key elements of the built environment: *buildings* (residential and public); *infrastructure* (eg for transportation, communication, power, water, and markets); and *production facilities* (eg greenhouse and livestock pens). Table 2 provides a matrix showing which of the 3 elements of the built environment are relevant to each of the sustainability issues summarized above. On the basis of this matrix, RBESAS was established—a framework of issues and indicators assessing how well different elements of the rural built environment help to

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FIGURE 6 Elements of sustainable development in mountainous rural areas. (Figure by Li Wan)



achieve different aspects of sustainability in mountainous rural areas (Table 3).

Testing the new framework

The 3 study villages were analyzed using RBESAS to validate its suitability for use in mountainous rural areas. The quantitative assessment method for each indicator requires further study, because the development of RBESAS remains in the initial stage. For the phase of the study reported on here, Village 1, a typical traditional village, was considered as a baseline to obtain a general idea of the applicability and sensitivity of RBESAS. The performance of Villages 2 and 3 were compared with this baseline to investigate the advantages and disadvantages of these 2 rural development models. Results are presented below in terms of whether or not an indicator was found to be applicable in the mountainous rural context, and if it was applicable, whether each village scored above, below, or on the baseline for that indicator.

Results and discussion

As discussed above, the RBESAS framework recognizes 2 levels in the effort to meet human needs in environmentally sustainable ways—self-reliance and development—each of which, in turn, encompasses a series of issues (Table 3). The *self-reliance* category includes 10 issues. Issues 1, 2, and 3 aim to avoid environmental damage and biocapacity reduction, which

TABLE 2 Matrix showing the relationship between different aspects of rural sustainability and key elements of the rural built environment.

Sustainability issues			Elements of rural built environment		
			Buildings	Infrastructure	Production facilities
Self-reliance	Environmental conservation	Land and resources conservation	•	•	•
		Waste management	•	•	•
		Pollution control	•	•	•
	Meeting needs for survival	Food self-reliance			•
		Water self-reliance	•	•	•
		Housing self-reliance	•		
		Safety and security	•	•	
		Health and well-being	•	•	
		Energy self-reliance	•	•	
		Economic self-reliance	•	•	•
Development	Environmental regeneration	Sustainable landscaping		•	
		Sustainable agriculture			•
	Meeting needs for well-being	Culture and context	•	•	
		Inclusiveness and participation	•	•	
		Education and information	•	•	

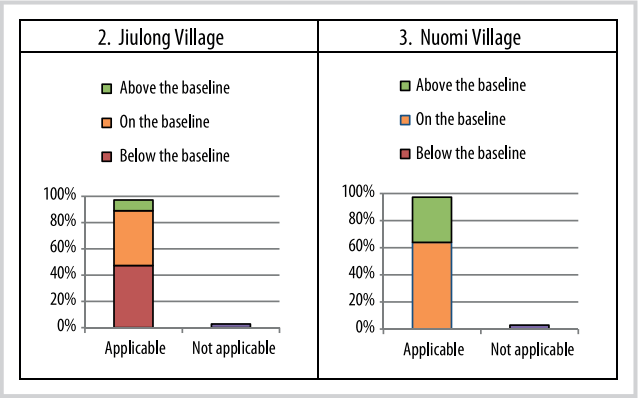
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TABLE 3 RBESAS indicators.

	Issues	Indicators
Self-reliance	1. Land and resources conservation	1.1 Sensitive areas conservation
		1.2 Agricultural land conservation
		1.3 Soil and water conservation
	2. Waste management	2.1 Construction and demolition waste management
		2.2 Operational waste management
	3. Pollution control	3.1 Pollution-free construction and demolition
		3.2 Pollution-free agriculture
	4. Food self-reliance	4.1 Local food production
		4.2 Diversified farming
	5. Water self-reliance	5.1 Water quality
		5.2 Water-efficient irrigation
		5.3 Water-efficient buildings and appliances
		5.4 Water reuse
	6. Housing self-reliance	6.1 Use of regional materials
		6.2 Efficient use of materials
		6.3 Indoor environmental quality
		6.4 Housing affordability
	7. Safety and security	7.1 Settlement location
		7.2 Settlement design
	8. Health and well-being	8.1 Sanitation
		8.2 Basic community services
		8.3 Community recreation facilities and open spaces
	9. Energy self-reliance	9.1 Embodied energy of materials
		9.2 Energy-efficient buildings and appliances
		9.3 Local and renewable energy
	10. Economic self-reliance	10.1 Improvement of local economy
		10.2 Empowerment of local laborforce
Development	11. Sustainable landscaping	
	12. Sustainable agriculture	
	13. Culture and context	13.1 Protection of historical and cultural heritage
		13.2 Preservation of local characteristics
		13.3 Coordination with natural environment
	14. Inclusiveness and participation	14.1 Barrier-free facilities
		14.2 Public engagement
	15. Education and information	15.1 Educational space and facilities
		15.2 Information facilities

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FIGURE 7 Applicability of RBESAS to the study villages. RBESAS data from Village 1, Liudou, were used to generate the baseline against which the other 2 villages were assessed.



are relevant to environmental sustainability. Issues 4, 5, and 6 encompass self-reliance with regard to human physiological needs and are relevant to environmental and social sustainability. Issues 7, 8, 9, and 10 include self-reliance with regard to human safety needs and consider environmental, social, and economic sustainability. The *development* category includes 5 issues. Issues 11 and 12, which are relevant to environmental regeneration, consider environmental recovery and biocapacity enhancement. Issues 13, 14, and 15 focus on improving the rural built environment to support the fulfillment of the human need for love, belonging, esteem, and self-actualization. These issues are relevant to social sustainability (Gibberd 2003). Clearly, this assessment framework is quite comprehensive, considering both environmental limitations and human needs in mountainous rural areas and covering the 3 dimensions of sustainability.

Testing of RBESAS (Figure 7) show it to be highly suitable to the study villages. Almost all indicators were applicable to the 3 villages, because this framework was developed based on the real situation of mountainous rural areas and considers the entire rural built environment, including buildings, infrastructure, and production facilities. RBESAS clearly identified the advantages and disadvantages of the 3 villages and recognized the significance of the rural sustainable development model. As mentioned previously, Village 1 is a typical traditional village with low income, poor infrastructure, and uncomfortable living conditions. Its advantage is its full use of local resources and low environmental impact. Village 2 may provide better living conditions and infrastructure than Village 1, but it has a greater environmental impact, relies more heavily on outside resources, and pays less attention to the psychological needs of the local people. Therefore, the self-reliance and development capabilities of Village 2 are low, although a considerable amount of money has been spent in the reconstruction of the village. By contrast, Village 3 maintains the advantages of Village 1 without its disadvantages. During reconstruction, Village 3 achieved improved rural living conditions without damaging the environment or incurring high costs. At the same time, it successfully preserved the local culture. More important, the villagers felt that they were the real masters of their homeland because they were fully engaged and empowered in the reconstruction process (UNESCO 2011; Mu et al 2012). Thus, Village 3 provided better solutions to concerns such as housing self-reliance, human health and well-being, energy self-reliance, and economic self-reliance, compared with the other 2 villages. This indicates that Village 3 has the highest consistency with the rural sustainable development model, notwithstanding several problems to do with waste management and agricultural pollution. Therefore, RBESAS has good applicability and sensitivity in assessing the sustainability of the built environment in mountainous rural areas. Details are provided in *Supplemental material*, Appendix S2 (http://dx.doi.org/10.1659/MRD-JOURNAL-D-15-00067.S1).

Conclusions

A comprehensive understanding of the sustainability of the rural built environment is necessary in solving development and conservation problems in mountainous rural areas. The results of this study show that RBESAS, as an alternative framework for assessing mountainous rural areas, is appropriate for 2 reasons. First, it was based on the concept of sustainable development and rural built environment sustainability. Second, its scope and the issues it covers are based on the existing situation of mountainous rural areas. These ideas have ensured the scientific validity and adaptability of the assessment framework, as well its suitability to other rural areas where the rural sustainable development model is followed.

Furthermore, the simultaneous consideration of urban and rural issues is not only necessary in the architectural field but also significant in other fields of sustainable development. Rural areas, as well as urban areas, are changing and developing. The exchanges of resources, capital, and personnel between urban and rural areas are rapidly increasing. Therefore, from the macro-perspective, urban and rural development should be linked and considered together. At the operational level, rural development strategies should be scientifically and systematically established and not just borrowed from urban contexts. Additional research relevant to the concept and strategies of rural sustainable development should be conducted in the future.

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Supplemental material

APPENDIX S1 Detailed assessments of the 3 study villages.

APPENDIX S2 Details of RBESAS testing.

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