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Original Article

A new conceptual model for social-ecological environment capacity of debris flow waste-shoal land based on sustainable development in mountainous area

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ABSTRACT

Background and objectives: Debris flow waste-shoal land (DFWSL) is a unique land resource with significant use prospects and development value (e.g. agriculture, urbanization, and infrastructure land). However, a lack of understanding of environment capacity hinders the development and use of such land.

Materials and methods: Therefore, this study examines DFWSL and relevant human and natural factors and proposes the concept of the social-ecological environment capacity (SEEC) of DFWSL. We explain the connotation by exploring the evaluation index system based on various theories, such as the dissipation structure theory, ecological disaster and change theory, ecosystem balance theory, ecosystem functional value assessment theory, land cover/land change, and related knowledge.

Results and conclusion: Moreover, we form the framework for and research approaches to the SEEC of DFWSL. In this method, the number of active agents and the activity intensity are considered to evaluate the SEEC of the DFWSL system, and the distribution characteristics of active agents with dynamic states in different spatial and temporal scales are used to characterize the heterogeneity within the DFWSL system. We attempt to provide theoretical guidance for improving land use efficiency in mountainous areas relevant to maintaining ecological security and sustainable economic development.

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1. Introduction

Debris flow waste-shoal land (DFWSL), often called a debris flow fan, is the product of debris flow movements and is therefore located in the lower reaches of a valley (He et al., 2018). Although debris flow causes many casualties and property losses, it is also a valuable marginal land resource (Cui et al., 2009; Jalayer et al. 2018). In the debris flow prone areas of China, there have many watersheds with abundant DFWSL coverage, including the lower Jinsha River (48 km2), the Bailongjiang basin (28.082 km2), and the Jiangjiagou basin (3.96 km2), et al (He et al., 2020). With the acceleration of global climate change, population growth, and urbanization, the use and development of DFWSL aims not only to provide sufficient space for industrialization and urbanization but also to serve as an effective buffer for ecological construction. Consequently, in mountainous regions, DFWSL constitutes a significant approach to dealing with the dilemma of protecting cultivated land while pursuing development (Cai, 2010). In addition, such approach represents another attempt to develop and use the available resources in unfavorable environments, such as desert land (Cao et al., 2018), karst land (Chen et al., 2017), and mining wasteland (Liu et al., 2016). With the efforts to optimize and improve DFWSL, its ecosystem has been transformed gradually from an original natural state into a social-ecological system combining socio-economic elements with the natural ecology (Liu, 2007; Accastello et al. 2019).

The ecological environment of mountainous areas is inherently fragile owing to the frequent occurrence of mudslides. Accordingly, mountain ecosystems are unstable, leading to difficulties in improving its biological production capacity, as well as determining the features of a poor feedback mechanism, disaster-proneness, and the slow pace of restoration (Zhao et al., 2020). The development and use of DFWSL are highly susceptible to socio-economic, institutional, and environmental factors (Glasby, 2002; Lesschen et al., 2005). Therefore, it is critical to managing the feedback of the land ecosystem and humans to realize sustainability by land managers and policy-maker (Collins et al., 2011; Martin, 2019), especially for the effective protection of land resources and the promotion of economic development. Cumming and Allen (2017) summarized the research trends over the past 50 years, conservation biology and applied ecology have gradually recognized that natural resource management was affected by the combined elements of society, economy, and ecology. Ecosystems and social systems constitute an inseparable entity; therefore, the protection and use of resources should be carried out from a multidisciplinary and multi-program perspective (Allen et al., 2011). In the process of developing and using this type of land, improving land quality, in a broad sense, as well as disaster prevention and relief have become basic and long-term efforts for sustainable development.

With the growing awareness of the importance of socio-ecological science, new interdisciplinary research perspectives are flourishing, the most popular of which are the social-ecological systems (SESs, also termed coupled systems, or coupled human-natural systems) (Berkes et al., 2003). DFWSL is one of the most important types of SESs, that not only be control by human and natural factors but also influence the eco-geo-environment and the development of socio-economic. In a promising development, Ostrom (2009) proposed a general analysis framework for the sustainable development of social ecosystems that provide theoretical guidance for ecosystem governance. This proposed framework has attracted significant attention relevant to the exploration of the theory and practice of social ecosystems. Subsequently, Collins et al. (2011) proposed a comprehensive conceptual framework for long-term socio-ecological research, namely, Press-Pulse Dynamics (PPDs). Their framework bridges the divide between geophysical systems and social systems for quantitative or qualitative expression of pressure feedback. Furthermore, the proposed framework promotes awareness of the SSEs and improves the understanding of the SSEs of developed and undeveloped land resources. The same concept, namely, "social-economic-natural complex ecosystem," was previously expounded by Ma (1984) and Zhao (1999), who promoted the idea of integrating the human socioeconomic system with the natural ecosystem. In view of the above, more attention should be paid to DFWSL as a reserve resource for developing mountainous areas, particularly because of the special site conditions (ecologically fragile mountainous areas). The natural and socioeconomic attributes of this land should be combined organically to identify the convergence and to foster greater development, finally, maximizing one or several ecosystem services by changing the use of DFWSL (Karp et al., 2013).

The successful practice of DFWSL development demonstrates that preliminary knowledge of DFWSL has been obtained already; however, there are several challenges, including (1) certain risks (such as debris flow), (2) blind and disorderly development, and (3) ignorance of desertification. Collins et al. (2011) have pointed out the necessity of continued research on the ecosystem and the social system while simultaneously developing a new, targeted theoretical framework and indicators for quantitative and qualitative description and understanding of the unique dynamics of the social-ecological system. The method and indicators for ecosystem service evaluation need to clarify the evaluation results and have broad consistency and comparability (Lamarque et al, 2011; Maes et al., 2012). Moreover, one of the research topics from Future Earth (2013) is to explore the limits and critical factors of the life carrying capacity of the planet and to provide early warning of the effects of global environmental changes on food, water, health, and energy.

Accordingly, how to increase the utilization of the DFWSL to the same height as the debris flow control and unify the two together, still lacks the relevant theory support and discussion. The vulnerability scoping diagram (VSD) (Polsky et al., 2007) and Agents' Differential Vulnerability model (Acosta-Michlik and Espaldon, 2008) provided a clear and comprehensive way of vulnerability assessment for the researchers. However, Present studies mainly focus on quantitative changes and lack consideration of spatial-temporal dynamics, especially in debris flow-prone areas with extreme spatial heterogeneity, where homogeneous models are difficult to use for understanding and developing the DFWSL. Thus, this study is to formulate the basic framework of the SEEC of DFWSL, to determine the problems associated with developing this type of land. The significance of the study is to offer theoretical guidance for the development and use of the resources, as well as a reference for policymakers to facilitate the harmonious co-existence of humans and the environment.

2. Theoretical Framework

2.1. Definition of social-ecological environment capacity of DFWSL

Because of the particularity of mountainous landforms and the complexity of natural environmental processes, the social-ecological environment capacity (SEEC) of DFWSL cannot be summarized simply by the maximum capacity of the natural and human environment. In disaster-prone areas, the regional environmental composition is characterized by poor structural stability, strong sensitivity, and weak anti-interference ability. Under the dual influence of natural and human activities, the fragile habitat is extremely vulnerable to change, which, in turn, affects the evolution of the regional ecological environment and even changes the direction and nature of evolution (Shang, 2000). The SEEC of

DFWSL includes the quantitative relationship, intensity, dimension, and the risk rate of the change process. Furthermore, SEEC is a systematic concept, which means that while studying the environmental capacity of the land, it is necessary to consider the subsystem capacity and pay attention to the weight distribution.

The DFWSL is a particular land system with both availability and vulnerability. Because of the involvement of human activities, the concept of motility is introduced before defining the SEEC (Fig. 1). Motility defines the total number of participants (scale) and their associated intensity. It should be noted that participants here refer not only to people and animals but also to various disasters, such as mudslides and landslides.

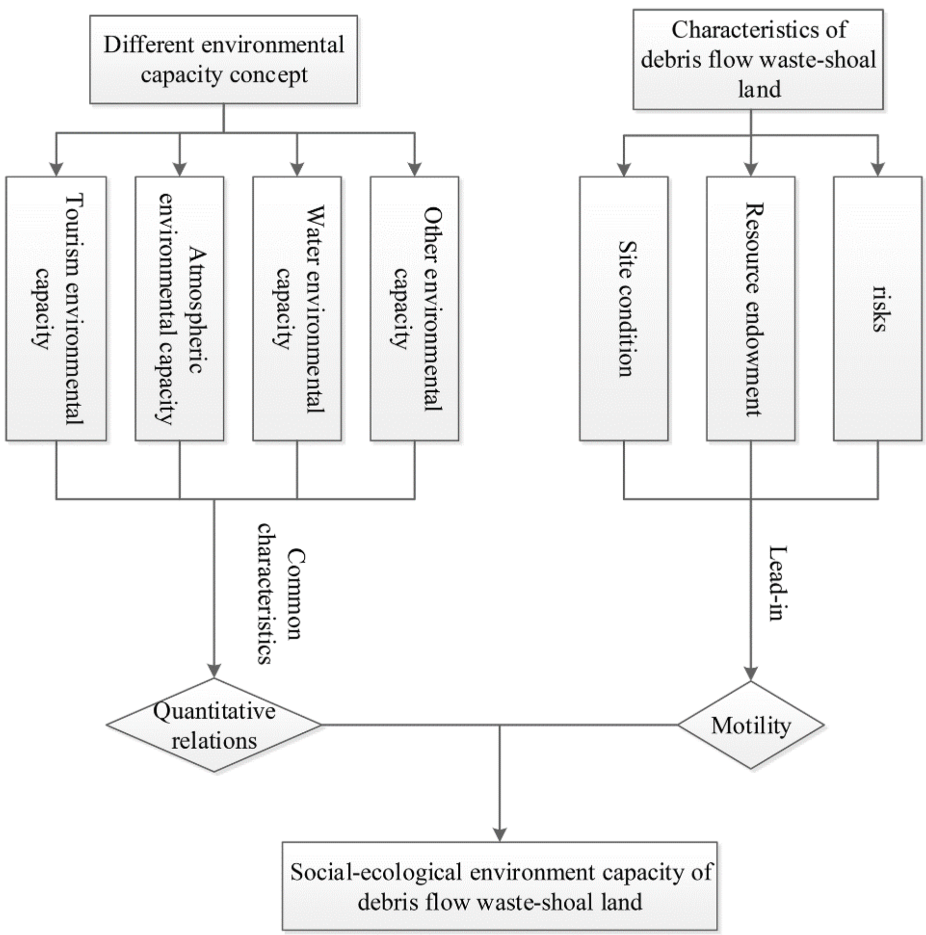

Fig. 1 - Conceptual derivation of the environmental capacity of debris flow waste-shoal.

Therefore, to the debris flow waste-shoal land system, within certain temporal and spatial scope, SEEC refers to the carrying capacity or the endurance to the motility of the participants contained in the system under the condition of normal and orderly operation (Fig. 2). This capacity refers to the comprehensive reflection of the flows of material, energy, and information; it can be demonstrated by the following expression in Equation 1 and 2:

$$M = NI \qquad (1)$$

$$SEEC = R*(NI/A)*T = R*(M/A)*T \qquad (2)$$

where M represents motility, R represents the risk, N represents the number, T is time, I is intensity, A is area, and SEEC represents social-ecological environmental capacity.

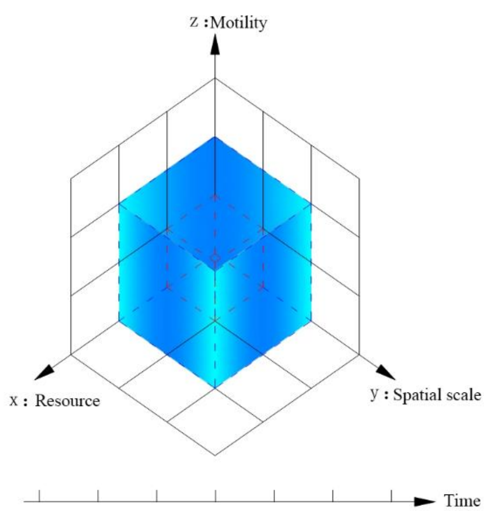

Fig. 2 - Concept of the social-ecological environment capacity of debris flow waste-shoal land, where the Z axis represents the activity, the X axis represents the resource, and the Y axis represents the spatial field. The space enclosed by the XYZ axes represents the social-ecological environment capacity of the debris flow waste-shoal land.

Firstly, it should be noted that normal operation means healthy and coordinated development between the natural and humanistic systems. This concept of normal operation comprises shared economic development, resource use, ecological protection, and social civilization in terms of total volume and development speed. Therefore, a feature of the SEEC of DFWSL is a significant emphasis on safety factors. Namely, if the system were affected by the environment and were at significant risk, the SEEC of the land would be affected seriously. Under significant threat, the SEEC would decrease to an extremely low value or even zero. Secondly, this concept avoids the disadvantage that the environmental capacity of other elements is expressed only by the size of the capacity. Buckley (1999) and Seidl and Tisdell (1999) pointed out that in ecological environmental protection, capacity study sometimes appeared meaningless, because if the study only focused on a maximum conceptually, eventually, it would lead the capacity study into a blind valley (Wall, 1983). Consider that if the concept of land capacity were reflected only by a quantitative relationship, it could not reflect the effect of the intensity of the motility of participants in the entire system. To use a simple comparative analysis: the damage to the DFWSL system would certainly be different between 10 people lying quietly versus 10 people jumping on the same debris flow waste-shoal land. If the quantity only were taken as the standard to measure the SEEC of DFWSL, the size of the SEEC of DFWSL could not be described accurately; therefore, the potential value of the development and use of the land cannot be determined. Furthermore, although DFWSL is generally flat, the interior of the system is heterogeneous. The area in the concept of the SEEC can refer to both the size and the location, as well as the density and the resource features of DFWSL. Therefore, the SEEC of an entire DFWSL comprises several secondary capacities.

2.1. A comprehensive analysis of SEEC for DFWSL

To illustrate the SEEC of the DFWSL, the structure and function of the DFWSL system must be understood. As a special land resource, the DFWSL system consists of the land itself and its carrying objects (flower, grass, trees, wood, humans, buildings, and animals) over the time dimension. The spatial structure of this system comprises a common system (grassland, woodland, construction land, and cultivated land), component structure (atmosphere, hydrology, plants and animals, and infrastructure), and a functional structure (aesthetic value, economic value, and adjustment feedback).

However, the relationship between the motility of the carrying objects in the system and the SEEC needs to be explained clearly. The social-ecological environment capacity of the DFWSL system is actually similar to a normal circuit system, in which the total power is fixed. The more equipped with electrical appliances, the more likely the circuit system will be too overloaded to break down. In addition, the SEEC of the DFWSL is dynamic and under the influence of various other attributes, such as its own properties (vulnerability, sensitivity, and resilience), the categories of the objects, and the activity manners and intensity of various motilities. Therefore, SEEC is more than a simple number. Motility serves as the vital component of the environmental capacity of the system, and, in particular, the effect of people on the natural environment.

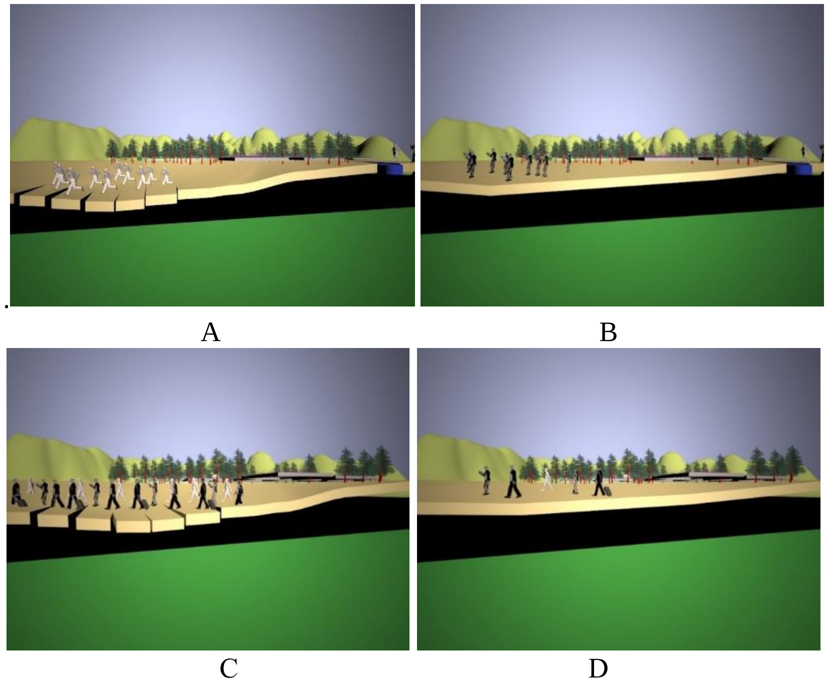

Fig. 3 - The relationship between system status and disturbance indicators. A&B is the contrast of activity intensity; C&D is the contrast of distribution density.

Generally, the concept of SEEC has three levels of meaning. These are (1) combinations of different forms of motility, which refer to the active objects and their behaviors. Notably, different behaviors by the same objects would have different effects on the DFWSL system. As already mentioned, the effect of 100 people standing quietly on the DFWSL and 100 people jumping on the DFWSL system would be entirely different (Fig. 3 A&B). Furthermore, the same action by different objects would have different effects on the land system. For example, the effect of 100 people and 100 cattle running on the same DFWSL would be different. Even different objects and different behaviors would have different effects on DFWSL or cause different damage to the DFWSL system. Accordingly, motility is considered important and is part of the concept of DFWSL SEEC. (2) Another is the temporal and spatial distribution of the active objects (Fig. 3 C&D). If motility were added to the time dimension, the tolerance of the system to the carrying objects would differ. The duration of the motility would determine the extent of the effect on the land. Therefore, measuring the SEEC of DFWSL has to consider the time factor. Similarly, the difference in the spatial distribution of the carrying objects in the system would cause a difference in the SEEC. Furthermore, the spatial distribution difference consists of the density difference and the spatial position difference. The differences in density are reflected in the following way. For the same DFWSL, if the motilities acted on an area of 10 m2 and an area of 100 m2, respectively, the damage caused by them would obviously differ. The differences in the spatial position are reflected in the following way. For the same land, the different positions of the carrying objects would affect the capacity of land differently. Therefore, the degree of spatial-temporal distribution is related closely to the SEEC of the DFWSL and, to some extent, reveals the dynamics, and variability of the SEEC. (3) As a special land resource, the DFWSL is affected by the mountainous environment and is highly sensitive, so that any insignificant activity could cause significant fluctuations in or even the collapse of the system. Therefore, the attributes of the land system itself (site conditions, resource endowments, and risks) must be considered in the SEEC of the DFWSL.

3. Social-ecological Environmental Capacity Evaluation Index System

It is imperative to construct an indicator system to gain a clear understanding of the SEEC of the DFWSL and to describe the SEEC qualitatively and quantitatively. Before establishing the indicator system, the following points must be clarified: (1) the guiding ideology of the construction of the indicator system, (2) the principle of the index system, and (3) the purpose of the evaluation (Fig. 4).

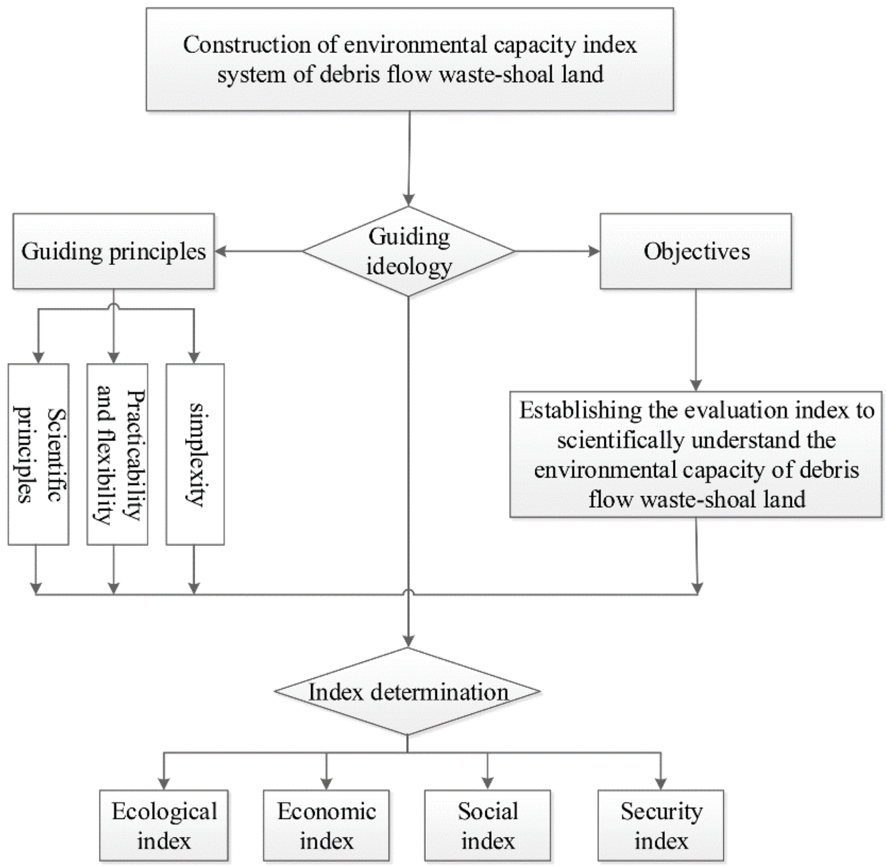

Fig. 4 - Construction framework of the environmental capacity index system for debris flow waste-shoal land (He et al., 2020).

The DFWSL system is a typical natural-economic-social compound system, i.e., it is a representation of the interaction between humans and the natural environment. The SEEC of the DFWSL system includes all aspects of ecology, economy, and society. Therefore, the selection of the evaluation index should be considered from these aspects (ecological, economic, and social). This was pointed out by Stomph et al. (1994), namely, that the evaluation of sustainable land use had to include an ecological, economic, and social evaluation. Therefore, the core of the evaluation process is a comprehensive ecological, economic, and social evaluation. Fu (1997) divided the land use system into various levels related to these natural-ecological and socio-economic aspects. At a lower level, natural-ecological factors (plant-crop) play a decisive role, whereas, at a higher level, social-economic factors (regional-national) play a significant role. Although natural-ecological factors and socio-economic factors play various roles at various levels, they are linked closely with each other and form an organic entirety. Therefore, it is necessary to take the three aspects, namely nature, economy, and society into consideration in evaluating the SEEC of the DFWSL. Furthermore, the establishment of the indicator system should reflect the way, intensity, after effect, potential, material flow, energy flow, and information flow between the natural and the social systems of the debris flow land, as well as the mutual hierarchical relationship.

Based on the aforementioned of the conceptual framework and equations, we evaluated the SEEC of the DFWSL from the perspective of nature, economy, and society. Furthermore, we considered the risk indicators of DFWSL, i.e., we comprehensively evaluated the SEEC of the DFWSL. The indicators of ecology, economy, and society are mutually restrictive and complementary, whereas the risk indicators play a decisive role.

Ecological sustainability is the basis for the sustainable use of DFWSL. Generally, ecological indicators (Table 1) refer to the natural attributes of the DFWSL and are representations of their inner environmental conditions, which include climatic conditions, water resources, biological resources, and site conditions.

Table 1 - Classification of ecological indicators.

Factors	Primary indicators	Secondary indicators
Climatic conditions	Solar radiation	Radiation intensity, seasonal distribution, sunny days, sunshine duration
	Temperature	Annual accumulated temperature, annual average temperature, monthly average temperature, inter-annual variation
	Precipitation	Annual average precipitation, seasonal distribution, annual variability
Site conditions	Soil condition	Fertility, structure, erosion
	Land scope	Area, boundary
	Geomorphological features	Geomorphological type, underlying surface characteristics, slope gradient, slope aspect, altitude
Water resources	Water resources quantity	Water network density, water area, inter-annual variation
Biological resources	Vegetation	Vegetation coverage, artificial/natural vegetation composition, dominant species, wildlife

Economic indicators reflect the economic benefits generated by the use of the DFWSL. The quantitative indicators of economic evaluation generally include profit, cost, yield, and the commodity rate, whereas the importance of the various evaluation indicators depends on the attitude of the decision-makers toward the DFWSL. These economic indicators relate mainly to economic resources, economic environment, and comprehensive benefits. Table 2 shows the classification.

Table 2 - Classification of economic indicators.

Factor	Primary indicators	Secondary indicators
Economic resources	Labor resources	Labor source, seasonal change in labor
	Sources of funds	Credit and loan mode, capital recovery

	Intellectual resources	Illiteracy rate, popularity level of education
	Power resources	Power resource type, available mode
	Efficiency	Land area/labor, capital/labor, input-output ratio
Economic environment	Market condition	Infrastructure, accessibility, product supply, and market distance
	Population environment	Population density, population mobility, population composition level
	Credit feasibility	Credit availability, usage mode, interest rate
	Traffic accessibility	Road level, quantity
Comprehensive income	Income	Total income, net income

Social indicators (Table 3) include mainly the macro level social and political environment, social acceptability, and public awareness. Most of these secondary indicators are difficult to quantify, but they are inconsequential and they can guide the future development and use of the DFWSL. As evaluation criteria for the SEEC of the DFWSL, social indicators reflect the current supply-demand relationship between humans and the land. The DFWSL is an integrated ecosystem that combines natural, economic, and social factors. Social indicators can, therefore, evaluate the SEEC of the DFWSL and the degree of exploitation and use of the DFWSL based on the natural and economic indicators.

Table 3 - Classification of social indicators.

Factor	Primary indicators	Secondary indicators
Macroscopic social environment	Overall plan	Medium- and long-term plan of country and region
	Policies and regulations	National, regional, and targeted policy
Social acceptability	Intentions of utilizing debris flow waste-shoal land	Individual and collective acceptance
	Development prospect forecast	Period of validity, preferential development targets
	Aesthetic value	Natural and artificial landscape

Risk indicators (Table 4) are unique indicators that distinguish the DFWSL from other lands, as the DFWSL is located usually in mountainous and disaster-prone areas where the ecology is fragile. The regional environmental composition of these areas is characterized by an unstable structure, high sensitivity, and susceptibility to disturbance. Under the dual influence of natural and human activities, the fragile habitat is extremely vulnerable to damage. Therefore, it is imperative to consider the risk prevention and safety guarantee measures, both of which are indispensable parts of the SEEC assessment system. If the risk were neglected, the ecological, social, and economic indicators established previously would not make sense.

Table 4 - Risk prevention and safety guarantee indicators.

Factor	Primary indicators	Secondary indicators
Risk index	Disaster	The magnitude and frequency of debris flow disasters
	Ages of debris flow fan	Ancient debris flow fan, newly formed accumulation fan
Security guarantee	Geotechnical engineering measures	Type of geotechnical engineering measure, functions, and effects
	Bioengineering measures	Type of bioengineering measures, functions, and effects

In the debris flow prone areas, due to the complex eco-geo-environment and great spatial heterogeneity, it is not reasonable to evaluate SEEC in ecological, social, and economic terms alone. The risk assessment is the premise of the development and utilization of the DFWSL, and the assessment of others is further considered based on the development and utilization. According to the present studies, we found that the contribution rates of a subsystem can be determined by the subjective methods (e.g. AHP, GRA), the objective methods (e.g. PCA, EWM, SPA), and the combination method (e.g. AHP-EWM). Each method has its advantages and disadvantages, and researchers can choose to depend on actual needs.

4. Discussion

4.1. The similarities and differences between the SEEC of DFWSL and similar concepts

The term environmental capacity derives from ecology and describes the environmental conditions and their limits of available resources that met the growth of the total number of organisms. Subsequently, the term was applied to various fields involving different elements (water, atmosphere, tourism, and land). The terminology used for the different elements of environmental capacity might be inconsistent. For example, the water environment capacity is also called the assimilative capacity, maximum allowable pollution capacity, or water body allowable waste discharge capacity. As another example, the capacity of the tourism environment, which has been a popular research topic, is also called the recreation environment capacity, and this term is gradually being replaced by the concept of the limits of acceptable change. Furthermore, the term population-food-land environment capacity is gradually being replaced by the term population-resource environment capacity. Despite the components of environmental capacity varying slightly, they represent the maximum allowable amount of every single item in the environment.

Concepts similar to environmental capacity are ecological carrying capacity and ecological threshold. Ecological carrying capacity (Smaal et al., 1998; Xie et al., 2011; Peng et al. 2019) refers to the ability of a particular ecosystem to accommodate a particular item. Ecological carrying capacity equals the environmental capacity in terms of this definition, but it emphasizes the system rather than a single factor. Both capacities attach increasing importance to the effects of socioeconomic factors on the environment, with the relevant research proceeding from easy to difficult and complicated. Moreover, research in both fields is paying increasing attention to the dynamics of mutual feedback between the carrying object or hosting object and the system.

The concept of the ecological threshold was first proposed in 1977 (May, 1977), referring to the breakpoint or transition state in the multiple homeostases of the ecosystem. It marks one state of the ecosystem transforming to another state or region (Muradian, 2001; Friedel, 1991; Dalei and Gupt 2019). This threshold is the boundaries of the state in terms of both temporal and spatial scope (Walker, 1995; Gompertz, 1825). Although currently, there is no widely accepted definition of the ecological threshold, a conclusion can be reached from various definitions, which is that ecological threshold is an unstable state, because it is the transition and buffering state of different states of the ecosystem. The ecological threshold can be either maximum or minimum, or even the intermediate value of the transformation. Ecological thresholds are related generally to the elasticity of ecosystems. The greater the elasticity of the ecosystem, the greater would be the ecological threshold of the ecosystem.

Therefore, compared with the environmental capacity and carrying capacity, the value of the threshold does not necessarily indicate the condition of the system. The ecological threshold can only reflect the possible degree of transformation of the two states of the ecosystem. As mentioned above, the ecological threshold is an indication of the size of the social-ecological environmental capacity of the DFWSL because the changing threshold indicates that the system is highly volatile and needs to transform from one state to another frequently. However, for ecologically vulnerable areas, it is likely that such transformation is irreversible. For example, the system would stay in a low-capacity state for a long time and would crash over time.

Briefly, (1) the scope of environmental capacity research is currently expanding continuously and the research on a single indicator has increased gradually to comprehensive research on multiple indicators. (2) The promotion of sustainable development has placed the focus of study on environmental capacity on the relationship between various elements, as well as the mutual feedback of the system, such as population-resource-environment. However, the study on the relationship between environmental capacity among the various elements (atmosphere, water, and tourism) paid more attention to the quantitative relationship. However, environmental capacity, especially the SEEC of DFWSL cannot be determined simply by quantity, as the variability of time and space, and the intensity response of the active subject is lacking. The concept of the SEEC of DFWSL proposed in this paper derives from the essence of environmental capacity and environmental threshold. It not only considers the flexible interaction of the DFWSL with the carrying objects but also considers the decisive role of risk factors in the use of the land, which has never been used before in the concept of the environmental capacity. We placed DFWSL in front of social-ecological environment capacity to emphasize that the social ecological environment capacity here is exclusively for the DFWSL and not for other normal land types. Furthermore, the conceptual system (including concepts and indicators), established according to the characteristics of the DFWSL was designed exclusively for this land type. This concept not only reflects the causes and effects relationship between factors and capacity but also reflects the dynamic change in it.

4.2. Relationship with other frameworks

Ecosystems and socioeconomic elements interact with each other, thereby forming a complex structure of social ecosystems (Yu et al., 2014；Cumming et al., 2005). The complex structure of the social ecosystem determines the complexity of its functions, and such a structure is more volatile and uncertain than a single social system or natural ecosystem would be. Currently, two well-known research frameworks for social ecosystems are being used, of which the first is the Driving force–Pressure–State –Impact–Response model (Ohl et al., 2007). This is a modified version of the Pressure-State-Response (PSR) model (FAO, 1997; Cao, 1999). Compared with the original, the improved model has more comprehensive coverage of the driving force, pressure and system status, and the impact indicators and response indicators of the social ecosystem. It has the following advantages, namely, (1) comprehensiveness, and, for the driving force, the pressure, and impact factor, all contain natural factors and human factors. (2) Emphasis on the cause-effect relation. In particular, the relationship between economic development and the environment. However, because of the broadness of the indicators, this model is a general model, with ambiguous classification and a lack of a specific target. Therefore, the framework is suitable for large-scale regional development research but has an insignificant effect on small-scale research. There are two main reasons why this model is not suitable for small-scale research. On the one hand, for small-scale research, data collection cannot meet the requirements of establishing the system, whereas, on the other hand, for a limited research scope, it is highly likely that a certain factor would dominate and the other indicators would therefore hardly play a role.

The second similar conceptual framework for social ecosystems is the PPD (press-pulse dynamics) model (Collins, 2011). The model presents an iterative framework, describing how human behavior exerts pressure on and influences the social ecosystem, as well as a dynamic process that describes the entire system. Similarly, the feedback given by the press and pulse of the social ecosystem, in turn, affects the social ecosystem values and human behavior. The conceptual framework emphasizes the effect and feedback of human behavior on the system, and the PPD model provides generalization assumptions that can guide comprehensive, long-term research.

Compared with the former two conceptual frameworks The SEEC of the DFWSL was more targeted and established for the use of DFWSL. It is based on the concept of the preceding two conceptual frameworks and pays more attention to the spatial and temporal distribution, as well as the dynamic changes in the various indicators, and the effect feedback. Furthermore, not only people are considered as carrying objects but also the animals within the system, as well as natural disasters (debris flows and landslides). The SEEC of DFWSL emphasizes the distribution pattern of the activities of the carrying objects in spatial and temporal scope. Therefore, it is a theoretical framework that contains the concept of dimension. Furthermore, the evaluation index is based mainly on the characteristics of the environment (an ecologically fragile area) in which the DFWSL is located. The integration of social and ecological indicators facilitates the full understanding of the DFWSL. In addition, considering the risk coefficient fully, the SEEC of DFWSL can be quantified based on the established index.

5. Conclusion

The DFWSL is a heterogeneous land system and therefore using the SEEC of the DFWSL to describe the status of this landform should not be evaluated only by the quantitative relation but also should consider the duration of the motility of the active objects and the location of the distribution in space. Simultaneously, the risk rate of such land should be considered carefully. The study of the SEEC of the DFWSL provides a theoretical reference and facilitates the realization of human influence in the exploitation and use of this land resource.

With the acceleration in urbanization and population growth, the demand for land is increasing. As regards difficult-use land resources (marginal land) in mountainous areas, it is necessary to improve the investigating and planning, strengthen the security and ecological construction, and balance rational allocation. Research perspectives should shift toward exploring land resources that were previously deemed unavailable, and It is possible to increase the demand for land use in terms of quality and quantity. In addition, for both social and biophysical scientists, it is necessary to have a conceptual system framework, including multi-disciplinary integration, multi-consideration, and multi-index combination, to provide a roadmap to social ecological environmental problems. The SEEC of DFWSL framework provides a clear roadmap to understanding the state of the DFWSL and draws attention to the interaction between humans and the environment in a complex environment.

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Declarations

Conflict of Interest /Competing interests： The authors declare no conflict of interest.

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