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Deciphering Land Use Transitions in Rural China: A Functional Perspective

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Abstract: Although research on land use transitions has gradually received widespread attention since its introduction to China at the beginning of the new millennium, the lack of a clear portrayal of the transitional characteristics and pathways of land use at the theoretical level has prevented this research from providing adequate support for the regulation and management of rural land use activities. This study aims to bridge this research gap from a functional perspective, since the transition of land system functions—also known as land use functions—heralds the completion of a regional land use transition. The methods employed included a literature review and theoretical analysis. The results show the following: (1) the relationships between land use morphology, land use multifunctionality, and land use functions transition (LUFT) were identified; (2) the connotation of the multifunctional agriculture transition theory was analyzed, and the applicability and limitations of drawing on the theory for researching the transition of land use functions in rural China elucidated; (3) a method for characterizing LUFT is proposed from the "state" and "quality"; (4) a theoretical framework for the LUFT was constructed and anchored in transition theory; and (5) it was summarized that there are three transitional pathways: weak-strong, strong-weak, and dynamic balance. In conclusion, while theories originating from the West can provide references for Chinese research, the significant difference between their socio-economic backgrounds necessitates reconstructing these theories in the light of the actual situation in rural China. The theoretical construction of land use transitions from a functional perspective can more clearly delineate the process, the trend, and the characteristics of the transitions of rural land use, thus offering valuable insights for the regulation and management of land use.

Keywords: land use functions transition; multifunctionality; land system science; coordinated development; research framework

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1. Introduction

Since the latter half of the 20th century, the increase in intensive land use activities resulting from the surge in population has triggered land use transitions on a global scale [1,2], and is already posing significant challenges to ecosystem functions [3,4]. Against this background, studies on land use transitions offer valuable insights for policymakers engaged in land use planning and management, aligning the region's social, economic, and environmental objectives [5].

Research on land use transition has its roots in the forest transition hypothesis at the end of the 20th century [6,7], with its related concepts formally proposed by Grainger in 1995 [8]. Land use transitions refer to the observed trend shifts in the time series of land use morphology within a region [9], which typically align with the conditions of regional development [8,10]. This concept was introduced in China by Prof. Hualou Long at the beginning of the 21st century [11,12] and has received widespread attention and flourished since then.

Extensive research has been conducted on various aspects of the land use transition, such as conceptual and theoretical frameworks [5,13–15], measurement methods [16,17], influencing mechanisms [13,18], and effects [19–21]. These studies cover various land use types, such as farmland [22,23], construction land [24,25], and rural settlement [26,27], at scales ranging from the national level down to the town and village level, thus initially forming a comprehensive research system that encompasses multiple contents, regions, types, and scales. In the early stage, many scholars focused primarily on land use transitions through spatial and quantitative lenses. However, it was not until Professor Long [28] differentiated land use morphologies into dominant morphology (e.g., quantitative and spatial distribution) and recessive morphology (e.g., soil quality, input, output, and property rights) that the importance of land system functions transitions became apparent. This is because changes in the dominant morphologies signify changes in the spatial arrangement of land use, while transitions of land system functions herald the completion of regional land use transitions [10]. The latter occurs due to changes in land use functions (LUFs), driven by the combination of the quality, property rights, management patterns, input, and output of land use [29]. The transition of land system functions is, therefore, also referred to as the land use functions transition [30,31]. Land use functions refer to the private and public products and services provided by different land use approaches, which include not only production functions related to the intended land use (e.g., production services such as agricultural and industrial production) but also social and ecological functions that are often unintended or intended by the land users (e.g., landscape, cultural heritage, biodiversity, and social stability) [31–34]. In addition, focusing research on land use transitions from a functional perspective is more conducive to understanding the state of land use and its changes, and it plays an important role in improving scientific decision-making on land resource management [29,32]. Consequently, research on the transition of land use functions, particularly the transition of farmland use functions, has been increasingly emphasized by scholars [9,33,34], with some initiating insightful studies from this functional perspective [34,35]. However, compared to research on the transitions of dominant morphologies (e.g., spatial structure), studies on the land use functions transition (LUFT) are still in their early stages. The analysis of its characteristics often adopts similar approaches and methods as those used in research on land use spatial structures [36,37]. Nonetheless, there remains a scarcity of theoretical elucidation on LUFT.

Generally, the current research on the LUFT has achieved notable progress; however, its theoretical exploration is still in its infancy and these findings have yet to offer adequate support for land use practices and management in rural China [10]. Therefore, there is an urgent need for the development of localized theories and analyses that take into account China's socio-economic background. Furthermore, it is essential to establish a methodology that can portray the characteristics and transitional pathways of LUFs, thereby rendering land use transitions a clear and tangible concept. This will enable it to become an important concept that can both highlight academic issues and be associated with practical decision-making [9].

2. Interrelationships between Key Concepts

2.1. Land Use Morphology and Land Use Functions

Land use morphology serves as a foundational concept for understanding land use transitions since these transitions entail changes in regional land use morphologies over time [8]. Land use morphologies can be classified into dominant and recessive morphologies. Dominant morphologies refer to the structure of an area, consisting of the main land use types in a certain period, characterized by both quantitative and spatial attributes; recessive morphologies represent invisible land use characteristics, such as soil quality, property rights, operation mode, inputs, and outputs, that are associated with the dominant morphology and can only be revealed through analysis, testing, detection, and investigation [38]. Changes in recessive morphologies of land use do not necessarily cause changes

in dominant morphologies, whereas alterations in the latter typically exhibit as the external manifestation of changes in the former's change.

Land use morphology typically aligns with the socio-economic conditions of an area at a particular stage of development, and the onset of a land use transition indicates a change in these conditions [8,39]. Thus, changes in socio-economic development goals may render existing land use morphologies as not being able to meet the needs of the new socio-economic stage [38]. This discrepancy often results in structural contradictions and functional mismatches within land use, inevitably leading to conflicts among multiple sectors of interest regarding both dominant and recessive morphologies [39,40]. In addition, according to the logical relationship of element–structure–function, it is well known that changes in land use elements lead to alterations in land use morphologies, which in turn reflect the structural change, such as spatial structure and right structure, of the land system. As the structural effects from changes in the land system intensify, the functional benefits or outputs of land use will also undergo transformation, leading to changes in LUFs [10,41]. In addition, changes in land use morphologies, whether dominant or recessive, are likely to impact directly the changes in LUFs that are susceptible to multiple factors such as the type and size of land use and land quality (Figure 1). Furthermore, the transition of LUFs means the completion of a land use transition on the regional scale [39].

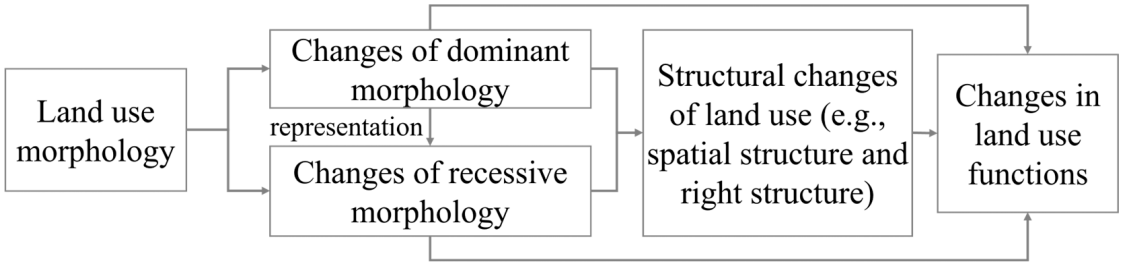


Figure 1. The relationship between land use morphology and land use functions.

Therefore, it is safe to say that land use morphology/structure and LUFs are two distinct yet closely related aspects for understanding land use transitions, but the latter contributes to a more profound understanding of land use transitions. This is because the change in land use morphologies heralds the beginning of a regional land use transition, while the transition of LUFs marks its completion.

2.2. Land Use Multifunctionality and Land Use Functions Transition

The concept of "multifunctionality" was originally applied in fields such as forestry, agriculture, and landscape [42–44]. Western scholars have explained agricultural multifunctionality from the perspectives of economics [45] and socio-culture [43], considering it both as a characteristic of agricultural production and as societal expectations for agricultural development. However, multiple outputs of a socio-economic activity often have both positive and negative externalities [42]. This suggests that "multifunctionality" is a demand- and outcome-oriented concept [46].

Rural land resources, serving as the material foundation and spatial carrier for most socio-economic activities and multifunctional agriculture, have been assigned higher value and functions due to growing social demand [38]. The utilization of rural land resources has expanded from purely agricultural land to encompass the entire rural land system such as construction land, agricultural land, and ecological land. Additionally, the functional demands have shifted from traditional productivism focused on production function to multifunctionalism, which includes public service, provisioning, and leisure functions. Consequently, rural land resources have entered a stage of multifunctional utilization [42,47,48].

In addition, the importance of rural land has become increasingly prominent with the growing population. Since the concept of sustainability was introduced in the 1980s,

research on multifunctionality has been beyond agriculture into areas such as rural development and land use, thereby strengthening the theoretical foundations of multifunctionality [47]. With the vigorous development of the Global Land Program (GLP), the concept of "multifunctionality" has received further attention in sustainable land use discussions [36], giving rise to derivative concepts such as LUFs and multifunctional land use. LUFs stand for the products and services provided by different land use modes, encompassing economic, social, and environmental functions [46], or production, living, and ecological functions [49]; multifunctional land use denotes the process of employing different land use approaches to meet the diverse demands for products and services from both private individuals and the public [42,46]. Currently, multifunctional land use serves as an important way to drive rural spatial restructuring, promote rural revitalization, and achieve sustainable development [50]. Furthermore, land consolidation has been proven to be a vital tool for realizing the multifunctional utilization of rural land resources [51,52].

The research on multifunctionality and LUFT is of great significance for understanding the complex interactions among different land use structures and for further enabling decision-makers to promote rural sustainable development through the implementation of effective land use policies [53,54]. However, many studies have conflated land use multifunctionality with land use functions since the introduction of the concept of multifunctionality in China. Actually, land use multifunctionality represents the result of multifunctional land use, a comprehensive characterization of LUFs, and a concretization of land use sustainability [46]. In other words, land use multifunctionality can be portrayed by the extent to which land use changes in a given region affect the sustainability of land system functions [55,56]. Moreover, the introduction of "multifunctionality" implies a paradigm shift in agricultural and rural development [57,58], with its evolution reflecting the transitional processes within agricultural and rural system functions [44]. Similarly, the evolution of land use multifunctionality, as a process reflecting the sustainability impacts of multifunctional land use on land system functions, mirrors the transitional trajectory and direction of LUFs (Figure 2). Therefore, the evolution of land use multifunctionality serves as a specific representation of the transition of LUFs, significantly enhancing the scope and depth of research land use transitions [14,37].

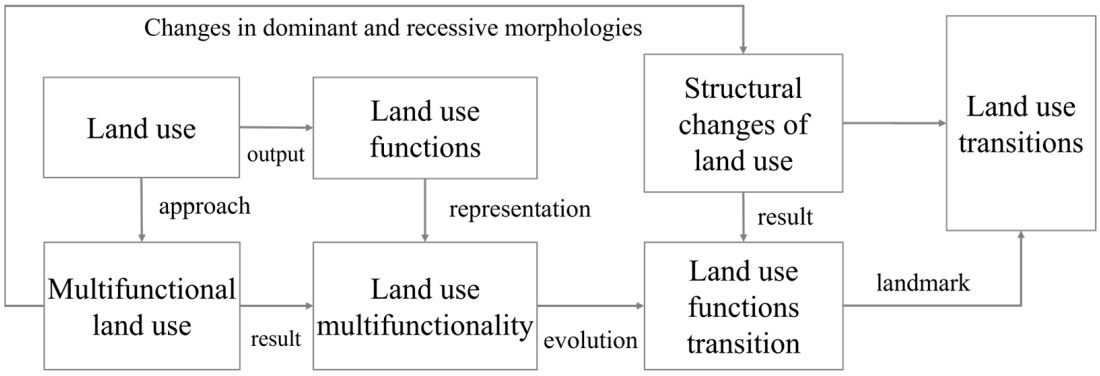


Figure 2. The relationship between land use multifunctionality and LUFT.

3. Multifunctional Agricultural Transitions Theory and LUFs Transition

3.1. Multifunctional Agricultural Transitions Theory

From the end of World War II to the 1980s, agricultural and rural development of European countries transitioned from a "productivism" model, which focused on economic benefits and product output, to a "post-productivism" model characterized by consumption and environmental protection [59]. However, this trend toward rural development with deagriculturalization has been challenged by traditional agricultural powerhouses in Europe such as France and the Netherlands. Meanwhile, "post-productivism" has been deemed more applicable to economically developed regions rather than universally applicable across all rural areas at different stages of development [57,60,61].

To ameliorate this epistemological impasse, Professor Geoff A Wilson, an internationally renowned human geographer, proposed the concept of "multifunctional agricultural regime" to explain and guide the development and transformation of agriculture [57]. Building on "transition theory", Professor Wilson then systematically introduced the "multifunctional agricultural transitions" theory [44], developing it into an important theoretical tool to deepen the understanding of agricultural and rural transitions [62–65].

The multifunctional agricultural transitions theory posits that agricultural multifunctionality is a concept for evaluating the development of multifunctional agriculture. It suggests that the evolution of agricultural multifunctionality is the result of stakeholders' behaviors under the joint influence of the ideologies of productivism and non-productivism, as well as the initial memory of the system, reflecting the transformation process of agricultural functions. By constructing an analytical framework for the "evolution of multifunctionality", i.e., multifunctional quality [63], in agriculture, this theory vividly demonstrates the complex transformation process of agricultural functions, creating a multifunctionality spectrum composed of weak, moderate, and strong qualities (Figure 3). This provides a powerful conceptual framework for addressing the nonlinearity, heterogeneity, and complexity often associated with the transitions of agricultural functions.

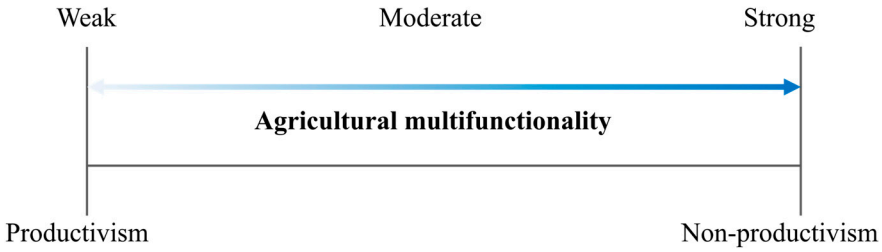


Figure 3. Spectrum of multifunctional agricultural transitions (Adapted from [44]).

3.2. Applicability to the Research on Land Use Functions Transition

As agricultural land is critical in terms of its area share and its socio-economic and ecological roles, it can be inferred that the theory of multifunctional agricultural transitions also applies to areas closely related to multifunctional agriculture, such as multifunctional rural development and land use [44]. Specifically, the evolution and transformation of land use structures and functions inevitably entail changes in the planting structure and utilization methods of agricultural land, thereby promoting the transition of agricultural system functions. Thus, multifunctional agricultural transitions, as the results of land use transitions, are also applicable to the studies on LUFT.

Building upon Wilson's work [57], some Chinese scholars have analyzed the characteristics of productivism and post-productivism countryside in the West, compared rural development between China and the West, and drawn insights applicable to rural China [66–69]. Additionally, some scholars have employed post-productivism concepts in empirical research on domestic agricultural and rural development [70,71], finding that certain features of post-productivism in Western rural areas are observed in economically developed regions of China, such as the eastern coastal areas [68]. Moreover, in terms of policy, China's agricultural and rural policies have transitioned from being primarily productivism-oriented [66] towards embracing multifunctional agriculture and rural development [72,73]. In addition, addressing land issues is crucial for solving China's "Sannong (countryside, farmer, and agriculture) problems" and promoting rural revitalization [74–76]. Although the LUFT throughout the country may lag behind policy transitions, in the practice of rural revitalization, multifunctional land use has become the prevailing trend in rural territorial development [58,77]. Thus, the theory of multifunctional agricultural transitions can be instrumental in uncovering the underlying patterns of the transition of LUFs in rural China, which is similarly a non-linear and heterogeneous process.

However, the transition from productivism to non-productivism in agricultural system functions does not fully align with the practical realities of China's national conditions. Non-productivism, which prioritizes social attributes and environmental protection, is characterized by de-commodification and low market participation [44]. This approach is not in line with the development demands of rural China, where ensuring food security and alleviating highly tense human–land relationships are topics that cannot be bypassed in discussing agricultural and rural issues [78,79]. An excessive emphasis on ecological protection in land use practices and management might exacerbate conflicts between providers and beneficiaries of ecosystem services [80]. Therefore, applying the ideologies of productivism and non-productivism directly to guide the development of rural China in the near future has inherent limitations. The multifunctional development of land use in rural China does not entail a linear transition between productivism and non-productivism paradigms but rather seeks a balance between these two ideologies.

In conclusion, while the multifunctional agriculture transitions theory holds significant implications for conducting research on the transition of LUFs in rural China, the substantial differences in socio-economic contexts between China and Western countries necessitate a grounded approach that considers China's specific conditions. We should draw upon and assimilate the general principles of Western research while constructing a theoretical framework tailored to the unique features of China.

4. Explaining the LUFT in Rural China

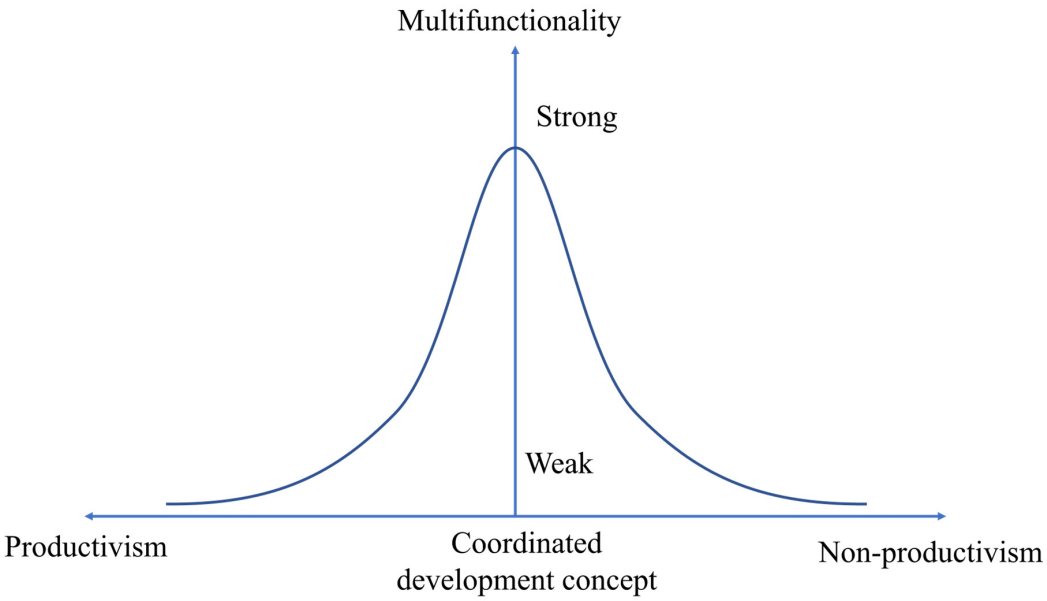
4.1. Connotation and Definition of LUFT

Based on the findings of previous researchers and the analysis of the current socio-economic situation and related policies[1] (see Notes) of rural China, it was found that, unlike Western developed countries, the highly tense human–land relation in rural China is a fundamental national condition as well as a critical premise for discussing China's agricultural and rural issues. The supply of LUFs, influenced by non-productivism which advocates for a return to the original ecology and is characterized by radical environmentalism, does not align with the demands of most areas in China. This study argues that the current land use practices in rural China are shaped by a combination of productivism and non-productivism[2], with most areas seeking strong multifunctionality by balancing these two ideologies. On this basis, this paper constructs a conceptual framework of land use multifunctionality, illustrating how the intertwining of ecological, living, and production functions creates different spaces of land use multifunctionality (Figure 4).

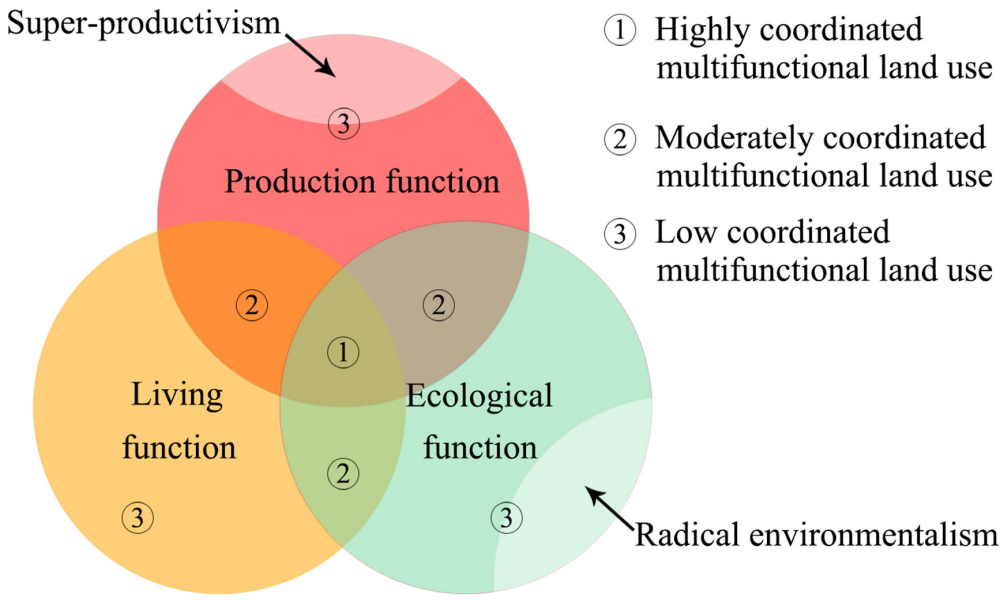
Currently, land use practices in rural China are searching for a point of harmonization between productivism and non-productivism to promote the multifunctional quality of land use (Figure 4a). The essence of enhancing the land use multifunctionality lies in optimizing the supply structure of LUFs, promoting the development of various functions, and guaranteeing their coupling coordination, so as to serve the revitalization and sustainable development of the countryside (Figure 4b). At the extremes of this spectrum, "super-productivism" and "extreme environmentalism" represent the far ends of productivism and non-productivism, respectively. Super-productivism prioritizes maximum economic returns, often at the expense of local ecological and social functions, while extreme environmentalism emphasizes de-production, advocating a return to the original ecology and rejecting the market economy. These extreme views are antithetical to the strong multifunctionality which emphasizes the coordinated development of different LUFs (Figure 5).

LUFT results from the combined effects of human activities and natural influences. Although these transitions have both positive and negative directions [44], the concept began to be endowed with some promises and meanings upon its introduction and development [39]. However, the definition of "positive" varies based on the development ideologies of humanity. The ideology underpinning this study emphasizes coordinated and sustainable development, distancing itself from both anthropocentrism and radical environmentalism. The coupling and coordinated development among the different land

use functions have been crucial for promoting the sustainable development of China [49]. Also, the transformation of a single land use function—for example, changing the agricultural production function to the residential function—cannot be treated as LUFT; LUFT refers to the overall optimization of the land system functions to achieve the coupling and coordinated development among various functions [29,34]. The purpose of LUFT, therefore, is to promote the coupling coordination among various land system functions, aiming to achieve sustainable development in rural China [81]. Accordingly, the quality of land use multifunctionality can be evaluated by the extent to which the coupling coordination among different functions, such as living and production functions, has been achieved, that is the coupling coordination degree of LUFs.



(**a**)



(**b**)

Figure 4. The conceptual framework of land use multifunctionality. (**a**) the change of multifunctionality under the influence of productivism and non-productivism. (**b**) land use multifunctionality and the intersection between production, living and ecological functions.

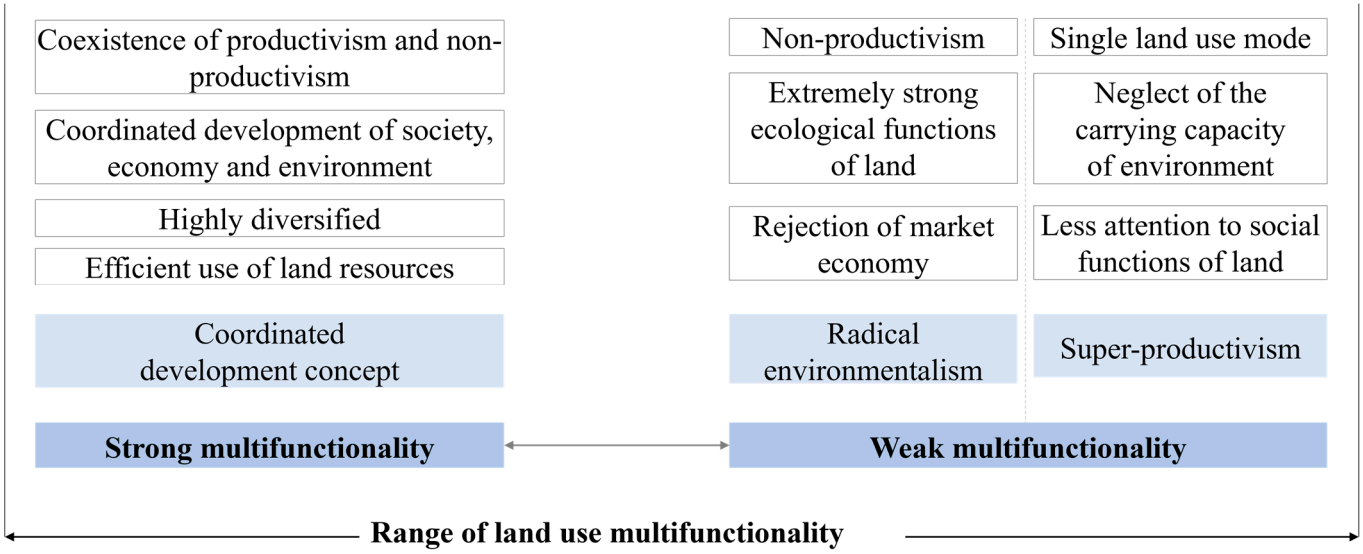


Figure 5. The range and characteristics of land use multifunctionality.

In addition, this study argues that the characteristics of LUFT can be portrayed through multifunctional state and quality of land use. Specifically, the multifunctional state refers to the supply condition of LUFs at a certain moment during the transitional period. It can be represented by functional intensity, mainly reflecting the breadth and depth of land use as well as the supply intensity of land use functions. Moreover, changes in the multifunctional state can reflect which ideology, e.g., productivism and non-productivism, has a greater influence on land use during a certain period. In addition, given that the current land use transition in rural China remains demand-oriented, land use multifunctionality, i.e., multifunctional quality [63] of land use at a given time, can also be adapted to characterize the state of LUFT. The essence of adopting multifunctional land use is to fulfill the needs of socio-economic development, thereby enhancing local resilience for sustainable development [63]. The multifunctional quality of land use reflects the impact of land use on local sustainable development; the stronger the multifunctionality, the higher the degree of positive effect. As mentioned above, land use transition in China has been advancing rapidly and has been recognized for its role in promoting coordinated regional development. In addition, the multifunctional state and quality, usually typically over time, correspond to the stage of socio-economic development of the region. It is because the state of socio-economic development is largely determined by the multifunctional quality and manifested in the multifunctional state. In this sense, the transition of LUFs can be seen as the evaluation of land use multifunctionality over time and the transitional pathway of LUFs in a given area can be presented by the moving trail of the multifunctionality of local land use.

Based on the above analysis, this study defines LUFT as the process wherein the land use multifunctionality of a given region shifts from one level to another over a certain period, driven by socio-economic change and innovation. This shift is accompanied by the change of multifunctional states. Additionally, the evolutionary trajectory of multifunctional quality of land use demonstrates the transitional pathway of LUFs.

4.2. Characteristics of LUFT

4.2.1. Land Use Function Intensity: Multifunctional State

Based on the above analysis, it is evident that the state of LUFs can be portrayed by the land use functions intensity (*LUFI*). Similar to the land use intensity [82,83], both of them can reflect the extent and depth of land use; the difference is that the land use intensity index is typically used to represent the urbanization level of a region [84], whereas the *LUFI* index specifically represents the supply capacity of LUFs of a region.

Following the "element–structure–function" framework, the study identifies LUFs based on land use structures in accordance with the Land Use Classification (GB/T21010-2017) [85] and field experience in rural China. From the multifunctional perspective, it is recognized that a single land use type typically serves multiple functions and produces various outputs [45–47]. The study, therefore, classifies land use types into four primary land use types and eight secondary land use types as well as categorizes LUFs into four primary functions and thirteen sub-functions, where the potential function lacks substantial or available uses and outputs. Additionally, given that the inconsistencies of the intensity of different land use types lead to differences in their corresponding functional intensity, the study divides land use intensity into five levels based on previous research findings [83,86] and assigns intensity coefficients to each major land use type in order to respond to the intensity of different LUFs (Table 1).

Table 1. Relationship between land use types and land use functions.

Land Use Types		Land Use Functions		Intensity Coefficient
		Primary Functions	Sub-Functions	
Agricultural land	Agricultural land (e.g., farmland, grassland, orchard, and aquafarm)	Production function	Agricultural production function	7
		Living function	Employment function	
			Heritage function	
		Ecological function	Maintenance function	
Construction land	Housing land	Living function	Residential function	8
	Public administration and service land	Living function	Public service function	10
			Heritage function	
			Educational function	
	Infrastructure land	Living function	Public service function	10
	Commercial service land	Production function	Commercial production function	8
		Living function	Employment function	
	Industrial and mining land	Production function	Industrial production function	10
		Living function	Employment function	
Ecological land	Ecological land, e.g., woodland, grassland, and water area	Ecological function	Provisioning function Supporting function Leisure function Maintenance function	2
Unutilized land	Unutilized land, e.g., saline-alkali land, sandy land, abandoned land	Potential Function	Potential Function	1

The *LUFI* index measures the intensity of LUFs across various land use types, offering insights into the functional supply capabilities of land use within a specific time. The formula for calculating *LUFI* is crafted to reflect the multifaceted relationships between land use types and their respective functional outputs, which is especially pertinent in assessing the influence of differing developmental ideologies like productivism. Based on the interrelationship between land use types and LUFs, the formula for the composite index of land use functions intensity is as follows (Equation (1)):

$$LUFI = \sum_{i=1}^{n} (A_1 \times C_1 + A_2 \times C_2 + \ldots + A_x \times C_x)/A \quad (1)$$

where *LUFI* is the composite index of the intensity of LUFs, A represents the total land use area, C represents the intensity coefficient, n is the number of land use function types under consideration, x refers to the number of major land use types that generates the i-th

function, and A_x is the area of x-th land use type that can produce the i-th function. The higher the value of *LUFI*, the greater the intensity of the functional supply of land use at its particular period, indicating the greater the degree to which its local development is influenced by productivism and vice versa.

4.2.2. Land Use Multifunctionality: Multifunctional Quality

Professor Wilson argues that the strongest multifunctionality of the agriculture and rural community is achieved when all three 'capitals' (i.e., social, economic, and environmental capitals) are equally well developed [63]. This scenario represents what he describes as the coordinated and coupling development of the three capitals. This concept parallels the idea in land use where the strongest multifunctionality is achieved when ecological, living, and production functions are harmoniously developed. Thus, the multifunctional quality of land use can be assessed by examining the degree of coupling coordination among these three functions. The steps of model construction are as follows:

1. Comprehensive Index of LUFs. Due to regional differences, there is no one-size-fits-all evaluation index system. A tailored approach is necessary to accurately reflect the unique characteristics of different areas. The construction of a comprehensive index involves several methodical steps. First, it is necessary to construct an evaluation index system of LUFs based on the understanding of the living, production, and ecological functions in the study area. Then, the values of each index can be obtained through various approaches because the multi-source approach ensures a robust dataset that captures the complexities of land use functions. For example, statistical yearbooks provide historical data, remote sensing images offer spatial distribution information, and field investigations contribute firsthand observational data. Subsequently, a combination of subjective and objective methods is used to assign weights to the indicators. Finally, based on the weights assigned to each indicator and sub-functions and the standardized values of these indicators, a comprehensive evaluation model (e.g., weighted sum method) can be selected to calculate the development indices a(l), b(p), and c(e) for the living, production, and ecological functions, respectively, and to derive the comprehensive functional index T of the study area (Equation (2)).

$$T = w_a \times a(l) + w_b \times b(p) + w_c \times c(e) \quad (2)$$

where T represents the comprehensive function level; l, p, and e, respectively, denote the weights of the living, production, and ecological functions; w_a, w_b, and w_c are the weights assigned to living, production, and ecological functions, respectively. Provided these three functions are considered to be of equal importance in the sustainable development goals, then $w_a = w_b = w_c = 1/3$ may be applied.

2. Coupling coordination degree. The coupling coordination degree model [81] (Equations (3) and (4)) is constructed to reflect the degree of coupling and the overall coordination status in the coupling relationship of the three functions:

$$C = \frac{3\sqrt[3]{a(l) \times b(p) \times c(e)}}{a(l) + b(p) + c(e)} \quad (3)$$

$$D = \sqrt{C \times T} \quad (4)$$

where C represents the degree of coupling, with values ranging from 0 to 1; the larger the value, the higher the degree of coupling. D indicates the coupling coordination degree, the value of which ranges from 0 to 1; a higher value indicates a higher level of coordination among the development levels of the three functions.

3. Multifunctional quality. According to the preceding analysis, it is evident that under the guidance of the coordinated development concept, the land use multifunctionality of rural China is more likely to reach its maximum value, referred to as strong multifunctionality. At the same time, the current land use transition in rural China

represents a process whereby multifunctional land use drives supply-side reforms to meet the demands of coordinated and sustainable rural development. This implies the multifunctional quality of land use, also known as land use multifunctionality (LUM), can be quantified by the coupling coordination degree among different LUFs. This measurement, denoted as D (i.e., the coupling coordination degree), serves as a direct indicator of LUM. Also, LUM takes values in the range 0 to 1, but it will not reach 0 or 1 because it is meaningless or nearly impossible to achieve.

The above models not only support a holistic view of land management but also underscore the importance of integrated approaches that consider the interdependencies of different land use functions. Such approaches are crucial for ensuring sustainable development in rural areas, facilitating a land use strategy that aligns with the overarching goals of environmental conservation, social stability, and economic growth.

4.3. Pathways and Modes of LUFT

The transitional pathways of LUFs are significantly influenced by the dynamics of LUM, which typically evolves in a nonlinear manner. This evolution suggests that regions are unlikely to remain in a state of extreme productivism/non-productivism for an extended period. Instead, the LUM fluctuates between 0 and 1, reflecting transitions between strong and weak states of multifunctionality (Figure 6). The transitional pathways of LUFs can be understood from the following which are theoretically anchored in transition theory.

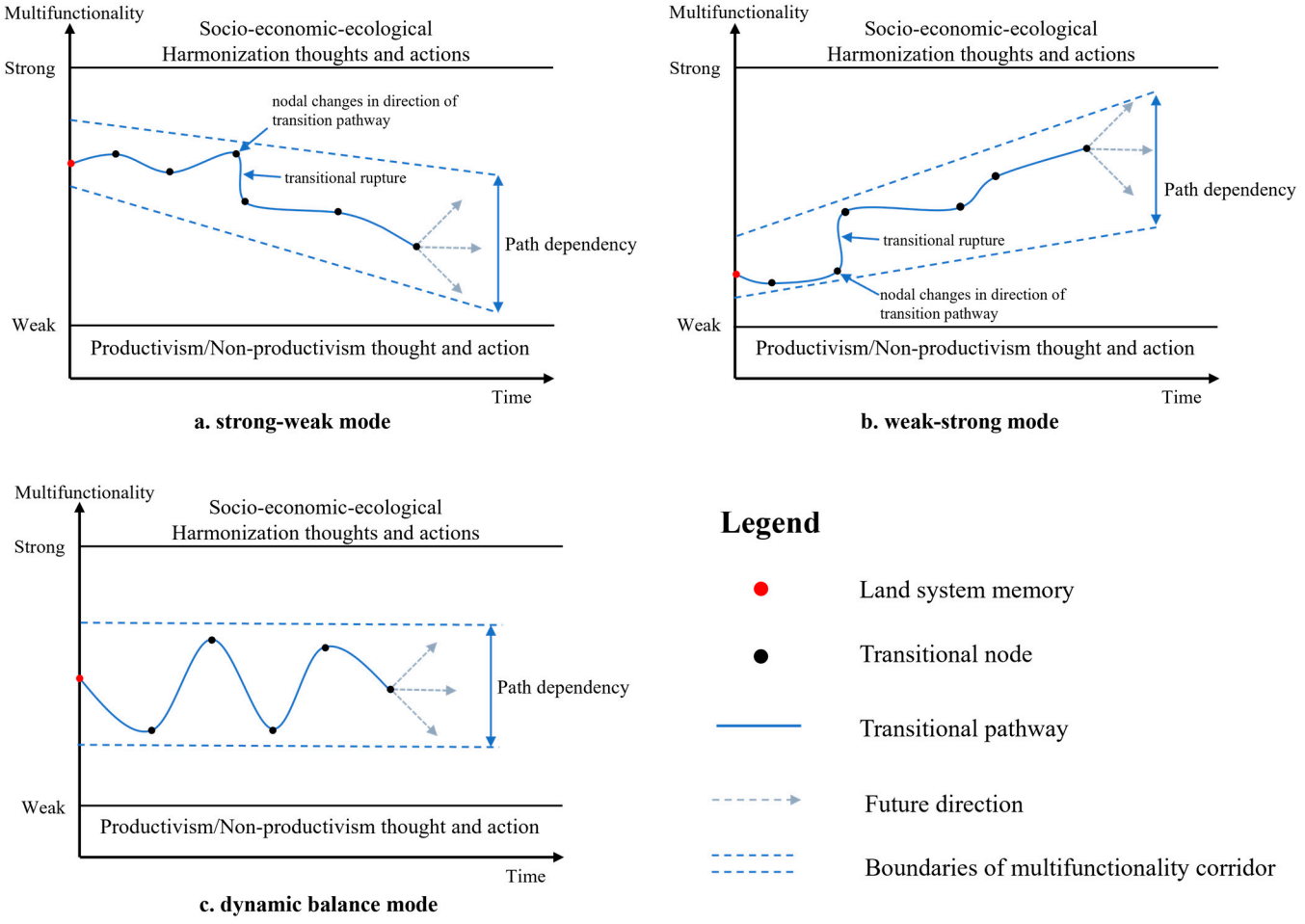


Figure 6. Pathways and modes of land use functions transition.

First, according to transition theory, it can be argued that there are certain key stages or periods in a regional land use transition (but never an "end point") and that any one of these stages may, in turn, be the starting point for the next land use transition [44,87,88]. Any land system, even the whole social system, will be at a specific starting point in a transition precisely because there is a history of multifunctionality trajectories that precede the starting point; that is, a system carries with it the memory of previous multifunctionality trajectories, that is, system memory [44]. Thus, there is an important notion of *land system memory* for the transitional pathways of LUFs. This memory, incorporating knowledge, experience, and regulations, is transmitted across generations or participants, significantly influencing future land use strategies. Additionally, in rural China, this is particularly relevant as land use is intertwined with socio-economic and ecological factors, leading participants to continuously negotiate their positions within a multifunctionality spectrum. This implies that transitional pathways of LUFs in rural China are long-term dynamic rather than static.

Second, the process of LUFT involves many notes that reflect the multifunctional quality of land use. These nodes are closely connected over time, forming the transitional pathway of LUFs. The nodes are defined within specific boundaries influenced by path dependence, suggesting that changes are typically confined to a range of probable outcomes [89,90]. Path dependence exists in almost any social system. In the case of land systems, the path dependence depends on the starting state of the land system in a given area as well as on the local socio-economic context and geographical conditions. The starting state (i.e., land system memory) usually has an obvious effect on the potential transitional pathways because, probabilistically, the probability for a land system located at a specific position within the multifunctionality spectrum to move away rapidly from that starting position is low [91]. However, the influence of the initial system memory diminishes as the land use process diverges from its starting point, increasing the range of decision-making options available. This means the shape and size of the multifunctionality corridor depend on the time span of the study and the starting point for assessing the next transition. Meanwhile, although the system memory has an important influence on the transitional path, land use multifunctionality may increase or decrease by jumps under the combined driving force of various factors, resulting in a directional turnaround in the transitional pathways of LUFs, also known as the transitional rupture [44]. This phenomenon highlights the importance of both external factors (such as policies, market forces, and regulations) and internal factors (like local leadership and community cooperation) in shaping land use transitions.

Third, as a part of the social system, the transition processes of a land system are typically more predictable than natural systems. This is because system actors can simplify transitional pathways by learning and adapting land use processes based on past experiences from the system memory. This, in turn, leads to non-deterministic transitions in land systems. Therefore, no two social systems will undergo identical transitional pathways, even if they share similar memories, socio-economic contexts, or geographical conditions. This results in a diversity of pathways of LUFT and the multiple possibilities for its future direction, driven by a mix of productivist/non-productivist ideologies and socio-economic–ecological considerations.

Although the transitional pathways of land use systems vary significantly, they can be generally categorized into three distinct modes based on the degree and direction of change in land use multifunctionality over time: strong-weak mode, weak-strong mode, and dynamic balance mode. Each mode reflects different dynamics and outcomes in the evolution of land use systems: The strong-weak transition mode signifies a situation where, in the initial stage of the system, the multifunctional quality is at a strong or moderate stage, but with the occurrence of transitional ruptures due to sudden or pivotal events, there is a noticeable and irreversible weakening trend in the LUM over a period of time. The decline in multifunctionality under this mode is typically driven by path dependency, where historical decisions and patterns constrain future changes, limiting the

ability to recover or enhance multifunctional qualities. The weak-strong transition mode, in contrast to the strong-weak mode, means one in which the multifunctional quality of land use is in a weaker state at the initial stage, but there is a notable upward break in the transitional pathway due to internal and external dynamics, such as innovative policy shifts, technological advancements, or significant socio-economic changes. Subsequently, there is a sustained upward trend in LUM for a certain period of time, showing resilience and adaptability despite potential temporary setbacks. The positive trajectory suggests effective responses to opportunities or challenges, driving improvements in land use multifunctionality. The dynamic balance mode is marked by fluctuations in the LUM throughout the study period, with the multifunctional quality remaining relatively stable when compared to the initial state. This mode indicates a state of equilibrium where changes in internal and external factors are effectively balanced, maintaining the status quo of multifunctionality. This stability can be seen as either a success in managing competing land use demands or a stagnation that prevents significant progress in any direction.

4.4. Case Analysis

A case study of two villages in rural China, where we conducted two field investigations in 2022 and 2024, is adapted to illustrate the above theoretical framework. Dazhai Village and Xiaozhai Village are two geographically neighboring villages of the Yao ethnic group located in Longji Town, Longsheng County, Guangxi, China. Both villages share similar natural and social environments and are situated deep in the mountains of southwest China. Historically isolated and impoverished, these villages primarily engaged in traditional rice farming and only gradually became known to the outside world in the 1980s. It was found to be a place of great natural and human resources, despite its extreme poverty. With the development of the socio-economy and the implementation of China's poverty alleviation policies, folklore characteristics of the Yao ethnic group and the terraced fields in this area were considered to be high-quality tourism resources that could be used to promote local development. In response to the central government's poverty alleviation policies, local initiatives in the 1990s focused on improving infrastructure, such as roads, to enhance accessibility and promote tourism based on the folklore of the Yao people and the scenic terraced fields. In this context, impervious surface roads reached Dazhai in 2003 and Xiaozhai in 2008, marking significant milestones in connecting these villages to external markets and visitors. Despite their proximity and shared backgrounds, LUFs in the two villages have undergone distinct transitional pathways in the aftermath (Figure 7).

In the year that the road access was realized, Dazhai village began to promote tourism through large-scale changes in land use. This not only alleviated the village's poverty but also greatly enhanced the local socio-economic conditions in a short period of time. Initially, a lack of funds restricted the village's ability to improve infrastructure and fully capitalize on the burgeoning tourism sector. However, in 2007, a strategic turn occurred when Dazhai Village entered into a cooperation agreement with a tourism company. This partnership facilitated significant infrastructure improvements, catalyzing a leapfrog growth in the multifunctional quality of land use. Subsequently, Dazhai implemented numerous measures aimed at terracing and ecological land protection, adhering to a philosophy of coordinated social, ecological, and economic development, which contributed to the continuous growth of the LUM in the following decade. For example, Dazhai Village in 2022 was recognized as one of the "Best Tourism Villages" by the World Tourism Organization (UNWTO), a testament to its exemplary practices of nurturing rural areas and preserving landscapes, cultural diversity, local values, and culinary traditions.

Similar to Dazhai, Xiaozhai Village initially followed a path of economic improvement and multifunctional land use enhancement in the years following the access to hardened roads. This trajectory led to the village being designated as a "Chinese Traditional Village" in 2016, recognizing its efforts to preserve cultural heritage. In 2017, Xiaozhai, with the help of the local government and enterprises, shifted focus to developing specialized village tourism, aiming to adjust and enhance the supply of land use functions further.

However, the mindset of focusing on economic development without paying enough attention to social and ecological safety in the past few years with the rapid economic growth and social transformation led to an accidental fire on 30 September 2018 that destroyed most of the traditional buildings inhabited by the residents in the village. In fact, this accidental fire disaster, according to on-site interviews, was caused by negligent waste management, that is, a fire in a garbage heap in the villagers' centralized living area. This tragic event drastically altered the village's transitional pathway, leading to a decline in land use multifunctionality and narrowing the possibilities for future land use development, especially as the challenges were compounded by the impacts of the COVID-19 pandemic.

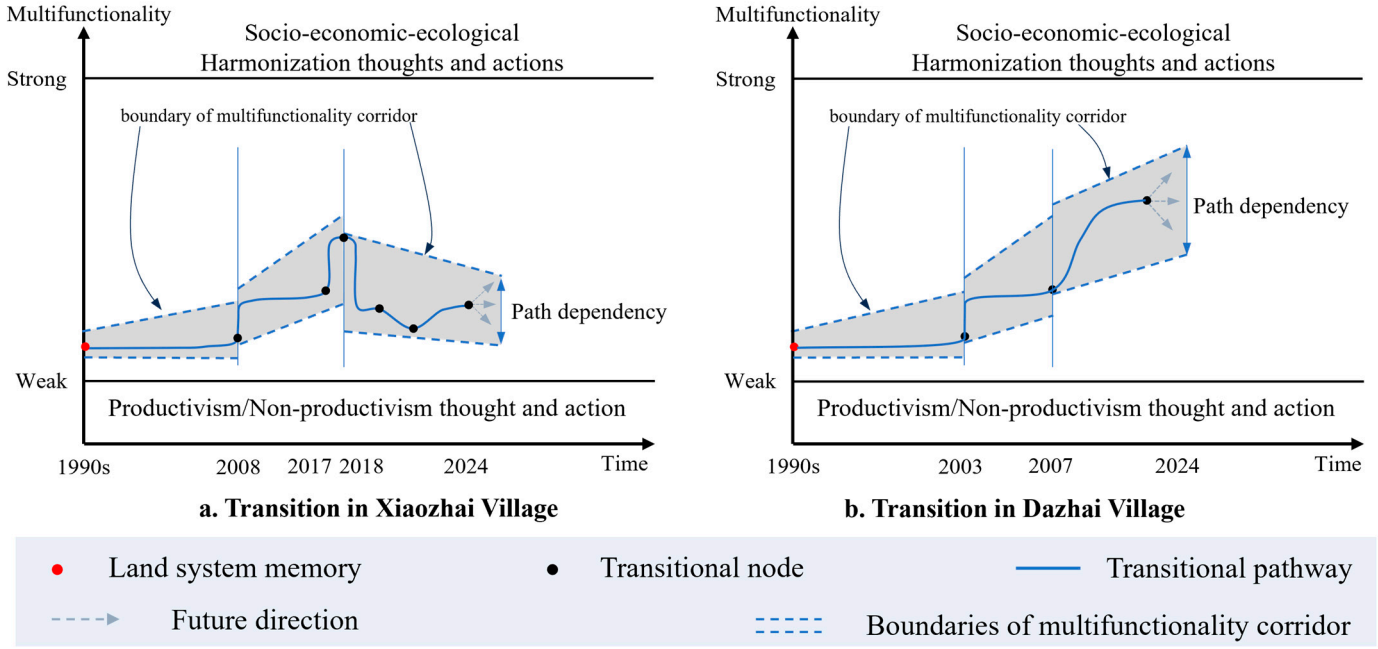


Figure 7. Schematic pathways of LUFT in two case villages. (Note: The values of multifunctional quality, i.e., land use multifunctionality, are represented by the relative position of the nodes on the *Y*-axis of the figure, but these values are estimated based on the results of field investigations rather than calculated values based on actual land use data and socio-economic data of these two villages during the past few decades, as some of the data have not yet been accessible. Although they are just estimates, changes in the relative positions of the different nodes are capable of reflecting the changing state of multifunctionality of two villages over time, their transitional pathways, as well as transitional modes and the change of modes at different times.).

The experiences of Dazhai and Xiaozhai Villages illustrate the complex dynamics of rural development and the critical role of strategic planning and risk management in shaping sustainable land use transitions. While Dazhai's approach shows how well-coordinated partnerships and a balanced focus on social, economic, and ecological objectives in multifunctional land use can lead to sustainable community upliftment, Xiaozhai's unfortunate setbacks highlight the vulnerabilities and potential consequences of rapid development without sufficient safeguards.

5. Discussion

5.1. Policy Implications

Land serves as the fundamental spatial carrier for socio-economic activities, making the effective management of land use systems pivotal for sustainable development [38]. In rural China, many challenges stem from irrational land use practices, which have historically led to mismatches between the supply of and demand for land use functions [54]. These

mismatches often manifest as overexploitation or underutilization of land, negatively impacting both ecological integrity and community well-being.

The transition of a land system is fundamentally about evolving the supply-demand relationship of land use functions towards greater multifunctionality. This involves moving from weaker states, where land use is less optimized and possibly more detrimental to development, to stronger states characterized by enhanced multifunctionality. The development of effective management and control measures to facilitate such a transition is critical to achieving coordinated regional development, as they contribute to the rural revitalization and integrated urban-rural development [39]. Additionally, the contrasting outcomes of these two case villages underscore the need for comprehensive planning that includes robust risk management strategies and sustainable practices to safeguard and enhance the multifunctional quality of rural land use. Specific measures that could be implemented in rural land use management are outlined as follows.

First, land use approaches such as comprehensive land consolidation can be applied to facilitate the multifunctional use of land resources, so as to meet increasing functional demands [51,92,93]. Second, the real-time monitoring, tracking, and scenario forecasting of the operation of land systems can be achieved provided we can rationalize the integration of state-of-the-art techniques, such as artificial intelligence, 3S technology (RS, GPS, GIS), and big data [39]. This integration enables the rational design of land use programs and the prediction of the comprehensive impacts associated with land system operations, i.e., the evaluation of LUM. Monitoring and analyzing the value of LUM is crucial for assessing the progress toward achieving strong multifunctionality. It helps in identifying areas where improvements are needed and in guiding policy adjustments to enhance the overall sustainability and efficacy of land management practices. Third, achieving the benign transition of LUFs relies on core strategies such as the regulation of land use practices and the supervision of the land market, which are instrumental in ensuring a stronger multifunctional quality. This is accomplished by scientifically allocating land use quotas and adjusting land use intensities based on comprehensive evaluations of LUM. Additionally, decision-makers need to adapt policies and measures to changes in land use morphologies and multifunctional states while emphasizing the concept of coordinated socio-economic–ecological development in planning and management, thereby optimizing the supply structure of LUFs to meet the evolving requirements of regional socio-economic development [39,94]. This has been evidenced in Dazhai village. Furthermore, protective measures, and timely alternatives after the events, are needed to prevent unexpected events from leading to transitional rupture, so as to avoid causing irreversible impacts on the direction of transitional pathways. For example, the recovery and renewal of multifunctional land use in villages like Xiaozhai will require breaking through the existing path dependence barriers, necessitating concerted efforts from both local stakeholders and external partners to re-establish a resilient and dynamic development pathway. These strategic approaches are essential for maximizing land value output, optimizing the allocation of land resources for different purposes, and facilitating rural revitalization while mitigating urban-rural disparities.

5.2. Contributions and Future Research

This study contributes significantly to the discourse on rural land use management by integrating theoretical constructs with empirical research and localized context analysis, offering actionable insights for policymakers and stakeholders involved in land resource management in rural China. Specifically, there are four main innovations and contributions. First, unlike traditional studies that interpret land use transitions mainly in terms of spatial and quantitative aspects, this study emphasizes understanding these transitions from a functional perspective. This approach allows for a more nuanced understanding of the relationship between land use practices and regional sustainability, offering deeper insights into how land functions affect developmental outcomes. Second, on the basis of multifunctional agriculture transition theory, this study constructs a theoretical framework tailored

for LUFT in the Chinese context. This framework serves to identify, measure, and describe the multifunctional states and quality of land use, providing a methodological approach to characterize these transitions. In addition, the article anchors its explanation of LUFT within the broader transition theory rooted in political economy and employs a comparative case study of two villages in China to illustrate the theoretical part. This approach strengthens the theoretical foundation of land use transitions. More importantly, compared with other studies on LUFT [34], this research simplifies the theoretical framework of LUFT, combs the mathematical logic behind the transitional pathways, and succinctly summarizes the transitional modes. This not only clearly depicts transitional characteristics and pathways that have been overcomplicated in some studies, but also enables land use transitions, an important concept that bridges academic research and practical decision-making. In summary, the innovative approach of this article lies in its holistic and immediate view of land use transitions, emphasizing the multifunctional characteristics of land use and the critical role of land use functions transition in achieving sustainable land management. By focusing on the functional aspects of land use, the study contributes to a more effective and sustainable approach to rural land development and management.

It's essential to emphasize that the theoretical analysis of LUFT presented in this paper is specifically tailored to the context of rural China. While this framework provides valuable insights that may serve as a reference for research in other developing countries and regions, it is not universal. The adaptability of this framework to other contexts depends on local conditions and may require significant modifications. Meanwhile, the land classification standards and functional intensity coefficients, integral to the application of this framework, may need to be adjusted according to the actual situation in specific case studies. Such adjustments ensure that the theoretical concepts proposed here are relevant and effectively applied to diverse geographical and socio-economic settings. In addition, this study, while proposing a theoretical framework for understanding land use transitions from a functional perspective and employing a case study approach to illustrate this framework, does not delve into the mechanism analysis and quantitative empirical research of these transitions. Understanding the underlying mechanisms that drive land use changes is crucial for deepening the theoretical and practical implications of LUFT, while quantitative methods are essential for testing the validity and reliability of the theoretical propositions and for providing statistically sound conclusions. Therefore, future research in this domain should aim to expand these theoretical insights through detailed mechanism studies and robust quantitative analyses. Such efforts will enhance our understanding of the dynamics of land use functions transition and improve the generalizability of the proposed framework.

6. Conclusions

This study, based on a systematic review of research on land use transitions, reveals a lack of clear characterization of its transitional characteristics and pathways at the theoretical level, which undermines the effective standardization and management of land use activities. The concept of land use transition is explored both structurally and functionally: structural changes mark the onset of regional land use transition, while the transition of land use functions signals the completion of a transition cycle. Therefore, investigating land use transitions from a functional perspective is particularly valuable as it unveils the intricacies of these transitions and aids in enhancing scientific decision-making regarding land resource management. Subsequently, the intricate relationships between land use morphology (both dominant and recessive), land use multifunctionality, LUFs, and LUFT are elucidated to provide a framework to comprehend how changes in the socio-economic backdrop influence land use structures and functions. Meanwhile, this study reviews the connotation of multifunctional agricultural transitions theory and examines its applicability to the research on land use function transitions within the socio-economic context of rural China. Finally, a scientific analysis of the LUFT is provided from four aspects: connotation and definition, characteristics, pathways, and modes, as well as case analysis. The main conclusions are as follows:

1. Given the close relationship between agricultural development and rural land use, the multifunctional agricultural transitions theory offers an apt lens through which to decipher land use transitions in the multifunctional background. However, the significant differences in socio-economic backgrounds between China and the West necessitate grounding our approach in the Chinese context. This involves integrating general principles from Western research while adjusting them to meet the unique characteristics of China, thus developing a theoretical analytical framework that is both relevant and practical.
2. In the Chinese context, LUFT refers to the process, under the joint influence of productivism/non-productivism and coordinated development ideologies, by which the multifunctional quality of land use, i.e., land use multifunctionality, in a specific region shifts from one level to another over a defined period driven by socio-economic change and innovation, which is accompanied by the change of multifunctional states and quality of land use. Among them, the multifunctional state is portrayed by the composite index of function intensity (i.e., *LUFI*) within the study area; multifunctional quality, i.e., land use multifunctionality, is measured by analyzing the coupling coordination degree between ecological, living, and production functions of land use, with values between 0 to 1 representing the range of multifunctionality spectrum from weak to strong. In addition, the evolutionary trajectory of multifunctional quality of land use represents the transitional pathway of LUFs.
3. Similar to the multifunctional agricultural transition, LUFT is anchored in transition theory. Any LUFT begins at a specific historical point and is influenced by the land system memory of past multifunctionality trajectories. While the impact of this historical context diminishes over time, changes in the nodes that make up the transitional pathway usually occur within specific boundaries defined by path dependence. Nevertheless, the transitional pathway may experience ruptures due to significant events, leading to directional shifts. This underscores that the transitional pathways of LUFs in rural China are dynamic and diversified, offering multiple possibilities for their future directions.
4. Transitional pathways, based on the degree of change in the land use multifunctionality in a given time, can be categorized into three modes: strong-weak transition, weak-strong transition, and dynamic balance. Many regions exhibit a trend towards strengthening land use multifunctionality by balancing productivism and non-productivism ideologies, i.e., promoting the weak-strong transition of multifunctionality with coordinated development ideology. Enhancing the land use multifunctionality, i.e., pursuing weak-strong transition, involves optimizing the quality of LUFs from the supply side, which supports comprehensive local development and ensures harmonized coordination among different sub-functions. This strategic approach contributes significantly to achieving national strategies such as rural revitalization and urban–rural integration.

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Conflicts of Interest: The authors declare no conflicts of interest.

Notes

[1] From the *Recommendations of the Central Committee of the Communist Party of China on the Formulation of the Eleventh Five-Year Plan for National Economic and Social Development* promulgated in 2005 to the *Recommendations of the Central Committee of the Communist Party of China on the Formulation of the Fourteenth Five-Year Plan for National Economic and Social Development and the Visionary Goals for the 23rd Five-Year Plan* promulgated in 2021, China's approach to territorial spatial development has been shifted from a predominantly production function to a multifunctional and integrated development mode, and it is committed to the promotion of the coordinated development of the economy, society, ecology, and culture.

[2] This study follows the productivism/non-productivism model proposed by Professor Geoff A. Wilson in the multifunctional agricultural transition theory, which argues that post-productivism is a product of the process of transition from productivism to non-productivism.

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