Review

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Review

A Conceptual Framework for Sustainable Development of Ecosystem Services in Rice-Fish-Duck Forests: Systematic Literature Review

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Abstract: Agroforestry with a sustainable model of production is considered to be an effective solution to the unsustainability of the existing model in agricultural production, and it is also an important topic for ecosystem services and sustainable development goals to improve human well-being. In addition, existing literatures confirm that the importance of forest functions in increasing agricultural production and maintaining agro-ecological sustainability. The "rice-fish-duck-forest" is an important representative of the agroforestry complex ecosystem because of its unique management mechanism and characteristic social culture. As a result, "rice-fish-duck-forest" ecosystem services are beginning to be studied. In the absence of a systematic scientific understanding of the ecosystem services of "rice-fish-duck-forest", there are potential challenges to its sustainable development. This study thoroughly analyzed the current literature on rice-fish-duck-forest ecosystem services in order to have a more thorough grasp of it and to be more sustainable. This research found that research on the ecosystem services of "rice-fish-duck-forest" involves four themes: "regulational", "ecology", "economy", and "socio-culture". Deforestation, socio-cultural marginalization, and Low community management participation are the three main issues facing the "rice-fish-duck-forest" ecosystem service. To address these issues, this paper builds a framework for the sustainable development of rice-fish-duck-forest ecosystem services within the context of current management frameworks for agriculture and forestry, and further discusses its relevance to the Sustainable Development Goals. This study will provide a theoretical decision-making guide for the transformation of agriculture to agroforestry and the sustainable development of agroforestry.

Keywords: agroforestry; rice-fish-duck-forest; ecosystem services; sustainable development

1. Introduction

Agricultural systems are one of the most extensive forms of land use globally, covering 36.5 percent of the global land area [1,2]. It has been shown to provide a wide range of functions and services to the population, such as the production of food, fiber, feed, and medicines [3,4]. The Green Revolution, which introduced new technologies and policies to increase food crop yields in developing countries, began in the 1940s as a response to the problems posed by rapid population growth. This movement towards intensification of agriculture eventually led to the gradual unsustainable of current production patterns [5,6]. For example, the extensive use of pesticides and fertilisers and the intervention of industrial technology [7]. On the one hand, that has increased food production and productivity to a certain extent and promoted agricultural development [8]. On the other hand, this intensive mode of agricultural production has exacerbated existing social, economic and ecological problems [9–11]. For instance, in India, where agriculture is under pressure from water scarcity in many regions, water-consuming crops were introduced during the Green Revolution, resulting in the loss of nearly 100,000 indigenous rice varieties and seriously affecting the sustainability of traditional agriculture [12–19]. It is widely recognized in the academia that existing production patterns need to be transformed in a more sustainable way, in order to cope with the above impacts [20–22].

To date, agroforestry is increasingly being discussed as an effective solution for modern agriculture [23,24]. Compared to other production methods like intense monoculture farming and slash-and-burn, agroforestry has a better potential to provide high yields and preserve ecological stability in a variety of ecological and socioeconomic contexts across the world [25,26]. In addition, the Millennium Ecosystem Assessment noted that sustainable agroforestry can meet human needs for food and fuel, and contribute to the conservation of biodiversity [27]. Agroforestry is essentially a combination of agriculture and forestry [8]. It is the intentional use of woody perennials (trees, shrubs, palms, bamboos, etc.) in a particular form, e.g., spatial arrangement or chronological order, on the same land management units as crops and/ or animals [25,28]. Yet, its ultimate purpose is to produce food, instead of generating/creating trees. Agroforestry is therefore an important complement to existing ecosystem services. For example, timber production and water supply in provisioning services, carbon sequestration, water retention, soil conservation and biodiversity protection in regulating services, and forest recreation, entertainment and cultural and religious services in cultural services [29–31].

Moreover, forests could provide multiple functions within existing ecosystem services [32]. Forest functions (FF) are terms used to define the link between forests and people, which is related to and vital for community livelihoods [33,34]. For instance, the biological diversity provided by forests is a source of support for the livelihood security of surrounding communities [35]. FF also plays an important role in increasing agricultural production and maintaining agro-ecological sustainability [36]. For instance, forests play a key role in terraced farming systems by controlling water supply, lowering hydrogeological hazards, providing windbreaks, preventing soil erosion, regulating the climate, providing adequate habitat for crops, and fertilizing them [37–39]. Similarly, FF also fundamentally support the achievement of the Sustainable Development Goals (SDGs), such as providing livelihoods for populations to eradicate hunger (SDG2); increasing employment (SDG8); conserving biodiversity (SGD15); hydrological cycle (SDG6), etc. [40–42]. Likewise, in the Globally Important Agricultural Heritage Systems (GIAHS) project, forests and agroforestry complexes have important multifunctional roles in almost half of the sites [43].

The "Rice-Fish-Duck" (RFD) agro-ecosystem is an important component of the GIAHS, it has high ecological, socio-cultural and economic values [44–46]. The rapid expansion of land for construction and the development of terraced tourism at the expense of large areas of forest above the system has led to severe soil erosion, destabilising the RFD ecosystem and affecting the sustainability of RFD ecosystem services (RFDES) [47]. However, it was found that the Hani terraces in China's Yunnan Province serve as a complementary example of how RFDES can also be carried out in a sustainable manner. The reason for this is that they systematically manage forests, terraces, water and villages as a whole [48]. Additionally, they created a sustainable rice farming organism and harmonized the interactions between the components [49]. Therefore, agroforestry systems will contribute to environmentally friendly practices for restoring agricultural landscapes and land management strategies with high benefits [50].

In this regard, co-management of forests and terraces is an important process in the transition from RFD agricultural systems to rice-fish-duck-forest (RFDF) agroforestry systems. Research on the ecosystem services provided by RFDFS has been widely discussed and validated. Examples include a proven role in restoring degraded ecosystems in RFD areas, providing additional economic benefits to First Nations, such as increased agroforestry products and tourism revenue [48]; Socio-cultural benefits include food and livelihood security, natural beauty, religious culture, and so forth [51]. However, RFDFES was found that it is not a complete concept, forest ecosystem services were treated as a complement to RFDES, and there was fragmentation of RFDFES. This leads to our research question: i). what is the RFDFES in the context of sustainable development? ii). what are the recurring issues for RFDFES in interdisciplinary discussions? iii). what is theoretical framework to integrate the themes, content and objectives of RFDFES to support the sustainable development of RFDFES, and iv). whether this framework could contribute to the achievement of SDGs.

Given the above, this article employs a systematic literature review (SLR) approach, to answer the research questions and fill the knowledge gaps. It could enhance the overall understanding of RFDFES knowledge. From a global perspective, the RESEARCH focuses on the current research themes of RFDFES, summarises and analyses the specific research progress that has been made in RFDFES, and extracts the common problems that exist in the sustainable development of RFDFES. The RFDFES sustainable management framework is then built to address these concerns and is compared to the SDGs to investigate the framework's role in assisting in the accomplishment of the SDGs.

2. Materials and Methods

The SLR analyzes specific issues or explores specific hypotheses via critical review, not merely summarizing 'all the information' about a subject, in order to eliminate systemic mistakes and effectively integrate facts and views from different disciplines [52–54]. This paper, in order to gain a more thorough understanding of RFDFES and to support its sustainable development, systematically compiles and analyzes the literature related to RFDFES, identifies the pertinent research themes of RFDFES, and builds a framework for sustainable management of RFDFES in conjunction with existing frameworks for the sustainable management of agriculture and forestry.

In this way, this study suggests the following methodological steps previously employed by Petticrew and Roberts [52]: i). depict the important components of RFDFES in the context of sustainable development; ii) explore the solutions to the identified problem; iii) conduct a comprehensive literature search to locate publications relevant to the research question; iv) screening of search results against inclusion and exclusion criteria; v) Evaluate articles related to the topic based on selected literature; vi) synthesize the outcomes from the literature and extract research data; and vii) analyze the results of the extracted data (see Figure 1).

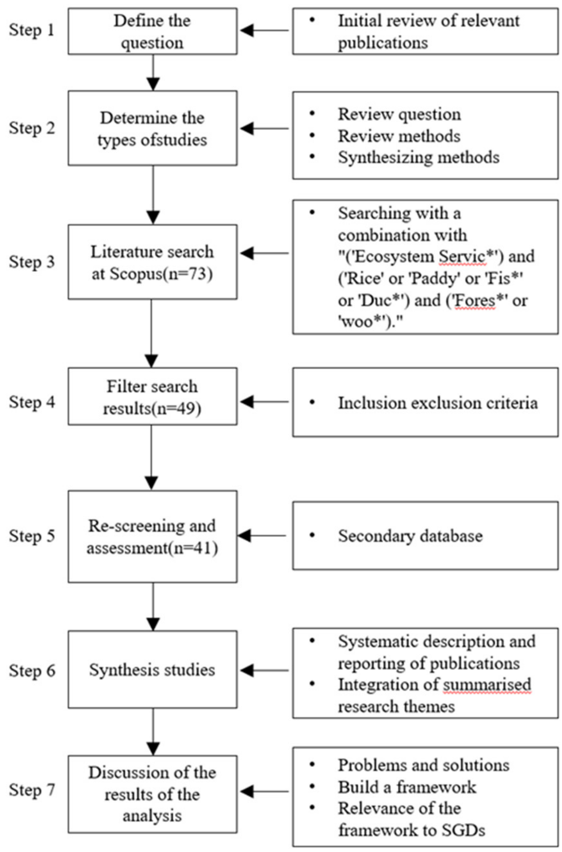

Figure 1. Research methodology.

2.1. Search and Appraisal

Based on the research questions in Steps 1 and 2, relevant keywords were identified (steps 3, 4, 5), including "ecosystem services", "rice", "fish", "duck", and "forest". The search string "title-abstract-keyword": "(" Ecosystem Servic*") and ("Rice" or "Paddy" or "Fis*" or "Duc*") and ("Fores*" or "woo*")" was used to search article in Scopus, 73 publications were retrieved. To minimize the ambiguity and ensure accuracy, three researchers finalized 41 publications according to the criteria in Table 1.

Table 1. Publication inclusion and exclusion criteria.

Step	Publications	Process
1	73	Publications that were retrieved
2	66	Publications not in the Environmental Sciences, Agricultural and Biological Sciences, Social Sciences are excluded（n=7）
3	50	Publications that are not articles, reviews are excluded（n=6）
4	44	Publications with keyword frequencies below 4 were excluded（n=6）
5	49	Publications that are not in English are excluded（n=5）
6	41	Publications not related to the topic of this review（n=8）

2.2. Synthesis

To identify and classify core elements from which information and conclusions might be deduced, we carefully reviewed the subjects and contents of 41 articles (Step 6). We found that RFDFES involves research on four core elements: ecological, economic, socio-cultural and regulational (Figure 2) [55–57]. The categorization of economic and ecological service functions and the debate of service valuation remain the key areas of attention for current RFDFES research, and there are gaps in the socio-cultural and managerial elements of RFDFES. We will go into the socio-cultural and regulational aspects in the discussion section to more thoroughly elaboration.

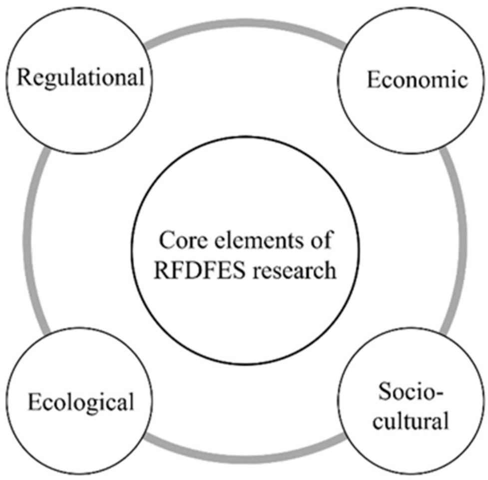

Figure 2. Core elements of the RFDFES study.

In Step 7, we discussed the problems in the RFDFES study, combined with the existing agricultural and forestry management frameworks, constructed a sustainable management framework for RFDFES. It consists of 4 themes, 10 sub-themes, and 29 indicators for management (3 sub-themes, 6 indicators), ecology (2 sub-themes, 7 indicators), economy (2 sub-themes, 6 indicators), and socio-culture (3 sub-themes, 10 indicators). Furthermore, Its relevance to SDGs is further discussed.

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2.3. Report

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3. Results

The results of the study are presented in the following order. i) describing the basic characteristics of the analysed publications, including year of publication, geographical distribution, and periodicals in which they were published, and ii) summarising and categorising the themes in the publications that are relevant to the research questions.

3.1. Descriptive analysis

3.1.1. Year of publication

Figure 3 shows the distribution of the number of publications between 2006 and 2023. We find that the number of publications starts to increase from 2012 (40/41 97.6%), which may be related to the fact that agroforestry is exploring more interdisciplinary issues, such as climate change, multifunctional agriculture, ecosystem services, land-use change, and enhancing environmental resilience [58–63]. In addition, with the establishment of the SDGs in 2015, there was a second increase in the number of publications [64–67].

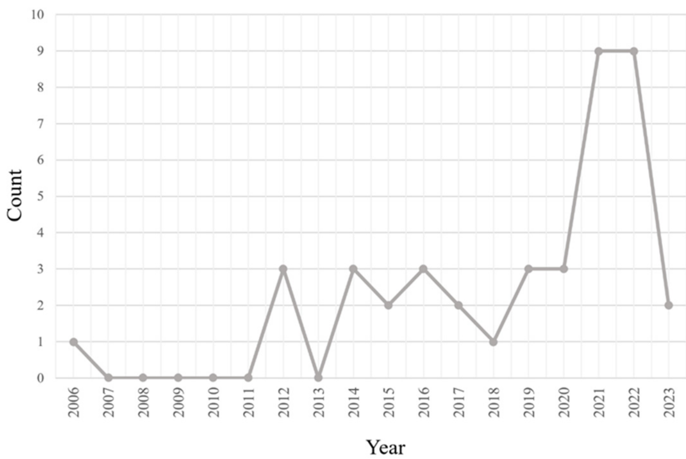

Figure 3. Number of publications issued, 2006-2023.

3.1.2. Geographical distribution of analysed publications

Figure 4 shows the geographical distribution of the analysed publications. Asia accounted for 78.94% (30/41), dominated by China (12/30, 40%) and Japan (6/30, 20%), followed by Laos (3/30, 10%) and the Philippines (3/30, 10%); Africa accounted for 10.52% (4/41); and the Americas and Europe both accounted for 5.27% (2/41). The two continents, Asia and Africa, together accounted for 89.46%of the documents reviewed, which is related to the fact that Asia and Africa account for about 90% of the world's rice sown area and 91% of the world's production.

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Figure 4. Geographical distribution of analysed publications.

3.1.3. Areas covered

Figure 5 shows the journals in which the publications were published. With the exception of one journal, publications related to RFDFES were mainly published in journals of environmental sciences and ecology (22/41, 53.7%), agricultural and forestry sciences (11/41, 26.8%) and agricultural and biological sciences (2/41, 4.9%). T The journals with the highest number of publications were Ecological Indicators and Land both with 4, followed by Ecosystem Services, Journal of Environmental Management, Journal of Resources and Ecology) and Paddy and Water Environment both with 2.

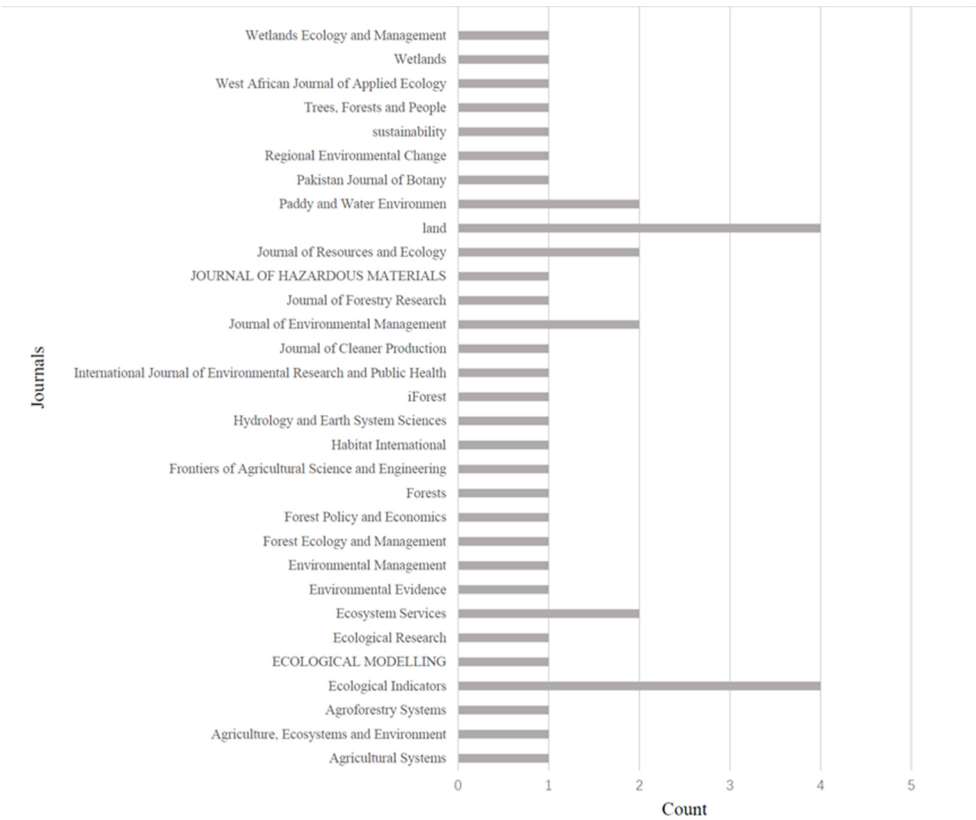

Figure 5. Journals in which publications were issued.

3.2. Core elements of RFDFES in publications

First, we reviewed four of the more current mainstream frameworks for sustainable management of agriculture and forestry, including Montréal Process Criteria and Indicators (MPCI

2015); Indicateurs de Durabilité des Exploitations Agricoles (IDEA 2008); Sustainability Assessment of Food and Agriculture systems (SAFA 2013); and International Tropical Timber Organisation (ITTO 2016). All of which are frameworks that encompass the ecological, economic, and social aspects. In addition, MPCI (2015), SAFA (2013), and ITTO (2016) also address the management and culture themes. Second, we effectively combined the above framework themes with the content of the articles to finalise the four RFDFES themes of ecology, socio-culture, management and economy. In addition, depending on how the article describes RFDFES, we categorised the article content into one or more themes. Ultimately, the categorised data showed 41 publications describing socio-cultural and ecological aspects of RFDFES; 34 publications describing management aspects of RFDFES; and 29 publications describing economic aspects of RFDFES.

3.2.1. Socio-cultural

SGDs identified that food and livelihood security issues deeply impact human well-being [65–67]. Our review showed that food and livelihood security was also the social issue with the highest number of publications describing RFDFES (29/41, 70.7%). In addition, RFDFES describes social problems such as urban sprawl population growth, ageing and labour migration, resource scarcity and unequal distribution [68–70]. Cultural aspects of RFDFES, including the neglected importance of cultural knowledge and community participation (19/41, 46.3%). Cultural knowledge issues relate to heritage preservation, traditional knowledge and ecological wisdom, and cultural awareness; community participation is mainly concerned with community management [43,69,71–77].

3.2.2. Ecological

Traditional rice farming systems are considered to provide the most valuable ecosystem sources [69]. Our review also indicate that RFDF agroforestry systems provide not only agriculture-type ecosystem services, but also forest ecosystem services. For example, land use change (11/41, 26.8%), soil and water conservation by composite farming (22/41, 53.7%), conservation of biodiversity (30/41, 73.1%), provision of species habitat (6/41, 14.6%), carbon storage (13/41, 34.1%), and coping with climate change (10/41, 24.4%). Current research has proved that RFDFES can solve these ecological problems. For instance, Wan-Yu Liu and Yi-Lin Chuang argue that converting farmland agriculture to agroforestry improves farmers' livelihoods, protects nature, increases the soil and water conservation benefits of farmland, and responds to climate change and the food crisis. It can also reduce pest populations, reduce agrochemical inputs, provide habitat for species to conserve biodiversity, increase soil fertility and improve crop yields [78–83].

3.2.3. Regulational

Continued agricultural expansion and inappropriate management have long been the main drivers of biodiversity loss [84–86]. However, recent studies have shown the traditional agriculture that properly managed could maintain rich biodiversity and ecosystem integrity, sustaining ecosystem flows [1,87,88]. Based on our review, we categorise the regulation involved in RFDFES into three types: rule of law, recommendations and self-governance. Rule of law (17/41, 41.5%) is the policy, measures, laws and regulations issued by the government and local authorities [78,89]; The recommendations (7/41, 17.1%) were NGOs and experts [90]. Self-governance (21/41, 51.2%) is the management of the community and the local population [91,92]. We find that there are some differences between Legal management, advice governance and self-governance management in dealing with social problems such as population growth and food shortages. For example, governments may respond through deforestation to expand agriculture [36,70,93], while local communities in the Union Terraces region of Fujian Province, China, see the forest as a provider of livelihoods and a creator of cultural services [94]. For more effective management, Berkes [94], Qiu [95], argued that local residents of the community should be involved in aspects such as resource management and land-use planning, and that there may be a need to establish community-based management organisations with shared responsibility and management authority.

3.2.4. Economic

While calculating the economic value of ecosystem services has been the subject of much research attention [96,97], our review found that the economic aspects of RFDFES have been less mentioned. Economic value (5/41, 12.2%), enhanced agricultural production and quality (16/41, 39.0%), and higher income and stability (25/41, 61.0%) are the key topics covered by the economic research in RFDFES. Most often, mathematical models are employed to study and assess economic value. Examples include Examples include the use of the Monte Carlo model by Wan-Yu Liu and Yi-Lin Chuang [78], and the use of logistic regression models by Elham Sumarga and Lars Hein [77]. Improving agricultural production and quality was the most frequently cited. According to Nian-Feng Wan [98], Keiko Sasaki [99], agroforestry improves people's quality of life by increasing agricultural production and maintaining food security. RFDFES is the economic base of farmers [100]. The diversity of agroforestry ecosystems allows farmers to access a wide range of agroforestry by-products and reduce farming inputs in response to changes in prices and crop yields [101,102]. In addition, RFDF attracts government and corporate investment and promotes tourism [91], thereby increasing the stability of farmers' incomes and reducing economic risks [103–105].

4. Discussion

4.1. Current gaps in literature

4.1.1. Deforested forests with multifunctionality

The selected publications pointed out that the multifunctionality of forests serves as the foundation of RFDFES, e.g. physical energy, materials, food security, and livelihood security [69]. However, the publications also revealed (10/41, 24.3%) that multifunctional forests have been facing deforestation for the expansion of agricultural production, and the types of forests deforested are mainly primary secondary forests [89,106,107]. Although most of the publications advocate sustainable forest management from the perspectives of diminishing forest ecosystem services and loss of biodiversity in order to mitigate the problem of deforestation of multi-purpose forests. Unfortunately, however, they do not go further than proposing specific management measures and assessment indicators, resulting in the fact that the problem of deforestation has not yet been comprehensively addressed. In addition, the transformation of the subsistence needs of local small farmers into global demand for food and crops is also one of the driving factors for deforestation [108]. Therefore, we believe that specific measures for sustainable forest management and securing food crop production are potential solutions to the problem of deforestation.

4.1.2. Marginalized socio-cultural aspects

To address the socio-cultural issues of RFDFES mentioned in Section 3.2.1, we found that the traditional culture and ecological wisdom of the local people in the community can effectively mitigate the above issues [69]. For example, the aborigines of the Hani ethnic group in Yunnan hold rituals before and after the sowing of rice in order to obtain a good harvest. These ceremonies have also been developed into a local tourism industry, which provides employment support for local residents and raises their incomes, solving the problem of labour outflow to a certain extent. We also found references to both traditional culture and traditional knowledge as co-occurring in publications. Traditional culture frequently results from local traditional knowledge, and both increase local cultural ecosystem services while preserving local livelihoods and forest environments. As a result, both have an equal facilitative impact on resolving socio-cultural issues [109,110]. However, only 13 publications dealt with descriptions of traditional culture and ecological wisdom, suggesting that traditional culture and ecological wisdom have been marginalised in research.

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4.1.3. Low-participation communities

Similarly, with regard to the disagreements and conflicts between different managers in the management of RFDFES in Section 3.2.3, this study argued that the cause of these disagreements and conflicts was the lack of community participation by policy makers in the formulation of management policies. In the case of tourism development in Ifugao, Philippines, the failure of the local community to participate in and implement the planning of the tourism development project in a timely manner resulted in the development of the tourism planning project destroying a significant amount of the local community's Moyong (forest above the terraces of Ifugao). Consequently, the soil in the terrace system was eroded, water sources were contaminated, and sustainable production was undermined [111]. In addition, the expansion of oil palm cultivation in Indonesia has likewise had an impact on the daily lives of the local population [106] However, the Longji terrace system in the Guangxi Zhuang Autonomous Region of China has maintained the sustainability of terrace tourism due to a high level of multi-stakeholder involvement [112]. In this way, we believe that the level of community involvement in management has an impact on the daily lives of local residents.

4.2. RFDFES framework Establishment

4.2.1. Correlation between forests, socio-cultural and community participation in management

This study further examined the interrelationships between forest, socio-cultural and community participation (see Figure 6). For example, the forest above the Jabang terraces in Guizhou, China, is known as the "Sacred Forest", a place where the indigenous people pay homage to their ancestors and worship the mountain gods. Forest worship is part of the traditional culture of the Jiabang Miao people. They consider that forests, terraces and rivers build their homes together and have incorporated forest protection into their village rules. Thus, forest worship and village rules have effectively prevented deforestation [57]. In addition, they gain ecological wisdom from dealing with the relationship between mountains, forests, water, terraces and people [91]. This is also the fundamental reason for the sustainable development of Jiabang terraced field cultural landscape and villages [113]. Not only that, the Jiabang Miao people maintain a high level of intergenerational transmission of traditional knowledge, mainly through various practical activities led by their parents, as well as some traditional culture taught by school teachers [114]. Therefore, the participation of forest, socio-cultural and community people is essential to keep RFDFES sustainable.

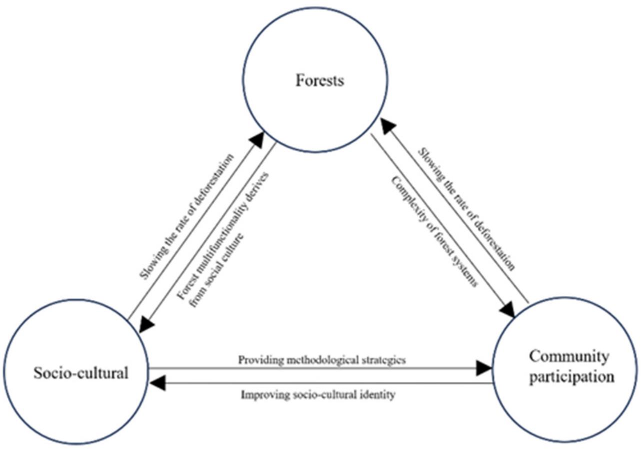

Figure 6. Correspondence between forest, socio-cultural and community participation in management.

4.2.2. Gaps in existing frameworks

Agroforestry and forestry management frameworks that are more often utilized are examined in the current study. It is found that the metrics used in these frameworks tend to be heavily weighted toward ecological and economic sustainability. The study of forest management, socio-cultural, and

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community participation is nevertheless constrained and has shortcomings. Of these, only the forestry framework addresses forest management indicators, while the agricultural framework has no corresponding indicators. In terms of socio-cultural indicators, only ITTO (2016), SAFA (2013) and IDEA (2005) contain a part of the content, but still do not fully cover the socio-cultural aspects provided by RFDFES, such as local culture and religious beliefs. While these frameworks include community participatory management, the frameworks are too macro in scale and too broad in coverage to fully address the low level of community participation in RFDFES. Therefore, we integrated the management of forests, socio-cultural and community residents covered by RFDFES into the existing framework (see Figure 7).

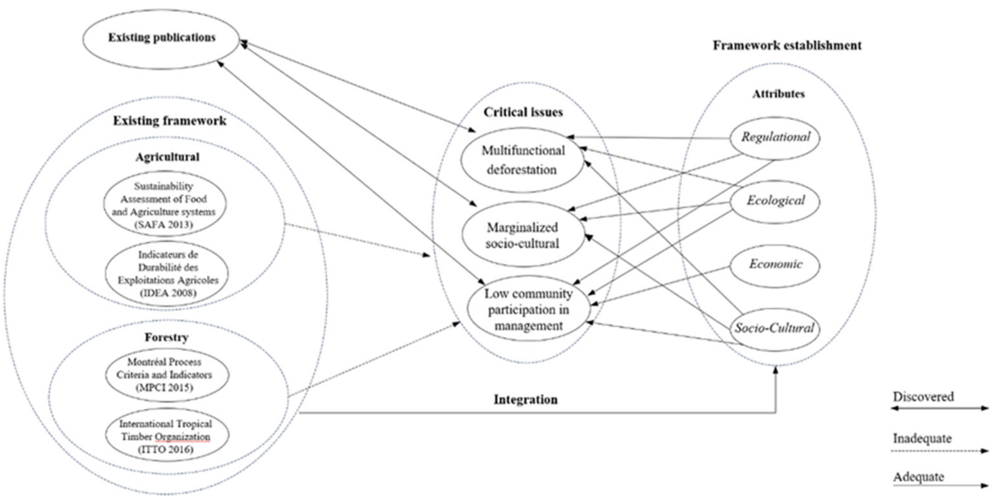

Figure 7. Conceptual Framework for RFDFES.

4.2.3. RFDFES Sustainable Management Framework

Table A1 shows where each of the indicators in the RFDFES sustainable management framework comes from and to which types of issues it applied (See Appendix A). The regulational aspect of RFDFES involves the participation of multiple stakeholders, such as communities and local people. To create targeted policies and actions that balance the interests of all parties and successfully prevent conflicts in the protection and development of local resources, policymakers could combine the perspectives of many stakeholders on RFDFES. The ecological indicators of the RFDFES include assessing the integrity of the RFDF's natural resources and ensuring that the RFDF fulfils essential ecological functions. The economy of RFDFES reflects the incomes and expenditures of local residents and the incomes of their economic diversification. The socio-cultural aspects of RFDFES reflect the consideration of the quality of life of the local population, emphasising the local population's claim to well-being from RFDFES.

4.3. RFDFES Sustainable Management Framework and SDGs

We further compared the RFDFES sustainable management framework with the SDGs and explored a clear correspondence between them. We present the correlations between the indicators and the SDGs in Table A2 (See Appendix B). In addition to SDG 5, SDG 10, SDG 14 and SDG 16, the regulatory framework covers 13 other SDGs, of which SDG 2, SDG 15 are most relevant to the regulatory framework, followed by SDG 4, SDG 7, SDG 8 and SDG 11. SDG 2 ZEREO HUNGER is focused on ending hunger, achieving food security, enhancing nutrition, and promoting sustainable agriculture, all of which are core goals of the RFDF and are detailed in our preface. Furthermore, SDG 15 LIFE ON LAND centres on the protection, restoration and promotion of the sustainable use of terrestrial ecosystems, the sustainable management of forests, combating desertification, halting and reversing land degradation, and halting the loss of biodiversity, which are precisely the core issues addressed by RFDFES. As a result, our regulatory framework indicators have contributed to the realisation of all aspects of the SDGs. In addition, the management framework provides theoretical support for research on ecosystem services in the context of the SDGs, which provides an opportunity for synergistic development of the subsequent SDGs.

5. Conclusion

This study synthesizes and analyses recent academic research on RFDFES from the perspective of the shift from agriculture to agroforestry, with the aim of gaining a more thorough understanding of RFDFES in the context of rapid population growth and sustainable development. Through a systematic literature review, we evaluated a total of 41 articles that were pertinent to the study topics. First, we synthesised the core elements of RFDFES research from 41 publications into four categories: regulatory, ecological, economic and socio-cultural. Then, we analysed and summarised the core issues of RFDFES research, and found that there are problems of deforestation for agricultural expansion, socio-cultural marginalisation, and low community and local participation in RFDFES management.

To do this, we developed the RFDFES sustainability framework based on accepted mainstream frameworks for sustainable management in agriculture and forestry and within the scope of our research topics. The proposed framework tackles the RFDFES's current issues and significantly advances the field of study of sustainable agroforestry management. Additionally, this study compares the Framework to the SDGs and concludes that the Framework aids in the accomplishment of a number of SDGs. It further reflects that the framework will help to ensure food and livelihood security for local populations and improve their lives and well-being.

The main limitation of the RFDFES sustainable management framework proposed in this study is that it uses only one bibliographic database (Scopus) and relies exclusively on existing published academic research, which may inhibit other relevant research. Despite the limited scope of our research, it fills a temporary gap left by the lack of an agroforestry-specific framework for sustainable development. In the subsequent phase of more extensive study and application of particular practical examples, the framework will be refined and augmented with the goal of demonstrating and promoting it internationally.

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

Appendix A

Table A1. RFDFES Sustainable Management Framework.

RFDFES Sustainable Development Framework			Sources					Problems		
Themes	Sub-Themes	Indicators	ITTO (2016)	SAFA (2013)	MPCI (2015)	IDEA (2008)	Publications	Deforestation	Marginalised socio-cultural	Low-Participation Communities
Regulational	1.1Rule of Law: governments and locals	1.1.1policies、laws、regulations	×	×			×	×		
		1.1.2Decentralisation management					×		×	×
	1.2Recommendations: NGOs and experts	1.2.1Applying modern knowledge and skills	×				×			
		1.2.2Assisting governments and communities	×	×	×		×			
	1.3Communities and indigenous	1.3.1Village Rules					×	×	×	×
		1.3.2Indigenous Knowledge Management	×	×			×	×	×	×
Ecological	2.1Ecological environment	2.1.1Different land uses	×			×	×	×	×	×
		2.1.2Soil use and protection	×	×	×		×		×	×
		2.1.3Water use and protection	×	×	×	×	×		×	×
		2.1.4Forests use and conservation	×		×		×	×	×	×
		2.1.5Climate regulation		×	×		×	×		
	2.2Biodiversity	2.2.1Landscape/habitat conservation plans		×			×	×		×
		2.2.2Species diversit (Rice varieties, fish varieties, plant diversity)	×	×	×	×	×	×		×
Economic	3.1Economic investments	3.1.1Material investments (Money, equipment farming tools, buildings, production materials, water and energy)		×	×		×			
		3.1.2Non-material investments (manpower, time, and,Operation & Management)		×			×			
	3.2Economic benefits	3.2.1Crop yield and production	×	×	×	×	×			
		3.2.2Production subsidies					×			
		3.2.3Participant's investment (Suppliers)					×			
		3.2.4Production added value (Tourism, education, cultural activities)	×	×	×		×			×
Socio-cultural	4.1Quality of life	4.1.1Working conditions (Environment, farm equipment, time)		×			×			
		4.1.2Public Health and Health Safety		×			×	×	×	×
		4.1.3Provide employment		×		×	×		×	×

	4.1.4Food Security and Livelihood Protection			×	×	×	×	×	×
4.2Cultural diversities	4.2.1Indigenous knowledge	×	×			×	×	×	×
	4.2.2History and Culture	×				×	×	×	×
	4.2.3Religious beliefs	×				×	×	×	×
	4.2.4Cultural activities					×	×	×	×
4.3Conflict resolution among stakeholders	4.3.1Resource management rights	×		×		×			×
	4.3.2Recognition of indigenous knowledge and skills	×				×			×

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Appendix B

Table A2. Relevance of the RFDFES Sustainable Management Framework and the SDGs.

RFDFES Sustainable Development Framework			**Sustainable Development Goals (SDGs)**																	
Themes	Sub-Themes	Indicators	SDG 1	SDG 2	SDG 3	SDG 4	SDG 5	SDG 6	SDG 7	SDG 8	SDG 9	SDG 10	SDG 11	SDG 12	SDG 13	SDG 14	SDG 15	SDG 16	SDG 17	Count
Regulational	1.1Rule of Law: Governments and Locals	1.1.1policies, laws, regulations											×	×			×		×	4
		1.1.2Decentralisation management						×					×				×			1
	1.2Recommendations: NGOs and e×perts	1.2.1Applying modern knowledge and skills		×		×				×										3
		1.2.2Assisting governments and communities																	×	1
	1.3Communities and Indigenous	1.3.1Village Rules															×			1
		1.3.2Indigenous Knowledge Management						×					×							0
Ecological	2.1Ecological environment	2.1.1Different land uses															×			1
		2.1.2Soil use and protection		×					×					×			×			3
		2.1.3Water use and protection						×						×			×			3
		2.1.4Forests use and conservation													×		×			2
		2.1.5Climate regulation																		0
	2.2 Biodiversity	2.2.1Landscape/habitat conservation plans															×			1
		2.2.2Species diversity (Rice varieties, fish varieties, plant diversity)		×																1
Economic	3.1Economic investments	3.1.1Material investments (Money, equipment farming tools, buildings, production materials, water and energy)																		0
		3.1.2Non-material investments (manpower, time, and,Operation & Management)																		0
	3.2Economic benefits	3.2.1Crop yield and production		×					×											2
		3.2.2Production subsidies																		0
		3.2.3Participant's investment (Suppliers)																		0
		3.2.4Production added value (Tourism, education, cultural activities)							×					×						2
Socio-Cultural	4.1Quality of life	4.1.1Working conditions (Environment, farm equipment, time)			×					×										2
		4.1.2Public Health and Health Safety			×			×												2
		4.1.3Provide employment		×										×						2
		4.1.4Food Security and Livelihood Protection							×					×						2
	4.2Cultural diversities	4.2.1Indigenous knowledge		×		×														2
		4.2.2History and Culture				×					×		×	×						4
		4.2.3Religious beliefs								×										1
		4.2.4Cultural activities				×							×	×						3
	4.3Conflict resolution among stakeholders	4.3.1Resource management rights	×	×						×										3
		4.3.2Recognition of indigenous knowledge and skills		×		×				×										3
		Count	1	8	2	5	0	4	3	5	1	0	5	7	1	0	8	0	2	

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