Proposals of forest management approach according to identified trade-offs and synergies between forest ecosystems services: A literature review

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ABSTRACT

This paper explores the trade-offs and synergies between forest ecosystem services (FES) by reviewing scientific literature. The focus is primarily on research in European forests, including other countries with boreal and temperate forests. Through content analysis, we reviewed 167 articles from the licensed Web of Science database using specific keywords, from which 38 articles discussed relationships between forest ecosystem services. The research study shows that using one service often affects others due to the complexity of the ecosystem. Wood provisioning with other services often presents a trade-off relationship. However, wood provisioning can coexist with other forest ecosystem services when appropriately managed. It can even positively impact carbon sequestration, water retention and recreation. Based on these findings, the paper offers possible forest management approaches for reducing the number of trade-offs and increasing the share of synergy relationships with an assumed positive impact on the economy of the forest enterprise.

KEYWORDS

Forest management, ecosystem services, trade-offs, forest enterprises, synergy

1 INTRODUCTION

Ecosystem services are the benefits that ecosystems contribute to human well-being. As part of the classification of forest ecosystem services, we know several classification systems at the international level. The 2018 CICES V5.1 updated and extended the older 2013 version CICES V4.3 (CICES, 2018). Based on this classification, ecosystems and ecosystem services have been mapped and assessed since 2013 as part of the program

- Strategy of the European Union in the field of biodiversity until 2020 (MAES, 2013). According to CICES (2018), it divides FES into three sections. Provisioning services (wood supply, wildlife supply, non-wood forest products, water supply), regulatory services (water retention, erosion control, carbon sequestration, gene pool protection, noise reduction, pest protection) and cultural services (recreation, tourism, natural monuments).

Due mainly to anthropogenic influences, FES come into mutual interaction and synergistic "synergies" or competitive "trade-offs" relationships arise between individual services (Vallet et al., 2018). These relationships between FES can be bidirectional. Individual FES can influence each other positively and negatively (e.g., provisioning services influence regulatory ones and vice versa).

Correctly understanding these relationships is essential because, in recent years, the proper use of forest ecosystem services (FES) has been debated more than ever before. The paper aims to identify the relationships between forest ecosystem services within the scientific review and propose possible forest management approaches that decrease the number of trade-offs and support synergies between FES.

2 METHODS

The main objective of this review was to identify the relations between FES according to CICES classification and suggest proposals on how to manage them. Therefore, the search focused on finding publications in this field. As part of the qualitative data collection (Guest et al., 2013), we used the licensed Web of Science (WoS) database. The review process has been carried out following the guidelines applied by Rejeb et al. (2022). Figure 1 shows the research process based on the five phases.

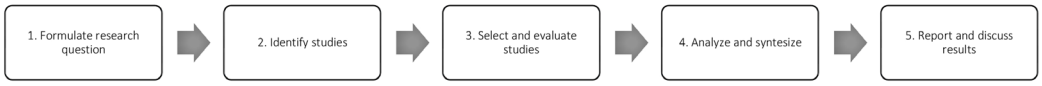

Figure 1. The steps of a systematic literature review

In the first phase, research questions (RQ) have been formulated to guide the research:

- RQ 1: Which ecosystem services are in a trade-off, and which are in a synergy relationship?
- RQ 2: With which managerial approaches can we properly affect identified FES relationships?

In the second phase, we did a preliminary search in the database in January 2023 based on the keywords ("forest ecosystem services" - Title) and ("relationship" or "correlation" or "affect" or "influence" or " impact" - All fields). Subsequently, we supported the preliminary search by brainstorming with other members of the VEGA project [1/0271/22] and determined the exact search terms. Based on the search terms we identified, in the second phase, in February 2023, we searched the database using the keywords ("forest ecosystem services" - Title) and ("trade-offs" or "synergies" - All fields). Such a search yielded 155 ("forest ecosystem services" and "trade-offs") and 73 ("forest ecosystem

services" and "synergies") articles. In the third phase, from the given articles, we selected those whose research area was in Europe, the USA, Canada, or China. The main reason was to find similar conditions to Slovakia due to the maturity and natural conditions of the countries (boreal and temperate forests). In the fourth phase, we used content analysis (Mayring, 2003) to identify and analyse relationships between FES and assign them to sections and classes according to the CICES V5.1 classification. We prepared and applied a coding table (Table 1) for the assignment. In the fifth phase, we used semi-structured interviews (Ying and King, 2003; Horrocks, 2011) with forest managers (heads of forest enterprises) to discuss and evaluate experts' proposals on managing identified trade-offs and synergy relations between FES (Tables 2-3). Proposals for possible forest management approaches to FES relationship management were presented by experts from the university. So, we used the systematic approach of using multiple sociological methods which is commonly referred to as triangulation (Zohrabi, 2013). Suggested forest management approaches (Tables 2-3) include combinations of appropriate silviculture, logging and transportation, distribution services, and economic approaches. In the long run, these approaches aim to reduce the number of trade-offs relationships, reduce costs in forest management, and strengthen the quality of forest management. In the short term, they aim to increase initial investments in renewing logging and transportation, increasing costs due to close-to-nature management, etc.

Table 1. Coding table using CICES classification on the example of one provisioning ecosystem service

Identified key words	Classified by authors	Equivalent class by CICES 2018 (code)	Division by CICES (2018)	Section by CICES (2018)
biomass production, woody biofuel, residues extraction	Biomass provisioning	Cultivated plants (including fungi, algae) grown as a source of energy (1.1.1.3)	Biomass	Provisioning

3 RESULTS

The findings indicate how often the desired relationships (trade-offs and synergy) occurred during the studied timeframe. According to published papers, the period is limited to 2005-2023.

Table 2. Proposals of forest management approaches from the review based on identified trade-offs between

Number of reviewed scientific papers (n)	Identified relations between FES according to		Management approach
	Authors (Bumbera, Halaj)	Equivalent section classification by CICES V5.1 (2018)	
1	Wood provisioning vs. Biomass provisioning	Provisioning vs. Provisioning	Timber sale optimization
2	Wood provisioning vs. Non-wood forest product provisioning		Integrated forest management with emphasis on non-wood forest products
2	Venison provisioning vs. Wood provisioning		
4	Biomass provisioning vs. Biodiversity	Provisioning vs. Regulation and Maintenance	Close-to-nature forest management
4	Biomass provisioning vs. Carbon sequestration		Final processing of biomass at the heating plants
4	Wood provisioning vs. Water retention		Close-to-nature forest management
2	Wood provisioning vs. Erosion control		
19	Wood provisioning vs. Biodiversity		
19	Wood provisioning vs. Carbon sequestration		Partial implementation of sawmilling, pallet manufacturing, etc. at the forest enterprises
10	Wood provisioning vs. Recreation and tourism	Provisioning vs. Cultural	Quality enhancement of supply services Integrating own logging and transport mechanisms
5	Venison provisioning vs. Recreation and tourism		Integrated forest management with focus on cultural services
2	Recreation and tourism vs. Biodiversity	Cultural vs. Regulation and Maintenance	

Table 3. Proposals of forest management approaches from the review based on identified synergies between FES

Number of reviewed scientific papers (n)	Identified relations between FES according to		Management approach
	Authors (Bumbera, Halaj)	Equivalent section classification by CICES V5.1 (2018)	
2	Wood provisioning vs. Biomass provisioning	Provisioning vs. Provisioning	Small-scale silviculture
1	Wood provisioning vs. Venison provisioning		
1	Wood provisioning vs. Water supply		
1	Wood provisioning vs. Erosion control	Provisioning vs. Regulation and Maintenance	Selective logging
5	Wood provisioning vs. Biodiversity		Quality maintenance of supply services
12	Wood provisioning vs. Carbon sequestration		Close-to-nature forest management
2	Biomass provisioning vs. Carbon sequestration		
1	Water supply vs. Soil formation		Selective logging Small-scale silviculture
1	Wood provisioning vs. Natural heritage	Provisioning vs. Cultural	Enhancement of forest road network
7	Wood provisioning vs. Recreation and tourism		
1	Venison provisioning vs. Recreation and tourism		Integrated forest management with focus on game management

The literature review results confirmed the assessment of FES relations to a large extent as trade-offs. The significant share of wood provisioning (provisioning services) in the portfolios of forest enterprises with more than 80% of total sales substantially influences the findings. Most trade-offs were evaluated between provisioning vs. regulation and maintenance services, concretely wood provisioning vs. biodiversity and wood provisioning vs. carbon sequestration. An interesting finding is that even the provisioning services themselves compete (e.g., wood vs. biomass provisioning). The public most criticise the impact of wood provisioning on cultural services (recreation and tourism). As a part of the literature review results, it was confirmed that this relationship was considered one of the most significant trade-offs. On the contrary, the greatest synergy was considered paradoxically between wood provisioning vs. carbon sequestration and between wood provisioning vs. recreation and tourism.

4 DISCUSSION AND CONCLUSION

The results of the survey reflect the assessment of relations between FES author teams in individual articles. To a certain extent, despite the literary review, a specific degree of their subjectivity was present in the assessment of relations between FES. In some cases,

the articles we identified dealt only marginally with the relations between FES (Torralba et al., 2020). However, the assessment followed their results. The findings, to a considerable extent, point to the fact that the individual FESs are very connected to each other. It cannot be unequivocally claimed that the relationship between FES data is only a trade-off or synergy. To ensure objectivity in our evaluation, we need to examine FES throughout its entire life cycle rather than just focusing on certain phases (Hardaker et al., 2022). Such an example is the relationship between wood provisioning vs. carbon sequestration.

Proposals for forest management approaches are largely based on close-to-nature management or integrated forest management, focusing on quality maintenance of supply services. These approaches preserve the compliance of provisioning services with regulation, maintenance, and cultural services. Understanding the relationships between FES, looking for intersections between these services, and the degree of their impact on other services is the basis of integrated forest management as well as a way of economic efficiency of forest enterprises.

5 REFERENCES

// European Commission. 2013. Mapping and Assessment of Ecosystems and their Services: An analytical framework for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. doi:10.2779/12398ISO 11799.

// Guest G., Namey E., Mitchell M. 2013. Collecting Qualitative Data: A Field Manual for Applied Research. SAGE Publications, https://doi.org/10.4135/9781506374680

// Haines-Young R., Potschin M. 2018. Common International Classification of Ecosystem Services (CICES) V5.1 and Guidance on the Application of the Revised Structure. www.cices.eu (21.6. 2023).

// Hardaker A., Styles D., Williams P., Chadwick D., Dandy N. 2022. A framework for integrating ecosystem services as endpoint impacts in life cycle assessment, Journal of Cleaner Production, 370, 133450. https://doi.org/10.1016/j.jclepro.2022.133450.

// King. N., Horrocks Ch. 2011. Interviews in qualitative research, Sage publications, London.

// Rejeb A., Rejeb K., Keogh J. 2022. The Circular Economy and Marketing: A Literature Review. Etikonomi, 21: 153-176. https://doi.org/10.15408/etk.v21i1.22216.

// Mayring P. 2003. Qualitative Inhaltsanalyse. Beltz Verlag, Weinheim und Basel.

// Torralba M., Lovric M., Roux J., Budniok M., Mulier A., Winkel G., Plieninger T. 2020. Examining the relevance of cultural ecosystem services in forest management in Europe. Ecology and society. doi:10.5751/ES-11587-250302

// Vallet A., Locatelli B., Levrel H., Wunder S., Seppelt R., Scholes R., Oszwald J. 2018. Relationships between ecosystem services: Comparing methods for assessing tradeoffs and synergies. Ecological Economics. https://doi.org/10.1016/j.ecolecon.2018.04.002

// Yin R.K. 2003. Case study research. In: Design and Methods, Third Edition. SAGE Publications, California

// Zohrabi M. 2013. Mixed method research: Instruments, validity, reliability and reporting findings, Theory and Practice in Language Studies. doi:10.4304/tpls.3.2.254-262

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