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Article

Harvesting and Impacting Agro-Ecosystem Services in Agriculture

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Abstract: Merits of AES include provisioning, regulating, supporting and cultural services which underpins sustainable agricultural development Goal of this study is to evaluate AES in various contexts. However, to date, understanding of AES remains in its infancy, with many questions regarding AEDS remaining unanswered, little consensus on how best to scale up ecosystem disservices assessment to an operational level, and little attention given to geographical disparities in AES research. In this mixed-methods study, bibliometry, literature synthesis, and cross-source analysis are used to assess global trends, key figures, and methodological approaches in AES research. The overall results show a significant development of AES literature, however, unanswered questions and research implications are identified, in particular, the need for the development of more specific indicators, inclusion of the AES concepts into the holistic theoretical framework, as well as contextualisation of methodologies and approaches. These results highlight the inherent complementarity or trade-offs between AES, and provide information to enhance the understanding of agroecosystem management. The potential applications are vast, informing the realistic pursuit of sustainable agricultural productivity and the conservation of ecosystems and the SDGs for the future development of research for global agroecosystems.

Keywords: Agroecosystem services (AES), Ecosystem disservices (AEDS), sustainable agricultural development, biodiversity, trade-offs and synergies, Sustainable Development Goals (SDGs), multi-source data integration, agricultural landscape management, ecosystem service assessment

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1. Introduction

It focuses on the cultivated farmlands which are the core productive units of agroecosystems, and their surrounding area which provides other valuable ecosystem services. Though these services are described collectively as Agroecosystem services (AES) it comprises of provisioning services which include food production, regulating services which is carbon sequestration and pest control and eventually the cultural services which embraces recreation and heritage. However, these services have been disrupted by the growing phase of agricultural industrialization and intensification as this has led to loss of biodiversity, soil and water degradation and pollution an aspect that threaten most of the current sustainable development goals (SDGs).

One of the major research areas of AES is how agricultural practices interact with ecosystem functions. AES is defined with reference to two related theoretical constructs – the value the natural environments bring and the roles of agricultural systems in the maintenance of ecological balances. These systems are interrelated, and therefore, requires a systematic approach in the management of agro ecosystems with more production and

less degradation. While other researchers like Zhang et al., (2007) and Power (2010) have worked on AES indicators like nutrient cycling and pollination, they rarely take into account the intricate often interdependent relationships between different factors in the structure of agricultural production.

However, there is still a lack of comprehensiveness in the current research on spatial and temporal distribution of AES, lack of conceptualization and quantification of AEDS and their integration into AES framework. Literature studies of participatory approaches and mechanism models show that they do not provide a high scale or resolution for evaluations. Third, the skewed geographical representation of the existing research hinders current knowledge generalizability as the developed nation leads the research ON while the Global South lags behind. These gaps serve to suggest that some form of more novel approaches to the evaluation of AESs coupled with new ways of handling data integration are desirable.

To deal with these problems, this research applies a method of bibliometric analysis, literature synthesis, and the use of indicators. Hence, based on the evaluation of worldwide research trends in AES and when defining the indicators and methods to establish the current state of AESresearch, this experiment should present rather a sound concept. Special programs like VOSviewer are applied to define the research activity heat map, and multiple source data analysis allows to assess AES activity at various tiers. The study's conclusions will be for development of sustainable agroecosystem management practice and the contribution to the realization of the AES with SDGs goals. The findings of this research will inform policy directions towards the enhancement of AES, which will be valuable for different policy-makers and stakeholders who want to understand balance between increasing yield and preserving the environment. Overall, the research presented in this work focuses on examining current insights into AES and identifying potential directions for further studies to improve AES theory and practice and support sustainable and resilient agroecosystems around the world.

2. Materials and Methods

The approach used when conducting this study on AES was intended to all-encompassingly capture the dynamics of AES through the use of a basis of a bibliometric study, alongside a critical literature review, together with an assessment based upon AES indicators. In order to look at historical trends, research gaps and the geographical spread of AES related research a bibliometric analysis was done. Publications identified relevant to AES were retrieved from the Web of Science Core Collection using terms derived from identified keywords which resulted in a set of 764 articles. Hence, various analytical tools as discussed below were employed to forge these data into understandable research themes and regional characteristics of AES scholarly output.

The literature review explored these three broad areas of concern in an effort of trying to establish an understanding of what the existing knowledge is in regards to AES indicators, quantification methods, and with specific emphasis on their plausibility when applied to sustainable agricultural management. The review of earlier research conducted on AES led the author into classifying AES into provisioning, regulating, supporting, and cultural services. They considered important bioindicators including food production; carbon storage; soil quality; nutrient cycling; and species richness and abundance. Specifically, the study used a contingent approach to AES identification; recognizing that the spatial definition and level of complexity in these interactions may vary among regions and landscape types.

In order to evaluate AES, different qualitative and quantitative approaches were incorporated such as part and participatory, empirical and mechanism models and value

methods. All participatory methods utilised qualitative data from stakeholders to show perceived AES importance. Some of the services established by empirical models such as regression models and index-based systems included quantification of vital services such as pollination and pest control. There were computational models for ecological processes including carbon, InVEST and APSIM with indices for large scale AES indices like erosion. Valuation methodologies of services converted AES into economic terms and made comparisons easier by utilizing emergy analysis technique, equivalent factor.

The study engaged a multi-scale approach because of the spatial and temporal nature of AES. Remote sensing, field observations and statistics were integrated to establish extensive models that underpinned interdisciplinary data integration. This approach led to tracking and managing agroecosystem objectives and also provided current feedback for decision-making processes in sustainable agroecosystem management. Through integrating these methods, the current study was able to identify and compare AES trade-offs and opportunities in relation to sustainable development goals and provide recommendations where required to enhance agricultural practices. This integrated approach supports the idea that AES is a central to moderating between productivity in agriculture and protection of the environment as a form for future work and reference.

3. Results and Discussion

In light of this study findings, there is need to consider AES as a complex concept the provision of which is central to sustainable agriculture. From the early 2000 a clear bibliometric trend was identified with an exponential increase of AES related research because of globalization and global initiatives such as the United Nation's Sustainable Development Goals (SDGs) and the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services (IPBES). Nevertheless, the geographic distribution of the research remains unbalanced as the developed countries including USA, European nations and China advance with less scholar correlated areas of the global south. Such variation underscores the dearth or efficiency in capacity development and knowledge sharing in such regions to improve AES frameworks for broad applicability. After consulting current literature and methodologies, it was ascertained that AES indicators and assessment methods are diverse in nature.

Hence, whereas provisioning ecosystem services such as food production have been researched extensively, regulating, supporting and, particularly, cultural ecosystem services can be characterized by sparsely developed and often weak measurement standards. For example, nutrient cycling on the soil, balancing of species richness, and pollination services are identified as essential ecosystem functions but they are missing universally acceptable measures for comparison across the regions. The study highlighted the objective importance of additional theoretical research in order to define general standards and specific parameters of AES, which would allow for quantifying this phenomenon in a more reliable and manageable manner.

In the light of this, empirical, analytically rigorous, participatory and mechanism models signal a direction toward bringing meaning and purpose to AES evaluation. However, the current approaches are conducted individually, and, therefore, provide fragmented information. One of the major limitations of current research and knowledge on AES is the absence of standard models built for evaluating one AES, let alone several of them when studied at different temporal and spatial resolutions. Further, the managers should target the creation of the unified frameworks that will imply the incorporation of multi-source data and that will enable dynamic assessment of AES. Such an approach might have potential to contribute to the resolution of the problems of spatial and temporal

dys-synchronization between the supply of AES and AES demand, the solving of which is crucial for improving the efficiency of the use of the agroecosystem.

The conclusions also pointed to such extrinsic AES relationships as intrinsic trade-offs and intrinsic synergy between various AES indicators. For instance, while intensive agriculture ensures high provision of commodities such as crops, it reduces provision of regulating and cultural services such as carbon sequestration and conservation of species' diversity respectively. The case studies that relate to sustainable intensification especially through belief practices such as conservation agriculture and agroforestry show the possibilities of reversing such trade-offs. However, there is relatively little research on how these practices affect the socio-ecological world at the theoretical level. Thus, some additional ecosystem disservices (AEDS) should be investigated to improve the results of AES assessment of trade-offs and get a clearer insight into the dynamics of an agroecosystem. As such, it was demonstrated that current AES assessments are fundamentally based on field scales, annual averages, thus not very useful for direct and immediate application in the management of arid ecosystem sensitivity to environmental change. Better use of data assimilation methods and involving remote sensing and artificial intelligence in AES assessment could improve their high-resolution and real-time data.

Further, achieving congruency between AES management and SDGs requires consideration of socio-economic drivers especially in developing solar and other resource poor areas. Such an alignment would ensure the wise use of agroecosystem products to affected groups and stakeholders, caring for the scores of needs concerning the groups such as those of food, poverty eradication, and climate change. However, there are still unexplored areas as AES research has not reached a total optimal condition. It is about time that AES researchers aim for further conceptual development of this research field by investigating the relationships between biophysical and human-driven change across different spatial scales. Such mechanisms might include the integration of socio-ecological feedback mechanisms into AES models in order to offer further guidance to policy and practice. Secondly, practical research has ceased to be an academic discipline that can say that its approaches are applicable on an A-to-Z basis in many regions of the word, but it has become a field that needs to establish relationships with local communities and stakeholders to produce scientific knowledge on the one hand and socially acceptable solutions on the other.

The same applies to future research investigating agroecosystem landscape planning and governance with respect to boosting biodiversity-based ecosystem services. Idee s, Promoting Multi-Stakeholder Partnerships: New Forms of Collaborative Governance Systems That Involve Farmers, Policy Makers, and Conservationists Could Resolve Conflicts of Interest and Interdependency between Agriculture Productivity and Biodiversity Conservation. Thus, filling the current gaps in AIS research trends and promoting an integrated, transdisciplinary approach, AES can make a valuable input for attaining sustainable agricultural development and improved ecological stability. This work can be conceived as laying the groundwork for theoretical and applied foci for AES research in order to adhere to international sustainability goals.

4. Conclusion

Accordingly, this study underlines the importance of AES towards realization of sustainable agricultural development in different categories of the PSA dimensions of provisioning, regulating, supporting, and cultural services. However, there are still important gaps in knowledge about AES despite the general increase in the AES literature through, for example, the number of relevant publications: knowledge integration of ecosystem dis-

services (AEDS); standardized assessment indicators; and systematic, multi-scale evaluation. This global distribution of AES studies also supports the argument that further research and capacity development should be targeted to the geographical regions not well covered. These findings have important implications for the need of policies and practices that enhance agricultural production while maintaining ecosystem integrity and substituting between the services with techniques such as agroforestry and conservation agriculture. More work remains to create broad conceptual frameworks that include AEDS, improve the monitoring of AES in real-time using different technologies, and synchronize agroecosystem management approaches with sustainability in line with the SDGs. Future research can help enhance the development of sustainable agroecosystems for environment protection and human welfare by filling these gaps.

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