Nexus Between GIScience and Sustainable Agriculture

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Abstract

Human civilization is rapidly developing in the age of advanced science and technology. Intact, the acute crisis for food, clothing, and shelter has been resolved to a large extent, but the spatial disparity of overall development is still a problem for humanity. Highly technology-based development is only sometimes friendly to the environment. The alternative thought for environmentally unfriendly development is crucial for civilization. In this context, the philosophy of sustainable development is highly appreciated. Also, the concept of balanced development is very much relevant in agriculture. Agricultural scientists are keenly interested in seeking sustainable ways to grow agrarian production. The development strategies for agriculture also appreciate the philosophy of balanced development. Contemporarily, data science has been developed notably due to the innovation of technologies in GIScience. Indeed, detailed geospatial data about the different aspects of agriculture has improved the research in agricultural science and its development-related studies. In the last few decades, many research works on sustainable agriculture have been published in which GIS and RS technologies have been used remarkably. Many studies about sustainable development in agriculture have also been performed using geospatial data appreciably by researchers worldwide. Despite the remarkable tendency of the current researchers to build different models suitable for balanced development in agriculture using geospatial data, a gap is needed in linking GIScience and sustainable agriculture. Thus, this chapter attempts to analyze why and how a strong linkage can be made between GIScience and sustainable agriculture. The strong connection between GIScience and research about the development of agriculture using geospatial data will enhance the progress.

Keywords

Geospatial science · Sustainable agriculture · GIScience · Balanced development · Geographical information system · Agrotourism · Agroclimatic zone

1.1 Introduction

The thought of balanced development is an unquestionable philosophy to the environmentalist, humanists, and also for ordinary people of

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the world (Fang et al. 2023; Stables and Scott 1999; Tyburski 2008). The present civilization is keenly interested in searching the strategies for sustainable development. There are many hurdles to implementing the design for balanced growth in a real-world situation. Especially in the developing world, weak economic background and a massive need for food and shelter to sustain a large population compel a nation to continue the environmentally unfriendly but cheap production methods in agriculture and industry (Omisore 2018). To some extent, developed countries continue to use modern technologies to maintain their living standards compared to developing nations (Gollakota et al. 2020). Thus, the necessity of rational pathways to attain sustainable development is the main thrust of the researchers who think about balanced product (Zhang et al. 2022). While making a good strategy for properly managing some systems or events, a clear understanding of the systems or events is necessary. Knowledge of phenomena depends on detailed information (Boal and Schultz 2007). When discussing an activity like agriculture which depends on the geo-environmental condition, we need much geographical information for better management.

In this connection, geographic information science (GIScience) is a reliable discipline for efficiently collecting, analyzing, and representing real-world data. The prime goal of GIScience is to seek the best ways to expand geographical information system (GIS)-related data, software, and practice professionally (Ricker et al. 2020). Indeed, the current technologies and research fields of geographical information systems (GIS), cartographic techniques, remote sensing, photogrammetry, and geomatics are included in GIScience (Goodchild 2010). GIScience uses GIS to analyze and visualize spatial data in a concrete form to understand the real-world situation of geo-environmental phenomena (Jiang and Yao 2010). In earth sciences like Geomorphology, Geology, Climatology, and many more, the application of GIScience has revolutionized the research arena. As an important sector of the economy, agriculture also needs beneficial strategies for its development in a sustainable way (Jhariya et al. 2021). Thus, modern agriculture research requires detailed geospatial data for crisis management in real-world situations. In this context, incorporating GIScience is too relevant in advanced agricultural research (Hussain et al. 2021). In recent decades, many researchers have used GIS to analyze geospatial data about agriculture-related geo-environmental conditions. However, there is an urgent need to make a strong interlinkage between GIScience and research to attain a balanced development in the agricultural sector. This chapter attempts to understand the nature and status of recent research articles using GIScience to acquire and analyze geospatial data. In this chapter, our objective is to track how to connect GIScience and sustainable agriculture effectively.

1.2 Data Source and Methodology

This chapter is an analytical review work. Thus, the sources of data of the chapter and the published research articles in agricultural research specially applied GIScience to obtain spatial data. A systematic study of the research papers has analyzed the status of the application of GIScience in agricultural research. For re-establishing a substantial nexus between GIScience and sustainable agriculture and synthesizing the different published research works about the strategy of improvement in the farm sector, it has been explored practical ways to make a torch-bearing interpretation.

1.3 What is GI-Science?

GIScience is a discipline that uses the geographical information system (GIS) to understand the world (Clarke and Gaydos 1998; Lü et al. 2019). Goodchild (2010) defined *GIScience* as 'the science behind the systems, concerned with the fundamental questions raised by GIS and allied technologies'. GIScience is the tank of knowledge that assists GIS in performing its works more and more effectively (Fuhrmann

et al. 2008; Kraak and Ormeling 2020). The continuous research in GIScience seeks effective, efficient, and rapid processes to acquire and visualize geospatial data to assist the research activities in the different fields of geography (Andrienko et al. 2007; Phung 2022). Therefore, a systematic scientific discipline works for searching technology-based systems to collect geospatial data intelligently to assist the geospatial analysis of the earth's phenomena. In the present age of machine learning, the demand for data science has been increasing rapidly in academic and industrial research. Consequently, an urgent necessity feels by the researchers to make a strong relationship between data science and GIScience (Arribas-Bel and Reades 2018; Zaman et al. 2021).

1.4 Why Sustainable Agriculture is Needed?

The societies of the modern world face problems in agriculture in two dimensions. The first one is the eco-environmental threats due excessive use of biotechnologically generated seeds and chemical fertilizers (Chen 2020; Ingrao et al. 2018). The other is the spatial inequality of the growth and development of agriculture worldwide, increasing economic disparity in human society (Señoret et al. 2022). A tremendous increase in agricultural production is obligatory to sustain the livelihoods of a large population in developing nations (Awazi et al. 2022). Generally, developing countries use high-yield variety (HYV) seeds, chemical fertilizers, and groundwater for irrigation to fulfill the ever-increasing demand for food and beverages of citizens (Kumar et al. 2021a, b). Consequently, environmental deterioration is joint in these nations (York and McGee 2016). Developing countries and developed nations face the problems of environmentally unfriendly agricultural practices to some extent (Hussain et al. 2022). Therefore, sustainable development in agriculture is urgently needed to shake human well-being and restore ecological balance.

1.5 Results and Discussion

1.5.1 Applicability of GIScience for Sustainable Agriculture

Balanced development in agriculture requires those strategies which can keep the ecological environment intact as much as possible on the one hand. On the other hand, increase agricultural production in such a way that the needs of all people for food, clothing, and shelter can be ideally met without hampering the future generation's needs (Keijzers 2002). Exploring strategies for suitable agriculture is a tough challenge for world agricultural science and social science practitioners (Braun et al. 2022; Meyfroidt et al. 2022). To meet this challenge, a proper understanding of geo-environmental factors that influence the nature and growth of agriculture in a spatial context is necessary. Thus, detailed and reliable updated geospatial data is required for the researchers to analyze agricultural conditions to assist sustainable agriculture. GIScience is the most dependable discipline for accumulating geospatial data in this context.

1.5.2 Present Scenario of the Application of GIScience in Agricultural Research

Indeed, in many agricultural research works, RS and GIS have been appreciably used to understand the agricultural crises concerning the physical environment and socio-economic aspects that influence crop production and trading. In the recent few decades, many research articles have been published about the agroclimatic zone, soil suitability classification, prediction of climatic disasters that hamper agricultural production, changing cropping patterns due to climatic change, and prediction for crop production, and so on, in which RS and GIS technology used for collecting, analyzing, and visualizing the geospatial data. An analysis of such works with examples has been included.

The summary of this analysis is displayed in tabular form (Table 1.1). Examples of recent works about sustainable development in agriculture using remote sensing and geographical information show that researchers are kingly interested in applying the technologies for collecting geospatial data. *Nevertheless*, in the research articles, more effort is needed to link sustainable agriculture and GIScience in the real world. Thus, there is necessary to take the initiative to connect sustainable agriculture and GIScience.

1.5.3 Need for Strong Connection Between Sustainable Agriculture and GIScience

GIScience, as an applied discipline, attempts to explore systematic and efficient methods and tools for extracting geospatial data quickly and reliably with the help of intelligent technologies (Machiwal et al. 2018; Teixeira et al. 2021). The researchers and professionals use these geospatial data according to the motives of the research. Thus, the purpose of applying this science depends on the thought of the users, which might be sustainable or not (Devillers et al. 2007; Vermeulen-Miltz et al. 2022). By analyzing the geospatial data related to agriculture, a researcher can explore the strategy (s) for the growth of agriculture that might be sustainable. Balanced development in agriculture aims to preserve the ecological balance and achieve an equilibrium condition in human welfare (Mensah 2019). So, the use of GIScience while seeking a strategy for agricultural development should always follow the philosophy of sustainability. The researchers in the field of agricultural development will likely aim to use the geospatial data provided by GIScience to implement sustainable methods and strategies for its development (Tian et al. 2022). Even though research works on agricultural development using the GIS and RS technologies, a gap is found while linking GIScience and sustainable agriculture. Therefore, there is a need to make a bridge linking sustainable agriculture and GIScience. Now, the debate is why sustainable agriculture and GIScience are strongly liked. The answer to the question is that more and more advanced strategies are needed for the complete implementation of the concept of balanced development in agriculture. The innovation of new techniques for sustainable agriculture requires more detailed geospatial data to be obtainable in GIScience. The need for precise geospatial in agricultural research will inspire the discovery of novel technologies in the GIScience. With the innovation of new technologies in GIScience, progress in agriculture will be enhanced. Therefore, nexus between sustainable agriculture and GIScience is necessary for researchers searching for balanced agricultural development strategies.

1.5.4 Pathways for Linking Sustainable Agriculture and GIScience

One of our objectives in this analytical chapter is to explore ways of connecting sustainable agriculture and GIScience. Recent studies on agricultural development rely on geospatial data to a large extent, and the use of GIS and RS is widespread almost in every agricultural research (Rao 2007; Tian et al. 2022). Thus, GIScience is accustomed by the researchers performing studies about agricultural development (Ghute et al. 2022). Now, the researchers must use the geospatial data obtained from the platform of GIScience more carefully from the sustainability angle. Researchers must seek a more efficient strategy for achieving sustainable agriculture in a real-world situation using the ground-level data collected by field surveys and geospatial data accrued by intelligent technologies innovating in GIScience. Scientists should focus on developing new technologies to assist sustainable agriculture. In this way, a substantial nexus can be established between GIScience and sustainable agriculture. However, Fig. 1.1 gives a descriptive idea about the overall links between the subject matter of ‘GIScience’ and ‘sustainable agriculture’.

Table 1.1 Example of the works on sustainable agriculture using remote sensing and geographical information

Examples of research work on sustainable agriculture (Title)	Author(s)	Empirical insights into the work	Material and method used	Theory used in the work	Gaps in research agenda	Type of technology used form GIScience	Relevance for real-world applications
Is there a need for a more sustainable agriculture?	Gomiero, et al. (2011)	Artificial intensification of agricultural production causes environmental deterioration	An analysis based on literatures review	Agriculture to be in more sustainable pathways	Only a theoretical approach is used	There is no space for using RS and GIS technologies	Relevant for building a conceptual model
Modeling of alternative crops suitability to tobacco based on analytical hierarchy process in Dinhata subdivision of Koch Bihar district, West Bengal	Das et al. (2017)	Alternative crop suitability to tobacco toward the FAO-FCTC treaty	Analytical hierarchy process (AHP)	Climate and soil suitability traditional crops exist to replace tobacco cultivation	Cost–benefit analysis for alternative cultivation has not been considered	RS-GIS has been applied intensively	Relevance toward sustainable crop suitability
Modeling and assessment of irrigation water quality index using in semi-arid region for sustainable agriculture	El Behairy, et al. (2021)	Rational use of water for irrigation reduces the risk of environmental hazards	Inverse distance-weighted algorithms and the model builder function	Sustainable management of water resource	Generalized model has not been built for optimal use of water resource	RS and GIS technology were used efficiently	Applicable in areas suffers from water shortage
Assessment of spatial variability and mapping of soil properties for sustainable agricultural production using geographic information system techniques (GIS)	Denton, et al. (2017)	Selection of crop for cultivation is profitable by judging the suitability of the soil	Soil suitability classification model is used	Soil suitability classification is suitable for profitable farming	Feasibility for using the model not assessed	Geospatial data have been analyzed with smart technology	Can be applicable in a region when it is feasible in the socio-economic condition of the concerned region
Intelligent analysis of precision marketing of green agricultural products based on big data and GIS	Tian et al. (2022)	Decision for green farming is prosperous while understanding the market's status	Modern information technology is used for managing big data	Market analysis is necessary for the success of farming	Cost and profit analysis for green cultivation have not been considered	GIS and RS have been used efficiently	Universal application of this concept needs more analysis

(continued)

Table 1.1 (continued)

Examples of research work on sustainable agriculture (Title)	Author(s)	Empirical insights into the work	Material and method used	Theory used in the work	Gaps in research agenda	Type of technology used form GIScience	Relevance for real-world applications
Developing spatial model to assess agro-ecological zones for sustainable agriculture development in MENA region: Case study Northern Western Coast, Egypt	Amin et al. (2022)	Sustainable agricultural practice needs the identification of agro-ecological environments of a region	NDVI and land use/covers maps prepared by using Sentinel-2 images	Climate and ecological setup are the most important determining factors of agriculture	Other factors of agricultural development have not been considered	GIS and RS data have been used intensively	Relevance for the application in a real-world situation
Research on the use of aerial scanning and GIS in the design of sustainable agricultural production extension works in an agritourist farm in Romania	Călina, et al. (2022)	The integration of agrotourism and sustainable agriculture is a strategy for the balanced development	Spatial analysis of agricultural aspects	Integrated development is a good way for sustainable agriculture	Management strategy for agrotourism and sustainable agriculture has not been included	Areal Scanning and GIS have been used	Relevance for integrated development
Sustainable agricultural development: a micro-level GIS-based study on women's perceptions of environmental protection and entrepreneurship in Japan and Bangladesh	Ahamed et al. (2021)	Perception of the environment from an eco-friendly approach leads to the way of sustainable development	Multi-criteria decision analysis (MCDA)	Perception about the environment is the first step to the sustainable development	Approach of the decision-makers about sustainable development has not included	GIS has been applied intensively	The thought is relevant for sustainable development
Nano-fertilizer use for sustainable agriculture: Advantages and limitations	Zulfiqar, et al. (2019)	Environmentally friendly input in agriculture is less risky	Direct field observation method used	Eco-friendly agriculture is better for the present and future	Micro-level analysis has not included	GIScience is not used for getting geospatial data	Relevant for medium and large farming
Profitable and viable alternative to tobacco crop in Dinhata Subdivision of Koch Behar district, West Bengal	Das and Bhattacharya (2016)	Successful strategies require that address the availability of alternative crops to promote the transition away from tobacco cultivation	Direct field observation method and cost–benefit analysis	Profitable sustainable crops exist to replace tobacco cultivation	Social factors were not considered	There is no space for using RS and GIS technologies	Relevance for FAO-FCTC treaty toward alternative crops

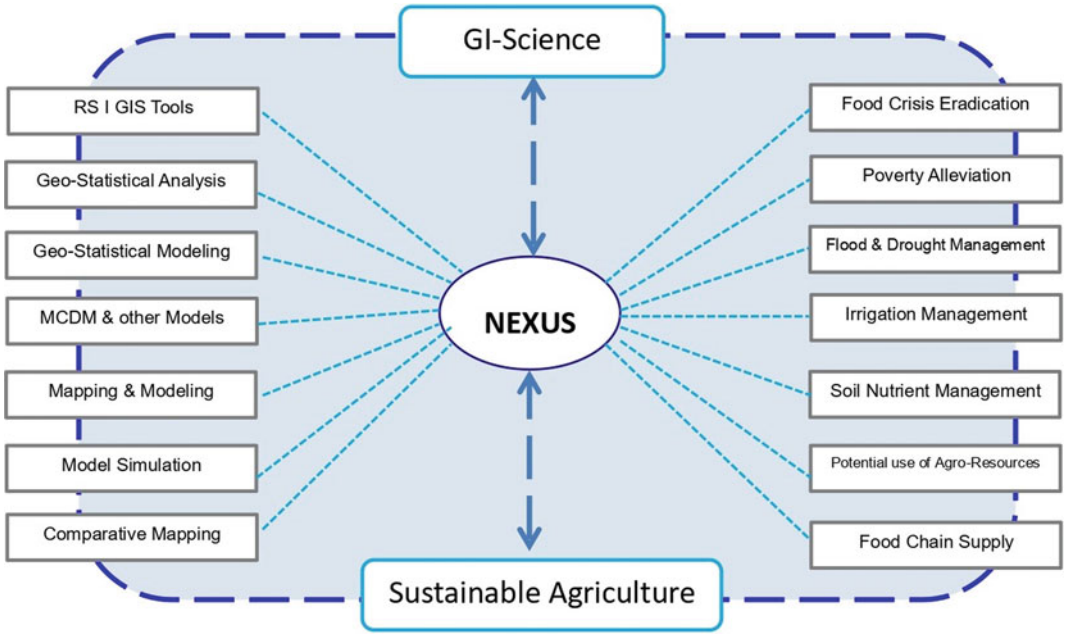

Fig. 1.1 Simplified linkages between 'GIScience' and 'sustainable agriculture'

1.6 Conclusions

Using geospatial data in agricultural science research and studies about agricultural development has opened a new horizon of scientific thinking worldwide. In this context, GIScience has induced a revolutionized scenario in the innovation of technologies that assist in extracting geospatial data. The researchers use this geospatial data to investigate the agriculture crisis related to physical or socio-economic phenomena. Sustainable agriculture is relevant to ecologists, humanists, and ordinary people worldwide. Consequently, searching for realistic ways to implement a wholly balanced development in agriculture is a challenge for the decision-makers of any nation. In this connection, GIScience is a reliable discipline that can assist in assessing agricultural aspects in the spatiotemporal context. So, there is a need for a perfect linkage between sustainable agriculture and GIScience. Researchers in farm development and GIScience must take responsibility for the relationship above to achieve balanced agricultural development and progress in GIScience, respectively.

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