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Do Natural and Technological approaches have any impact on Agri-farms?

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Short Paper

Abstract

Agriculture's considerable role in the existence of mankind has been offset by its significant contribution to the deterioration of the natural ecology due to factors such as, the expanded use of the land surface and the use of technologies to enhance food production. Accordingly, there is a perceived need to examine how sustainability in this domain can be enhanced and promoted. Relatedly, the domain is advancing in the use of digitalization such as, Artificial Intelligence (AI) tools and techniques. This research paper theorised that the implementation of natural and technological approaches can affect economic and sustainability outcomes in agriculture. Research related to different agricultural practices revealed that permaculture and digital solutions can facilitate achieving sustainability and economic goals in agriculture. Furthermore, an empirical investigation using the case of a Bangalore-based company (Hosachiguru), which provides managed farm plots, indicated that natural and technological practices, in combination, supported economic and sustainable outcomes.

Keywords: Sustainability, agriculture, agro-forestry, lifestyle, permaculture, technology, case study

Introduction

Agriculture is the single largest contributor to loss of biodiversity due to its transformation of natural ecosystems into ranches and farms; extension of management in longstanding cultural landscapes; discharge of pollutants, as well as greenhouse gases (GHGs); and related impacts to the value chain, such as, usage of transport and energy, and wastage of food (Dudley and Alexander 2017). These have resulted in calls for a "reformed, sustainable approach" to agriculture or sustainable systems for agriculture. Sustainable agriculture systems fundamentally denote systems with the capacity to persevere (Robertson 2015). In this regard, the second Sustainable Development Goal (SDG2) to "End hunger, achieve food security and improved nutrition and promote sustainable agriculture" accepts the interconnections between encouraging sustainable agriculture and empowering small farmers as well as other issues such as, supporting gender equality, putting a stop to rural poverty, safeguarding healthy lifestyles, and dealing with climate change (United Nations 2015).

Relatedly, contemporary advancements in technology coupled with the increased emphasis on sustainable farming have resulted in the exploration and use of innovative natural and digital approaches for sustainable farming. One of the natural approaches, permaculture is a form of agroecology that evolved in response to rising fears regarding the adverse effects of industrial agriculture and consequently is an "international movement and ecological design system" (Ferguson and Lovell 2014, p. 252). From a digital solutions perspective, the concepts and practices of smart farming and precision farming/agriculture have consequently emerged. Precision farming/agriculture can be described as an "information-led management concept in both plant and animal production that is based on a wide range of technologies" (Linaza et al. 2021, p. 3), and its basis is the digital processing of definite information so as to support the process of decision-making. On the other hand, smart farming pertains to a "knowledge-based approach in which machines can at least take partially autonomous decisions in collaboration with management systems. The decisions taken by machines are based on autonomously obtained and processed information in real-time, even though farmers always have the possibility to correct them" (Munz et al. 2020, p. 2). Artificial Intelligence (AI) applications and techniques in the context of PA include machine learning (ML), deep learning (DL), robotics, and drones (Linaza et al. 2021). However, most current smart farming focuses on monitoring, without utilizing the observed data in other ways (Wongpatikaseree et al. 2018).

While permaculture principles and the use of digital solutions to support sustainable agriculture can be frequently encountered in scientific and academic research over the past few decades, existing research related to innovation and sustainability in agriculture, and the role of Information Systems (IS) in sustainability, appears to be preoccupied with prospective goals or outcomes rather than with empirical evaluations of the sustainable operations and outcomes of farms in real life. Relatedly, in the agri-farm industry context, there seems to be an increasing number of organizations providing managed farm plots to interested investors in India, and there is limited knowledge related to their processes and contribution towards sustainability goals while delivering positive economic impacts to such investors. Consequently, this study will attempt to bridge these gaps in research by empirically evaluating how two farm types, namely, agro-forestry and lifestyle farming projects, employ permaculture principles and/or digital solutions to derive their required economic and sustainability outcomes. *Agro-forestry* signifies "land use management system in which trees or shrubs are grown around or among crops or pastureland" (Morel et al., 2019, p. 3). *Lifestyle farming* refers to a style of farming adapted to "lifestyle/values choices and not strongly shaped by subsidies/grants" (Morris et al., 2017, p. 141). The two types of farms were chosen due to their availability in the managed farm context. We measure the impact through the case study of agri-farm type approach from a Bangalore-based farming company (Hosachiguru) which provides managed farm plots.

The following overarching research question was formulated to inform the study:

- What is the impact of natural and technological approaches on the economic and sustainability objectives on agri-farms?

We are going to measure the economic objectives (e.g., cost of labor, farming cost) and sustainability objectives (e.g., reduced water usage, reduced chemicals) at a farm level using interviews and surveys.

The associated objectives are as follows:

- To assess the impact of natural approaches on the economic and sustainability objectives on agri-farms.
- To assess the impact of digital solutions on the economic and sustainability objectives on agri-farms.

This research work is expected to contribute to the academic and practitioner audience. The key contribution of this paper is to measure the impact of natural and technological approaches when used to derive economic and sustainability outcomes for agri-farms. Practitioners can use the research work to apply suitable permaculture parameters and the relevant digital technologies to reduce the farm operations cost (reduced labor cost, farming cost). At the same time, improve the overall farm sustainability (for example, reduced water usage, reduced chemical usage, and others). Academics can use this research to identify opportunities for future research with different dimensions of permaculture and new emerging digital technologies when implemented together across different farm types and the potential impact it has on farm economics and sustainability. To our knowledge, this is the first research that currently, has no published literature covers the combined impact of permaculture and digital solutions implemented at the farm level covering agro-forestry and lifestyle farm types.

The remainder of the paper is organized as follows: first, the chief concepts of interest to the paper are discussed namely, permaculture, the use of digital solutions/technologies in agriculture, and theoretical perspectives related to sustainability. A brief overview is then provided of the method used by the study, followed by an update on the current status of the research and present conclusions.

Permaculture

Permaculture is a form of agroecology that evolved in response to rising fears regarding the adverse effects of industrial agriculture. The debate regarding the feasibility of shifting from industrial agriculture to other approaches to agriculture which have the capacity to offer a wide range of ecosystem services while simultaneously generating produce for human utilization resulted in what is termed the "agroecological transition." This transition can be considered to be a "complex, multi-sector project, operating at multiple temporal and spatial scales and involving diverse constituencies" (Ferguson and Lovell 2014, p. 252). Permaculture, specifically, is an alternative agroecology movement and consequently is an "international movement and ecological design system" (Ferguson and Lovell 2014, p. 252). The advent of permaculture can be traced to the 1970s where it was proposed as a "practical in situ approach" to fashioning human communities that were cooperatively sustainable (Suh 2014). This approach differs from industrial systems of agriculture principally in its use of small-scale polyculture and its dependence on renewable energy sources and soft technology which is in contrast to the characteristic yearly market-dependent monoculture and heavy utilization of energy sources which are fossil-based of industrial agriculture (Suh 2014). The use of fossil fuels may be direct such as, fertilizers, or indirect such as, electricity (Anand 2014).

The implementation of permaculture in agriculture has been found to resemble, rather closely, other alternative approaches to farming, such as, organic or biodynamic farming, agroecology, or agro-forestry, movements which have traditionally supported the creation of agroecosystems which use resources efficiently and are free from pesticides. Such agroecosystems prefer local cycling of nutrients (e.g., utilizing compost, animal or green manure) and support biological control by nurturing an elevated extent of biodiversity to maintain plant and animal health (Morel et al. 2019). Permaculture resembles agroecology and agro-forestry, in that "spatial association of species," that is, the grouping of trees, crops, animals; intercropping; and varied topographies; is given the central place. In addition, soil fertility is given great significance as in biodynamic and organic farming. Overall, permaculture shares with conventional organic farming, biodynamic farming, and agroecology a common endorsement for a balanced and reverential assimilation of humans into the environment. It may be noted, however, that the origins of the three approaches are vastly different. For example, while biodynamic farming can trace its origins to theosophy (spiritual concerns), agroecology and organic farming have a deeper relationship to farm workers' crusades, their cooperative and political struggle for sovereignty. In contrast, permaculture was the outcome of self-sufficiency schemes, at individual and community levels, preparing for a world after petrol resources are exhausted (Morel et al. 2019). We will be including the key concepts of the permaculture (for example: care of earth and care of the people) and ImPACT framework (for example: technology, social and economic sustainability) as part of the research design.

Information Systems in Agriculture

The use of ICT (information and communication technology) has showed considerable savings as regards time and cost for extension services in the context of African small-scale farmers (Aker 2011). Again, the usage of precision tools such as, GPS (global positioning systems), monitoring through satellite and drone, and information related to meteorological conditions that is progressively itemized and promptly available, have become essential to contemporary large-scale agriculture (Oliver et al. 2010).

Interventions using digital technology have been reported to enhance market transparency and farm productivity, and facilitate efficient logistics (Deichmann et al. 2016). Specifically, information can play a key role in the context of productivity on farms as it can help change farmer behavior and prevent loss (via early warning systems) due to climate-related shocks. Digital tools serve as the basis for early warning systems and utilize information from different sources such as, traditional surveys and satellite imagery. Relatedly, Big Data analytics can aid agricultural research by integrating vast amounts of diverse data from diverse sources and predicting such aspects as, livestock behavior, pest outbreaks, or soil and climate (Deichmann et al. 2016). Big data analytics signifies the "use of advanced analytic techniques against very large, diverse big data sets that include structured, semi-structured and unstructured data, from different sources, and in different sizes from terabytes to zettabytes" (IBM 2023). While these digital tools can be utilized in all sizes of farms, more technologically advanced farms can utilize state-of-the-art precision farming systems. The underlying logic for such systems can combine different satellite images and remote sensing data for a specific section of a farm to offer detailed information such as, soil status, level of ground water, rain water precipitation, etc., for growth. Associated tools include sensors (for condition of soil), detectors (for detection of precipitation), and systems for irrigation optimization (Deichmann et al. 2016). Moreover, precision farming systems have been demonstrated to aid environmental sustainability. This is due to their continuous monitoring of natural resources and the appropriate taking of action before the occurrence of drought or nutrition depletion (Deichmann et al. 2016).

AI, specifically, has found application in various aspects of agriculture and consequently many applications were either specially developed for this area or were adopted and adapted from other industries for farming (Popa 2011). AI applications in agriculture include expert systems and software which are utilized for their capacity to isolate management zones after considering relevant factors such as, soil properties, meteorological data, and so on. In addition, expert systems have the ability to suggest appropriate crop rotations, ideal crop density in the planting phase, requirements for water and irrigation calendar, fertilizer rates and the suitable time for their use. Moreover, expert systems have the capacity to diagnose crop diseases and pests and to suggest precautionary or remedial measures. Further, they can specify the appropriate time for harvesting and indicate how the efficiency of farm machinery and personnel can be enhanced (Popa 2011). Another application of AI in the agricultural sector is the use of sensors for data collection and transmission (Aqeel-Ur-Rehman et al. 2014; Kaewmard and Saiyod 2014; Morais et al. 2021). The use of special sensors for this purpose improves the precision of expert systems and reduce the time and effort required for these operations. Special sensors may be embedded in farm buildings, complex agricultural machines, or in their vicinity. Electronic identification tags, prototype collars, and sensors are also utilized for farm animals. A third facet of AI in the agricultural sector is the usage of robotics and automation. These intelligent agents prospectively implement measures to increase efficiency (technical and economic) and to decrease farming's adverse environmental impacts (Popa 2011).

Information Systems (IS) field experts have been sharing insights for many years on how IS has played an important role in improving the economic objectives of organization operations but also the sustainability aspects of it (example Green IT research paper, Molla et al., 2009). Despite increased attention from business, government and more recently, Information Systems (IS) researchers, a measure to determine the capability of organizations to Green their IT remains elusive (Molla et al., 2009). Richard Watson and colleagues (Watson et al. 2010) initiated a discussion on a subfield of IS that acknowledges the probable role of IS in decreasing consumption of energy and consequently carbon emissions, namely energy informatics. Watson et al. (2010) indicated that the scope of environmental sustainability is not limited to a single organization. Instead, ecological sustainability can be developed through an awareness that ecological problems are completely and symbiotically interrelated. In another study, Watson et al. (2012) contended that similar to their role in driving improvements to productivity, information systems could drive sustainability improvements. They suggested several imperatives for computing professionals to support sustainability. First, to develop information systems and networks that offer the capability to ensure that noteworthy environmental expenses are integrated into prices (Watson et al. 2012, p. 29). A second imperative is to design reporting systems for corporate sustainability that accomplish the objective of a society that is more sustainable (Watson et al. 2012, p. 29). The third is to use effective methods for collecting and convincing means of portraying product sustainability information to boost green buying outcomes whereas the fourth is to create information systems that offer information to individuals regarding the environmental impact of personal decisions which are precise, actionable, and meaningful (Watson et al. 2012, p. 30). Overall, the research insights of Watson et al. (2012) provide a good foundation to apply key IS field concepts in the context of agri-farm industry economic and sustainability objectives.

Theoretical lens

Theories related to sustainability, as a research field and a discipline, appear to be in a stage of evolution. However, various convergent theories such as, resilience theory; multi-level perspective (MLP); decoupling theory; and behavioral change theory; have been submitted as theoretical frameworks for theorizing transitions to sustainability (Peter and Swilling 2014). Loorbach and Rotmans (2006) submit that complexity theory has a central role in aiding understanding and executing transitions to sustainability. Additionally, it can function like a theoretical framework to amalgamate the different theories of sustainability. Agency, in complexity theory, is assigned to all structures, substructures, and elements of the substructures, not merely to participants. All, consequently, can prospectively rise to authority and control behavior at the system level based on the specific conditions that direct the systems and their progress (Heylighen et al. 2007). Complexity theory, thus, is specifically related to the manner in which systems organize/disorganize themselves as regards structure, functions, restraints, and procedures (Gershenson and Heylighen 2003; Weaver 1948). The resilience theory submits that a social-ecological system can either adapt to maintain itself in a certain regime or transform itself to a completely fresh regime. Both approaches demonstrate its resilience. Consequently, resilience theory endeavors to gain awareness of the resilience of social-ecological systems which is supported by their adaptive/transformable capacity and which permit it to deal with exogenous stresses, change and ambiguity through self-organization (of internal structure, agents, controls, networked linkages, processes, and functions) and/or innovation (Peter and Swilling 2014).

The basis of the multi-level perspective (MLP) is socio-technical systems (STSs) which in their turn contain three conceptual levels namely, regimes (meso-level), landscapes (meta-level), and niches (micro-level). These three levels encompass policy, structural, regulatory, social, institutional, and environmental systems, the global scale, and spaces of innovation (Geels and Schot 2007; Grin et al. 2010). In contrast, the decoupling theory submits that the positioning of sustainability should be around approaches and actions to dissociate development (population and economic) from exploitation of resources and impacts to the environment (UNEP 2011). Additionally, sustainability-related behavioral change theories stress that behavioral change is necessitated for transitions for sustainability. This in turn entails modifications in the principles, standards, rules, and behaviors that regulate society and its connections with natural systems, and their common progression (Ehrlich and Levin 2005; Stern 2000). Since all these theories implement systems and complexity theory to different levels (Peter and Swilling 2014), these theories comprise the theoretical lens for the present study.

Method

We will be using multiple case studies approach with qualitative and quantitative analysis. This is because the case of a managed farm organization could be studied in its real-life setting. Also, the approach can generate awareness from an in-depth investigation of permaculture/digital solutions in a managed farm context. A case study approach combining qualitative, and a quantitative analysis was thus proposed for the research. This approach is chosen since it permits researchers to perform a thorough exploration of a situation, in this instance, of the functioning of a system of managed farms (Andreoli and Tellarini 2000). The aim of taking the case study approach is to highlight what occurs when permaculture and/or digital solutions are utilized in two types of agri-farms managed by the case organization (called Hosachiguru - https://www.hosachiguru.com/): agro-forestry and lifestyle farms. Hosachiguru is a company based in Karnataka, India, and they provide managed farm services covering agro-forestry and lifestyle farms. Agro-forestry was the first offering of the organization and the bulk (~80-90%) of the projects at the present time seem to be agro-forestry projects with about fifteen agro-forestry projects currently in progress with a further five in the process of being established. The initial focus of the agro-forestry projects was toward timber forests with food forests being recently introduced. Three lifestyle farming projects were introduced more recently, in the past five years. In both project forms, Hosachiguru takes care of all farm operations including such aspects as, curating, development, maintenance, keeping it updated, security, manpower management, and agronomy. About 150-200 people are employed in the farms directly on a monthly basis.

The study will use the following information sources:

- Review of existing literature related to sustainability, sustainable agriculture, innovative approaches to agriculture using permaculture and digital solutions, and the impacts of these on sustainability in agriculture
- Farm operation records, annual reports related to the operations of the two types of farms and their outcomes
- Semi-structured interviews with employees of the case organization to obtain insights regarding operations and outcomes of the managed farms; and
- Surveys with investors/purchasers/co-farmers of the managed farms to obtain insights regarding their perspectives regarding the operations and outcomes of their managed farms

With this data collection approach, we get access to unique on-ground farm-level insights from the employees who implement permaculture and digital solutions and manage the farm operations. In addition, we get insights from the investors/purchasers/co-farmers who measure the farm operation outcomes, cost management, and improvement in sustainability parameters. We truly unlock a significant potential for academics and practitioners to analyze the farm-level collected actual data and capture insights. Currently, there is very scarce work on using real data insights of permaculture and digital solutions when implemented at the farm level covering agro-forestry and lifestyle farm types.

Preliminary Findings and Next Steps

The empirical component of the study is mid-way with the theoretical and empirical phases having commenced and nearing completion. The review of literature was utilized to prepare a questionnaire for Hosachiguru customers and interview questions for Hosachiguru employees. The collection of data through semi-structured interviews has been completed, and the survey is currently in progress. Semi-structured interviews were performed with employees of Hosachiguru (n=5) to obtain insights regarding operations and outcomes of the managed farms. The employees played diverse roles in the organization such as, Head of business development and hospitality, Founding director/partner, Operations head, Junior agronomist, and Senior agronomist.

The following findings could be derived from the theoretical phase:

- *Permaculture*:
    - Permaculture is one of many approaches to sustainable agriculture and involves practices such as, applying a systems approach, using ecosystem amenities and biodiversity, agro-forestry, use of animals, promoting soil nourishing, regulating water flow, among others (Oberč and Arroyo Schnell 2020). However, its implementation, however, involves the buy-in and participation of many layers of participants including farmers and non-farmers (Fadaee 2019). Permaculture practices can be inferred to promote sustainability; however, they are not typically considered to be scalable which impacts their economic outcomes (McLennon et al. 2021; Oberč and Arroyo Schnell 2020).
- *Digital solutions*:
    - Have the capacity to ensure the environmental soundness of farming practices by ensuring climate smartness and reducing toxins which can prospectively facilitate achievement of sustainability goals (Lakshmi and Corbett 2020; Shankar et al. 2020; Vadlamudi 2019). Their support for improving the efficiency and productivity of farming practices serves a twofold purpose by reducing the usage of natural resources and increasing farmer incomes (Clapp and Ruder 2020; Lakshmi and Corbett 2020; Linaza et al. 2021). The use of digital solutions in agriculture may be accompanied by technical and non-technical challenges (Bacco et al. 2019; Eli-Chukwu 2019; Giri et al. 2020; Visser et al. 2021).

The following findings could be derived from the empirical phase:

- *Agro-forestry projects*:
    - Are farther away from the city. The focus is more on returns, less on facilities and biodiversity, although all projects are timber forests and forests in nature.
- *Lifestyle projects*:
    - The emphasis is very heavy on biodiversity, natural methods of farming and place to stay. Good facilities are provided for the customers to enjoy with the option to build their own residence in their farm as it is equipped for those things without disturbing the existing greenery.
- *Permaculture*:
    - Permaculture principles have been used by Hosachiguru for several years although not in their entirety in the earlier projects. The implementation of permaculture principles was lower in the agro-forestry projects, whereas they are very intensively applied in the lifestyle projects. Hosachiguru's rationale for using permaculture was to make the farms sustainable and regenerative. The effort and expenditure in setting up permaculture projects is high. However, the rewards are much more long-term and sustainable and hence more enjoyable for the customers. The transition to permaculture is a long process, as encountered in their agro-forestry projects.

- *Digital solutions*:
  - The digital solutions used by the organization include sensors for moisture, rain prediction, wind velocity, and air moisture, and satellite data to forecast rainfall, temperature, humidity, etc. In addition, a drone-based survey is initially used to mark the boundaries and ensure that they are properly marked and tracked. The data are then digitized and fed into the TalkingLands platform. These data are then used to facilitate plot cutting and numbering and transferring them to the revenue records. The MyFarm app is also utilized by Hosachiguru. This is a customer-facing application through which Hosachiguru provides periodic (daily, weekly) updates to customers. Customers can additionally use the digital application to book rooms and cottages so that they can come and stay in the farm.
- *Economic outcomes*:
  - In combination, the implementation of digital solutions which brings transparency to the customer, together with permaculture which brings nature to the farmers helped Hosachiguru grow their numbers significantly.

Conclusions

Although the current study is in the early stages, it appears that from extant research, that permaculture and digital solutions are beneficial in achieving sustainability and economic goals in agriculture, with the latter perhaps having an edge. Moreover, the initial findings from the qualitative empirical component indicate that the combination of natural and technological solutions has been beneficial to the case organization from the perspectives of both sustainability and economic outcomes. Specifically, permaculture has a beneficial impact on sustainably pursuing agro-forestry and lifestyle farming projects. In contrast, digital solutions help increase the efficacy of practices and resource utilization and facilitate transparency to the end customer. With this paper, we contribute to the academics and the practitioner community by giving them with key insights on how natural and technological approaches can be used to derive economic and sustainability outcomes for managed agri-farms. The next steps are to do the detailed analysis of the interview and survey data is anticipated to provide further insights to confirm/refute this.

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