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Research Article

Agricultural Sustainability in a Mining Context: An Empirical Inquest in Hemgir Block of Odisha, India

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Agricultural sustainability plays an important role in improving air, water, soil, and the general environment around the world. The concept of sustainability depends primarily on economic, environmental, and social aspects. These aspects vary by region and type of crop grown, and the environment in which it is grown, so they usually work together to standardize agricultural sustainability. Mining has widespread effects on agriculture especially in the Hemgir block of Odisha, India, which has serious implications for agricultural sustainability, especially for small and marginal farmers. Current research involves designing a structural equation model (SEM) to assess the relationships between indicators that measure agricultural sustainability in the Hemgir block. Primary data were collected from 112 paddy farmers in Hemgir block to assess environmental, social, and economic interactions. The study found that there was a significant and positive correlation between environmental and economic indicators. One of the important things to learn from this study is to help stakeholders and the agricultural sector to understand the interrelationships between specific indicators. The government also needs to emphasize the environmental aspect and facilitate social and economic-focused handholding support.

1. Introduction

Agriculture has been considered the main occupation of rural poor in India. Therefore, there is a significant relationship between the sustainability of agriculture and the livelihood issue [1, 2]. Chambers and Conway [3] reported that a livelihood is sustainable only when it manages the stress and shocks by recovering its capability and assets, and also increases the opportunities for a better life for the next generation.

The interrelated components of sustainability are economic, environmental, and social equity. The environmental dimension emphasizes on preservation and development of the resource based on the economy; the economic dimension focuses on the utilization of capital and human resources in the existing technological situation; and the social dimension covers the intergenerational equity in the distribution of economic benefits in terms of livelihood security particularly for socioeconomically vulnerable people [4]. Agricultural sustainable livelihood (SL), according to Swaminathan [5] is livelihood options that are ecologically secure, economically efficient, and socially equitable. It implies the protection or assurance of the means of livelihood for the masses not only at present but also in the future.

Previous research has mainly focused on sustainable strategies or tactics in isolation, and the relationship among environmental, economic, and social aspects has not been focused. The study defined sustainable agriculture as an integrated approach that considers environmental, economic, and social aspects. It also explained the impact of controlling factors (collaboration, institutional governance, and innovation) on the relationships among these three indicators and sustainable agriculture. The study was designed so that sustainable agriculture could be defined as a method by using three aspects of the UN's proposal for sustainable development, "Our Common Future," [6].

Despite consistent efforts from agricultural policies, institutions, and development schemes, the base of agricultural livelihoods such as paddy, vegetables, horticulture, and livestock of small and marginal farmers in mining areas of Hemgir block of Odisha continues to be not sustainable.

The impact of mining on the livelihoods of the local communities is largely neglected. Often, all the benefits accrue to the mining industry and its workforce, depriving the rest of the population in the locality. These populations bear only costs, while the provision of benefits is lopsided.

The objectives of the study are: to ascertain the state of agricultural sustainability and allied livelihoods among marginal and small farmers; and to work out a model of agricultural sustainability for marginal and small farmers.

2. Literature Review

Hota and Behera [7] and Dash and Priyadarshini [8] examined the impact of opencast coal mining on the local livelihoods of rural households in Odisha, India. It was found that mining activities had both positive and negative effects on the income, employment, food security, health, education, and social capital of the affected communities. The positive effects included increased income from mining-related jobs, improved infrastructure and facilities, and enhanced access to markets and services. The negative effects included displacement from land and loss of access to forests, loss of fertility of lands and increase of wastelands, shrinkage of grazing fields for domestic animals, pollution of air, water, and soil, deterioration of health and increase of diseases, disruption of education and cultural values, and erosion of social cohesion and trust among the people. Pradhan and Patra [9] analyzed the health status of mining people in the Keonjhar district of Odisha, India, where there are large reserves of iron ore and other minerals. The article uses primary data collected from a survey of 200 households, focus group discussions, key informant interviews, and observation of the mining areas in the Banspal block of Keonjhar district. Nayak and Mishra [10] investigated the gender issues in the mining sector in India and how they impact the sustainable development goals of the industry. The article argues that the mining sector is male-dominated and neglects the needs, rights, and roles of women in the industry. The article also highlights the adverse effects of mining on the environment, health, education, income, and social security of the women and their communities. The impact of mining on tribals in Keonjhar and Kalahandi districts was studied by Das and Pradhan [11]. The article uses the data from the Mining and Minerals for Sustainable Development (MMSD) project, which was a global research initiative that aimed to identify how mining and minerals can contribute to the global transition to sustainable development. The article argues that Keonjhar district, which has been experiencing mining activities for a long time, has remained one of the poorest regions in Odisha and has a high percentage of people living below the poverty line. The article also claims that there have been no successful anti-mining protests in Keonjhar district, despite the adverse effects of mining on the environment, health, education, income, and social security of the tribal people. On the other hand, the article asserts that Kalahandi district, which witnessed an organized and successful protest by the Kondh tribes against the Vedanta plan of extracting minerals from Niyamagiri mountain, has shown a positive trend of development and empowerment of the tribal people. The article also states that the protest was based on the cultural and religious significance of the mountain for the Kondh tribes, as well as the ecological and livelihood implications of the mining project.

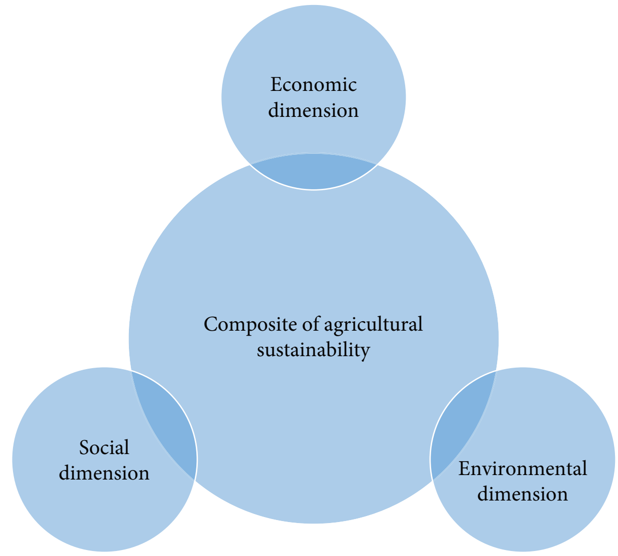

Figure 1: Three dimensions of sustainable agricultural sustainability.

Despite a few articles available on the related subject, the research gap is still observed in the evidence-based linkage between the mining and agriculture sectors from a sustainability perspective. Through this present paper, an attempt has been made to empirically establish the above linkage.

3. Conceptual Framework

Sustainability means the capacity to sustain the benefit through a process for a longer period. Researchers and policymakers have proposed several different definitions of sustainable development. The most commonly used definition of sustainable development is Brundtland's [6] definition, which defines it as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [12]. Sustainability is based on three interrelated pillars: environmental, social, and economic, which are intertwined [13, 14].

This approach assumes that sustainability can only be achieved if all three pillars—economic development, social improvement, and environmental protection—are considered together (Figure 1). Only then can sustainable development become the dominant paradigm in public policy. Any long-term strategy for growth must be beneficial to the environment, socially acceptable, and economically feasible to be adopted by the citizens. Balancing the importance and effects of the three pillars implies that sustainable development requires balancing the importance and effect of each pillar [15, 16].

Environmental sustainability means maintaining the ability of biological systems to function and operate indefinitely.

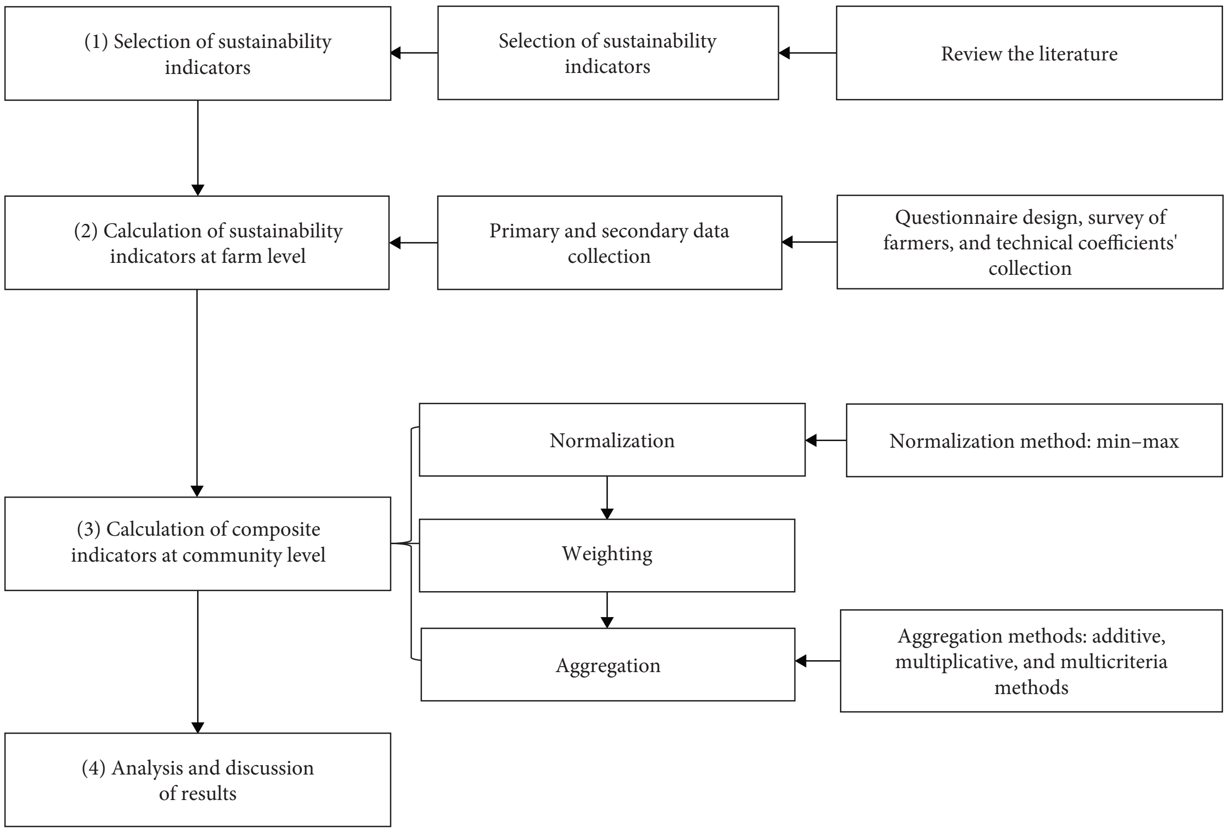

Figure 2: Methodology followed by the study.

It focuses on natural resources and highlights their irreplaceability. The benefits for the environment are concerned with conserving fossil fuels and maintaining natural ecosystems. We understand ecosystems as "dynamic complex of plants, animals, micro-organisms, and the surrounding still-life acting as a functional unit" [17, 18]. A natural ecosystem is considered a renewable resource when it does not exceed its overexploited threshold [19].

Social sustainability must ensure a good quality of life for everyone and that they receive adequate social services. It must also protect them from any kind of danger [20]. According to Stren and Polèse [21], the social pillar consists of "the development (and/or growth) compatible with the harmonious development of civil society, creating an environment conducive to the cohabitation of culturally and socially diverse groups, while encouraging social integration, with improvements in the quality of life for all segments of the population." Bramley and Power [22] argue that questions on social sustainability (such as access to services, opportunities, facilities, and social capital) raise concerns about social equity (equality between people) and cohesion (the sense of belonging). According to Baehler [23], social sustainability refers to the fundamental tensions of democracy, including the tension between individualist values and collectivist values.

Social sustainability is challenged with the increasing development concerns, including environmental and social issues. According to the United Nations, "societies must create the conditions for people to have quality jobs that stimulate the economy without harming the environment. Decent employment opportunities and decent working conditions are also necessary for the entire working-age population" [24]. From this perspective, we can limit the depletion of natural resources by implementing policies and practices aimed at conserving nonrenewable natural resources and substituting them with renewable ones.

To achieve these objectives, the sustainability livelihood index (SLI) is used to determine whether there are sufficient conditions for sustainable development in a given region or ecosystem or not.

4. Methodology

Both quantitative and qualitative methods are used in this paper. The main approach used in the paper is the use of the partial least-squares structural equation model (PLS-SEM). Structural equation modeling (SEM) is used to assess latent relationships among multifaceted variables [25]. SEM could be described as a set of methods that work based on the hypotheses representing means, variances, covariance, and correlations of empirical data concerning a small number of "structural" factors distinct by a hypothesized underlying theoretical or hypothetical framework. Combining factor

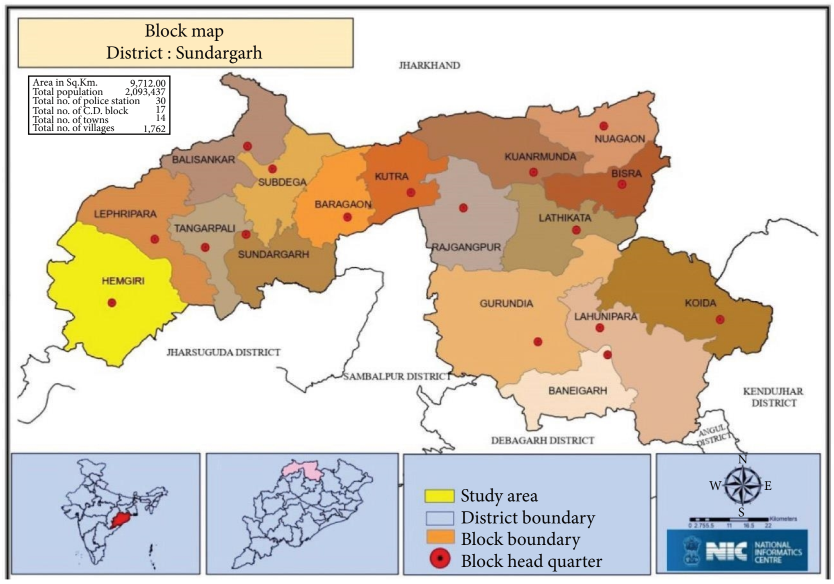

FIGURE 3: Study area.

analysis and multiple regression allows one to analyze the structural relationship between latent (unobserved) and observed variables [26]. SEM tactics can be quantified by different methods, including covariance-based SEM (CB-SEM) and PLS-SEM [27]. The study used PLS-SEM because it was superior to CB-SEM for dealing with a small data set. There were no interpretations of the data distributions. The data were analyzed using Smart PLS (Version 4) software as it is free for worldwide research. Analytical processes are carried out in three (3) steps.

The cross-sectional approach was first developed based on the results from the previous study. The tools were then used by independent random to conduct surveys among small and marginal farmers. Once the answers were validated using statistical methods, they could be used for further study. Figure 2 shows the steps followed in designing the methodology used in the study.

Primary data were collected from 112 paddy farmers in 10 villages of Hemgir block (a minimum of 10 farmers from each village based on a simple random sampling technique). One village was selected from each of the 10 mining-affected gram panchayats based on a simple random sampling technique. To analyze agricultural livelihood sustainability, four steps are followed: *selection of basic indicators; calculation of sustainability indicators at the farm level; calculation of sustainability composite indicators at the farm level, and calculation of composite indicators at the community level.*

4.1. Study Area. Hemgir block of Odisha in India is located 52 km away from the district headquarters in Sundargarh (Figure 3). The block consists of 153 villages and 84,559 population [28]. This block has been experiencing increasing mining activities around coal. Inhabitants of this block largely depend upon agriculture. The main crops are paddy, pulses, and vegetables. The agriculture is mostly rain-fed. Hemgir has 18,951 ha. forest land, 2,600 ha non-agri. use land, 1752 ha. barren land, 2,244 ha. permanent pasture and grazing land and 26 ha. land under misc. tree, crop, groves, etc. It has 579,692 indigenous and 20,839 cross-breed cows, 32,933 buffalos, 563,586 goats, 31,744 sheep, 48,349 pigs, and 106,437 poultry. Total milk production is 59.53 MTs, freshwater fish production is 1,227 MTs and total egg production is 528.58 lakhs.

Even today, quite a few cutting-edge and revolutionary technologies have been regarded to boost crop yield. But, typically within the mining situations confronted by way of the small and marginal farmers in Hemgir block, to boost crop yields, extra chemical fertilizers are required, which will increase environmental pollutants. Besides, it contributes to the accelerated use of pesticides. However, chemical fertilizers are not sustainable; as a result, farmers within the research place have suffered from a consistent waft of money because of inefficient farming. This result is horrific no longer only from a monetary viewpoint, but, also the ecological stability, which has also created impacts on the maximum important social troubles. Mining has greatly affected the agriculture of the small and marginal farmers in Hemgir, especially in mining areas:

(1) Every day 1,200–1,600 trucks are passing through the villages, causing air pollution. The black dust particles settle on the paddy crop, which prevents photosynthesis. Moreover, the color of rice became black, which led to declining demand for such rice;
(2) In Hemgir, there are many open-cast coal mines such as MCL, NTPC, OPCL, etc., through which nearby waterbodies get polluted, and hence agriculture gets adversely affected;
(3) Rain water used to stay in the fields for 10–15 days, now it is drying out for 2–3 days;
(4) The water table is going down, observed from wells and water table for new bore wells;

FIGURE 4: Mining activity's effect on the agricultural product.

(5) The yield of paddy in the area has reduced to 10–12 quintals per acre against 20–25 quintals per acre before the mining operation;
(6) Paddy and other crops get a black coating on them. Rice too is being blackened;
(7) Sale of the paddy in the *mandi* is a difficult task now due to its black color;
(8) Grass and other vegetation get affected by mining dust resulting in a scarcity of fodder for animals;
(9) Eatable green leaves (*saga*) like drum stick leaves and vegetables like bitter gourd, and papaya have lost their taste and are no longer adored by the community, hence captive food baskets suffered;
(10) All the water bodies in the area are affected and have black layers, leading to skin diseases;
(11) NTFPs like mahua flower, sal leaf, char, etc. are important livelihood means for tribals distorted due to the high-level pollution;
(12) The water of the mines during the rain drains into Chaturdharanala which joins Basundharanala, that flows down toward Laikera;
(13) Heavy trucks bring accidents and social evils too.

Figure 4 shows the mining activities' effect on the agricultural product.

4.2. Composite Index. The Agricultural Sustainability Composite Index is an operational measure to check whether or not the conditions essential for sustainability livelihoods are present in Hemgir block, the following major factors were considered:

(1) The composite index should be composited with inherent synergy between the three aspects of livelihood;
(2) It should be flexible and simple;
(3) It should be understood by the local administrators policymakers and the general public.

To convert the conceptual framework to the operational concept, we followed the slightly modified analytical framework used by the United Nations Development Program (UNDP, 1992), So *LIJ* is the index measuring the livelihood preferences of the Hemgir block, it can be represented as follows:

$$I_{ij} = \frac{X_{ij} - \min_j X_{ij}}{\max_j X_{ij} - \min_j X_{ij}}. \quad (1)$$

It considers that the numerator indicates the extent by which X_i, differs from its minimum value, and the calculation represents the range, which is a simple statistical measure of variability. I_i, on the other hand, expresses the variability of the main indicator as a ratio of the total variability in the *LIJ* component. As a result, the higher the variability of the main indicator, the better its performance in the *LIJ* component, and vice versa. The composite *LJI* can be calculated either as a weighted average (i.e., equal weights) of the three components as follows:

$$LIJ = \frac{W_{\text{economic}} I_{\text{economic}} + W_{\text{envi}} I_{\text{envi}} + W_{\text{Social}} I_{\text{Social}}}{W_{\text{economic}} + W_{\text{envi}} + W_{\text{Social}}}. \quad (2)$$

Similarly, the efficiency of an environmental Hemgir block can be represented by such variables as soil and land quality, weather conditions and adaptability, environmental resources and efficiency, and biodiversity.

Social equity can be represented by such variables as food self-sufficiency, access to social institutions and resources, empowerment, and gendered equity, adaptability including attitude (to adopt emerging technology).

4.3. The Model. There are different theoretical methods and operational approaches, which are developed by the researchers and experts, that can be used to evaluate the sustainability of agriculture.

An extensive literature review has been done and 22 indicators under three sustainability dimensions have been identified based on the research context's condition. Figure 5 shows the output through the structural equation modeling technique. A theoretical model has been developed for sustainable agriculture and integrated into the three main dimensions of sustainable agriculture. The PLS software has been used in this paper as it is appropriate to the context.

The path optimization method considers itself a partial model because the agile PLS-SEM technique generally calculates the ordinary linear regression [29]. Besides, sustainable farming technique is becoming an increasingly important way for farmers to gain competitiveness and enhance their economic efficiency. However, if we are talking about competitiveness among individual farms, then there should be competition

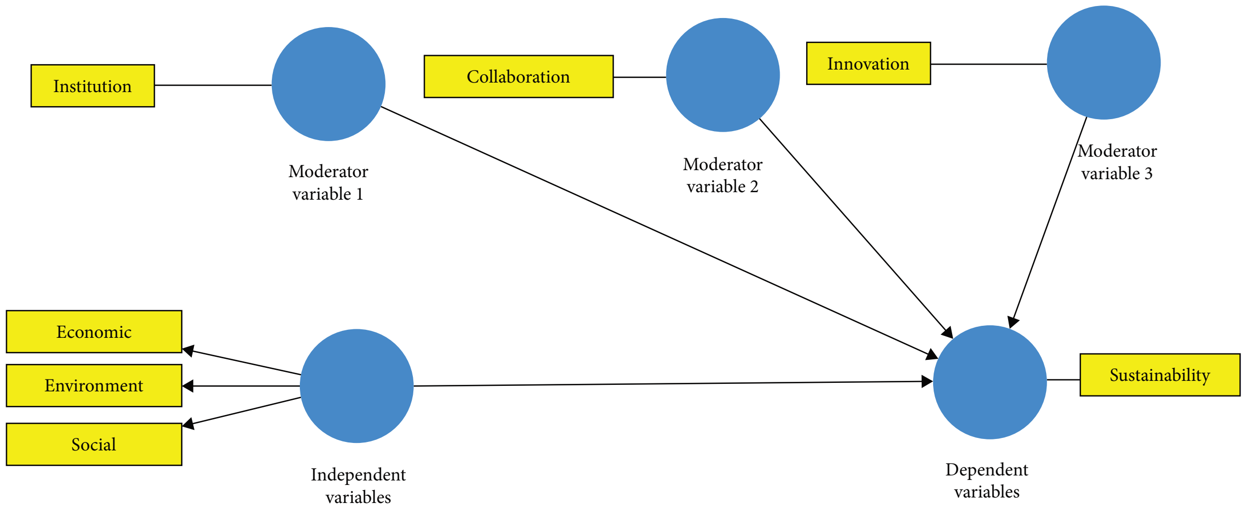

FIGURE 5: Model of the study.

TABLE 1: The main and subcomponents of the economic sustainability composite index.

Major dimensions	Subdimension	Components	Value of subdimension	Value of major dimensions
Economic	Crop efficiency	—	0.51	0.62
	Land productivity	—	0.52	
	On-time access to resources	(a) Inputs include (credit, infrastructure, transport) (b) Market (c) Support services	0.94	
	Economic empowerment and equity	(a) Ownership of agriculture assets and land (access to assets) (b) Capacity to negotiate market (No distress sale—information, volume, institutional sale)	0.52	

TABLE 2: The main and subcomponents of the environmental sustainability composite index.

Major dimensions	Subdimension	Components	Value of subdimension	Value of major dimensions
Environment	Soil and land quality	Soil quality Land maintenance Agricultural practice concerning soil quality, technology, irrigation	0.32	0.31
	Weather conditions and adaptability	Affected by rainfall, Coping strategy	0.42	
	Environmental resources and efficiency	Resource use efficiency—fertilizer and water Water use efficiency Fertilizer use efficiency Land efficiency	0.30	
	Biodiversity	Availability of natural species such as insects, pests, worms, birds, fishes, natural silt from ponds, and others in terms of their status (increase, decrease, almost changed, endangered, extinct)	0.18	

Table 3: The main and subcomponents of the social sustainability composite index.

Major dimensions	Subdimension	Components	Value of subdimension	Value of major dimensions
Social	Food self-sufficiency	Depending on PDS	0.28	0.55
	Access to social institutions and resources	Membership in a community-based organization (Benefited access to services Access to resource organization)	1.00	
	Empowerment and gendered equity	Information on different social development programs Participation of CBOs Participation in decision-making	0.55	
	Adaptability including attitude (to adopt emerging technology)	Adaption of different technologies available Following new practices	0.36	

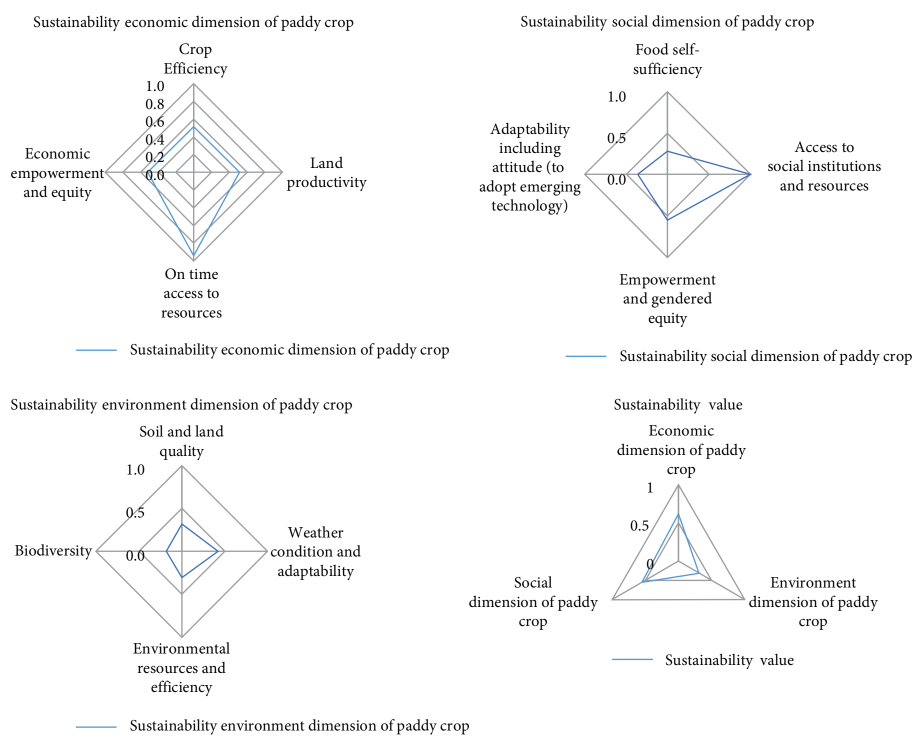

Figure 6: Results of the whole dimensions.

among different sustainable farming approaches. In this model, the following hypotheses are developed:

H1: Economic, social, and environmental parameters (independent variables) are significantly interconnected for ensuring agricultural sustainability (dependent variable);

H2: Institutional governance, collaboration, and innovation indicators significantly moderate the relations between the independent variables (economic, social, and environmental indicators) and dependent variables (agricultural sustainability).

4.4. Novelty of the Paper. The following are the novelty of this paper:

(1) This paper contributes the empirical (evidence-based) dimensions of agricultural sustainability in the mining context of Odisha which is one of its kind;

(2) As explained in the result and discussion section, this paper has identified collaboration, innovation, and institutional governance as moderating factors that influence the extent of association between the dependent variable (agriculture sustainability) and independent variable

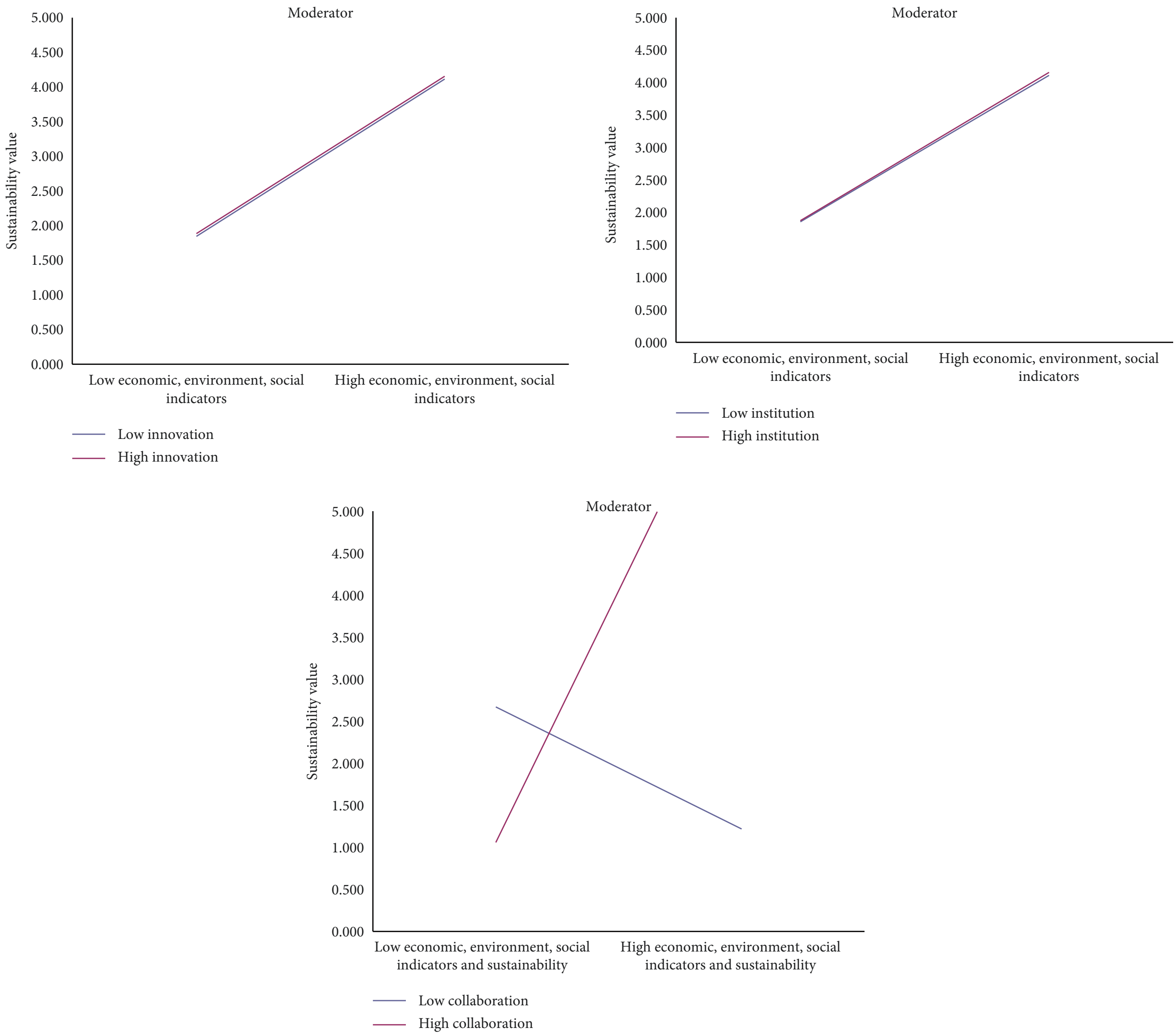

Figure 7: Effects of moderator variables.

(economic, environmental, and social aspects of agriculture). The other two moderating variables, viz. risk coverage and value addition were found to be grossly missing in the study area.

5. Results and Discussion

5.1. Economic Sustainability Indicators. The economic dimension of agricultural sustainability in Hemgir block has been represented by crop efficiency, land productivity, on-time access to resources, and economic empowerment and equity (Table 1).

5.2. Environmental Sustainability Indicators. The environmental sustainability of paddy farms corresponds to four aspects, viz. soil and land quality; weather condition and adaptability; environmental resources and efficiency; and biodiversity. Ten indicators were selected to determine the degree of achievement of each aspect (Table 2).

The results indicate that biodiversity in the Hemgir block has a negative impact on environmental sustainability, in some ways or others, maybe because of the mining activities in the Hemgir block.

5.3. Social Sustainability Indicators. Social factors play an important role in agricultural sustainability. According to three principles: (a) access to social institutions and resources, (b) empowerment and gendered equity, (c) adaptability including attitudes (to adopt emerging technologies).

In line with the effects demonstrated in Table 3, access to social institutions and resources contributed the most to agricultural sustainability with a value of (1) and food self-sufficiency contributed less to sustainability agricultural value of (0.28).

Finally, it was found that environmental sustainability contributed less to agricultural sustainability than other economic and social aspects. environmental sustainability contributions were estimated at (0.31), and economic and social sustainability contributed at (0.62, and 0.55), respectively (Figure 6).

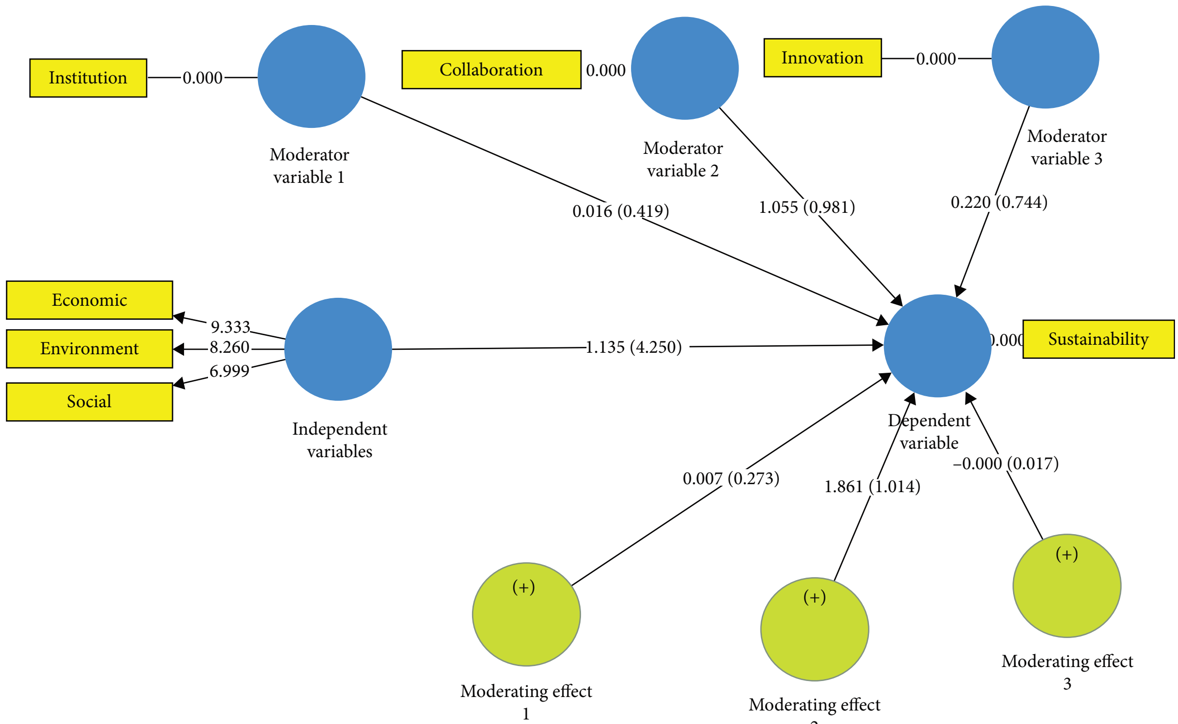

Figure 8: Relationship between the DV and IV.

Based on this result, the government must intervene to strengthen the policies in controlling mining activities, mitigating environmental degradation, and protecting crops from insects caused by the use of chemicals by focusing on organic farming.

5.4. Effects of Moderating Variables. In addition to quantitative indicators, this study has developed an integrated framework for economic, environmental, and social aspects. Within this framework, we have found combinations that can influence the relationship between the above three aspects and agricultural sustainability. The results as shown in Figures 7 and 8 show that each variable (collaboration, innovation, and institutional governance) actively improves the relationship between the independent variable (economic, environmental, and social) and the dependent variable (sustainability). However, collaboration contributed more to controlling the factors.

The other two moderating variables, viz. risk management and value addition were explored, but both of these were found to be grossly missing in the study area. It might be due to the following reason: Being the farmers are small and marginal landholders, they need to be organized for collective strength in ensuring agricultural sustainability. This may be done in line with the agriculture production cluster model of the Odisha government. However, the said FPC model needs to enable the farmers in terms of facilitating the above five moderating variables.

5.5. Future Scope

5.5.1. Implementation. The agricultural sustainability facilitating agencies, including the agriculture and horticulture department and other authorized organizations may focus, as discussed in organizing the marginal and small farmers in the APC approach. Moreover, they need to emphasize the following five areas as discussed earlier—innovation, collaboration, institutional governance, risk management, and value addiction.

5.5.2. Research. More empirical (evidence-based) study is required on above mentioned areas.

6. Conclusion

From the results and discussions section, it is evident that environmental indicators contribute the lowest as compared to the other dimensions in agricultural sustainability. The specific indicators under the environmental dimension that need to be focused on include soil and land quality, biodiversity, environmental resources and efficiency, weather conditions, and adaptability. It is also evident from the earlier section that the association between the dependent variable (agricultural sustainability) and independent variables (indicators of economic, environmental, and social dimensions) was strongly moderated by innovation, collaboration, and institutional governance. Two such (moderating) potential areas, biz. risk management and value addition, which were not in practice, may be prioritized by the facilitating agencies. As mentioned in the earlier section, being the farmers are small and marginal landholders, they need to be organized for collective strength in ensuring agricultural sustainability. This may be done in line with the agriculture production cluster model of the Odisha government. However, the said FPC model needs to enable the farmer in terms of facilitating the above five moderating variables.

Data Availability

The data will be available when its required from the authors.

Disclosure

The authors are solely responsible for the analysis and interpretation of the data presented in this article. It is part of the regular activities; no other than authors were involved in manuscript writing, editing, or decision to publish.

Conflicts of Interest

The authors have no conflicts of interest to declare.

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