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RESEARCH ARTICLE

Applying Fuzzy Cognitive Mapping to Analyse Project Impact and Enhance Future Initiatives: The Case of Bio-Village Project in West Bengal

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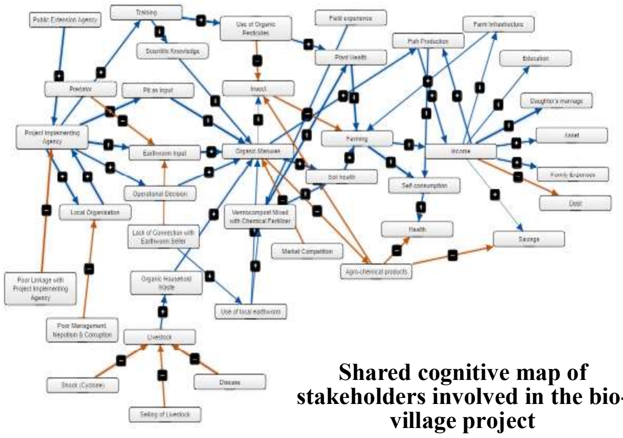
HIGHLIGHTS

- Fuzzy cognitive mapping (FCM) effectively illustrates project impact pathways that are often overlooked by traditional project assessment methods.
- Applying FCM to a bio-village project in West Bengal revealed that capacity building, input support, and social capital are key drivers of the project's impact.
- Scenario analysis indicates that progressively integrating socio-technical intervention modules can enhance the long-term sustainability of projects.

GRAPHICAL ABSTRACT



Shared cognitive map of stakeholders involved in the bio-village project

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ABSTRACT

Context: Most impact assessments of natural resource management projects rely on quasi-experimental designs and indicator-based approaches to connect technological interventions with changes in livelihoods, sometimes complemented by qualitative research and success stories.

Objectives: Objectives of this study were to: a) develop a shared cognitive map of stakeholders to capture the project's impact, b) analyse the structure of this map to identify critical factors in the project's impact pathways, and c) simulate potential outcomes of future projects under various realistic scenarios.

Methodology: The study employed a fuzzy cognitive mapping (FCM) approach to elicit and combine the cognitive maps of stakeholders involved in the Bio-village project. We converted the combined map into an adjacency matrix for analysing both map-level and concept-level properties. The analyses were performed using the Mental Modeler platform.

Results and Discussion: The project's multi-faceted approach of employing training, input support, and operational monitoring, resulted in significant improvements in organic manure production, soil health, and farm income. However, its success experienced challenges due to reliance on external sources for essential inputs like earthworms, occasional application of chemical fertilizers, and complexities arising from grassroots-level organisation. Scenario analysis indicates that while baseline interventions are effective, integrating local organisations, predator control, and improved livestock management could substantially enhance the project's sustainability.

Significance: Understanding the process of impact creation in rural development projects and the preconditions of their success may provide valuable guidance for future bio-village projects and their underlying theories of change.

Public extension agencies, along with non-profit and donor agencies, frequently implement technology transfer projects related to natural resource management, only a part of which is subjected to rigorous scientific evaluation, especially impact assessment, due to resource constraints (Joly *et al*., 2016). Most impact assessments use quasi-experimental designs and indicator-based approaches to connect technological interventions to livelihood improvement, often supplemented by qualitative research and success story documentation (Reed *et al*., 2021). However, determining how these interventions impact rural livelihoods remains challenging. Understanding the 'invisible' pathways through which project impacts are created can identify the pre-conditions of success for future projects. Conceptually, these pathways form a complex network of interrelated factors that link drivers (e.g., technological intervention) to impacts in a socioecological system (Monge *et al*., 2021). Assessing the impact of technological interventions requires consideration of both physical and non-physical, tangible, and intangible factors, along with system outcomes such as soil fertility, water quality, biodiversity, income, food security, and autonomy.

To address this challenge, fuzzy cognitive mapping (FCM) can be employed to construct pathways of project impacts and develop formal models to support informed decision-making by the project managers. FCM, as a systems analysis approach, is particularly adept at identifying the hidden causal chains or pathways that lead to project impacts. Models developed from multi-stakeholder perceptions and their parameterisation can enhance the likelihood of success in technological intervention projects (Pregnolato *et al*., 2024). These models can also conduct ex-ante assessment of livelihood impacts under different future scenarios, enabling development agencies to plan for contingencies before project implementation (Hjortsø *et al*., 2005). In the Indian context, most assessments have relied on statistical methods (Koner & Laha, 2021) or indicator-based approaches (Laxmi *et al*., 2007), with systems analysis being relatively rare (Rajaram & Das, 2008). The Theory of Change, widely used in many donor-supported technology intervention projects, is typically used ex-post to attribute interventions to impacts, and linking project outcomes to program goals remains challenging (Douthwaite *et al*., 2003). Alvarez *et al*. (2010) proposed Participatory Impact Pathways Analysis, which allows researchers and stakeholders to collaboratively develop project theories of action, create network maps, and utilise them for planning (Reed *et al*., 2021). In India, Rajaram and Das (2008) introduced a cognitive map-based integrated assessment, but this approach has not been widely adopted outside specific project contexts.

FCM can effectively map project impacts but is rarely applied in India's rural development sector. For the first time, we have formally used the FCM tool to map the impact pathways created by technological interventions, thereby enhancing the development of a precise, generic model based on multi-stakeholder perceptions. This effort is entirely absent in the existing literature and has never been attempted by practitioners in Indian rural extension. To demonstrate this, the case of Bio-village project was selected for the current research, implemented in South 24 Parganas district of West Bengal. FCM was employed as a tool to map the impact pathways of the project, and the structure of shared cognitive map covering stakeholder groups were developed. Then, the performance of the impact pathway's elements was simulated under different hypothetical scenarios to examine the best possible intervention strategy for future Bio-village projects.

METHODOLOGY:

The research approach: Fuzzy Cognitive Mapping : Fuzzy Cognitive Mapping (FCM) is a semi-quantitative modelling technique designed to capture the complexities of real-world systems. These systems are comprised of various tangible and intangible components (also called elements or concepts) that interact through causal relationships. Within the system, these relationships are assigned weights ranging from -1 to +1, indicating positive or negative influences between pairs of concepts. FCM is particularly effective for studying complex systems when stakeholders are actively involved. Stakeholders with firsthand experience or involvement in the system can significantly enhance the effectiveness of FCM. Their familiarity with the system makes it easier for them to map their experiences within the FCM framework. Additionally, the flexible nature of FCM allows stakeholders to quantify qualitative aspects of a complex system. We used FCM, arguable for the first time anywhere in the world, to track the impact pathways of a project's impact.

Project selection and sampling of stakeholders: A Bio-village project funded by the Government of West Bengal was selected for the study. The project was implemented by the Agricultural Training Centre, Narendrapur (latitude 22°26′21"N and longitude 88°23′48"E), the State Agricultural Management and Extension Training Institute (West Bengal) with the objective of minimising the use of chemical fertilizer by using bio-based input in the field and to attract the rural unemployed youth towards organic farming. The project was purposively selected because it was completed six years ago (considering the data collection in 2023), and it created tangible financial impact or asset creation in the community. Teurhat village in Baruipur Block of South 24 parganas district was selected for data collection, where the project was implemented.

Elicitation of fuzzy cognitive map : Prior to elicitation of cognitive maps, in-depth exploratory interviews were conducted with stakeholders to gain a comprehensive understanding of the project and its impact on their lives. The interview questions for primary stakeholders focused on the project itself and its effects on their livelihoods, while for secondary stakeholders, the questions cantered around their perception and observation of the project's impact. Our fieldwork was carried out between July and September 2023.

Researchers have primarily employed two approaches to elicit mental models – direct elicitation and indirect elicitation. In direct elicitation, a participant forms the mental model's representation by participating in an individual interview or workshop. Researchers often use fuzzy-logic cognitive mapping exercises for direct elicitation. In indirect elicitation, researchers elicit mental models from verbal texts or written documents representing a network of concepts. Researchers typically analyse the transcribed interviews using network analysis (graph-theoretic approach). In the current research, the direct method of elicitation was employed. Participation in a face-to-face interview helped the participants create their cognitive maps more precisely. Face-to-face interviews elicited practical variables (or concepts) and helped us know the ground reality and the multi-dimensional impacts of the project.

Nine cognitive maps were elicited from individual stakeholders separately. Individual elicitation (to group elicitation) was preferred because the research wanted to understand a complex system (long-term impact of an NRM project) by drawing on multiple stakeholders' knowledge, thus allowing their comparison. This allowed us to scale down to individual maps and aggregate them to develop shared cognitive maps.

The selection of concepts, represented in the elicited cognitive map, are chosen in two ways – 'standardised concepts' and 'free association of concepts'. Researchers predetermine standardised concepts after an extensive study of scholastic documents, experience, and expert consultation. This method is preferred when the researchers have adequate time and resources for the identification of concepts. On the other hand, researchers use the free association of concepts when understanding of the system is limited and the researcher wants to capture a vivid, diverse picture of complex, unpredictable systems by encouraging creativity among participants. In our research, the free association of concepts was followed, where the stakeholders were asked to draw their cognitive map (on project impact) describing the diverse concepts and their nature of relationships.

After the exploratory interview, the respondents were asked to list the variables on paper that have an impact on their livelihoods because of their participation in the project. Also, the inclusion of other variables was allowed that came to their mind during the listing and discussion. The interviewees were asked to explain the relationships between the pairs of variables. The variables were drawn on paper and the lines were drawn in between two variables to represent these relationships with pointed arrows to indicate their direction. The interviewees were asked to allot a positive sign to list the positive effect of the relationship or a negative sign if the effect is negative. To measure the strength of the effect the interviewees were asked to score the relationship (positive or negative) between 1-10. The actual scoring scheme in FCM is between -1 to +1, but such technical scoring is complex, because the stakeholders with limited literacy may not distinguish between the positive and negative dimensions of a number series. Later, the score was converted into the '-1 to +1' range during the data entry.

Development of shared cognitive map : After the stakeholder/s draw/s the cognitive map, the concepts are coded and accommodated into a square adjacent matrix. Then, researchers value the pair of connections between concepts within a range (-1 to +1) to signify the weight and direction of connections. To develop the shared cognitive maps (from nine individual maps) the research work augmented and superimposed the matrices additively. First, an augmented matrix was created where all elements covering all individual maps are accommodated. The aggregation of weights between concept pairs (covering all maps) was a mean for the study.

Structural analysis of shared cognitive map: Graph theory offers various methods for analysing FCM-related data (Ozesmi and Ozesmi, 2004). To gain insights into the structure of the FCM, the shared map was converted into a square adjacency matrix, which contains the weighted values for all components. In the initial steps, after constructing the FCM(s) using Mental Modeler (MM) (Gray *et al.*, 2013), the software provides us with an analysis based on the network's incoming and outgoing transmissions. By default, the software categorises different components into driver (outward linkage only), ordinary (both outward and inward linkages), and receivers (inward linkage only) and offers basic information about the component network, including density, complexity, and other relevant measures. This information provides us with an overall understanding of the component network.

Indegree and Outdegree are types of variables that provide important insights into the FCM. Indegree refers to the column sum of a variable's absolute values, indicating the total input strength received from all other variables. On the other hand, Outdegree represents the row sum of an adjacency matrix variable's absolute values, indicating the overall potency of connections (Özesmi & Özesmi, 2004). Centrality score is another crucial measure in FCM analysis. It reveals the strength of connectedness among variables and their cumulative influence (Kosko, 1986). The complexity of the map, which refers to the ratio of concepts with only incoming connections to those with only outgoing connections, suggests that stakeholders perceive the system as dynamic and recognize multiple opportunities for influencing livelihood outcomes (Özesmi & Özesmi, 2004). Density is a measure that describes the level of interconnectedness among components in the map. It is calculated by dividing the actual number of links by the total number of potential links. Meanwhile, Betweenness Centrality, often considered as a gatekeeper in a network, indicates the power of transmission through a node.

A dense map indicates that stakeholders perceive numerous possible pathways to influence variables within their map (Özesmi & Özesmi, 2004). The Core-Periphery pattern, a fundamental network structure, classifies nodes into two distinct groups (Borgatti & Everett, 2000). The core section consists of densely connected nodes, while the peripheral section consists of nodes loosely connected to the core.

Scenario analysis: By conducting simulations, our aim was to determine potential future impact scenarios resulting from future bio-village projects. These simulations can provide valuable guidance to project implementers during the decision-making process. In our study, "what-if" type questions were asked to explore how the system might respond to different contextual scenarios. These calculations were performed on the shared cognitive maps, allowing for comparative analysis for diagnostic purposes. Initially, concepts with the highest or higher centrality values were selected, and their initial values were set as "clamped" or "activated." In this context, "0" represents "not activated" and "1" represents "activated." The concepts (SAMETI) or combination of concepts (SAMETI + local organisation) were defined as scenarios for which simulations were run. The input of local experts was sought for developing these scenarios. The research leveraged the field experience to design a set of scenarios feasible for the current project (baseline, Scenario 1, Scenario 2). The outcomes of scenarios were compared in the form of a clustered bar chart to represent simulation results.

The development of FCM was performed in Mental Modeler platform (https://www.mentalmodeler.com/), and the structural analysis was performed in UCINET software (Borgatti *et al.*, 2002).

RESULTS

We present the results of the study in three distinct sections – the description of the shared cognitive map (Fig. 1), the structural analysis of the map along with its core-periphery structure (Table 1, Fig. 2), and the scenario analysis of the map (Fig. 3).

Shared cognitive map: The State Agricultural Management and Extension Training Institute, West Bengal (SAMETI-WB), serving as the Project Implementing Agency, launched the Bio-Village

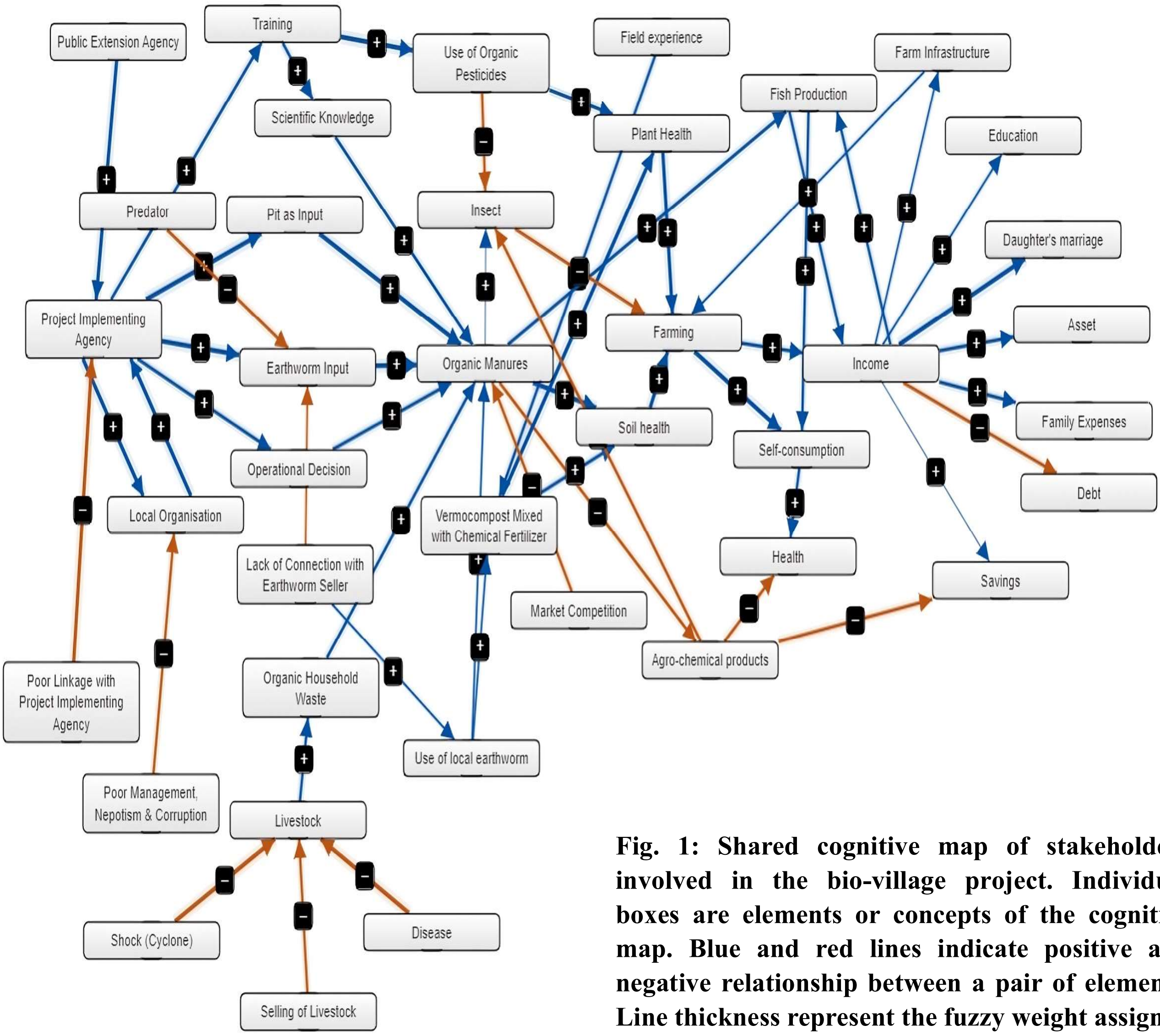

Fig. 1: Shared cognitive map of stakeholders involved in the bio-village project. Individual boxes are elements or concepts of the cognitive map. Blue and red lines indicate positive and negative relationship between a pair of elements. Line thickness represent the fuzzy weight assigned between element pairs.

project in collaboration with the Department of Agriculture by involving grassroot-level extension functionaries, and farmer's local organisations in the Baruipur Community Development Block, nearly a decade ago. The project continued with external financial support. Through training and input provisioning, and monitoring operational decisions through advisory services, SAMETI-WB successfully engaged beneficiaries in organic manures production and its application in farming. The training also covered the production of plant-based pesticides, further enhancing the project's impact.

Earthworm supply is driven by external sources (e.g., earthworm sellers and initial project support), and the predator attacks such as birds and ants. Lesser access leads to use of local earthworms, which is perceived to have lower production potential and thus offset by farmers by using fertilizers along with vermicompost. The supply of biomass in the form of waste material and animal excreta are contingent upon animal's number and their survival shaped by cyclones, animal diseases, and their distress sale. Summarily, training, input support, supply of organic household waste, and nature of earthworm used determine the volume of manure production. Higher volume of manure and their applications, coupled with biopesticides, improve soil and crop health, and is perceived to have higher farm production and income. Higher income leads to different forms of asset creation and improved well-being of farm household, namely household expenses, children's education, and social events such as marriages. The

Table 1. Results of structural analysis of the shared cognitive map. Central factors are emboldened

Component	Indegree	Outdegree	Centrality
Education of children	0.45	0.00	0.45
Fish production	1.00	1.25	2.25
Use of local earthworm	0.30	0.55	0.85
Public extension agency	0.00	0.90	0.90
SAMETI-WB	**1.85**	**4.08**	**5.93**
Earthworm as input	**1.95**	0.90	2.85
Local organisation	1.50	0.95	2.45
Training	0.79	**1.61**	2.40
Pit as Input	0.86	0.87	1.73
Disease	0.00	1.00	1.00
Livestock	**2.57**	0.71	**3.28**
Field experience	0.00	0.80	0.80
Use of Organic pesticides	0.90	1.30	2.20
Operational decision	0.53	0.53	1.07
Production of organic manures	**4.65**	**1.51**	**6.16**
Farm infrastructure	0.40	0.90	1.30
Vermicompost mixed with chemical fertilizer	1.05	**1.60**	2.65
Market demand	0.00	0.50	0.50
Income	1.16	**3.79**	**4.95**
Daughter's marriage	0.90	0.00	0.90
Assets creation	0.73	0.00	0.73
Family expenditure	0.61	0.00	0.61
Self-consumption	1.63	0.78	2.40
Soil health	1.46	0.84	2.30
Cyclone	0.00	1.00	1.00
Insect	1.25	0.55	1.80
Plant Health	**1.70**	0.90	2.60
Organic household waste	0.71	0.72	1.44
Indebtedness	0.60	0.00	0.60
Predator	0.00	0.70	0.70
Scientific knowledge	0.71	0.83	1.54
Mismanagement, nepotism, & corruption	0.00	0.50	0.50
Selling of Livestock	0.00	0.57	0.57
Use of agrochemicals	0.00	**1.91**	1.91
Savings	0.72	0.00	0.72
Health	1.56	0.00	1.56
Farm production	2.69	**1.53**	**4.22**
Access to earthworm seller	0.00	0.65	0.65
Total Components			38
Total Connections			53
Density			0.04
Connections per Component			1.39
No. of Driver Components			10
No. of Receiver Components			7
No. of Ordinary Components			21
Complexity Score			0.7

reduction in agrochemical usage also positively impacts the health of farmers and consumers, mitigating the negative effects associated with chemical pesticides.

There are several feedback loops in the map such as higher incoyme invested in farm infrastructure and fishery, which again increase farm income. Another loop is earthworm availability linked with use of local earthworm species, and mixing fertilizers to maintain manure's nutrient content.

However, challenges persist, such as the limited availability of suitable earthworms for organic manures production. Local connections with suppliers are inadequate, forcing organic manures producers to use local earthworms, raising questions about its nutrient content. This, in turn, leads to a continued reliance on agrochemical products alongside organic manures, impacting the project's objectives. Additionally, limited contact between beneficiaries and the project implementing agency, primarily through the local club president, raises concerns. Instances of corruption within the club, such as nepotism, have tarnished the club's reputation and impacted project outcomes negatively. External factors like predator attacks and natural calamities also pose challenges, disrupting project continuity.

Structural analysis: The total components (38) and total connections (53) of the cognitive map indicate the large size of the network and suggest its complexity (Table 1). The map consists of 10 drivers, seven receivers, and 22 ordinary components. In terms of indegree, outdegree, and centrality, the most central factors are project implementing agency (SAMETI-WB), 'production of organic manure', and 'farm production' (high values across centrality values). These are followed by 'earthworm as input', 'livestock', and 'farm income'. Addressing or managing these drivers can have a significant impact on the overall system behaviour.

Density of 0.04 suggests that the respondents focused only on relevant concepts and relationship (Giabbanelli *et al.*, 2024). Ten driver and seven receiver components suggest a complexity of network structure (complexity score = 0.7) implying the possibility of multiple outcomes of the system due to project interventions (Özesmi & Özesmi, 2004). Twenty-two ordinary components are mediating factors between outcome and interventions (Giabbanelli *et al.*, 2024).

The core-periphery analysis of the shared

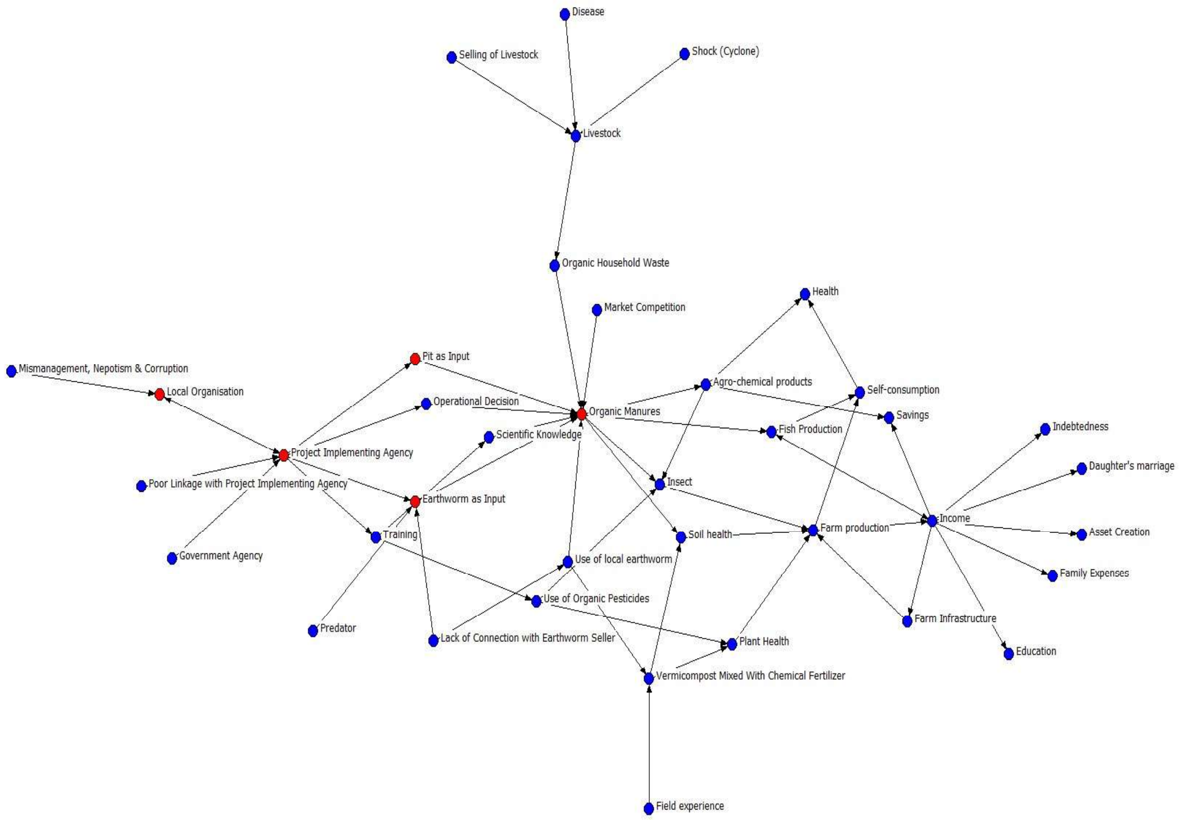

Fig. 2: Core-periphery structure of the shared cognitive map. Red nodes indicate the core elements.

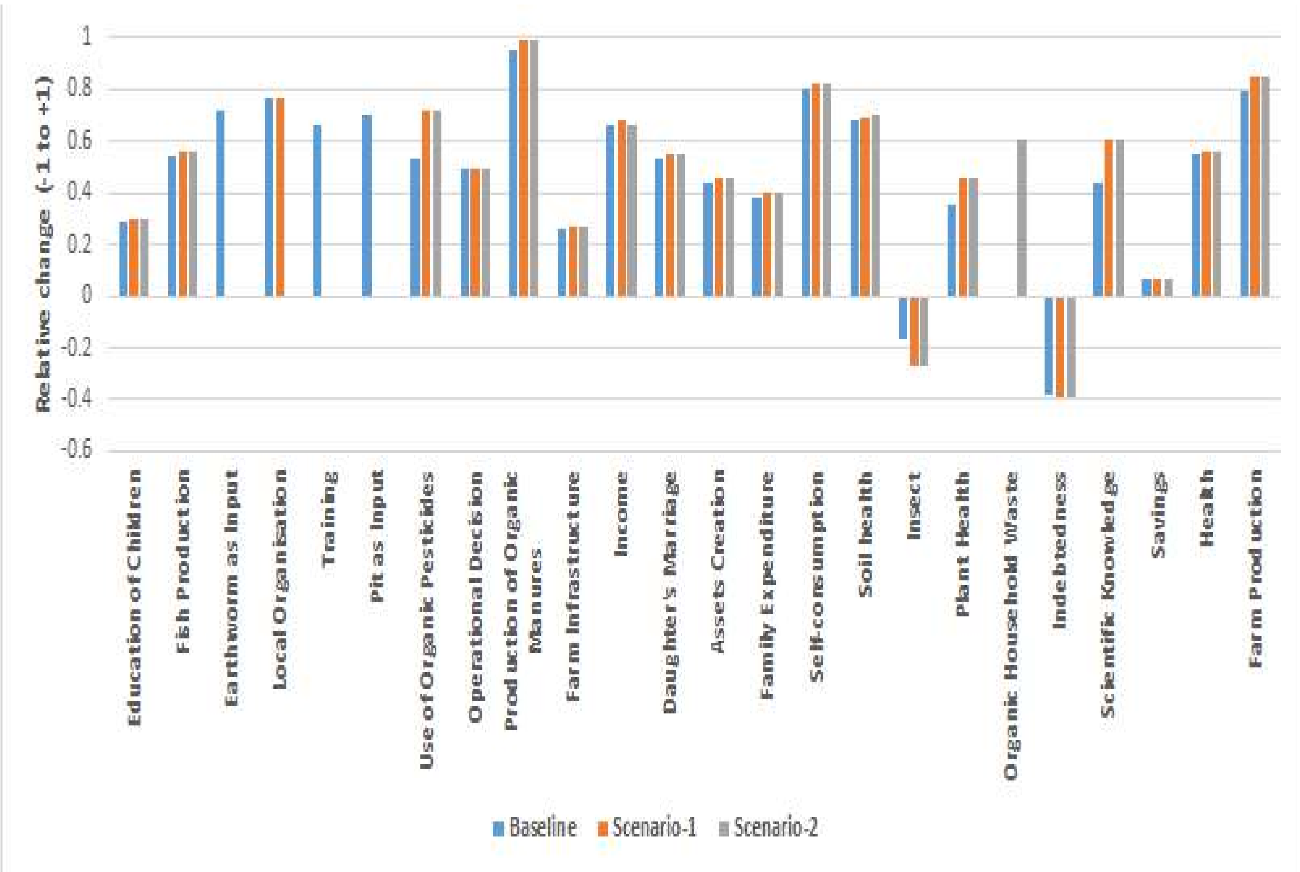

Fig. 3: Estimated changes in the elements of the shared cognitive map under three scenarios

cognitive map suggests five core components of the map, irrespective of their centrality values, that hold the key to the map structure (Fig. 2). In a network structure, the most significant components are called the core components, while the others are considered peripheral (Klimczuk & Klimczuk-Kochańska, 2023). For our research, these core components were project implementing agency (SAMETI-WB), 'earthworm as input', 'local organisation', 'pit as input', and 'production of organic manure'. So, this is a cross-validation of what we observed in Table 1.

The scenario analysis was run for three logically probable scenarios to check what will happen to the concepts of the shared cognitive map, which represent the project's interventions and impacts. The hypothesised scenarios were – a) the project is launched by the implementing agency by providing training and input (baseline); b) the project, in addition to baseline, engages local organisation, controls predators, and improve access to earthworms; and c) the project, in addition to scenario 1, ensures livestock and waste management. The results show that training and input can itself cause a significant impact on the project outcomes (Fig. 3). However, working with grassroots organisation, ensured supply of vermi, and livestock interventions can enhance the impact of the project further.

DISCUSSION

The Bio-village project implemented by the SAMETI-WB, in collaboration with line department and community-based organisation, offers a compelling case study of using FCM for improving project delivery in rural areas. The multi-faceted approach employed by the project through training, input provisioning, and operational monitoring, demonstrated the potential of production and application of organic manures and plant-based pesticides in community-level organic farming projects. Lack of biomass, access to earthworms, and the perception of lower production potential of local earthworm species, constrained manure production in a resource-constrained environment. This was due to the limited availability of suitable earthworm species at the disposal of line department and SAMETI. Also, farmers had less knowledge regarding the authentic sources of earthworms. Biomass availability was extremely low in smallholder farms with less than an acre of land and low or no cattle ownership. These observations are supported by recent literature (Vukovic *et al.,* 2021). Lack of access to earthworms and availability of biomass often necessitated the use of chemical fertilizers alongside organic manures, which might compromise with the project's objective of using lesser external inputs (Bernhardt *et al*., 2023). The project's outcomes, including improved soil health, higher farm production, and increased household income, suggest positive feedback loops present in sustainable agricultural practices. The use of higher incomes to build farm infrastructure and other assets further strengthens these loops, thus pushing the long-term sustainability of the initiative. However, maintaining these benefits are challenged by limited availability of high-quality earthworms and biomass, and the occasional reliance on chemical fertilizers, suggesting a continuous support and innovation system to sustain the project's gains (Pretty, 2018).

The findings of the research pinpoint social capital's importance in rural project management, particularly the role of local organisations linking beneficiaries and project implementers. Insufficient and non-transparent contact between beneficiaries and the implementing agency could have triggered corruption within the local organisation. This shows how social dynamics can influence project outcomes. Social network theory suggests, the effectiveness of such initiatives often depends on the strength and integrity of local networks (Bodin & Prell, 2011). The tarnished reputation of the local stakeholders due to nepotism and other corrupt practices indicates the need for transparency and accountability in community-based projects. External factors, such as predator attacks and natural calamities, are often beyond the control of farmers and challenges the project's outcome and continuity. The integration of adaptive strategies in the project design itself, that account for such uncertainties, can enhance the resilience of rural development projects (Adger, 2006).

The structural analysis of the cognitive map observed the map's large size and intricate structure, suggesting the multifaceted nature of the project and its contexts, which can draw support from the theoretical edited works of Giabbanelli *et al*. (2024). High centrality of concepts in the shared cognitive map, namely the project implementing agency, the production of organic manure, and farm production, indicated their significant influence on the project's impact. Managing these drivers is critical as they impact other components of the system, since they wield considerable control over the flow of information and resources (Freeman, 1978). The low density of the network suggests that respondents focused on relevant concepts and relationships only, avoiding an overly dense and potentially confusing map. Giabbanelli *et al*. (2024) Suggests that the selective focus highlights the practical considerations and constraints faced by the project's stakeholders, ensuring that the cognitive map remains a useful tool for understanding and managing the project

The core-periphery analysis identified five core components, regardless of their centrality values, which serve as the backbone of the cognitive map, providing stability and coherence to the network. We draw support from Klimczuk & Klimczuk-Kochańska (2023), who posits the importance of network core in economic exchange and social innovation. This finding cross-validates the centrality scores (Table 1), reinforcing the importance of these components in the overall impact pathway of the project. The central role of SAMETI-WB highlights the importance of a strong and effective implementing agency in driving project success. Similarly, the production of organic manure and farm production are critical outcomes that influence other aspects of the project, suggesting focused efforts on these elements. However, the network's complexity and the potential for multiple outcomes suggest that project interventions must be carefully designed and monitored to achieve desired outcomes. A systems thinking approach that considers the interdependencies and feedback loops within the network is essential for achieving sustainable and impactful results (Meadows, 2008).

The scenario analysis conducted on the shared cognitive map of the Bio-village project demonstrates how different interventions could shape the project's outcomes. By modeling three plausible scenarios, the analysis explores the potential impacts of varying levels of intervention by the project implementing agency. In the baseline scenario, where the project was launched with the provision of training and inputs, the results indicate a significant positive impact on the project's outcomes. This highlights the importance of capacity-building and resource provisioning in achieving the project's objectives, and is supported by broader literature (Farouque *et al*., 2024). Training equips farmers with the knowledge and skills necessary to adopt new practices, while the provision of inputs ensures they have the necessary resources to implement these practices (Anderson & Feder, 2004). The second scenario emphasised the engagement of local organisations for improved project's impact compared to the baseline. This suggests that community involvement and addressing ecological challenges can significantly amplify project benefits. The involvement of local organisations is particularly critical as it offers community ownership and enhances the project sustainability (Bandewar *et al*., 2017). Local organisations can act as intermediaries, facilitating communication between the implementing agency and farmers, to align the interventions with local needs and contexts. The third scenario suggested a comprehensive suite of interventions highlighting the interconnectedness of agricultural systems, where improvements in one area (e.g., livestock management) can have cascading effects on other areas (e.g., organic manure production and waste management) (Herrero *et al*., 2010). Existing literature (Bhunia *et al*., 2021) supports that effective livestock management can lead to increased availability of animal waste, which is a critical input for organic manure production. This, in turn, can improve soil health and crop yields, further boosting farm income and overall project success.

CONCLUSION

The Bio-Village project exemplifies the potential and challenges of sustainable agricultural development in rural settings. The project's multi-faceted approach, which includes training, input provision, and operational monitoring, has led to significant improvements in organic manure production, soil health, and farm income. However, the project's success is tempered by challenges such as the dependency on external sources for critical inputs like earthworms, the occasional reliance on chemical fertilizers, and the complexities introduced by local social dynamics. Structural analysis of the project's cognitive map highlights the centrality of key components emphasizing their critical role in driving project outcomes. The identification of core components and the network's complexity suggests that while the project has been effective, ongoing support and adaptive strategies are essential to sustain its benefits. Scenario analysis further illustrates that while baseline interventions are impactful, the inclusion of local organizations, predator control, and livestock management can significantly enhance the project's outcomes. This underscores the need for a holistic approach that addresses the interconnected challenges of agricultural systems. Sustainable rural development requires a nuanced understanding of local contexts, strong social capital, and continuous innovation to overcome the inherent challenges and achieve long-term success.

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