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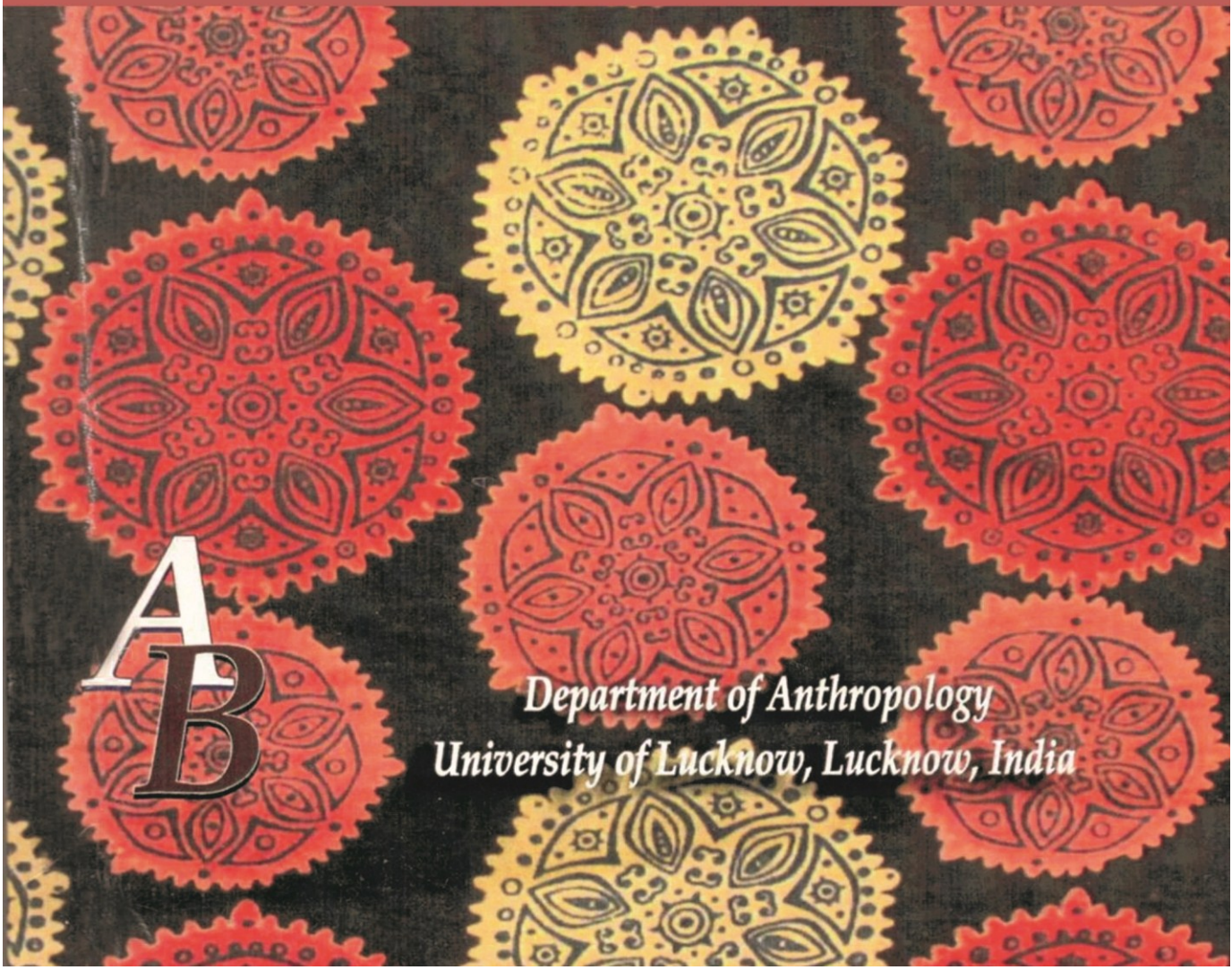

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Ecological Belonging and Everyday Spirituality: A Study of Lived Religion in the Swedish Program 12 steps to Global Wellbeing

Anna Rosengren♣

ABSTRACT

The contemporary ecological crisis has intensified scholarly interest in the intersections of spirituality, wellbeing, and environmental responsibility. This study examines the Swedish transformation program 12 Steps to Global Wellbeing through the theoretical lenses of lived religion, ecological spirituality, and relational wellbeing. Employing a qualitative textual analysis, the research explores how the program constructs meanings of human–nature relationships, responsibility, belonging, and transformative action in response to ecological challenges. Drawing on the works of Nancy Ammerman, Robert Orsi, Vandana Shiva, and Karma Ura, the study investigates how spiritual and ethical meanings emerge beyond traditional religious institutions and become embedded in everyday practices and experiences. The findings reveal that the program reframes ecological crisis as a manifestation of relational disconnection and promotes a holistic model of wellbeing grounded in interdependence among individuals, communities, and the more-than-human world. Transformation is conceptualized not merely as personal change but as a collective and ecological process supported through reflection, dialogue, vulnerability, and co-creative engagement. The study argues that the program represents a contemporary expression of lived religion, offering an alternative framework for meaning-making and ecological responsibility in secular societies. By linking existential concerns with environmental awareness, it contributes to broader interdisciplinary discussions on spirituality, sustainability, and human flourishing in an era of global ecological uncertainty.

Keywords: Lived Religion; Ecological Spirituality; Relational Wellbeing; Ecological Belonging.

Introduction

The accelerating climate crisis has generated not only ecological and political challenges but also existential questions about the human sense of identity, responsibility and belonging. In many contemporary contexts the traditional understanding of the role of humanity in relation to nature has been increasingly questioned.

The environmental crisis exposes severe limitations of anthropocentric worldviews and growth-oriented models for development. As a response to this, new forms of meaning-making and ethical reflection are emerging within as well as beyond established religious frameworks.

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Within the field of lived religion, it has been observed that contemporary spirituality often finds its expression through everyday practices and experiences, rather than through formal doctrines (Ammerman, 2013; Orsi, 1985). In Sweden, as in other secularized contexts, spiritual life often occurs outside of traditional religious settings. In this development, nature has become an increasingly significant arena for existential reflection and experiences of belonging (Thurfjell, 2020). This kind of development raises questions concerning how modern individuals and communities construct ethical and spiritual responses to the ecological crisis.

In this article I will examine an example of such meaning-making through an analysis of the Swedish transformation program *12 Steps to Global Wellbeing* disseminated through an online course and educational material building on an ecologically adapted version of the traditional 12 Steps program for Alcoholics Anonymous (Rosengren 2017). The program has been further developed in dialogue with its practitioners, in a context of ecological concern, recovery traditions and wellbeing-oriented social innovation, seeking to support individual, organizational and societal transformation through a structured process of reflection and practice. Inspired by recovery movements, Theory U and Gross National Happiness (GNH), the program provides an integrated framework for addressing ecological, social and existential challenges.

This article's objective is not to assess the effectiveness of the program, but rather to investigate how it shapes and communicates understandings of humanity, nature, wellbeing and transformation. More precisely, the study inquires how the material portrays responsibility, relational belonging and spiritual meaning within the context of contemporary ecological crisis.

The analysis is located within the multifaceted domains of lived religion, practical theology and ecological considerations. Particular emphasis is placed on how the text handles the dynamics between human beings and the more-than-human world and on how it conceptualizes transformation as both an individual and collective process. In dialogue with scholars like Nancy Ammerman and Robert Orsi alongside ecological thinkers such as Vandana Shiva and Karma Ura, the article delves into whether the *12 Steps to Global Wellbeing* can be seen as a modern interpretation of ecological spirituality and lived religion.

Rather than questioning if the program should be categorized as religious, the article explores how religious and spiritual meaning manifests within the text, through its narratives and ethical orientation. In doing so, it contributes to ongoing discussions about the evolving forms of lived religion, wellbeing and ecological consciousness.

Theoretical Background: Lived Religion, Ecological Spirituality and Relational Wellbeing

The present study draws upon the interdisciplinary field of lived religion, redirecting focus from official beliefs and institutional structures toward how religion is expressed, practiced and encountered in daily life. Rather than focusing primarily on religion as a set of beliefs, scholars of lived religion highlight how meaning is generated through common practices, relationships, material objects and social interactions (Ammerman, 2013; Orsi, 1985).

According to Nancy Ammerman (2013) spirituality emerges through ordinary narratives, relationships and daily routines rather than exclusively through institutional religious participation. Rituals, relationships, and embodied experiences frequently convey religious meanings beyond explicit theological discourse. Robert Orsi (1985) similarly highlights how the sacred and the ordinary are deeply intertwined. Orsi illustrates through his research that religious practices frequently take place outside formal institutional structures, embedded in family life, local communities and ordinary everyday practices.

An additional and alternative perspective on contemporary meaning-making is also offered by ecological spirituality, that highlights the interconnectedness of humanity and the rest of nature. In this way it challenges anthropocentric assumptions about humanity being superior to nature. Instead of understanding nature as a resource for humanity to use, the perspective of ecological spirituality brings in notions of relational belonging, mutual dependence and participation in a wider ecological community.

One scholar who has contributed in a significant way to this perspective is Vandana Shiva (1988; 2015), who questions prevailing development models, which are based on economic theories, human separation from and control over nature. She instead argues that nature is inherently intertwined with human life. Interdependence, diversity and ecological responsibility are guiding principles for Shiva´s idea of a contemporary spiritual response to environmental crisis. Although her theories are rooted in an Indian context, they have had a global impact on dialogues around alternative and sustainable visions of wellbeing.

Karma Ura offers another alternative perspective through the GNH framework, that has been practiced in Bhutan. Together with his colleagues, Ura argues (2012; 2017) that measures of wellbeing should not only be based on economic welfare. Equally important are other values such as inner and physical wellbeing, time use, culture, education, participation in society, good governance and ecological balance. GNH forms the foundation of Bhutanese national governance, thus challenging the traditional GDP. In this way GNH provides a view of wellbeing where the wellbeing of humanity is inherently connected to the wellbeing of society and nature.

These three theoretical perspectives together form a structure for exploring how meaning-making is formed in the material 12 Steps to Global Wellbeing. Lived religion brings in an ethically informed spirituality that moves beyond traditional religious institutions, while ecological spirituality offers a view of humanity and nature being closely interconnected. The GNH model offers a view of wellbeing that extends economic and connects personal growth to societal and ecological wellbeing.

Through these three interpretetive lenses, the material may be analysed as a method not merely for individual development or sustainability, but as an expression of a contemporary cultural movement toward relational interconnectedness between humanity and nature, in times of ecological change.

Methodology

The present study is an analysis of the textual material that is used within the program 12 Steps to Global Wellbeing, with a specific focus on human wellbeing, meaning-making and ecological awareness.

Rather than evaluating the program´s results, the purpose is to explore how the material negotiates individual and collective transformation. The focus is on recurring themes in the material, regarding wellbeing, responsibility and the role of humanity in relation to the more-than-human world. In the analysis, the material is seen as a cultural text, where these themes are expressed.

The aim is not to evaluate the effectiveness of the program, but rather to discover how the ideas of transformation and ecological interconnectedness are expressed. The analysis is influenced by lived religion, ecological spirituality and models for global wellbeing.

The 12 Steps to Global Wellbeing program: A Textual Analysis of Ecological Transformation

The primary subject for the analysis in this study is the textual material connected to the program 12 Steps to Global Wellbeing. This material offers a structured approach to individual as well as societal and ecological transformation. Inspired by the principles of

traditional 12-Step recovery programs, such as Alcoholics Anonymous, this program reformulates the steps and thus expands the notion of recovery beyond individual addictions toward an understanding of unsustainable ecological and social lifestyles described in the material as expressions of *global self-harm.*

The text thus suggests that transformation, rather than being just an individual shift, involves a process that includes the relationships between people, communities and the wider ecological world. An example of this can be seen through the inclusion of a project within the process, which is meant to be larger than individual components, and integrated into transformation. In this manner, groups, and possibly even ecosystems participate in the programs process as co-creators, in addition to individuals.

The adjusted version of the 12 Steps is, together with Otto Scharmer´s Theory U, and the wellbeing framework Gross National Happiness (GNH) the three interrelated influences that the program builds on. These factors come together to form a narrative structure that views transformation as internal as well as external, systemic and personal.

The criticism of separation is a recurrent issue in the material. Ecological crises are frequently explained as the result of disjointed modes of thinking that separate people from the natural world and from one another. On the other hand, the program encourages a perspective on life that is grounded in relational belonging and interdependence. Human wellness is portrayed as something that arises from having positive interactions with oneself, other people and the non-human world, rather than as a personal accomplishment.

The material consequently challenges the idea of human superiority in relation to the natural world, by employing methods for self-reflection, shared dialogue and concrete steps for collective transformation and co-creation with the more-than-human world. This way, the program encourages a lifestyle grounded in ecological awareness and relational belonging.

Similarly, vulnerability is highlighted throughout the material. By acknowledging the frailty of human life and society, the contemporary narratives about welfare grounded in efficiency, individual achievements and material values is challenged. In the program, experiences of vulnerability are seen as a potential for deepening the understanding of our human relation with each other and nature.

Another significant aspect of the program is the focus on collective transformation. Through deep listening and co-creative dialogue, the process fosters a view of wellbeing where individual, societal and ecological needs are intertwined.

The program thus integrates components from recovery movements, environmental ethics and wellbeing into a cohesive wellbeing framework. A vision thereby emerges of ecological awareness and human existence as interconnected with the more-than-human world.

Discussion: Ecological Spirituality and Lived Religion Beyond Religious Institutions

The analysis suggests that *12 Steps to Global Wellbeing* can be viewed as more than just a framework for sustainability or self-improvement. Read through the lenses of lived religion and ecological spirituality, the material appears as a modern attempt to create meaning, identity and ethical orientation in response to ecological crises.

The reinterpretation of the role of humanity in relation to nature is one of the most striking elements of the program. Ecological transformation is understood as a deep change of worldview, rather than as a mere behavioral modification. The material encourages readers to move away from assumptions of human superiority, toward a mindset of interconnectedness. In this way the program is in alignment with the perspective of Vandana

Shiva, who challenges lifestyles based on dominance and control, argues that relational conceptions of life are necessary for sustainable futures.

Another theme that is frequently found in the material is an expression of the lived religion presented by Ammerman and Orsi. The spirituality that becomes visible is of the kind that arises outside of traditional religious frameworks, although not necessarily contradicting them. Although not placed within a specific religious context, focus is on the experiences and practices of ordinary daily living, whereby the program handles many issues that are otherwise typically connected to religion, such as meaning, belonging and transformation.

This observation raises an important analytical question. It could be more beneficial to examine how the program carries out tasks traditionally connected wit religion, rather than asking if it is religious. The narratives in the material aid participants in understanding both individual and societal problems. It cultivates communities of practice, shared reflection and transformation. It also promotes self awareness that places people in the context of broader social and ecological realities.

The program's adaptation of Gross National Happiness further strengthens this interpretation. The idea of Global Natural Harmony presents wellbeing as essentially relational rather than individualized. This viewpoint is in line with Karma Ura´s theory that wellbeing arises from the interplay of social, cultural, ecological, and personal aspects of existence. Such strategy contradicts prevailing Western narratives that link economic development, consumption, or personal comfort and success to wellbeing.

Within the program existential issues are also reexamined. In many contexts, people no longer see traditional religious organizations as their main source for existential orientation. However, the questions about life and meaning, suffering, ethics and hope are still relevant. In relation to this, initiatives like the 12 Steps to Global Wellbeing may be seen as arenas for reinterpreting existential questions in new ways and contexts.

One of the significant roles of the program is therefore found in its potential for meaning-making. The text presents a foundation for this, based on ecological spirituality, vulnerability and relational responsibility. It provides a vision of wellbeing that is naturally linking individual happiness with a larger living environment. Consequently, the program may be interpreted as an expression of lived religion, establishing an arena for individuals as well as communities to process ethical and existential issues in an era of ecological change.

Reflexive Considerations

In this article academic analysis meets practical application of ideas. As the founder of the program 12 Steps to Global Wellbeing, I am upholding double roles, as both researcher and creator of the ideas in focus. This duality involves both potential and a challenge. The potential is a clearer understanding of the structure and the foundational theories of the program, than an external researcher would have access to.

On the other hand, this position demands that I be honest about my own perspective. The analysis I provide can't be completely unbiased, since the program itself was created by me. However, drawing from approaches in practical theology and lived religion, this personal viewpoint isn't necessarily a weakness in the way of conducting research. Here knowledge may be interpreted as situated rather than objective and detached.

The present study does not claim to provide an objective evaluation of the program, but rather a text-based interpretation of its underlying theoretical perspectives. In the future it would be beneficial to complement with a more in-depth study involving participant interviews and observations.

Conclusion

This article examines the 12 Steps to Global Wellbeing through the lenses of lived religion, and ecological thought. Instead of looking at religion mainly through doctrines, institutions, or formal beliefs, the study focuses on how existential meaning is found in daily practices, relationships, and lived experiences.

By relating to the work of Nancy Ammerman, Robert Orsi, Vandana Shiva and Karma Ura, this brief study shows that the program 12 Steps to Global Wellbeing, may be interpreted as a contemporary expression of lived religion, reflecting a larger cultural trend in which ecological issues are linked with existential issues, societal transformation and visions of holistic wellbeing.

From the angle of lived religion, one key point of the program is its effort to connect personal change with social change. Ecological awareness is not regarded as a theoretical subject, but rather as something emerging through lived experiences of shared reflection and practice. This shows how contemporary meaning-making may take place outside of organized religious frameworks, while still addressing the same type of questions.

The study does not imply that the 12 Steps to Global Wellbeing is a complete theoretical system. However, it suggests that the program may represent an example of how lived religion appears in modern society. It may be seen as a space for engaging with ecological issues while rethinking worldviews and reconnecting oneself, others and nature. In this way the material may be helpful in creating communities of practice, where new lifestyles may be formed, tested and shared and where spiritual and ecological questions may be handled in a transformative way.

Finally, this brief study highlights the significance of a creative dialogue between lived religion, research and ecological practice. In a time where ecological crises increasingly influence the world, it becomes more important to connect personal meaning-making with shared responsibility for society and nature. Such interdisciplinary dialogues may become interesting and necessary areas for future anthropological and theological research. The case of the program 12 Steps to Global Wellbeing shows that these issues are not merely abstract ideas, but real, lived experiences for individuals and communities searching for new ways to understand and sustainably live in an interconnected world.

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Routing Protocols in Mobile Ad-Hoc Wireless Sensor Networks: A Systematic Review

Sehba Masood♣

ABSTRACT

Mobile Ad hoc Wireless Sensor networks consist of many tiny autonomous mobile sensor nodes. Each node has processing capability, memory, a transceiver, power source, and sensors and actuators. The nodes are deployed in an ad hoc fashion and allowed to communicate wirelessly without relying on a fixed pre-established infrastructure. This study carries out a systematic literature review for evaluating the comparative performance, structural trade-offs, and operational limitations of the three dominant routing paradigms in MWSNs: Flat, Hierarchical, and location-based routing protocols under variable mobility configurations. This paper delivers a valuable resource for researchers and developers trying to further improve routing protocols for Mobile Ad hoc Wireless Sensor networks.

Keywords: Routing protocols, Sink, Flat, Hierarchical, location-based routing

1. Introduction

Mobile Ad hoc Wireless Sensor Networks represent a significant change in the paradigm of wireless communication and sensing. These networks are composed of many small, autonomous sensor nodes that communicate with each other without relying on a preestablished infrastructure. Each sensor node is equipped with sensors for data collection, processing capabilities, and wireless communication interfaces. After deployment in an ad hoc manner, the nodes self-organize and establish communication links to form a functional network (Stankovic, 2006). Nodes are equipped with mobilizers or wheels to achieve mobility. Such networks are termed as Mobile Ad hoc Wireless Sensor networks. These nodes can be attached to transporters like vehicle, animals, robots etc. Sometimes these nodes have to move due to the environment where they are deployed. When two nodes are not within direct communication range, connectivity is maintained through multi-hop communication via intermediate nodes. Conversely, if two nodes are within each other's transmission range, y can communicate directly in a peer-to-peer manner (Gowrishankar S.

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and Basavaraju, 2010). They are designed to work collaboratively in dynamically changing environments. These networks exhibit the capacity to autonomously adapt to changing conditions and recover from disruptions, making them highly versatile and suited to a wide range of applications.

Although numerous routing protocols have been proposed, their evaluation is challenging due to inconsistent simulation variables, distinct mobility models (Khan, A. R. et. al., 2010) (such as Random Waypoint versus Gauss-Markov Mobility) (Sandeep Kaur et. al 2012), and varied performance metrics across current literature. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology is adopted to fill these research gaps. This study provides a structured and reproducible comparative analysis of different routing protocols, focusing on their ability to withstand conflicting challenges of node mobility and energy consumption.

2. Methodology

This systematic review followed the PRISMA guidelines to reduce selection bias, ensure structural transparency, and facilitate fully reproducible extraction workflow. The scope of my study expands from 1994 to 1019, focusing on reviewing research work carried out in this area. The main aim of this study was to thoroughly explore the dynamic field of Mobile WSNs, routing protocols, and innovative developments, considering both foundational and recent research.

2.1 Search Strategy and Information Sources

In this study, digital libraries like IEEE Xplore, ScienceDirect, Springer, Scopus, ACM, Web of Science and Google Scholar are systematically explored. Systematic searches were carried across digital libraries like IEEE Xplore, ScienceDirect, Springer, Scopus, ACM Digital Library, Web of Sciences and Google Scholar. The search strings were formed by combining Boolean operators with concept-specific keywords to isolate research, explicitly analysing routing paradigms under mobile sensor conditions and ensure comprehensive retrieval of relevant literature, i.e. ("Mobile Ad hoc Wireless Sensor Network" OR "MAWSN" OR "Ad Hoc Sensor Network") AND ("Routing Protocol" OR "Flat Routing" OR "Hierarchical Routing" OR "Location-based Routing") AND ("Comparative Analysis" OR "Mobility Model" OR "Energy Efficiency" OR "Performance Metric"). The scope was targeted to capture both seminal protocol frameworks and highly cited modern iterations, assessed across major performance parameters.

2.2 Inclusion and Exclusion Criteria

Specific operational criteria were strictly used during evaluation and filtering process for assessing the accuracy and appropriateness of the selected data to exclude irrelevant or invalid literature.

Inclusion Criteria:

- Publications in peer-reviewed journals or conference proceedings providing full information about routing protocols for mobile ad hoc wireless sensor environments.
- Studies presenting a clear comparative performance framework.
- Publications presenting measurable outcomes on energy consumption per packet, packet delivery ratio, or scalability.
- Studies lined up with my research questions.

Exclusion Criteria:

- Informal literature, editorials, whitepapers, patents, or general extended abstracts.
- Literature emphasizing exclusively on purely static WSNs or traditional mobile ad-hoc networks MANETs with no sensor-specific constraints.

- Papers that present isolated security encryption or hardware antenna design without providing network-layer routing metrics.
- Manuscripts offering no innovative ideas or contributions to the existing literature on routing protocols for mobile wireless sensor networks.

2.3 Screening and Selection Framework

The study selection process focuses on evaluating whether the retrieved literature directly aligns with your study's core objectives. Initial searches to the database generated a broad set of records, from which duplicate or redundant information is removed. Screening of titles and abstracts were conducted according to the scope of the study and eligibility criteria, followed by a full paper assessment. Table 1. shows total number of research papers selected after this systematic selection procedure.

Table 1. The steps of systematic study selection procedure

Steps	Selection Guidelines	Number of Research Papers
1	Records identified through initial database search	140
2	Removed based on title/abstracts and conclusions	97
3	Selected for main studies	43

Data extraction was independently managed to capture protocol sub-types, baseline network lifetime metrics, performance under congestion, and deployment scale assumptions.

3. Structural and operational taxonomy of routing protocols

A routing protocol is a crucial procedure for the selection of an optimal path to facilitate data transmission from its source to the intended destination. The complexity of this selection process is contingent upon factors such as the network type, channel characteristics, and performance metrics.

Routing protocols play a pivotal role in dictating the communication patterns among nodes and the dissemination of information within a network.

Routing mechanisms in MWSNs are categorized based on two factors as shown in Figure 1:

- How routes are discovered and maintained
- Their structural network layout (how nodes are organized).

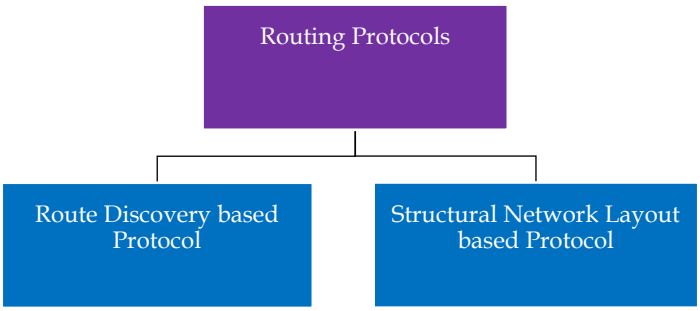

Figure1. Classification of Routing Protocols for MWSN

3.1 Route Discovery based Protocol

3.1.1 Proactive (Table-Driven) Routing

Proactive protocols maintain routing tables for the entire network. They disseminate network information from node to node, and routes are defined in advance, even in the absence of traffic flow. They rely on background control packets sent periodically to announce topological changes. Optimized Link State Routing (T. Clausen and J. Jacquet, 2003) and Destination-Sequenced Distance-Vector (C. E. Perkins and P. Bhagwat, 1994) are proactive routing protocols that utilize a table-driven approach.

Optimized Link State Routing (OLSR) is known for its significant overhead. To mitigate this overhead, it employs Multipoint Relays (MPRs). Each node designates three neighboring nodes as MPRs for data transmission. This approach minimizes the need for consistent control information, as each node takes turns sending it.

In Destination-Sequenced Distance-Vector routing protocol destination sequence number is added with every routing entry in the routing table maintained by each node. A node will include the new update in the table only if the entry consists of the new updated route to the destination with higher sequence number.

High node velocity in MWSNs compels frequent update broadcasts, producing control packet overhead that can deplete node batteries even when payload data is not being transmitted (S.R. Medidi and Y. Zhou, 2012). Since routes are pre-defined, initial packet latency is minimized in proactive routing (D. G. Reina et. at., 2013).

3.1.2 Reactive (On-Demand) Routing

Reactive routing protocols are activated on-demand when a node needs to send data to another node rather than maintaining the entire network structure. Routes are established on an as-needed basis, typically when queries are initiated.

Ad hoc On-Demand Distance Vector Routing (AODV) (C. E. Perkins and E. M. Royer, 1999) is a reactive on-demand routing protocol designed for infrastructure-less networks mobility. It employs an on-demand routing mechanism to build routes between nodes within the network area. A path is created only when the source node intends to transmit data packets, and the route is maintained till the source node requires it. The protocol enables mobile nodes to relay data packets to the desired destination node through neighboring nodes that cannot directly connect to the destination. Routing table information is periodically exchanged among neighbor nodes, allowing for rapid updates. AODV selects the smallest and loop-free path from the routing table to send packets. If errors or changes occur in the selected path, it is capable of establishing a new route for ongoing communication.

Dynamic Source Routing (DSR) (D. B. Johnson and D. A. Maltz, 1996) is a reactive routing protocol for wireless sensor networks. Instead of routing tables it exploits source routing. There are two phases of routing in DSR: path determination and its maintenance.

The source node initiates a path determination phase, which comprises route request and route reply messages. In DSR, only the destination node replies with a route reply message to the source node, unlike AODV, where every intermediate node would reply with route reply messages. The path maintenance phase serves to prevent the overflow of route reply messages and is exploited to shorten the number of nodes between the source and sink.

In reactive model, if a mobile node moves out of range and breaks a link, localized Route Error packets are used to trigger dynamic path repairs (S. Mueller et.al., 2007). This approach

introduces initial path setup delays, but it saves considerable idle energy compared to proactive models (S. J. Lee et.al., 1999)

3.1.3 Hybrid Routing Protocol

Hybrid routing protocols integrate the advantages of both proactive and reactive routing approaches, providing quick route accessibility while reducing the routing overhead associated with maintaining network paths.

Zone Routing Protocol (ZRP) (Z. J. Haas, et, al., 2002) is a hybrid routing protocol. It is an enhanced adaptation of the Ad hoc On-Demand Distance Vector (AODV) routing protocol, specifically designed for zone-based network architectures. In this framework, sensor nodes deployed within a monitored area immediately report events whenever activity is detected in their respective areas. The pattern of data transmission varies according to the application requirements and can generally be categorized into three scenarios: static nodes, partially mobile nodes, and fully mobile nodes, as commonly observed in target-tracking applications. Since ZBR imposes no restrictions on node mobility, it effectively supports both highly dynamic and densely populated network environments.

Regardless of the mobility scenario, member nodes communicate their sensed data to the corresponding zone head, which remains a one-hop neighbour to all nodes within the zone. The zone head is responsible for aggregating data based on the application's requirements and forwarding either the aggregated information or individual data packets to the base station. Additionally, the zone head manages critical routing functions, including route discovery, route maintenance, and ensuring continuous route availability to facilitate reliable data transmission throughout the network.

3.2 Structural Network Layout based Protocol

Routing protocols are categorized based on the structural network layout in mobile ad hoc wireless sensor networks (Al-Karaki, et.al., 2004).

3.2.1 Flat Routing Protocols (Topology-Based)

In a flat network architecture, all sensor nodes are assigned identical configuration profiles, processing capabilities, and routing responsibilities. Nodes cooperate globally to forward data to the Sink across multiple hops. Several routing protocols belong to this category.

Gradient-Based Routing (GBR) (Powell et al. 2005) is an energy efficient, distributed, and reactive routing approach that establishes routes using gradient values. In this routing the network nodes calculate a gradient, based on factors like distance to the sink, energy levels, or other relevant parameters, specifying the direction towards a desired destination. This gradient is exploited to find the route for data packets to follow, by moving in the direction of the steepest descent or ascent on the gradient. It is robust to network failures and changes in connectivity.

Cougar routing (Yao and Gehrke 2002) is a database-oriented approach that introduces a query layer between the application and network layers of the sensor nodes. Each sensor node is related to a query proxy, while gateway nodes process user queries. The protocol uses in-network processing to mitigate communication overhead, conserve energy, and increase the life span of the network.

Rumor Routing (RR) (Braginsky et. al., 2002.) is an event-driven routing protocol that propagates event information through special packets known as agents. When a node detects an event, it generates an agent that disseminates event information across the network. These agents accumulate information about newly encountered events and maintain records of recently visited nodes to minimize routing loops and improve query efficiency.

Greedy Perimeter Stateless Routing (GPSR) (Karp, B., and Kung, H. T., 2000) functions using two modes: greedy forwarding and perimeter forwarding. In the first mode, each packet is forwarded to the neighbour that is geographically closest to the destination. When no suitable neighbour is available, the protocol transitions to perimeter mode, where packets are routed around network voids until normal greedy forwarding can be resumed. GPSR scales efficiently and requires less routing state than traditional shortest-path protocols.

3.2.2 Hierarchical Routing Protocols

Hierarchical protocols partition the mobile network into localized subsets called clusters to limit the scope of long-range transmissions and coordinate channel access, with each cluster having a designated cluster head and standard nodes that function as member nodes (O. Younis and S. Fahmy, 2004). Member nodes transmit their sensed data exclusively over short distances to their respective cluster heads. The cluster head, after aggregating data received from all the nodes in the cluster, routes the data to the sink. (W. B. Heinzelman et. al., 2002). This Hierarchical approach is more energy-efficient and easier to manage.

Low Energy Adaptive Clustering Hierarchy (LEACH) (Heinzelman, W. et. al., 2000) is the pioneering hierarchical routing protocol based on data fusion. To distribute energy load evenly across the network, a cluster head is selected randomly that reduces energy consumption and prolongs network lifetime. LEACH operates in iterative rounds having two phases in each round, a setup phase for cluster formation and cluster head election, and a steady-state phase during which member nodes transmit data to their respective cluster heads using TDMA schedules. The cluster heads then aggregate the collected data and forward it to the sink node either directly or through cluster heads along the defined path to the sink.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS) (Lindsey and Raghavendra, 2002) enhances LEACH protocol by organizing nodes to form communication chain rather than directly forming clusters. To build a chain, a greedy algorithm is used, and the process starts with the furthest node from the sink. Each node communicates only with its nearest neighbour on the chain, while a designated node transmits aggregated data to the sink. When a node expires, the chain is constructed by using the same greedy mechanism by ignoring the dead nodes. Only one node in the chain is responsible to transmit data to the sink rather than multiple nodes. This protocol mitigates communication overhead and improves energy efficiency.

Threshold Sensitive Energy-Efficient Sensor Network Protocol (TEEN) (Manjeshwar A, Agrawal D.T., 2001) is a clustering and responsive approach suitable for time-critical applications. It employs two threshold values broadcasted by cluster head-

- Hard Threshold (HT), which represents the minimum value of a sensed attribute that triggers data transmission. When the sensed value exceeds this threshold, the sensor node activates its transmitter and reports the data to the cluster head.
- Soft Threshold (ST), which determines the minimum change in the sensed attribute required to initiate subsequent transmissions.

After the first transmission caused by exceeding the Hard Threshold, the sensed value is stored as a reference. Thereafter, a node transmits data only when the current sensed value remains above the Hard Threshold and the difference between the current and previously reported values is greater than or equal to the Soft Threshold. Now, the newly sensed value becomes the updated reference value. This threshold-based approach reduces unnecessary data transmissions and improves energy efficiency

The Adaptive Threshold Sensitive Energy-Efficient Sensor Network protocol (APTEEN) (Manjeshwar and Agrawal 2002) is an extension of TEEN that serves the dual

purpose of transmitting periodic data and responding to time-critical event. In APTEEN, the parameters issued by the cluster head are adjusted that can lead to alteration of related parameters based on the user needs or the type of use. It combines the energy efficiency of TEEN with the periodic monitoring capabilities of LEACH, making it suitable for applications requiring regular updates and sudden event detection.

Hybrid Energy-Efficient Distributed Clustering (HEED) (Younis and S. Fahmy 2004) presents a multi-hop clustering algorithm designed for Wireless Sensor Networks (WSNs) with a strong focus on energy efficiency**. This approach** selects cluster heads mainly based on residual energy of nodes, with communication cost considered as a secondary selection criterion. The protocol achieves balanced energy consumption and longer network lifetime while maintaining efficient cluster formation. Its limitation is that the cluster head selection process is complex, and it is meant for only static networks.

Hybrid Energy-Efficient Distributed Clustering for Mobile nodes (HEED-M) implement link-stability metrics (F. Bajaber and I. Awan, 2011). These protocols determine cluster membership by analysing a node's velocity and direction, in relation to potential cluster heads, thereby enhancing data stream stability in dynamic network environments (S. Deng, J. Li, and L. Shen, 2014).

LEACH-Mobile (D. S. Kim and Y. J. Chung, 2006) is an improvement over LEACH protocol that supports node mobility in wireless sensor networks. As mobile sensor nodes move within the network, they dynamically update their cluster memberships. This protocol verifies whether a node can successfully communicate with its designated cluster head during the assigned TDMA time slot. LEACH-Mobile approach significantly improves data delivery performance in mobile sensor networks by effectively managing changes in node location and maintaining cluster connectivity. It achieves a higher data transmission success rate than the LEACH protocol, particularly as the mobility of sensor nodes increases.

LEACH-ME (LEACH-Mobile Extended) (G. S. Kumar et. al., 2008) is an enhanced version of the LEACH protocol designed to support the mobility of both cluster heads and member nodes. The protocol considers a fixed sink node, homogeneous sensor nodes, and the availability of GPS-based location information for all nodes. Unlike the original LEACH protocol, LEACH-ME selects cluster heads based on node mobility and signal attenuation characteristics. Nodes with lower mobility and lower attenuation are likely to be cluster heads to improve network stability and communication efficiency. Once selected, cluster heads broadcast their status throughout the network, and sensor nodes choose their respective cluster heads based on the received signal strength indicator (RSSI). To accommodate node mobility, LEACH-ME incorporates a handover mechanism. During the steady-state phase, if a member node gets out of the communication range of its current cluster head, it sends a **DISJOIN** request to the existing cluster head and a **JOIN** request to a new cluster head. Following the addition and removal of member nodes, cluster heads generate updated TDMA schedules to maintain efficient communication within the cluster.

LEACH-ME is particularly suitable for large-scale networks where the sink node is positioned far from the sensing field, as it supports multi-hop data transmission. However, the protocol requires all mobile nodes to be equipped with GPS devices, which increases deployment costs. Additionally, frequent handovers and cluster reconfigurations introduce extra communication overhead, affecting overall network efficiency.

The Distributed Weight-based Energy-efficient Hierarchical Clustering protocol (DWEHC) (Ding et al. 2005), is a distributed clustering algorithm akin to HEED. It forms stable clusters, and every node first finds its neighbors, then computes its weight which is based on distance to its neighbors and its remaining energy. The node with maximum weight in a neighborhood is capable of becoming a cluster head. This protocol efficiently manages

energy consumption by considering node weights and a hierarchical structure. DWEHC intends to boost up the lifetime of overall network by optimizing energy consumption via clustering.

Virtual Grid Architecture Routing (VGA) (Al-Rahayfeh, Almi'ani, and Abuzneid 2010) is an energy efficient routing protocol. In VGA, network region is divided into virtual grid zones consisting of sensor nodes. Each zone elects a local aggregator responsible for data collection and aggregation. The master aggregator gathers information from local aggregators and communicates with the sink. This approach aims at increasing the network lifetime by data aggregation and in-network processing.

3.2.3 Location-Based Routing Protocols

Location-based routing completely removes the need for global routing tables, periodic updates, and end-to-end path discovery. Instead, it relies on physical coordinate data (M. Mauve et. al., 2001). Nodes track their own location via GPS or localized relative localization algorithms, and learn their immediate neighbours' coordinates through brief, localized beacon exchanges (Y. Cao and Z. Yao, 2017) to improve routing efficiency and support location-aware applications.

Greedy Forwarding and Perimeter Traversal (GPSR) (B. Karp and H. T. Kung, 2000) is a standard protocol in which, a node uses a greedy method to forward data packets, passing them to whichever immediate neighbour is physically closest to the destination Sink's coordinates. As this local hop-by-hop approach does not rely on permanent end-to-end paths it makes the protocol highly resilient to topology shifts (H. Frey and S. Stojmenovic, 2006).

If a packet reaches a local dead-end that is a "routing hole" where no neighbour is closer to the destination than the current node, the protocol shifts to a perimeter face-routing mode (K. Seada, et.al., 2004,). This mode guides the packet along the boundaries of the obstacle using the right-hand rule until it passes the dead-end and can resume greedy forwarding (C. Lochert, et.al 2005).

Geographic and Energy-Aware Routing (GEAR) ((Yu, Govindan, and Estrin 2001)) uses geographic information and residual energy to forward packets toward a target region. Within the destination area, recursive forwarding or restricted flooding mechanisms are employed to efficiently disseminate information while minimizing energy consumption.

Stateless Protocol for Real-Time Communication in Sensor Networks (SPEED) (Tian He et al, 2003) is a QoS-oriented protocol that provides soft real-time communication guarantees. It maintains a desired packet delivery speed through geographic forwarding, delay estimation, neighbourhood feedback mechanisms, and traffic re-routing. SPEED achieves low end-to-end delay and focuses on energy efficient routing.

SPAN: An Energy-Efficient Coordination Algorithm for Topology Maintenance in Ad Hoc Wireless Networks (Chen et. al., 2001) conserves energy by creating a dynamic forwarding backbone composed of coordinator nodes. Nodes independently decide whether to participate in routing or enter sleep mode based on local connectivity and energy conditions, thereby maintaining network connectivity with reduced power consumption.

Geographical Adaptive Fidelity (GAF) (W. B. Heinzelman et. al., 2002) is a location-based routing protocol that utilizes the geographic positions of sensor nodes to improve energy efficiency. This approach partitions the sensing area into virtual grid cells, each containing multiple sensor nodes. Since nodes within the same grid are considered equivalent from a routing perspective, only one node remains active while others enter sleep mode to conserve energy. By reducing the number of active nodes without affecting network

connectivity, GAF significantly lowers energy consumption and extends the overall network lifetime **(Roychowdhury and Patra 2010).**

Position-Based Aggregator Node Election (PANEL) (Buttyán and Schaffer 2010)) is a location-aware clustering protocol that selects aggregator nodes based on their geographic positions. The protocol supports efficient intra-cluster and inter-cluster communication while ensuring balanced aggregator selection and effective data aggregation.

Two-Tier Data Dissemination (TTDD) (Luo, H., Ye, F., Cheng, J. et al. 2005) (D. Xu, J. Gao, 2011) is a routing protocol for environments with multiple data sources and mobile sink nodes. When an event is detected by several sensor nodes, one node is designated as the source node to initiate data dissemination. The source node establishes a virtual grid structure by designating itself as a grid intersection point. Using a greedy forwarding mechanism, it identifies and selects the nearest nodes to serve as adjacent grid intersections, progressively extending the grid until the network boundary is reached or the process terminates. Each grid intersection stores information about the event and the source node.

For data retrieval, a sink node broadcasts a query to the nearest grid intersection. The query is then propagated through the grid infrastructure until it reaches the source node. Upon receiving the request, the source transmits the corresponding data back to the sink. The protocol supports sink mobility, allowing sink nodes to move while awaiting data delivery, and employs agent-based mechanisms to ensure reliable communication.

TTDD improves network lifetime compared with diffusion-based routing approaches by utilizing efficient data dissemination paths. However, its implementation requires nodes to be location-aware and assumes a relatively high node density. Additionally, the protocol involves complex grid construction and maintenance procedures, leading to increased computational and management overhead.

Scalable Energy-Efficient Asynchronous Dissemination (SEAD) (Hyung Seok Kim et. al., 2003) addresses the trade-off between forwarding delay and energy efficiency. It constructs dissemination tree rooted at each sensor node and enables mobile sinks to receive data without frequently updating their locations. The protocol relies on geographic information and operates as an overlay on location-aware routing schemes.

Robust Ad-hoc Sensor Routing (RASeR) (T. Hayes and F. Ali. 2016) and **Location Aware Sensor Routing (LASeR)** (T. Hayes and F. Ali. 2016) protocols are specifically designed for high-speed mobile ad hoc wireless sensor networks. They perform multipath routing by using blind forwarding method which permits the node to broadcast a data packet to its neighbours. Further, the receiving nodes are responsible to make the decision of either forwarding the packet or dropping it, utilizing a network-wide gradient metric to compare the values of the sender and receiver nodes to find which node is closer to the destination. But they maintain their gradient metrics in different ways - RASeR exploits the regular transmission of short message packets, in which nodes broadcast their current gradient, and LASeR depends on geographical location information of the mobile sensor node.

Mobility-Aware Routing (MAR) (Shahzad Ali, et. al., 2014) is a location-based and hierarchical routing protocol in which the sensing area is partitioned into geographical grids. The mobility factor of sensor nodes is used to select cluster heads, which indicates how frequently a node transitions between different zones. The primary goal of this approach is to choose nodes with the lowest mobility as cluster heads, thereby improving cluster stability and maintaining reliable connectivity with member nodes.

By favouring fewer mobile nodes during cluster head selection, MAR enhances communication efficiency within clusters. However, the protocol does not consider the

residual energy of nodes when electing cluster heads, making it unsuitable as an energy-aware routing solution. In addition, MAR does not fully exploit the available location information of sensor nodes, which can lead to increased packet loss. The protocol also faces communication challenges during inter-cluster transmissions, as mobile cluster heads may move out of each other's transmission range, leading to further loss of packets and reduced routing performance.

Distributed Efficient Clustering Approach (DECA) (J.H. Li, et.al., 2005) assigns a weight to each sensor node based on its residual energy, connectivity, and node identifier. A key benefit of DECA is that each node sends only a single clustering message, eliminating the need for multiple rounds of probabilistic message exchanges as required in protocols such as LEACH and HEED. Since communication consumes significantly more energy than sensing and computation, reducing the number of control messages during cluster formation improves the overall energy efficiency of the network.

To support cluster formation, a neighbour table is maintained by each node which is periodically updated through Hello messages. On getting clustering information, the node determines whether to join an existing cluster head or elect itself as a cluster head based on its computed weight. Simulation studies have demonstrated that DECA achieves better performance than several traditional clustering protocols, including HEED (Yu, M., Li, J. H., and Levy, R. 2006).

DECA also has some limitations together with its advantages. For the maintaining neighbour table Hello beacons are periodically transmitted which results in additional energy consumption and processing overhead. In mobile or highly dynamic environments, the frequency of these beacons must increase to maintain accurate neighbour information, making the protocol less suitable for such scenarios. Furthermore, mobility may cause neighbouring cluster heads to move beyond each other's communication range, leading to packet losses during inter-cluster data transmission and reducing overall network reliability.

4. Comparative evaluation framework

Analysis of the data gathered during the systematic literature review reveals real-world trade-offs across all architectural designs when subjected to node mobility and energy constraints. The protocols must be evaluated across several main performance metrics.

4.1. Performance Metrics Defined

- **Energy Efficiency** Wireless sensor networks rely on battery power, and energy scarcity is a significant concern, particularly in demanding environments. Sensor node performance is severely impacted when their batteries fall below a predefined threshold. Energy conservation represents a primary challenge for network designers, given the large number of nodes within a wireless sensor network, each with restricted energy resources. Energy efficiency deals with how well the protocol minimizes energy consumption during route formation, maintenance, and transmission of data.
- **Scalability** is the capability of the routing protocol to accommodate hundreds or even thousands of sensors in the network with ease and sustain satisfactory performance.
- **Packet Delivery Ratio** denotes the number of data packets successfully received at the sink out of the total number of packets sent by the source nodes.
- **End-to-End Delay** represents the time taken for a packet or data envelope to traverse the network from its source to the sink.
- **Routing Overhead** is the total number of control and management packets (e.g., RREQs, messages, clustering setup frames) sent relative to actual payload data packets.

4.2. Comparison Matrix

Table 2 represents the operational characteristics and performance trade-offs of the main routing protocols for mobile ad hoc wireless sensor networks.

Table 2. Comparison of Routing Protocols

Performance Parameter	Flat Proactive (e.g., OLSR)	Flat Reactive (e.g., AODV)	Hierarchical Mobile (e.g., LEACH-M)	Location-based (e.g., GPSR)
Mobility Tolerance	Low; high velocity causes table de-synchronization (C. E. Perkins and P. Bhagwat, 1994)	Moderate to High; reactive loops repair paths dynamically (M. K. Marina and S. R. Das, 2006).	Low to Moderate; frequent CH re-elections degrade performance (D. S. Kim and Y. J. Chung, 2006).	**Excellent**; completely resilient to dynamic topological shifts (H. Frey and S. Stojmenovic, 2006).
Energy Efficiency	Low; continuous table updates drain battery power (S. R. Medidi and Y. Zhou,2012)	Moderate; efficient during low traffic but drops under frequent route discovery floods (S. Mueller et.al., 2007)	High within stable clusters; data aggregation minimizes transmission costs (W. B. Heinzelman et. al., 2002).	Optimal; avoids large control packet overhead and routing tables (M. Mauve et. al., 2001).
Scalability	Poor; table sizes and updates grow rapidly with network size (T. Clausen and J. Jacquet, 2003).	Limited; control overhead increases exponentially with network size (S. J. Lee et.al., 1999).	High; clustering isolates local data traffic within explicit boundaries (O. Younis and S. Fahmy, 2004).	Very High; routing decisions depend entirely on immediate neighbors (B. Karp and H. T. Kung, 2000).
End-to-End Latency	**Very Low**; routes are pre-computed and immediately available (D. G. Reina, S. L. Toral, and F. Barrero, 2013).	High;source nodes must pause data streams to wait for path discovries (C. E. Perkins and E. M. Royer, 1999)	Medium; cluster formation and data compression queues introduce delays (S. Deng, J. Li, and L. Shen, 2014).	Low; immediate, localized hop-by-hop forwarding decisions (C. Lochert, et.al 2005).
Data Aggregation	Yes (At intermediate nodes)	Yes (At intermediate nodes)	Yes (At Cluster Heads)	No
Primary System Bottleneck	Constant table update broadcasts drain network bandwidth (S. R. Medidi and Y. Zhou, 2012).	High control-packet overhead during route discovery stages (S. Mueller et.al., 2007).	High energy spikes occur during dynamic cluster head elections and setup phases (D. S. Kim and Y. J. Chung, 2006).	Complete reliance on high-accuracy positioning hardware (like GPS) (Y. Cao and Z. Yao, 2017).

5. Discussion and analytical insights

Analysis and comparison of the performance of routing protocols highlight their advantages and disadvantages which indicates that they cannot be **optimized for every metric at once.** Flat and proactive routing approach has low latency but bears a high energy cost caused by constant table updates that makes it impractical for highly mobile, and energy-constrained sensor environments. Reactive mechanisms like AODV balance network overhead by only establishing routes on-demand, though the packet latency is high and the network can be flooded with control traffic when routes break frequently due to high mobility of the node.

Hierarchical clustering protocols perform data aggregation at the cluster head node and reduce long-distance transmissions to the sink node, which make these protocols more energy efficient. But if the cluster head moves rapidly or runs out of battery power then all

member nodes get disconnected with the sink node. The fast movement of nodes sharply increases the cost of constantly reforming the clusters. This re-clustering, route recalculation and broadcasting cluster head status generate huge packet overhead that consumes more energy and neutralizes the energy benefits of data aggregation.

Location-based routing protocols outperform flat and hierarchical routing approaches under high mobility because it depends on local positions of the nodes rather than end-to-end routes which conserves energy drastically. However, its efficiency relies heavily on the belief that nodes are aware of their exact physical coordinates. If GPS system does not exist in the network area (like underground tunnels, dense forests, under water or indoor environments) then nodes have to use local relative localization methods. The computational processing power needed to calculate the locations of the nodes can quickly surpass the communication energy saved by tableless routing.

6. Conclusion and future directions

This study demonstrates that selection of the optimal routing protocol for mobile ad hoc wireless sensor networks depends upon the specific requirements of the application and trade-off between performance parameters like packet loss, packet delivery ratio, and network lifetime.

- Location-based routing provides superior scalability and mobility tolerance for large-scale, high-velocity outdoor deployments with reliable location data.
- Hierarchical routing provides the best energy conservation for localized, high-density networks with low or predictable mobility patterns.
- Flat and Reactive routing is highly reliable for smaller, sparse networks characterized by sporadic, event-driven data streams.

To mitigate the weaknesses associated with conventional routing protocols, following two future research trends have been identified:

1. Machine Learning and AI Integration:

Explore the integration of machine learning and artificial intelligence techniques for more adaptive and self- learning WASNs. In this approach, mobile sensor nodes function as intelligent agents capable of learning from their operational experiences. By analysing factors such as historical transmission success rates, node mobility patterns, and energy consumption behaviour, these agents can identify and choose optimal routing paths over time. So, the network will become more adaptive, resilient, and capable of responding effectively to changing topology and unpredictable environmental conditions.

2. Cross-Layer Optimization:

Adopt cross-layer optimization techniques that enable the exchange of real-time information among different protocol layers. By considering parameters such as link quality, interference levels, and signal strength from the Physical and Data link layers, along with remaining energy of the sensor nodes, the routing layer can determine in advance the possible link failures and proactively choose more reliable routes for data transmission. This integrated approach can lead to more holistic solutions and improve performance, energy efficiency and reliability of the network.

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Ecological Consciousness and Sustainable Living: A Sociological Study of Environmental Values in Contemporary Indian Society

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ABSTRACT

Environmental degradation, climate change, biodiversity loss, and unsustainable consumption patterns have emerged as some of the most pressing challenges of the twenty-first century. These concerns have generated renewed interest in ecological consciousness and sustainable living as essential components of social development and environmental protection in recent years. This study examines the sociological dimensions of ecological consciousness in contemporary Indian society and explores how environmental values influence everyday practices, lifestyles, and social behavior. Drawing on classical and contemporary sociological perspectives, including environmental sociology, risk society theory, ecological modernization, and cultural sociology, this study analyzes the relationship between social structures, cultural beliefs, and environmental responsibility. This paper argues that ecological consciousness is not merely an individual awareness of environmental problems but a socially constructed phenomenon shaped by cultural traditions, education, media, economic conditions, and public policies. Furthermore, sustainable living is understood as a set of everyday practices that reflect ecological values and contribute to sustainability. The study highlights the relevance of traditional Indian ecological ethics alongside contemporary sustainability discourses. This study concludes that promoting ecological consciousness is crucial for achieving sustainable development and addressing environmental challenges in India. Strengthening environmental values through education, community participation, and cultural engagement can contribute significantly to creating environmentally responsible citizens and sustainable societies.

Keywords: Ecological Consciousness, Sustainable Living, Environmental Values, Environmental Sociology, Contemporary India

1. Introduction

The twenty-first century has witnessed unprecedented environmental challenges that threaten ecological stability and human well-being. Climate change, deforestation, biodiversity loss, air and water pollution, resource depletion, and unsustainable consumption patterns are major global concerns. These issues are no longer viewed solely as

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environmental problems; they are increasingly recognized as social, cultural, economic, and political challenges that affect the everyday life of people. Consequently, understanding the relationship between society and the environment has become an important area of inquiry in sociology. In this context, ecological consciousness and sustainable living have emerged as significant concepts for understanding how individuals and communities respond to environmental concerns.

Ecological consciousness refers to awareness, understanding, and concern regarding environmental issues and the recognition of the interdependence between human society and natural ecosystems. It involves not only knowledge of environmental problems but also ethical commitments and behavioral practices that promote environmental sustainability. In contrast, sustainable living refers to lifestyles and everyday practices that minimize negative impacts on the environment while supporting social and economic well-being. Together, these concepts highlight the importance of integrating environmental responsibility into daily life and through collective social action.

The growing significance of ecological consciousness is closely related to the broader processes of modernization and globalization. Industrialization, urbanization, technological development, and economic growth have significantly improved living standards. However, these developments have generated environmental problems on an unprecedented scale. Sociologists have argued that environmental degradation is deeply embedded in modern social systems and patterns of production and consumption (Beck, 1992). As societies become increasingly dependent on industrial and technological systems, environmental risks become widespread and difficult to control.

The emergence of environmental sociology in the late twentieth century reflected the growing recognition of these concerns. Earlier sociological traditions often treated society as being largely independent of ecological constraints. However, environmental sociologists have emphasized that human societies are fundamentally dependent on natural resources and ecological systems (Catton & Dunlap, 1980). This perspective challenges anthropocentric assumptions and encourages scholars to examine how social structures, cultural values, and economic systems contribute to environmental change.

Ecological consciousness is not equally distributed across societies or social groups. Rather, it is shaped by social experiences, educational opportunities, cultural traditions, political ideologies and economic conditions. Individuals learn environmental values through socialization processes within families, schools, communities, religious institutions, and media networks. Consequently, environmental concerns must be understood as a social phenomenon rather than merely an individual attitude. Sociological analysis helps explain why some groups demonstrate strong ecological awareness, while others remain less engaged with environmental issues.

In the Indian context, ecological consciousness occupies a particularly significant position because environmental concerns intersect with development, poverty, resource management, and cultural identity questions. India faces numerous environmental challenges, including air pollution, water scarcity, waste management, land degradation, and climate vulnerability. Simultaneously, Indian cultural traditions contain rich ecological philosophies that emphasize harmony between humans and nature. Ancient texts, religious practices, and Indigenous knowledge systems frequently portray nature as sacred and interconnected with human existence. These traditions provide important cultural resources for contemporary environmental thought.

The concept of sustainable living has gained increasing prominence in recent decades as governments, international organizations, and civil society groups seek solutions to

environmental issues. Sustainable living involves everyday practices such as responsible consumption, waste reduction, energy conservation, sustainable transportation, environmental stewardship and community participation. From a sociological perspective, these practices are shaped not only by individual choices but also by social structures, cultural norms and institutional arrangements. Therefore, promoting sustainability requires both behavioral change and broader social transformation.

Contemporary sociological theories provide valuable frameworks for understanding the concept of ecological consciousness. Ulrich Beck's (1992) concept of the "risk society" argues that modern societies increasingly confront environmental risks produced by industrial development itself. Environmental problems, such as climate change and pollution, are examples of manufactured risks that transcend national boundaries and affect diverse populations. Beck's theory suggests that growing awareness of environmental risks contributes to the development of ecological consciousness.

Similarly, Giddens (2009) emphasizes that environmental challenges require new forms of social responsibility and collective action. Environmental issues are often characterized by complexity and uncertainty, making it difficult for individuals to perceive direct connections between their everyday activities and ecological consequences. Sociological analysis helps bridge this gap by examining how social institutions influence environmental behavior and awareness.

Pierre Bourdieu's (1984) concept of cultural capital is also relevant to understanding ecological consciousness. Environmental values are often associated with educational attainment, access to information, and participation in specific social networks. Individuals with greater cultural capital may be more likely to adopt environmentally responsible behaviors and support sustainability initiatives. Thus, ecological consciousness is closely linked to the broader processes of social stratification and cultural reproduction.

In addition to modern sociological theories, traditional ecological perspectives are important. Indian philosophical traditions frequently emphasize interconnectedness, moderation, and a respect for nature. These principles resonate strongly with contemporary sustainability discourse and provide culturally meaningful frameworks for environmental responsibility. The coexistence of traditional ecological values and modern environmental concerns creates unique opportunities to promote sustainable living in India.

Despite the increasing awareness of environmental issues, significant challenges remain. Economic pressures, consumer culture, urban lifestyles, and social inequality often limit the adoption of sustainable practices. Environmental concerns may conflict with immediate economic needs, particularly in marginalized populations. Therefore, ecological consciousness must be understood within the broader social and structural contexts.

This study examines ecological consciousness and sustainable living from a sociological perspective. It explores how environmental values are formed, transmitted and expressed in contemporary Indian society. Drawing on environmental sociology and related theoretical perspectives, this study investigates the relationship between culture, social structures, and environmental behavior. This paper argues that ecological consciousness is a socially constructed phenomenon that plays a crucial role in promoting sustainable development and environmental responsibility. By analyzing the cultural and social dimensions of sustainability, this study contributes to broader discussions concerning the relationship between society, environment, and social change.

2. Theoretical framework

The relationship between society and the environment has become a significant area of sociological inquiry, particularly in the context of increasing environmental degradation and sustainability concerns. Ecological consciousness is not merely an individual awareness of environmental issues but a socially constructed phenomenon that is influenced by cultural values, social institutions, economic systems, and political processes. To understand this complex relationship, the present study draws on Environmental Sociology, Risk Society Theory, Ecological Modernization Theory, and Cultural Sociology. These perspectives provide important insights into how environmental values are produced, maintained, and translated into sustainable living practices.

2.1 Environmental Sociology and the Human–Nature Relationship

Environmental sociology emerged in the 1970s in response to growing environmental concerns and the limitations of traditional sociological approaches. Earlier sociological theories often assumed that human societies are largely independent of ecological constraints. Catton and Dunlap (1980) challenged this assumption through the development of the New Ecological Paradigm (NEP), which emphasized that human societies are fundamentally dependent upon ecological systems and natural resources.

According to environmental sociologists, environmental problems are not merely natural phenomena but are deeply connected to social structures and human activity patterns. Industrialization, urbanization, technological expansion, and consumer culture have significantly altered society-nature relationships. Therefore, environmental degradation reflects broader social and economic processes rather than isolated ecological events.

The New Ecological Paradigm argues that human beings are part of a larger ecological system and cannot remain unaffected by environmental change. This perspective rejects the belief that technological progress alone can solve environmental issues. Instead, it emphasizes the need for ecological awareness and sustainable practices. Ecological consciousness emerges from the recognition that environmental and human well-being are inseparable.

Environmental sociology highlights the role of social institutions in shaping environmental behavior. Families, educational institutions, religious organizations, media, and governments influence individuals understanding of environmental issues and their responses to them. Consequently, ecological consciousness is viewed as a socially learned orientation toward nature rather than simply being a personal belief.

In the Indian context, environmental sociology is particularly relevant because environmental challenges intersect with development, poverty, resource distribution, and social inequality issues. Environmental degradation often affects vulnerable populations disproportionately, making ecological issues inseparable from the broader concerns of social justice and sustainable development.

2.2 Risk Society Theory

One of the most influential contemporary sociological perspectives on environmental issues is Ulrich Beck's (1992) theory of the Risk Society. Beck argues that modernization has produced new forms of environmental risk that differ significantly from traditional social problems. Unlike earlier risks, which were localized and visible, contemporary environmental risks are global, complex, and often invisible.

Climate change, nuclear accidents, air pollution, chemical contamination, and biodiversity loss are examples of risks generated by modern industrial society. These risks transcend national boundaries and affect individuals, regardless of their social status or

geographical location. Consequently, environmental concerns have become central to public life and political decision making.

According to Beck (1992), awareness of environmental risks contributes to developing ecological consciousness. As individuals become increasingly aware of the consequences of industrial development, they question existing patterns of production and consumption. This process encourages greater environmental responsibility and supports sustainable alternatives.

Risk Society Theory also highlights the role of scientific knowledge in shaping ecological awareness. Environmental problems are often identified through scientific research, media reports, and expert analyses. Public understanding of climate change, pollution, and environmental degradation heavily depends on scientific information. However, individuals interpret these risks through social and cultural frameworks, rendering ecological consciousness a socially mediated phenomenon.

In contemporary India, environmental risks are increasingly visible due to rising temperatures, air pollution, water scarcity, extreme weather events, and ecological degradation. These challenges contribute to growing public concern regarding environmental sustainability and encourage new forms of ecological awareness among the citizens.

2.3 Ecological Modernization Theory

Ecological Modernization Theory offers a more optimistic perspective on environmental challenges. Unlike approaches that view modernization as inherently destructive, ecological modernization theorists argue that environmental protection and economic development can coexist (Mol and Spaargaren, 2000).

From this perspective, technological innovation, institutional reform, environmental policies, and sustainable production methods can reduce environmental impact while maintaining economic growth. Environmental problems are not seen as inevitable consequences of modernization but as challenges that can be addressed through innovation and social transformation.

Ecological modernization emphasizes the importance of environmental governance, green technologies, renewable energy, sustainable agriculture, and responsible consumption. These developments contribute to the formation of ecological consciousness by encouraging individuals and organizations to adopt environmentally responsible practice.

This theory is particularly relevant in the Indian context, where sustainable development has become a major policy objective. Government initiatives related to renewable energy, waste management, water conservation, and environmental education reflect attempts to integrate sustainability into development strategies.

However, ecological modernization has also faced criticism. Some scholars argue that technological solutions alone cannot address environmental problems because they often fail to challenge the underlying patterns of excessive consumption and economic inequality. Consequently, sustainable living requires not only technological innovation but also changes in values, lifestyle, and social behavior.

2.4 Cultural Sociology and Environmental Values

Cultural sociology provides an important perspective for understanding ecological consciousness. Environmental attitudes are influenced not only by economic and political factors but also by cultural beliefs, symbols and moral values. Individuals develop environmental concerns through socialization and cultural learning.

Geertz (1973) argued that culture consists of systems of meaning through which individuals interpret their world. Therefore, environmental values are shaped by cultural narratives concerning nature, responsibility, and human existence. Different societies construct different relationships with the natural environment based on their cultural traditions and historical experiences.

In India, cultural and religious traditions often emphasize the harmony between humans and nature. Rivers, forests, mountains, and animals are frequently regarded as sacred and deserving of respect. Such beliefs contribute to ecological values that support environmental conservation and sustainable living practices.

Bourdieu's (1984) concept of cultural capital further explains the variations in ecological consciousness. Individuals with greater educational opportunities and access to environmental information are more likely to develop ecological awareness. Environmental concerns reflect broader social inequalities and patterns of cultural participation.

Cultural sociology emphasizes the roles of media and education in shaping environmental values. Environmental campaigns, documentaries, educational programs, and public awareness initiatives contribute to the diffusion of ecological consciousness across societies. Through these processes, environmental concerns are integrated into everyday life and social identity.

3. Review of literature

Scholarly interest in environmental values and ecological consciousness has expanded significantly over the past few decades. Early environmental sociologists challenged the traditional assumption of the separation of society and nature. Catton and Dunlap (1980) argued that sociological analysis must recognize ecological limits and environmental interdependence. Their work laid the foundations for contemporary environmental sociology.

Beck (1992) emphasized that modern societies increasingly confront environmental risks produced by industrialization itself. His concept of the Risk Society highlights the growing importance of environmental awareness and collective responsibility. According to Beck, environmental concerns have become central features of contemporary social life.

Giddens (2009) examined the social implications of climate change and argued that environmental challenges require long-term collective action. He noted that environmental problems are often difficult to perceive because their consequences develop gradually over time. Consequently, environmental awareness must be supported through education, policy intervention, and public engagement.

Research on sustainable lifestyles has demonstrated that environmental values significantly influence daily behavior. Studies have indicated that individuals with stronger ecological awareness are more likely to engage in recycling, energy conservation, responsible consumption, and environmental activism (Dobson, 2007). However, researchers have also noted that awareness alone does not always translate into behavior because structural and economic constraints often limit sustainable choices.

Indian scholars have highlighted the importance of traditional ecological knowledge and cultural values in promoting sustainability. Indigenous communities frequently possess sophisticated environmental management systems based on long-term interactions with local ecosystems. These traditions provide valuable insights into contemporary sustainability efforts.

Recent research has focused on the role of education in fostering ecological consciousness. Environmental education programs contribute significantly to developing pro-environmental attitudes and behaviors among young people. Therefore, educational institutions play a crucial role in shaping future environmental citizens.

Overall, the existing literature demonstrates that ecological consciousness is influenced by social structures, cultural values, educational experiences, and environmental risks. These findings support the argument that sustainable living requires both individual commitment and broader social transformations.

4. Conceptual understanding of ecological consciousness

Ecological consciousness refers to an individual's awareness, understanding, and ethical concerns regarding environmental issues and ecological interdependence. It involves the recognition that human well-being depends on the health of natural ecosystems and that environmental degradation has significant social consequences.

Ecological consciousness operates at several levels. The cognitive dimension involves knowledge of environmental and sustainability problems. The affective dimension includes emotional concerns for nature and future generations. The behavioral dimension refers to the actions and lifestyle choices that support environmental sustainability.

From a sociological perspective, ecological consciousness is socially constructed rather than naturally occurring. Individuals acquire environmental values through socialization processes involving families, schools, peer groups, the media, religious institutions, and community organizations. Consequently, ecological awareness varies across social groups and cultural contexts.

Ecological consciousness reflects moral and ethical considerations. Environmental responsibility involves recognizing obligations to other people, future generations, and nonhuman life forms. Such ethical commitments motivate sustainable behavior and collective environmental action.

In contemporary society, ecological consciousness has become increasingly important because environmental problems require coordinated responses at the local, national, and global levels. Sustainable development depends not only on technological solutions but also on cultivating environmental values and responsible citizenship.

Therefore, ecological consciousness can be understood as a critical social resource that encourages sustainable living, environmental stewardship, and collective action for ecological sustainability.

5. Ecological consciousness and environmental values in contemporary India

Environmental values play a crucial role in shaping ecological consciousness and influencing individuals' interactions with the natural environment. In contemporary India, ecological awareness has gained increasing significance owing to the growing visibility of environmental problems such as air pollution, water scarcity, climate change, deforestation, biodiversity loss, and waste accumulation. These challenges have encouraged citizens, policymakers, educational institutions, and civil society organizations to engage more actively with environmental issues.

Ecological consciousness is closely linked to the value systems that individuals and communities develop through socialization. Environmental values refer to the beliefs and principles that guide attitudes toward nature and influence environmentally responsible behavior. These values determine how people perceive environmental problems, prioritize ecological concerns and respond to sustainability initiatives. Sociologists argue that

environmental values are socially constructed and shaped by cultural traditions, educational experiences, economic conditions, and social interactions (Catton and Dunlap, 1980).

Indian society has a rich tradition of ecological thought. Ancient philosophical and religious traditions frequently emphasize the harmony between human beings and nature. Concepts such as *Vasudhaiva Kutumbakam* (the world as one family), reverence for rivers, forests, animals, and sacred groves, and the principles of moderation and non-violence have historically contributed to ecological ethics. These traditions continue to influence environmental attitudes in many communities and provide culturally meaningful foundations for sustainability.

Religious practices often play an important role in promoting ecological value. Hinduism, Buddhism, Jainism, and various indigenous traditions emphasize respect for living beings and maintaining ecological balance. For example, Jain philosophy promotes *ahimsa* (non-violence) toward all forms of life, whereas Buddhist teachings encourage compassion and interdependence. Such perspectives contribute to environmental ethics that extend beyond purely utilitarian concerns of the environment.

Simultaneously, modernization and consumer culture have introduced new challenges. Economic growth and urbanization have increased consumption levels, resource extraction, and waste generation. These developments frequently create tensions between economic aspirations and environmental sustainability issues. Consequently, ecological consciousness in contemporary India reflects a dynamic interaction between traditional values and modern life.

Environmental movements have significantly contributed to ecological awareness. Movements such as the Chipko Movement, Narmada Bachao Andolan, and various community-based conservation initiatives demonstrate the importance of collective action in protecting natural resources. These movements highlight the social dimensions of environmental issues and encourage public participation in environmental decision making.

Media and digital communication have expanded environmental awareness. News coverage, documentaries, social media campaigns, and environmental activism have increased public knowledge of issues such as climate change, pollution, and biodiversity conservation. As environmental information becomes more accessible, ecological concerns are integrated into public discourse and everyday conversations.

However, environmental awareness remains unevenly distributed across social groups. Educational attainment, socioeconomic status, geographical location, and access to information influence the levels of ecological consciousness. Urban populations may have greater exposure to environmental information, whereas rural communities often possess practical ecological knowledge derived from direct interaction with natural resources. Understanding these variations is essential for developing effective environmental policies and educational programs.

Overall, ecological consciousness in contemporary India represents a complex combination of traditional ecological ethics, modern environmental concerns, social movements, educational influences and public engagement. Strengthening environmental values is crucial for promoting sustainable development and ecological responsibility.

6. Sustainable living and everyday practices

Sustainable living refers to behavioral patterns and lifestyle choices that minimize environmental harm while supporting social and economic well-being. It involves reducing resource consumption, minimizing waste, conserving energy, protecting biodiversity, and promoting environmentally responsible practices. From a sociological perspective,

sustainable living is not simply an individual choice but rather a social process influenced by cultural norms, institutional arrangements, and structural conditions.

Responsible consumption is one of the key dimensions of sustainable living. Contemporary consumer societies are characterized by an increasing demand for goods and services, often resulting in excessive resource use and environmental degradation. Sociologists argue that consumer behavior is shaped by social values, cultural expectations, and economic systems, rather than purely individual preferences (Giddens, 2009). Consequently, promoting sustainable consumption requires changes in both individual behavior and broader social structures.

Energy conservation is another important aspect of sustainable living. Simple practices, such as reducing electricity consumption, using energy-efficient appliances, and supporting renewable energy sources, contribute significantly to environmental sustainability. Such behaviors not only reduce environmental impact but also encourage greater awareness of resource limitations.

Waste management is equally important in this regard. Rapid urbanization and population growth have generated increasing volumes of solid waste in cities across India. Sustainable living encourages waste reduction through recycling, reusing, composting, and responsible disposal practices. Community-based waste management initiatives demonstrate how collective action contributes to environmental improvement.

Sustainable transportation is a significant concern. The dependence on private vehicles contributes to air pollution, traffic congestion, and greenhouse gas emissions. Public transportation, cycling, walking, and shared mobility systems are environmentally sustainable alternatives. Encouraging such practices requires supportive infrastructure and policy.

Food consumption patterns also influence the sustainability of the environment. Sustainable diets emphasize locally produced foods, reduced food waste, and environmentally responsible agricultural practices. Traditional Indian food systems often reflect principles of moderation and resource efficiency that align closely with contemporary sustainability goals.

Water conservation has become particularly important in India because of increasing water scarcity and environmental stress. Rainwater harvesting, efficient irrigation methods, water recycling, and responsible water use are essential components of sustainable living. Community participation in water management can significantly enhance conservation efforts.

Sustainable living also has social dimensions. Environmental responsibility is strengthened when individuals participate in community initiatives, environmental organizations, and local sustainability programs. Collective action encourages social learning and reinforces environmentally responsible behaviors.

However, adopting a sustainable lifestyle is often constrained by social and economic factors. Poverty, inadequate infrastructure, limited access to sustainable alternatives, and consumer culture can restrict opportunities for environmentally responsible behaviors. Therefore, sustainable living should be understood not only as an individual responsibility but also as a collective social objective that requires institutional support and policy interventions.

The sociological significance of sustainable living lies in its potential to transform everyday practices and promote sustainability. By integrating ecological values into their daily lives, individuals contribute to broader processes of social and environmental change.

7. Role of education, media, religion, and community participation

The development of ecological consciousness depends significantly on social institutions that shape knowledge, value, and behavior. Education, media, religion, and community participation play crucial roles in promoting environmental awareness and encouraging sustainable living.

Education is one of the most effective mechanisms for developing ecological awareness. Environmental education provides individuals with knowledge of ecological systems, environmental challenges, and sustainability strategies. Schools, colleges, and universities play important roles in cultivating environmental values among young people. Educational programs encourage critical thinking, environmental responsibility, and active participation in sustainability initiatives.

Environmental education extends beyond formal institutions such as schools. Workshops, awareness campaigns, community programs, and public outreach initiatives contribute significantly to environmental education. Individuals with greater environmental knowledge are generally more likely to engage in sustainable behavior and support environmental policies.

The media has become a powerful influence on ecological awareness. Newspapers, television programs, documentaries, social media platforms, and digital campaigns disseminate information on environmental issues and sustainability initiatives. Media coverage helps to transform environmental problems into public concerns and encourages civic engagement.

Social media has created new opportunities for environmental activism and awareness. Online campaigns, environmental movements, and digital advocacy networks facilitate communication among diverse groups and encourage public participation in environmental protection. These platforms help individuals connect local environmental concerns to broader global issues, such as climate change and biodiversity conservation.

Religion continues to influence environmental values in many parts of India. Religious teachings often emphasize stewardship, respect for nature, moderation, and ethical responsibilities. Sacred landscapes, rivers, forests, and animals hold significant importance in many religious traditions. These beliefs provide moral frameworks that support environmental conservation and sustainability.

Community participation is another essential component of ecological consciousness. Local communities often possess valuable environmental knowledge and play a critical role in resource management. Community-based conservation programs, afforestation initiatives, water management projects, and environmental campaigns demonstrate the effectiveness of collective action in addressing ecological challenges.

Participation in environmental activities strengthens social bonds and encourages a sense of shared responsibility. Communities that actively engage in environmental stewardship frequently develop stronger ecological values and a greater commitment to sustainability. Such participation enhances democratic decision-making by involving citizens in environmental governance.

Education, media, religion, and community engagement contribute to the development of environmental citizenship. These institutions encourage individuals to view environmental responsibility as an integral component of their social lives and collective well-being.

8. Environmental citizenship and social responsibility

The concept of environmental citizenship has gained increasing importance in contemporary environmental discourse. Environmental citizenship refers to the recognition that individuals possess rights and responsibilities related to environmental protection and sustainability. It emphasizes active participation in environmental decision-making and encourages citizens to consider the ecological consequences of their actions.

Environmental citizenship extends the traditional notion of citizenship beyond political and legal responsibilities. It recognizes that environmental problems affect present and future generations and therefore require collective action to address them. Dobson (2007) argues that environmental citizenship involves ethical commitments to sustainability, ecological justice, and global responsibility.

Ecological consciousness is the foundation of environmental citizenship. Individuals who understand environmental challenges and appreciate ecological interdependence are more likely to engage in environmentally responsible behaviors. Such behaviors include conserving resources, reducing waste, supporting environmental policies, and participating in community initiatives.

Social responsibility is also important. Environmental problems are often collective in nature and cannot be solved solely through individual action. Governments, businesses, educational institutions, civil society organizations, and local communities share the responsibility of promoting sustainability. Collaborative efforts are essential for addressing these complex environmental challenges.

In contemporary India, environmental citizenship is increasingly reflected in public awareness campaigns, environmental legislation, sustainable development initiatives and grassroots activism. Citizens are becoming increasingly engaged in issues related to pollution control, waste management, water conservation, biodiversity protection, and climate action.

The growth of ecological consciousness demonstrates that environmental responsibility is becoming an important aspect of civic identity. As environmental concerns continue to intensify, fostering environmental citizenship is essential for achieving sustainable development and ecological resilience.

Ultimately, ecological consciousness and sustainable living are not merely environmental concerns; they are social and cultural processes that shape human societies' future. Strengthening environmental values, encouraging responsible behavior, and promoting collective action can contribute significantly to building sustainable and environmentally just communities.

9. Discussion

This study demonstrates that ecological consciousness is a socially constructed phenomenon shaped by cultural traditions, social institutions, educational experiences, and environmental realities. Contrary to the assumption that environmental concern is merely an individual attitude, sociological analysis reveals that ecological awareness develops through complex interactions between individuals and the social environment in which they live. Environmental values are learned, reinforced, and transformed through socialization, cultural participation, and collective action.

The theoretical perspectives discussed in this paper provide important insights into developing ecological consciousness. Environmental sociology highlights the interdependence between society and nature, emphasizing that environmental problems are deeply connected to the patterns of production, consumption, and social organization (Catton & Dunlap, 1980). Risk Society Theory further demonstrates that environmental concerns are increasingly central to contemporary social life because industrial

modernization has generated new forms of ecological risk that affect all segments of society (Beck, 1992). These perspectives suggest that environmental awareness emerges not only from direct experiences of ecological degradation but also from broader social understandings of environmental risks.

This study also highlights the importance of cultural values in shaping environmental behavior. Traditional Indian ecological philosophies emphasize moderation, interdependence, respect for nature, and ethical responsibilities. These values provide a culturally relevant foundation for environmental sustainability. Simultaneously, modernization, consumerism, and rapid urbanization often encourage consumption patterns that conflict with ecological principles. Consequently, contemporary ecological consciousness reflects an ongoing negotiation between traditional values and modern living.

Education, media, religion, and community participation are critical mechanisms for fostering ecological awareness. Educational institutions contribute to environmental literacy, and media platforms disseminate information on environmental challenges and sustainability initiatives. Religious traditions often reinforce ethical commitments to nature, and community participation encourages collective responsibility for environmental protection.

The analysis further demonstrates that sustainable living cannot be understood solely as a matter of individual choices. Sustainable behavior is influenced by social structures, economic opportunities, public policies, and cultural norms. Therefore, environmental sustainability requires both individual commitment and institutional support. Governments, educational institutions, civil society organizations, and local communities must work collaboratively to create conditions that encourage environmentally responsible behaviors.

Another significant finding was the growing importance of environmental citizenship. Contemporary environmental challenges, such as climate change, pollution, and biodiversity loss, require active public participation and collective responsibility. Ecological consciousness encourages citizens to recognize the social consequences of environmental degradation and motivates them to engage in sustainability initiatives. Therefore, environmental citizenship represents an essential component of democratic participation and sustainable development.

Overall, this study demonstrates that ecological consciousness is a vital social resource for addressing environmental challenges. By promoting environmental values, responsible lifestyles, and collective action, ecological consciousness contributes to creating sustainable and environmentally resilient societies.

10. Conclusion

Environmental problems have become one of the most significant challenges confronting contemporary societies. Issues such as climate change, pollution, resource depletion, and biodiversity loss require not only technological solutions but also fundamental changes in social values, lifestyle, and institutional practices. This study examined ecological consciousness and sustainable living from a sociological perspective, emphasizing the social and cultural dimensions of environmental awareness.

The study shows that ecological consciousness involves more than just knowledge of environmental issues. This represents a broader awareness of the interconnectedness between human societies and ecological systems. Through socialization, education, cultural traditions, media influences, and community participation, individuals develop environmental values that shape their attitudes and behaviors toward nature.

The analysis also demonstrates that sustainable living is a socially embedded practice, rather than merely a personal choice. Everyday actions related to consumption, transportation, energy use, waste management, and resource conservation are influenced by social structures, cultural norms and institutional arrangements. Consequently, promoting sustainability requires both behavioral change and broader social transformation.

In the Indian context, ecological consciousness is strengthened by a rich heritage of ecological ethics and cultural traditions that emphasize harmony between humans and nature. These traditions continue to provide a meaningful foundation for environmental responsibility and sustainable development. Simultaneously, contemporary environmental challenges demand innovative approaches that combine traditional wisdom with modern scientific knowledge and policy interventions.

This study concludes that ecological consciousness is essential for achieving sustainable development and environmental justice. Strengthening environmental values through education, public participation, community engagement, and responsible governance can contribute significantly to building an environmentally responsible society. As environmental challenges continue to intensify, fostering ecological consciousness is crucial for ensuring a sustainable future for present and future generations.

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Embodied Traditions: Yoga, Health and Cultural Meanings in Contemporary Indian Society

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ABSTRACT

Yoga is one of the oldest and most enduring traditions of Indian civilization, representing a holistic system that integrates physical discipline, mental balance, ethical conduct, and spirituality. Although contemporary discussions frequently emphasize yoga's therapeutic and physiological benefits, it remains deeply embedded within broader cultural and philosophical frameworks that shape understandings of health, selfhood, and social life. This study examines yoga as an embodied cultural practice and explores its significance in contemporary Indian society through the perspectives of embodiment theory, interpretive anthropology, and medical anthropology. Drawing on classical yogic texts and anthropological scholarship, this study argues that yoga functions not merely as a form of physical exercise but as a cultural system through which individuals cultivate self-awareness, negotiate identity, and pursue holistic well-being. This paper traces the historical development of yoga from ancient Indian traditions to its modern global forms and analyzes its role in promoting physical, mental, emotional, and spiritual health. Particular attention was given to the cultural meanings associated with yoga, including discipline, self-realization, national identity, and cultural heritage. The study concludes that yoga represents a dynamic and adaptive tradition that successfully bridges ancient knowledge and contemporary health concerns, making it a significant framework for understanding the relationship between culture, embodiment and well-being in modern India.

Keywords: Yoga, Embodiment, Health, Well-being, Cultural Anthropology

Introduction

Yoga has become one of the most visible and influential cultural traditions in contemporary India. Practiced across continents and embraced by diverse populations, yoga is often presented as a system for improving physical fitness, reducing stress, and enhancing psychological well-being. However, limiting yoga to a form of exercise overlooks its historical and cultural significance. Originating in ancient India, yoga developed as a

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comprehensive philosophical and spiritual discipline concerned with understanding human existence and achieving harmony between the body, mind, and spirit (Eliade, 1969).

The relevance of yoga in contemporary society has increased significantly owing to rapid social and economic transformations. Urbanization, technological dependence, sedentary lifestyles, and increasing stress levels have generated growing concerns regarding physical and mental health. In response, many individuals seek holistic approaches to well-being that address not only bodily health but also their emotional and spiritual needs. Yoga has emerged as an important response to these concerns because it offers an integrated system of self-care and self-cultivation (Feuerstein 2003).

Anthropological scholarship provides valuable tools for understanding the broader significance of yoga in the West. Rather than viewing the body as a mere biological entity, anthropologists emphasize that bodily practices are shaped by cultural values, beliefs, and social relationships. Mauss (1973) argued that societies teach individuals culturally specific "techniques of the body," while Bourdieu (1977) demonstrated how repeated practices become embodied dispositions that guide everyday behavior. Yoga exemplifies these processes because it involves disciplined bodily practices through which individuals internalize cultural values related to self-control and balance.

The concept of embodiment further enhances our understanding of yoga practice. According to Csordas (1990), embodiment refers to the lived cultural experience through the body. Humans do not simply think about culture; they experience and reproduce it through bodily actions and perceptions. Yoga illustrates this principle, as practitioners cultivate awareness through movement, breathing, and meditation. Knowledge is acquired through practice and experience rather than through intellectual instruction alone.

The cultural significance of yoga extends beyond personal health. Classical texts such as the Upanishads, Bhagavad Gita, and the Yoga Sutras describe yoga as a path toward self-realization and liberation. These traditions conceptualize health as a balanced state involving physical, mental, ethical, and spiritual dimensions of health. Such perspectives differ considerably from biomedical approaches that primarily focus on disease prevention and treatment.

Modern yoga emerged through complex interactions between traditional Indian practices and global influences on them. During the colonial period, Indian intellectuals and reformers reinterpreted yoga as a symbol of cultural resilience and national identity (Alter 2004). During the twentieth century, teachers such as Swami Vivekananda, T. Krishnamacharya, and B.K.S. Iyengar and Pattabhi Jois helped transform yoga into a globally recognized practice. Despite these changes, yoga continues to be strongly associated with Indian cultural heritage.

This study examines yoga as an embodied cultural tradition that links health, identity, and social meaning. Drawing on anthropological theories and historical perspectives, this study explores how yoga contributes to holistic well-being while reinforcing broader cultural values. This study argues that yoga remains a dynamic tradition capable of addressing contemporary health concerns while preserving important elements of India's intellectual and spiritual heritage.

Theoretical framework

This study draws on embodiment theory, interpretive anthropology, and medical anthropology. Together, these approaches provide a framework for understanding yoga as a cultural practice that shapes bodily experiences, health, identity, and meaning.

Mauss (1973) introduced the concept of "techniques of the body," emphasizing that bodily practices are socially learned rather than biologically determined. Yoga exemplifies

this concept because practitioners acquire specific postures, breathing patterns, and bodily discipline through training and repetition. These techniques have become integral to everyday life and contribute to the formation of culturally valued habits.

Bourdieu's (1977) concept of habitus further explains how repeated practices become embodied dispositions. Through regular yoga practice, individuals internalize values such as self-discipline, patience, concentration, and the ability to regulate emotions. These dispositions influence behavior beyond the yoga mat and become part of the practitioner's everyday life.

Csordas (1990) proposed embodiment as a paradigm in anthropology, arguing that culture is experienced through the body. Yoga provides a powerful example of embodied knowledge because practitioners learn through direct physical experience. Awareness of breathing, posture, and mental states gradually develops through sustained practice.

Interpretive anthropology, particularly Geertz's (1973) work, views culture as a system of symbols and meanings. Yoga is a symbolic practice associated with balance, harmony, spirituality, and self-realization. Different practitioners may attach different meanings to yoga; however, its symbolic significance remains deeply rooted in broader cultural traditions.

Medical anthropology contributes an important perspective. Kleinman (1980) and Helman (2007) argued that health and illness are culturally interpreted experiences. Traditional Indian understanding of health emphasizes the balance among the physical, mental, social, and spiritual dimensions. Yoga reflects this holistic model by promoting harmony rather than merely treating diseases.

Together, these theoretical perspectives demonstrate that yoga is not simply a physical activity but a culturally meaningful practice through which individuals experience health, identity, and well-being in a holistic manner.

Historical evolution of yoga

The history of yoga reflects the evolution of Indian philosophical and spiritual traditions. Early foundations can be traced to the Vedic period, when practices of meditation, self-discipline, and contemplation were associated with spiritual development (Feuerstein, 2003).

The Upanishads further develop the ideas of self-knowledge and liberation through introspection and meditation. These texts emphasize the relationship between the individual self (*Atman*) and the ultimate reality (*Brahman*), laying the foundation for later yogic philosophies.

Patanjali's *Yoga Sutras* systematized yoga into an eightfold path consisting of ethical restraints, observances, postures, breath control, concentration, meditation, and liberation (Patanjali, 2009). Patanjali emphasized mental discipline and spiritual transformation over physical fitness.

Samuel (2008) notes that medieval yogic traditions, particularly Hatha Yoga, introduced greater emphasis on bodily techniques and energetic practices. Texts such as the *Hatha Yoga Pradipika* view the body as a vehicle for spiritual realization rather than an obstacle to enlightenment.

Colonial encounters have significantly transformed yoga. British observers often viewed yogic practitioners negatively, whereas Indian reformers sought to present yoga as a rational

and scientific tradition. Vivekananda played a crucial role in introducing yoga to international audiences and reframing it as a universal philosophy.

Modern yoga emerged through the contributions of teachers such as Krishnamacharya, Iyengar, Jois, and Sivananda. Their innovations emphasized postural practice, health benefits, and accessibility, contributing to the global popularity of yoga (De Michelis, 2004; Singleton, 2010).

Today, yoga exists simultaneously as a spiritual discipline, health practice, educational activity and cultural symbol. Its historical evolution demonstrates remarkable adaptability while preserving core concerns regarding self-discipline, awareness, and holistic well-being.

Yoga as an embodied cultural practice

Yoga provides a compelling example of embodiment because it integrates bodily movement, breath regulation, concentration, and ethical discipline into a single practice. Through yoga, individuals cultivate awareness of their bodily sensations, emotional states, and thought patterns. This process reflects what Mauss (1973) described as culturally learned, bodily techniques.

Repeated practice transforms external instructions into embodied habits. Bourdieu's (1977) concept of habitus explains how yoga practitioners develop dispositions such as patience, mindfulness, self-control, and resilience. These qualities are integrated into daily life and influence relationships, decision-making, and personal conduct.

Embodiment also involves experiential knowledge. Unlike purely intellectual forms of learning, yoga emphasizes direct experiential learning. Practitioners learn to recognize tension, regulate their breathing, and observe their mental processes through practice. Csordas (1990) argued that such experiences reveal how the body functions as the basis of this cultural knowledge.

Yoga significantly contributes to identity formation. Many practitioners describe yoga as a journey of self-discovery rather than merely a health-related activity. Through sustained practice, individuals construct narratives of personal growth, self-mastery and well-being. These narratives shape individual identities and social relationships.

Douglas (1966) emphasized that cultural systems often regulate the body in ways that reflect broader social values. Yogic practices encourage discipline, purity, and self-regulation. These values contribute to moral development and reinforce broader cultural understanding of responsible behavior.

Kakar (1982) observed that Indian healing traditions frequently integrate psychological, spiritual, and bodily dimensions of experience. Yoga reflects this integration by encouraging individuals to cultivate harmony between the internal and external aspects of their lives. Rather than separating the body and mind, yoga treats them as interconnected dimensions of human existence.

Through embodiment, yoga becomes a means of transmitting cultural knowledge across generations. Its continued relevance demonstrates the enduring significance of bodily practices as vehicles of cultural continuity and transformation.

Yoga and holistic health

One of the primary reasons for the contemporary popularity of yoga is its association with holistic health. Traditional Indian perspectives conceptualize health as a state of balance encompassing the physical, mental, emotional, social, and spiritual dimensions. Yoga promotes this balance through integrated practices that cultivate overall well being.

At the physical level, yoga enhances flexibility, strength, balance, and respiratory efficiency (Iyengar 2005). Breathing techniques improve oxygen utilization, and postural practices support musculoskeletal health. These benefits have contributed significantly to the acceptance of yoga in health and wellness communities.

Research has also demonstrated positive effects on mental health. Woodyard (2011) reported that yoga contributes to stress reduction, emotional regulation, and improved quality of life. Similarly, Telles et al. (2013) found that yoga practice positively influenced heart rate variability, suggesting improved physiological and psychological regulation.

Medical anthropology emphasizes that health is culturally interpreted rather than being purely biological. Kleinman (1980) argued that individuals understand illness and healing through culturally specific frameworks. Therefore, yoga's effectiveness is linked not only to physiological changes but also to the meanings practitioners attach to their experiences.

Helman (2007) emphasized that health involves social and cultural dimensions in addition to biological functioning. Yoga addresses these dimensions by fostering self-awareness, social connectedness and emotional balance. Group practice often creates communities that provide support, belonging, and a shared purpose.

The World Health Organization (1948) defined health as a state of complete physical, mental, and social well-being, rather than merely the absence of disease. Yoga aligns closely with this holistic definition, as it simultaneously addresses multiple dimensions of human flourishing.

Yoga also encourages preventive health approaches. Rather than focusing solely on disease treatment, yogic traditions emphasize self-care, moderation, and lifestyle regulation. Regular practice supports healthy behaviors related to physical activity, stress management, sleep, and emotional wellbeing.

Consequently, yoga offers a comprehensive framework for health that remains highly relevant in contemporary societies facing the increasing burden of stress-related disorders and chronic diseases.

Cultural meanings of yoga in contemporary Indian society

Yoga has meanings that extend far beyond physical health. For many Indians, yoga represents a living connection with ancient traditions and cultural heritage. References to yoga in classical texts reinforce the perception of continuity with India's philosophical and spiritual history.

Yoga also serves as a symbol of national identity. During the colonial period, Indian intellectuals promoted yoga as evidence of the sophistication and value of indigenous knowledge systems (Alter, 2004). Today, yoga continues to be a source of cultural pride and international recognition.

Geertz (1973) argued that cultural practices derive their significance from the symbolic meanings attached to them. Yoga symbolizes harmony, balance, self-discipline and self-realization. These symbolic associations contribute to its enduring appeal across diverse social groups.

Spirituality is another important dimension of the cultural significance of yoga. Even when practiced for secular reasons, yoga often encourages reflection on deeper questions concerning meaning, purpose, and self-understanding. Lambek (2013) notes that religious and spiritual practices frequently provide frameworks through which individuals interpret their experiences and construct meaningful lives.

The commercialization of yoga has introduced new cultural dynamics. Strauss (2005) observed that modern wellness industries often transform yoga into marketable commodities. While commercialization expands access, it may also shift attention away from the philosophical and ethical dimensions.

Nevertheless, the adaptability of yoga has contributed to its resilience. Contemporary practitioners frequently combine modern health goals and traditional values. This coexistence of multiple interpretations demonstrates yoga's capacity to remain relevant across changing social contexts.

Yoga functions simultaneously as a health practice, spiritual discipline, cultural symbol, and source of identity. Its significance lies in its ability to connect individual experiences with broader cultural narratives regarding well-being, morality, and self-realization.

Discussion and conclusion

The present study demonstrates that yoga is best understood as an embodied cultural tradition integrating health, spirituality, identity, and social meaning. Through bodily practice, individuals internalize cultural values and develop knowledge grounded in lived experiences. Anthropological theories of embodiment reveal how yoga transforms the body into a site for learning, self-cultivation, and cultural expression.

The analysis further highlights the contribution of yoga to holistic health. By integrating the physical, mental, emotional, and social dimensions of well-being, yoga offers an alternative to reductionist approaches that separate the body from the mind or health from culture. Its emphasis on balance, prevention, and self-regulation remains relevant in contemporary society.

Historically, yoga has demonstrated a remarkable adaptability. From ancient philosophical traditions to modern wellness movements, yoga has evolved while preserving core concerns of awareness, discipline, and self-realization. This capacity for adaptation explains its enduring significance in India and beyond.

In conclusion, yoga is one of India's most influential cultural traditions. As both a cultural heritage and contemporary practice, it provides a valuable framework for understanding the relationships among embodiment, health, identity, and well-being. Its continued relevance reflects the enduring power of embodied traditions in shaping human experiences and promoting holistic approaches to life.

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India's Green Journey in Modern Indian English Literature: An Analytical Study

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ABSTRACT

Environmental consciousness has emerged as one of the most significant thematic concerns in modern Indian English literature, reflecting India's changing relationship with nature in the wake of industrialisation, urbanisation, and globalization. Contemporary Indian writers have increasingly explored ecological degradation, environmental justice, biodiversity conservation, and indigenous knowledge systems through literary narratives that transcend aesthetic expression and function as ethical interventions. This paper examines the evolution of ecological consciousness in modern Indian English literature by analysing selected works of major writers such as Amitav Ghosh, Arundhati Roy, Anita Desai, Indra Sinha, Sarah Joseph and Ruskin Bond. Employing ecocriticism as its primary theoretical framework, the study explores how literary texts challenge anthropocentric attitudes, critique exploitative models of development, and foreground the interconnectedness of human beings and the natural world. The paper further argues that Indian English literature has become an important cultural space for articulating ecological ethics rooted in indigenous traditions and environmental activism. By integrating literary imagination with ecological concerns, these writers contribute to global environmental discourse while simultaneously addressing India's socio-cultural realities. Ultimately, the study demonstrates that modern Indian English literature not only documents environmental crises but also inspires sustainable thinking, ecological responsibility, and collective action toward preserving the natural environment for future generations.

Keywords: Ecocriticism; Indian English Literature; Environmental Justice; Ecological Consciousness

Introduction

Nature has occupied a central place in Indian philosophy, religion, folklore, and literature since ancient times. The Vedas, Upanishads, Buddhist texts, Jain scriptures, and epics such as the *Ramayana* and the *Mahabharata* portray human beings as inseparable from the natural world. Rivers, forests, mountains, and animals are represented not merely as

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physical entities but as sacred companions in human existence. Consequently, Indian literary traditions have historically reflected an ecological worldview that emphasizes coexistence, balance, and reverence for nature (Glotfelty & Fromm, 1996; Shiva, 1988). Modern Indian English literature inherits this rich tradition while simultaneously responding to the unprecedented ecological crises generated by industrialisation, rapid urbanisation, deforestation, pollution, and climate change.

The emergence of environmental consciousness in modern Indian English literature is closely associated with India's socio-economic transformation after Independence. The pursuit of economic development, technological advancement, and globalization has undoubtedly improved material conditions, yet it has also accelerated environmental degradation, biodiversity loss, and the displacement of indigenous communities. These realities have encouraged writers to reconsider the relationship between human beings and nature through literary expression (Guha, 2000). Rather than treating nature merely as a picturesque background, contemporary Indian authors increasingly portray it as an active participant whose survival is inseparable from human welfare.

The rise of ecocriticism during the late twentieth century has provided an influential theoretical framework for examining literary representations of the environment. According to Cheryll Glotfelty (1996), ecocriticism is "the study of the relationship between literature and the physical environment." Similarly, Lawrence Buell (1995) argues that literature plays a crucial role in shaping ecological imagination by encouraging readers to perceive environmental issues beyond scientific and political discourses. Greg Garrard (2012) further observes that ecocriticism investigates the complex interaction between literature, ecology, ethics, and culture while challenging anthropocentric assumptions. These theoretical perspectives have significantly influenced the study of Indian English literature, where environmental concerns intersect with questions of postcolonial identity, social justice, and cultural memory (Nayar, 2013).

Indian English literature presents a distinctive ecological perspective because environmental degradation in India is closely intertwined with issues of poverty, caste, displacement, gender inequality, and indigenous rights. Unlike many Western environmental narratives that primarily focus on wilderness preservation, Indian literary texts frequently examine the socio-economic consequences of ecological destruction upon marginalized communities. Consequently, ecological consciousness in Indian English literature extends beyond conservation to include environmental justice and sustainable development (Guha, 2000; Shiva, 1988).

As Chandra Das (2007) observes, Indian English poetry from the North-Eastern region is particularly rich in celebrating ecological diversity and environmental awareness. The poets of this region depict forests, rivers, mountains, and indigenous cultures as living entities whose survival determines the well-being of local communities. The Himalayan landscape, which encompasses Assam, Meghalaya, Nagaland, Arunachal Pradesh, Mizoram, Manipur, and Sikkim, has inspired numerous literary works that highlight both ecological beauty and environmental vulnerability. Such writings reveal that nature functions not only as a geographical setting but also as a repository of cultural identity and collective memory (Das, 2007).

Ecocritical discourse in Indian English literature also intersects with postcolonial criticism. Colonial policies transformed forests, rivers, and agricultural landscapes into economic resources for imperial expansion, thereby disrupting traditional ecological relationships. Postcolonial Indian writers revisit this history while simultaneously critiquing contemporary models of development that continue to exploit natural resources in the name

of modernization (Huggan & Tiffin, 2010). Their works expose the environmental consequences of unchecked industrialisation and question dominant narratives of economic progress.

One of the defining characteristics of modern Indian English green literature is its portrayal of nature as an active narrative presence rather than a passive backdrop. In The Hungry Tide, the Sundarbans emerge as a living ecosystem where human lives remain inseparable from tides, mangroves, rivers, and wildlife (Ghosh, 2004). Similarly, The God of Small Things depicts environmental degradation alongside social fragmentation, while Animal's People transform the legacy of the Bhopal Gas Tragedy into a powerful critique of corporate irresponsibility and environmental injustice (Roy, 1997; Sinha, 2007). These narratives demonstrate that ecological destruction inevitably produces profound human suffering.

Indian English literature further foregrounds indigenous ecological knowledge as an alternative to exploitative development paradigms. Traditional practices of water conservation, biodiversity protection, and community-based resource management receive renewed significance in literary narratives that advocate sustainable coexistence with nature. These works resonate strongly with environmental movements such as the Chipko Movement, the Narmada Bachao Andolan, and the Silent Valley Movement, which have demonstrated the importance of grassroots ecological activism in India (Guha, 2000).

The present paper analyses India's green journey through selected works of modern Indian English literature using ecocritical and postcolonial perspectives. It argues that contemporary Indian writers have transformed literature into a powerful medium for environmental awareness, ethical reflection, and ecological advocacy. Their writings not only document environmental degradation but also propose alternative visions of harmony between humanity and nature, thereby contributing significantly to both Indian literary studies and global environmental discourse (Buell, 1995; Garrard, 2012; Nayar, 2013).

Ecocriticism and the Indian Literary Imagination

Ecocriticism has emerged as one of the most influential approaches in literary studies because it examines the reciprocal relationship between literature and the natural environment. Unlike traditional literary criticism, ecocriticism analyses how literary texts construct ecological values, represent environmental crises, and encourage ethical relationships between humans and nature (Glotfelty & Fromm, 1996). Greg Garrard (2012) argues that environmental literature not only reflects ecological degradation but also shapes environmental consciousness by questioning dominant ideologies of development and consumerism. In the Indian context, ecocriticism acquires additional significance because ecological issues are closely linked with colonial history, economic inequality, indigenous rights, and sustainable development (Nayar, 2013).

Indian English literature provides a unique ecological perspective where environmental degradation is rarely portrayed as an isolated phenomenon. Instead, it is connected with social injustice, displacement, poverty, and cultural disintegration. Consequently, ecological narratives become narratives of human survival. This integration of environmental and social concerns distinguishes Indian English eco-literature from many Western ecological texts that primarily focus on wilderness preservation (Guha, 2000). Indian writers repeatedly demonstrate that environmental destruction inevitably leads to cultural fragmentation and the marginalisation of vulnerable communities.

Postcolonial ecocriticism further strengthens this perspective by examining how colonial exploitation transformed forests, rivers, and agricultural landscapes into economic commodities. Huggan and Tiffin (2010) observe that postcolonial literature exposes the continuing exploitation of natural resources inherited from colonial systems of governance.

Indian writers therefore critique not only colonial environmental policies but also contemporary development models that privilege economic growth over ecological sustainability. Such literary interventions encourage readers to reconsider conventional definitions of progress through an ecological lens.

Nature as a Living Character

One of the defining characteristics of modern Indian English literature is its representation of nature as an active participant rather than a passive setting. Rivers, forests, mountains, animals, and oceans possess agency and significantly influence the lives of human characters. This narrative strategy challenges anthropocentric assumptions by suggesting that humans are only one component of a much larger ecological system (Buell, 1995).

The Hungry Tide exemplifies this ecological imagination. Set in the Sundarbans, the novel portrays the mangrove forests as simultaneously nurturing and destructive. The tides, rivers, crocodiles, dolphins, and Royal Bengal Tigers collectively shape the destiny of every human inhabitant. Ghosh writes, "But to the world at large this archipelago is known as the Sundarbans—which means 'the beautiful forest'" (Ghosh, 2004, p. 154). The apparent beauty of the landscape conceals its ecological complexity and unpredictability, reminding readers that nature cannot be fully controlled by human intervention.

The Sundarbans become more than a geographical location; they emerge as a living ecosystem whose survival depends upon maintaining ecological balance. Human attempts to dominate nature repeatedly fail because the natural world possesses its own rhythms and laws. Thus, Ghosh dismantles anthropocentric notions of human supremacy and advocates coexistence between humanity and nature (Buell, 1995; Garrard, 2012).

Similarly, Fire on the Mountain presents the Himalayan landscape as a silent witness to human loneliness and emotional conflict. Nature functions not merely as scenery but as a symbolic extension of psychological experience. Desai's descriptions of forests, birds, and mountains reveal both the serenity and fragility of ecological existence. Her narrative also subtly critiques urban consumerism and environmental neglect by contrasting natural harmony with modern alienation (Desai, 1977).

Environmental Justice and Developmental Critique

Modern Indian English literature consistently interrogates the environmental consequences of industrialisation and economic development. Rather than celebrating modernization uncritically, many writers expose its devastating impact on marginalized communities and fragile ecosystems.

The God of Small Things demonstrates how ecological degradation parallels social disintegration. The polluted river in Ayemenem symbolises the gradual destruction of both environmental and human relationships. Roy illustrates how modernization, commercialization, and social inequality collectively erode traditional ecological values (Roy, 1997). The deterioration of the river becomes a metaphor for the collapse of moral and ecological harmony.

Likewise, Animal's People transform the Bhopal Gas Tragedy into a profound critique of corporate negligence and environmental injustice. Through the experiences of its disabled protagonist, the novel reveals the long-term consequences of industrial pollution upon economically disadvantaged communities. Sinha demonstrates that environmental disasters disproportionately affect those with the least political and economic power (Sinha, 2007). Consequently, environmental justice becomes inseparable from questions of human rights and social equality.

These novels reveal that environmental degradation cannot be understood independently of political structures, economic policies, and unequal power relations. Their ecological vision therefore extends beyond conservation towards broader ethical concerns regarding justice, responsibility, and accountability (Guha, 2000).

Indigenous Knowledge and Sustainable Living

An important contribution of Indian English literature lies in its recognition of indigenous ecological knowledge. Traditional Indian communities have historically maintained sustainable relationships with forests, rivers, wildlife, and agricultural landscapes through practices rooted in collective responsibility rather than commercial exploitation. Modern writers frequently recover these ecological traditions as alternatives to unsustainable models of development.

Gift in Green celebrates the intimate relationship between local communities and their natural environment. The novel presents wetlands, rivers, and forests not merely as economic resources but as sacred spaces essential for cultural identity and community survival (Joseph, 2011). Although written in Malayalam and translated into English, the novel occupies an important place in discussions of Indian ecological literature because it foregrounds indigenous environmental ethics.

Similarly, the writings of Ruskin Bond cultivate ecological sensitivity through simple yet profound depictions of Himalayan forests, birds, flowers, and village life. His stories encourage readers, particularly young audiences, to appreciate biodiversity and develop emotional connections with nature. Rather than advocating environmental conservation through political rhetoric, Bond inspires ecological awareness through affection, observation, and everyday experience (Bond, 1991).

This emphasis on indigenous knowledge resonates strongly with the environmental philosophy of Vandana Shiva, who argues that traditional ecological practices offer sustainable alternatives to industrial agriculture and global consumerism (Shiva, 1988). Indian English literature thus becomes an important archive of ecological wisdom that challenges purely technological solutions to environmental crises.

Water, Biodiversity, and Environmental Activism

Water occupies a central symbolic and ecological position in Indian literature. Rivers simultaneously represent cultural continuity, spiritual purification, livelihood, and ecological survival. However, contemporary writers increasingly portray rivers as endangered ecosystems threatened by pollution, dam construction, and commercial exploitation.

In *The Hungry Tide*, rivers determine every aspect of human existence. The unpredictable tides illustrate nature's immense power while emphasizing humanity's ecological dependence. Similarly, *Gift in Green* highlights the devastating consequences of destroying wetlands and water bodies for commercial development. These literary representations encourage readers to recognize water as a shared ecological heritage rather than a market commodity.

Indian English literature also celebrates biodiversity by depicting forests as habitats where humans and non-human species coexist. The protection of endangered wildlife becomes an ethical responsibility rather than merely an environmental concern. Such literary perspectives resonate with grassroots environmental movements including the Chipko Movement, the Silent Valley Movement, and the Narmada Bachao Andolan, all of which demonstrated that ecological conservation is inseparable from community participation and democratic resistance (Guha, 2000).

Consequently, literature itself functions as a form of environmental activism. By combining aesthetic expression with ecological awareness, Indian writers cultivate

environmental ethics among readers while questioning dominant narratives of limitless economic growth. Their works encourage reflection upon sustainable development, environmental responsibility, and the moral obligation to preserve nature for future generations.

Conclusion

Modern Indian English literature has evolved into a significant medium for articulating ecological consciousness by critically examining the changing relationship between human beings and the natural environment. While early literary representations of nature largely emphasized its aesthetic and spiritual dimensions, contemporary writers increasingly portray ecological degradation as one of the defining challenges of modern society. Through the lens of ecocriticism, Indian English literature demonstrates that environmental crises are inseparable from questions of social justice, cultural identity, economic development, and ethical responsibility (Glotfelty & Fromm, 1996; Buell, 1995). The literary imagination thus becomes a powerful means of exposing environmental exploitation while simultaneously envisioning sustainable alternatives.

The works of Amitav Ghosh, Arundhati Roy, Anita Desai, Indra Sinha, Sarah Joseph and Ruskin Bond reveal diverse dimensions of India's ecological reality. Their narratives move beyond romantic celebrations of nature to explore the consequences of deforestation, industrial pollution, biodiversity loss, displacement, environmental injustice, and climate vulnerability. By portraying rivers, forests, mountains, wetlands, and wildlife as active participants rather than passive settings, these writers challenge anthropocentric assumptions and advocate a more harmonious relationship between humans and the natural world (Garrard, 2012; Nayar, 2013).

Another important contribution of modern Indian English literature lies in its affirmation of indigenous ecological knowledge and community-based conservation practices. Traditional environmental ethics rooted in coexistence, restraint, and collective responsibility are presented as meaningful alternatives to exploitative models of development. Literary engagement with environmental movements such as the Chipko Movement, the Narmada Bachao Andolan, and the Silent Valley Movement further demonstrates that literature and environmental activism are mutually reinforcing. In this way, Indian English writers transform literary narratives into instruments of ecological awareness and social transformation (Guha, 2000; Shiva, 1988).

Ultimately, India's green journey in modern Indian English literature reflects a continuing search for ecological balance in an age of rapid globalization and environmental uncertainty. The selected literary works collectively remind readers that environmental sustainability cannot be achieved solely through technological advancement or governmental policies; it also requires cultural transformation, ethical responsibility, and ecological imagination. By foregrounding the interconnectedness of humanity and nature, modern Indian English literature contributes significantly to global environmental discourse while preserving India's rich ecological heritage for future generations. Therefore, these literary texts should be read not merely as artistic creations but also as compelling ecological interventions that inspire environmental stewardship, sustainable development, and a renewed respect for the natural world (Buell, 1995; Huggan & Tiffin, 2010).

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Muristerone (Phytoecdysone) as inhibitor of growth and reproductive potential of *Spodoptera litura* Fabr. (Lepidoptera: Noctuidae)

Khowaja Jamal♣

ABSTRACT

An experiment was conducted to evaluate the efficacy of topically applied five different doses viz., 0.5µg, 1.0µg, 2.0µg, 4.0µg, and 8.0µg of Muristerone on two advanced stages i.e. 5th and 6th instar larvae of Spodoptera litura. Following the topical application of the above said doses on the newly moulted 5th instar larvae, the total larval mortality up to pupal stage were 05%, 09%, 11%, 14% and 19% respectively as compared to control-I (00%) and control-II (00%), however the total larval pupal loss up to adult emergence were 08%, 11%, 19%, 28% and 43% respectively as compared to control-I (01%) and control-II (00%). The total number of eggs laid by the affected females emerged from the treated larvae were 1760, 1743, 1727, 1643 and 1509 respectively as compared to control-I (1765) and control-II (1781) and the total number of eggs hatched were 1729, 1701, 1661, 1523 and 1351 respectively as compared to control-I (1740) and control-II (1769). When the same doses of Muristerone were applied topically on the newly moulted 6th instar larvae, the corresponding larval loss were 02%, 05%, 04%, 13% and 17% respectively as compared to control-I (00%) and control-II (01%) however, the total larval and pupal death up to adult emergence were 06%, 11%, 11%, 25% and 33% respectively as compared to control-I (00%) and control-II (00%). The fecundity of the affected females emerged from the 6th instar treated larvae were 1771, 1763, 1733, 1658 and 1521 respectively as compared to control-I (1787) and control-II (1790) and the total fertility of the eggs were 1723, 1669, 1603, 1509 and 1301 respectively as compared to control-I (1770) and control-II (1779). The toxicity of Muristerone manifested itself by an increase in mortality, decline in larval-pupal formation, reduction in reproductive potential together with disruption of development.

Keywords: Armyworm; tobacco caterpillar, Spodoptera litura; Muristerone; Mortality; Development; Fecundity. Fertility

Introduction

The evolutionary success of arthropods, including insects, is accreditable to the development of the cuticle, which is a complex exoskeleton with diverse functions. The main structural components of the cuticle are cuticle proteins, chitin, lipids, catecholamines, and minerals. The exoskeleton supports muscle attachment for locomotion, prevents physical and

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chemical damage, and protects against infectious diseases and water loss. To meet the demands of development and metamorphosis, insects need to periodically shed old chitinous cuticles during their transformation into an adult through a process controlled by complex hormonal mechanisms known as ecdysis (Zhu *et al*., 2016).

In holometabolous insects the timing of moulting and metamorphosis is undoubtedly controlled by the moulting hormone "ecdysone" which is a prohormone secreted by the prothoracic glands of the larvae (Ishimoto *et al*., 2010) that controls the body size by regulating the duration of growth in coordination with juvenile hormone (Boulan *et al*., 2015; Nijhout *et al*., 2014; Mirth *et al*., 2005); Yamanaka *et al* (2013); Callier *et al* (2013). The ecdysones are steroidal structure therefore they are generally called ecdysteroids (Hoffmeister *et al*., 1965; Karlson and Hoffmeister, 1963).

The word ecdysteroid originates from the Ancient Greek word *ecdysis*, which means "peeling", ''the detaching of an old exoskeleton in insects". Depending on the nature of source, ecdysteroids (ECs) are subdivided into three groups: phytoecdysteroids (PEs), zooecdysteroids, and mycoecdysteroids.

Phytoecdysteroids (PEs) are naturally occurring steroid-like compounds found in various plants as secondary chemical (as a protection agent, toxins or antifeedants), primarily acting as chemical defenses against herbivores, particularly insects against herbivorous insects (Dinan *et al*., 2001). They share a similar four-ringed structure and are broadly classified based on the number of carbon atoms, 27 to 30, where Muristerone is a prominent C27 ecdysteroids found in several species of plants.

The exogenous application of ecdysone or its analogues including synthetic compounds or those extracted from plants (phytoecdysones) disorders moulting, metamorphosis and reproduction in several species of insects (Earle *et al*., 1970; Marielli, 1978; Singh & Russell, 1980; Ahmad & Khan 1982 & 1985; Khan *et al*., 1984; Kubo *et al*., 1984; Khan and Khan, 1986; Khan *et al*., 2002). The exogenous ecdysones or their analogues are generally non-toxic to non-target organisms and are environmentally safe particularly as a component of integrated pest management for the control of insect pests. With this view, investigations were carried on evaluating the toxicity of Muristerone against the leaf feeding polyphagous *Spodoptera litura.*

Spodoptera litura (Fab.) (Lepidoptera: Noctuidae), commonly known as the tobacco caterpillar or cotton leafworm, is a substantially devastating and extensively strewing agricultural pest that poses an expressive danger to world-wide crop production. Several factors support the endurance and prevalent dispersal of *S. litura*. According to Ramana *et al.* (1988), Armes *et al.* (1997), Qin *et al.* (2004), Shukla and Patel (2011), Ahmad *et al*. (2013), it is an iniquitous leaf feeding polyphagous insect having a wide host plants, invading more than 120 economically important plant species in India and worldwide such as cotton (*Gossypium* spp.), soybean (*Glycine max*), groundnut (*Arachis hypogaea*), tomato (*Solanum lycopersicum*), tobacco (*Nicotiana tabacum*), castor (*Ricinus communis*), and various vegetables from the Cucurbitaceae and Brassicaceae families. The adaptableness of *S. litura* to varied host plants, coupled with its fast developmental cycle and high fecundity, renders it a constant and austere menace to agricultural production, particularly in tropical and subtropical regions worldwide (Natikr & Balikai, 2017). This moth is mostly active at night, and because of their high mobility and capability to lay their eggs on a wide range of host plants, they help or even assures the existence of *S. litura* under a divers environmental condition (Anjali *et al*., 2014; & Naik *et al*., 2017). The larval stage shows voracious eating behaviour, devouring leaves, stems, flowers, and even fruits (Yinghua *et al*., 2017). This feeding activity leads to austere defoliation, demoted photosynthetic efficacy, and overall plant weakening, resulting in significant yield losses. Under grave infestations, plants may be totally defoliated, leading

to yield reductions of up to 80% in the absence of effective pest management strategies (Patil, 2015). Furthermore, the indirect impact of *S. litura* infestations includes increased susceptibility of crops to secondary infections by pathogens, further compounding economic losses. It also becomes resistant to many commonly used insecticides, particularly pyrethroids and carbamates, resulting in failure of effective controls (Wu *et al.* 1995; Kranthi *et al*. 2002; Ahmad *et al*. 2007; Huang and Han 2007).

Materials and Methods

Adults of *Spodoptera litura* F. were collected on light during the monsoon months and pairs of adults were kept in glass rearing jars (measuring 20x15 cms) and were covered with a piece of sterilized muslin cloth which was tightly fixed by means of a rubber band to maintain the stock-culture in a B.O.D. cabinet controlled at 28 + 2^{o}C temperature and 70-80 relative humidity. The adults were offered 5% glucose solution soaked in sterilized cotton wool. Folded sterilized paper strips 2"x20" were placed in each jar for egg laying. After hatching the larvae were provided with fresh sterilized castor (*Ricinus communis*) leaves to eat. These larvae pupated either at the surface of the jars or at the under surface of the leaves. The emergence of adults took place after a week following pupation. Then the newly emerged adults were transferred in pairs to separate rearing jars for further generations (Khowaja, 2018). For treatment one hundred newly moulted 5th and 6th instar larvae in 4 replicates were sorted out for experimental purpose. Five different doses of muristerone (viz, 0.5 µg, 1.0 µg, 2.0 µg, 4.0 µg, and 8.0 µg) were prepared in acetone solution. Freshly moulted 5th and 6th instar larvae were individually topically treated with 1 µl dose of each dilution with the help of a 2 ml tuberculin syringe fitted to a manually operated micro-applicator. A parallel acetone (Analytical grade) treated (control-I) as well as untreated (control-II) insects of the corresponding age and stage was maintained at the above-mentioned controlled conditions.

To record the egg production and egg hatching, the adult females which emerged from the treated larvae by each dose were paired with the males emerged out from untreated larval stock of same stage and age. For control, females emerged out from acetone treated larvae were similarly paired with the males emerged from untreated larvae. The response variables were subjected to one-way analysis of variance (Snedecor & Cochran, 1967; Sokal & Rohlf, 1981) to determine significance differences ($P<0.001$) among the treatments. The larval mortality was observed after 24 and the data were corrected by adjusting mortality in controls using Abbott's formula (Abbott's, 1925). The moribund larvae were also counted as dead. Finally, the mortality data were analysed by probit analysis (Finney 1985) to calculate Lc-50 value using SPSS statistical package programme.

Results and Discussion

Following the topical application of 0.5µg, 1.0 µg, 2.0 µg, 4.0 µg, and 8.0 µg doses of Musristerone on freshly moulted 5th instar larvae, the mortality of the larvae increases linearly with increasing doses showing positive correlation ($y = 1.6586x + 6.4583$, Fig 01). Similarly, the mortality of the pupae also increases linearly showing positive correlation with increasing doses ($y = 1.5403x + 0.625$, Fig. 01). The total larval death up to pupal stage was 05%, 09%, 11%, 14% and 19% respectively as compared to control-1, whereas, the total pupal mortality was 02%, 02%, 03%, 07%, and 13% respectively as compared to control (Fig. 02). The mortality of the larvae seems to be due to the direct toxicity of the chemical rather than due to its hormonal effects on the physiological processes because just after moulting the larval skin was soft, untanned and not fully sclerotized, that may be vulnerable to the hormonal treatment. Thus, it appears that freshly moulted partially sclerotized cuticle was more permeable to the exogenous application of the chemical rather than fully sclerotized cuticle of fully grown larvae. The abnormalities in pupae and adults also increase linearly

with increasing doses of Muristerone (y= 1.4005x + 0.4583 and y=1.8602x + 1.8333 respectively, Fig. 03). Out of the total pupae formed 01%, 00%, 05%, 07% and 11% pupae either died during pupal formation or could not cast off their exuviae completely leading to the total loss of 09%, 13%, 17%, 27% and 39% up to adult emergence as compared to control-1 (Fig.03). The respective adults which emerged from the affected survived pupae 02%, 07%, 09%, 16% and 21% adults were with malformed wings or legs or both (Fig. 04). Earlier Khan *et al.*, (2002) also tested 5 different doses (viz., 0.5µg, 1.0 µg, 2.0 µg, 4.0 µg, and 8.0 µg) of Polypodine-B (a phytoecdysone) on two advanced nymphal stages (4th and 5th) of *Dysdercus cingulatus* by topical and injection method and reported that the above said doses beside causing nymphal mortalities also produce the abnormalities in wings and legs of the adult.

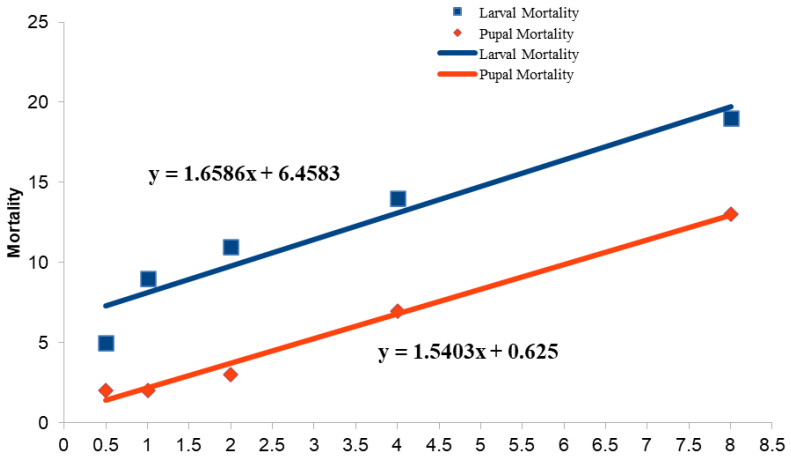

Figure 01: Larval and pupal mortality of Spodoptera litura following topical application of Muristerone on 5th instar larvae

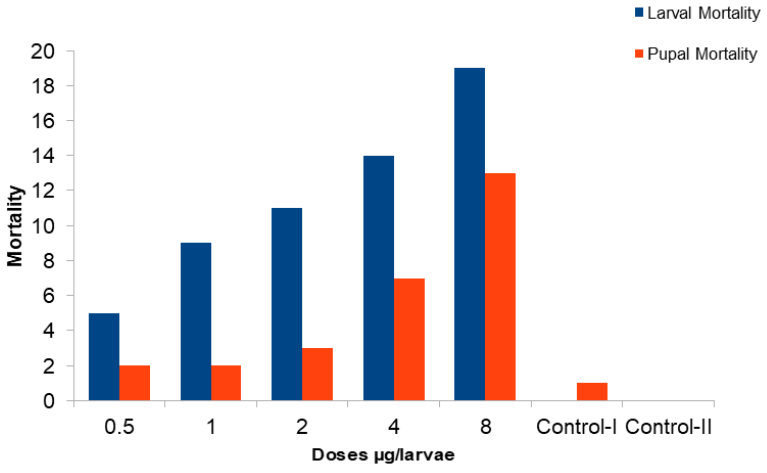

Figure 02: Larval and pupal mortality of *Spodoptera litura* following topical application of Muristerone on 5th instar larvae

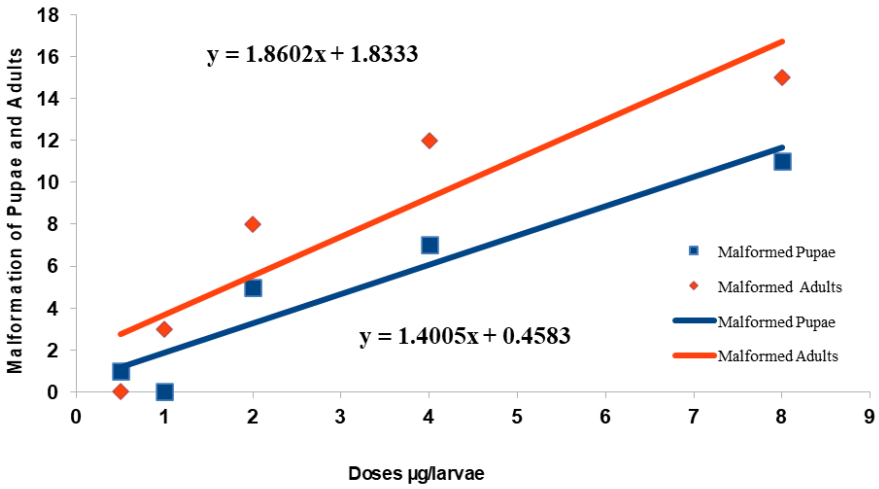

Figure 03: Malformation in pupae and adults of *Spodoptera litura* following topical application of Muristerone on 5th instar larvae.

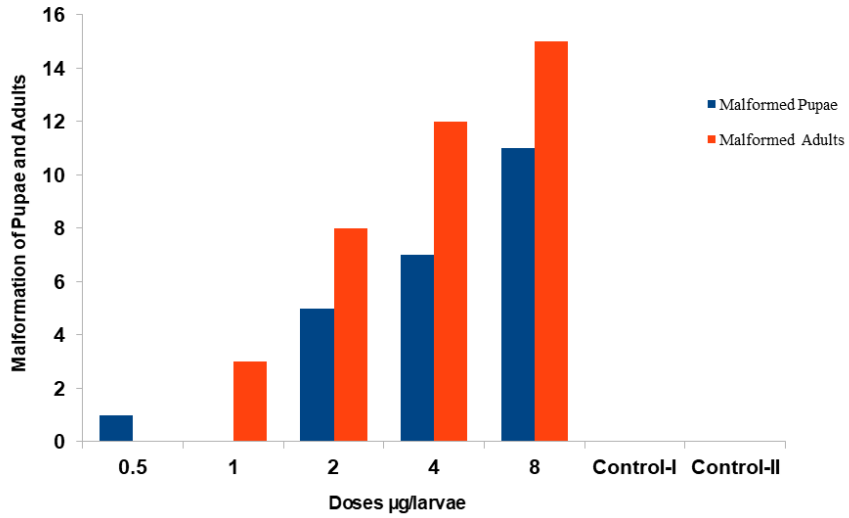

Figure 04: Malformation in pupae and adults of *Spodoptera litura* following topical application of Muristerone on 5th instar larvae.

When the same above said doses (0.5µg, 1.0 µg, 2.0 µg, 4.0 µg, and 8.0 µg doses) were applied on freshly moulted 6th instar, the mortality of the larvae and pupa also increase linearly with increasing doses (y= 2.0134x + 1.9583 and y= 0.4704x + 3.5417 respectively, Fig. 05) resulting in 02%, 05%, 04%, 13% and 17% larval loss as compared to 01% in the control-I and 04%, 03%, 05%, 06% and 07% pupal loss respectively (Fig. 06). Thus, the total larval pupal loss up to adult emergence following the topical application of the above said doses on 6th instar larvae was 06%, 08%, 09%, 19% and 24% respectively as compared to control-I

(00%). The abnormalities during pupal formation as well as the emergence of malformed adults also increase linearly with increasing doses of muristerone (y=1.1022x + 0.5833 and y=2.2043x + 0.1667 respectively, Fig. 07). The total number of deformed pupae following the exposure of various doses of muristerone was 00%, 03%, 02%, 06% and 09%, whereas 05%, 03%, 09%, 07% and 14% adults were with malformed wings or legs or both (Fig. 08).

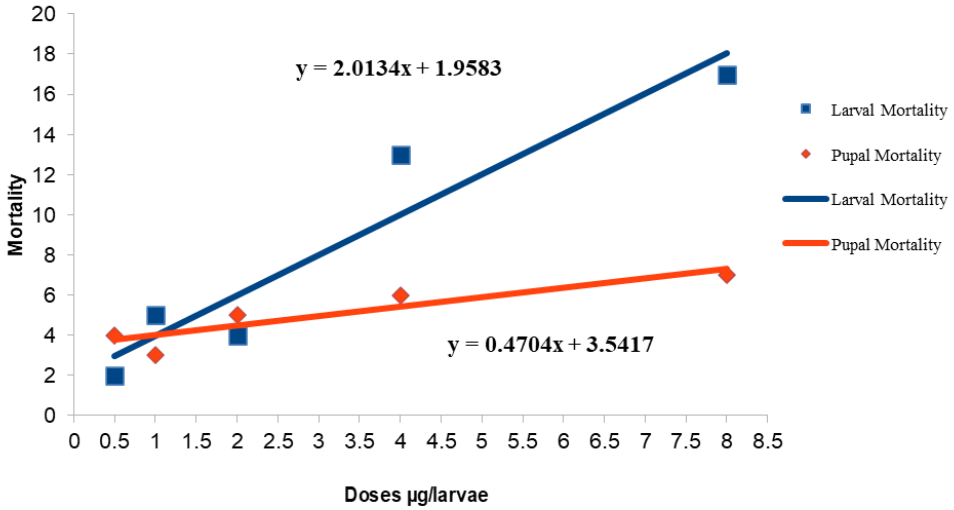

Figure 05: Larval and pupal mortality of Spodoptera litura following topical application of Muristerone on 6th instar larvae

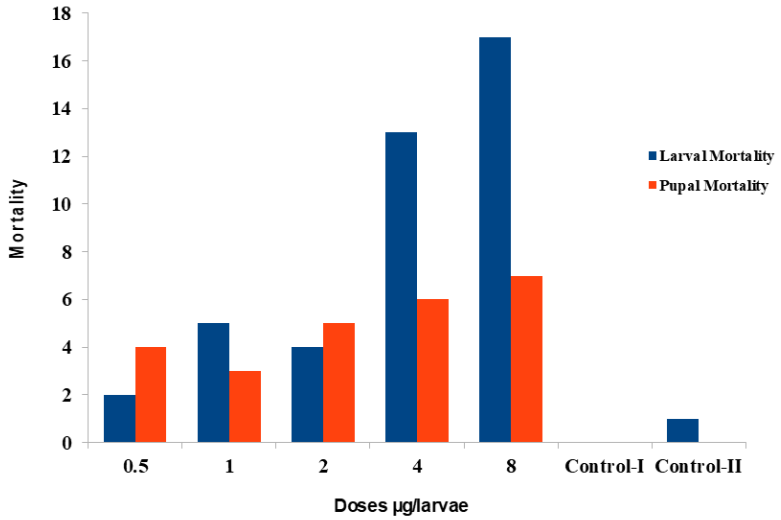

Figure 06: Larval and pupal mortality of Spodoptera litura following topical application of Muristerone on 6th instar larvae

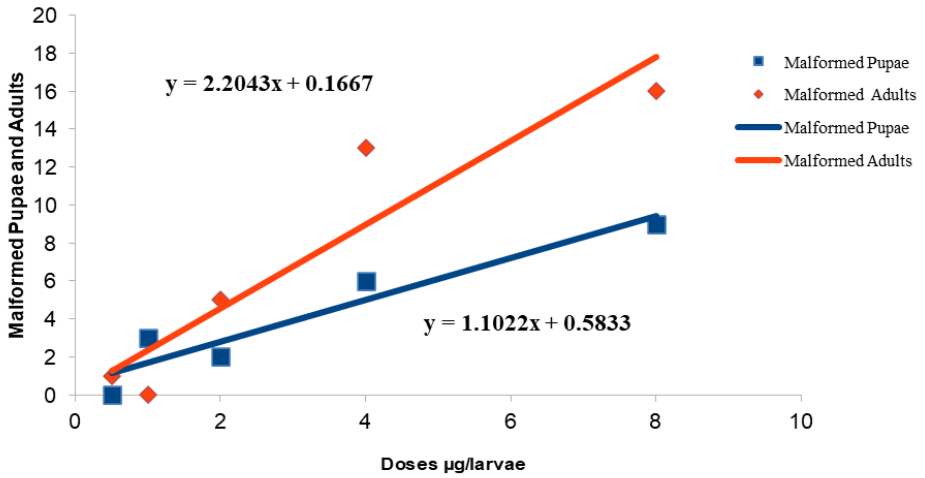

Figure 07: Malformation in pupae and adults of Spodoptera litura following topical application of Muristerone on 6th instar larvae.

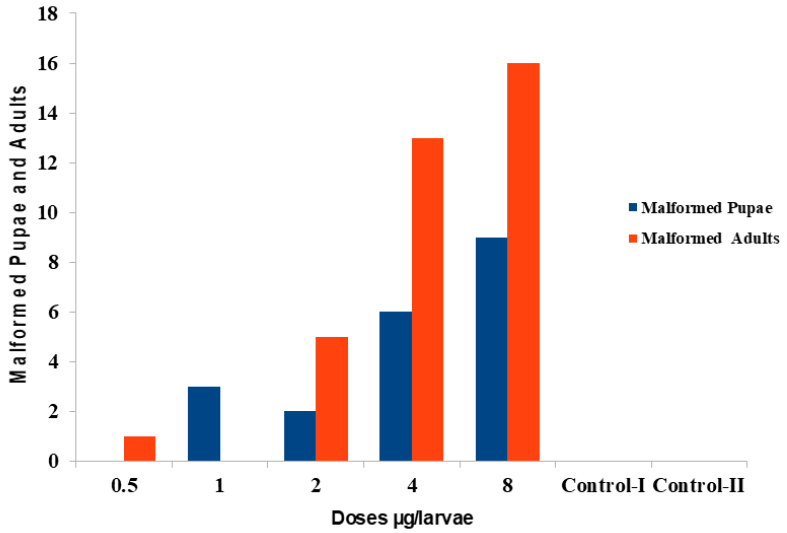

Figure 08: Malformation in pupae and adults of Spodoptera litura following topical application of Muristerone on 6th instar larvae.

Earlier Bachchan *et al*., (1992) also studied the effect of Muristerone at 8.0 µg, 04 µg, 02 µg, 01 µg and 0.5 µg doses on 4th and 5th instar larvae of *Utetheisa pulchella* by topical and injection method. The total larval death following the topical application muristerone on 4th instar larvae was 63, 44, 33, 19 and 11% respectively as compared to control, however, the injection of the same doses resulted in 68, 44, 31, 20 and 09% larval death. When the same doses of Muristerone was applied topically on the 5th instar larvae, the corresponding loss of

insects were 51, 37, 25, 21 and 06% respectively as compared to control however the corresponding treatment of 5th instar larvae by injecting these doses resulted in 55, 39, 31, 18 and 12% mortality up to adult emergence. Among these two methods, injection of these doses caused little more larval death as compared to topical application and the younger larvae (4th instar) were more susceptible than those of 5th instar larvae. Ingestion of 100 ppm 20-hydroxyecdysone, Postesterone, Makisterone-A, Ponasterone-C and Dacrysterone caused 84%, 77%, 63%, 25% and 09% larval mortality respectively in houseflies (Singh & Russell, 1980). Ahmad and Khan (1985) also recorded 65% and 43% nymphal mortality of *Dysdercus cingulatus* respectively following the injection of 04µg Triol/nymph. Khan and Khan (1986) recorded 66% and 48% nymphal death of *Dysdercus cingulatus* following the injection of 8.0µg Muristerone, however, the topical application of the same dose resulted in 58% and 41% nymphal loss respectively.

The fecundity and fertility of the females following the topical application of 0.5µg, 1.0 µg, 2.0 µg, 4.0 µg, and 8.0 µg muristerone on 5th instar larvae also decreased linearly with increasing doses (y = -33.957x + 1781.7 and y = -51.183x + 1751.7 respectively, Fig. 09) and showed negative correlation**.** The average egg production by the female *Spodoptera litura* which emerged from the survived 5th instar treated larvae that mated with untreated males of the same stock and age, suffered less adversely as compared to the fertility of the eggs. After the application of higher doses 2.0µg, 4.0µg and 8.0µg of muristerone, the average egg laying of the affected females which emerged from the survived treated larvae was dropped significantly by 02.15%, 06.91% and 14.50% respectively as compared to control-I (Fig. 10). Similarly, the hatching of the eggs, due to the topical application of 2.0µg, 4.0µg and 8.0µg muristerone/larva, was reduced by 04.54%, 12.47% and 22.36% respectively as compared to the control, however, the effect of the lower doses i.e. 0.5 µg and 1.0 µg muristerone particularly on fecundity was not appreciable (Fig. 10).

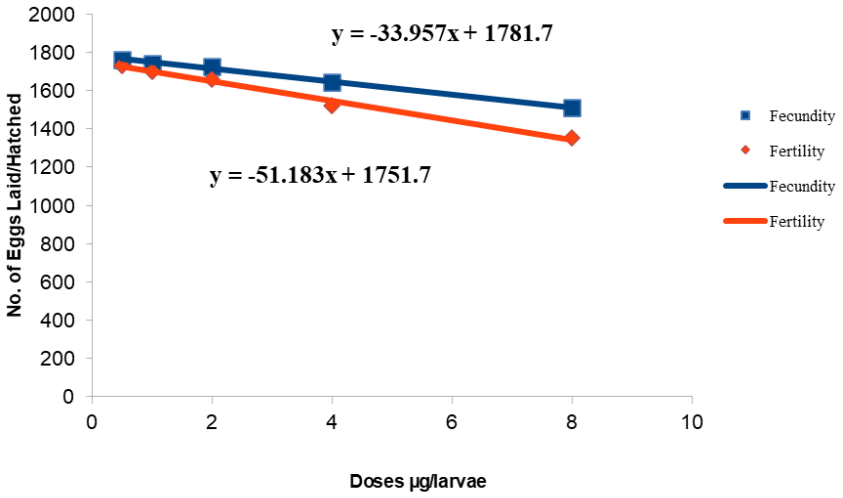

Figure 09: Fecundity and fertility of Spodoptera litura following topical application of Muristerone on 5th instar larvae

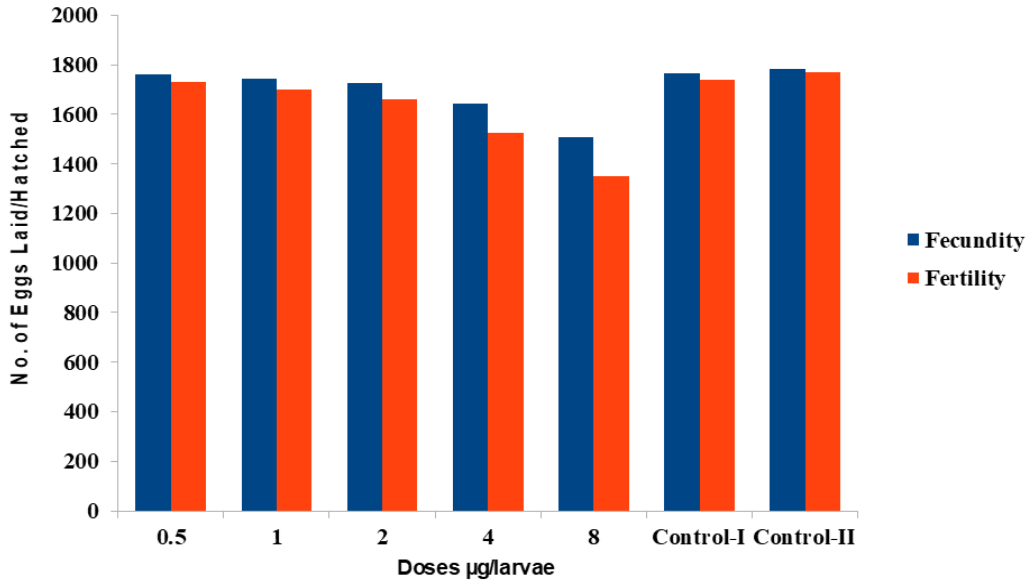

Figure 10: Fecundity and fertility of Spodoptera litura following topical application of Muristerone on 5th instar larvae

The average egg production and egg hatching of the females emerged from the 6th instar treated larvae following the topical application of 0.5µg, 1.0 µg, 2.0 µg, 4.0 µg, and 8.0 µg doses muristerone/larva, also declined linearly with increasing doses (Y= -34.089x + 1794.9 and Y= -54.167x + 1728.9 respectively, Fig. 11) showing a negative correlation coefficient. After the application of higher doses 2.0 µg, 4.0 µg, and 8.0 µg of muristerone, the average egg laying was dropped significantly by 03.02%, 07.22% and 14.89% respectively as compared to control-I, whereas the fertility of the eggs laid by the affected females was declined by 09.44%, 14.75% and 26.50% respectively as compared to the control (Fig. 12), however, the effect of the lower doses i e. 0.5 µg and 1.0 µg and muristeron particularly on fecundity and fertility was not appreciable. Earlier Khan *et al.*, (2002) also tested 5 different doses (viz., 0.5µg, 1.0 µg, 2.0 µg, 4.0 µg, and 8.0 µg) of Polypodine-B (a phytoecdysone) on two advanced nymphal stages (4th and 5th) of *Dysdercus cingulatus* by topical and injection method and reported that the effect of aforesaid doses on late nymphal instar (i.e. 5th instar) were less fatal as compared to the earlier instar.

Based on present observations, it can be concluded that Muristerone is toxic to *Spodoptera litura* when applied during the larval stages. Thus, it can be recommended for use in the control of this species.

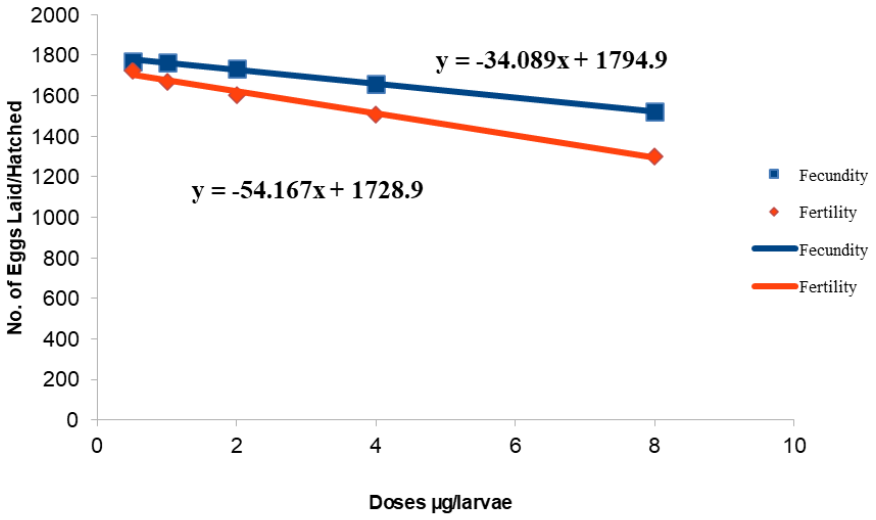

Figure 11: Fecundity and fertility of Spodoptera litura following topical application of Muristerone on 6th instar larvae

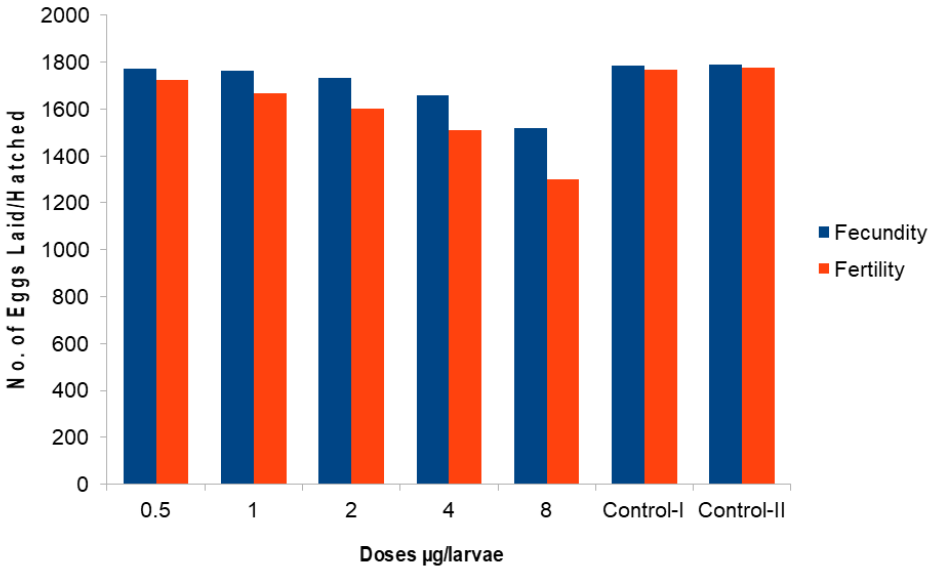

Figure 12: Fecundity and fertility of Spodoptera litura following topical application of Muristerone on 6th instar larvae

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Routing Challenges in Wireless Ad-Hoc Sensor Networks

Sehba Masood♣

ABSTRACT

Wireless Ad hoc Sensor Network is an autonomous network with no fixed infrastructure. It is a collection of tiny sensor nodes that can communicate wirelessly. Sensor nodes are equipped with low power batteries, small memory, and a short radio range. These limitations set routing in wireless ad hoc sensor networks apart from fixed networks. Routing protocols must handle these issues to ensure multi-hop communication reliable. This paper presents an in-depth exploration of challenges in routing in wireless ad hoc sensor networks.

Keywords: Wireless Ad hoc Sensor Network, MANET, dynamic topology, routing.

Introduction

Wireless Ad hoc Sensor Network is a group of small sensor devices that **work together** to share data over the network [Hannes Frey, et.al., 2009]. Each sensor node has processing unit (one or more microcontrollers, Central Processing Unit or Digital Signal Processor), storage unit, a transceiver, a power unit, positioning system and holds various sensors and actuators. The nodes have the ability to self-organize after their deployment in an ad hoc manner and there is wireless communication between them. [John A. Stankovic, 2006].

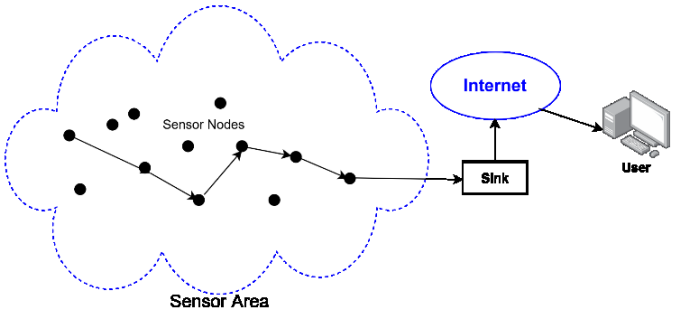

Figure 1. Architecture of Wireless ad hoc sensor network

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A large number of the sensor nodes can be deployed in the network area where they communicate with each other autonomously. A sensor node is a device in WASN that can perform some processing, sense environmental data, and communicate wirelessly with other nodes within the network.

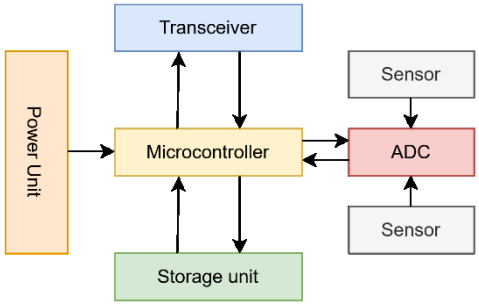

Figure 2. Architecture of a Sensor node

The sensor nodes can communicate either among each other or directly to an external sink. A sink is a fixed or mobile node. It links the sensor network to the Internet or to an existing communications infrastructure. This allows a user to access the collected data. Routing is a process to detect and maintain the best path to forward data packets from source node to destination through intermediate relay nodes. [M. Izuan et.al., 2009].

A mobile wireless ad hoc sensor network (MWSN) is a type of wireless ad hoc sensor network (WASN) where sensor nodes can move inside the boundaries of the network [Peter A. Boncz, et.al., 2007]. Nodes gain mobility by adding wheels or mobilizing units to them. These nodes can couple with transport mediums such as animals, vehicle, robots etc. Movement of these nodes is sometimes induced by the local environmental conditions.

Mobile wireless ad hoc sensor networks (MWSNs) offer significantly more versatility compared to conventional static wireless ad hoc sensor networks. The mobile sensor nodes can be deployed in unpredictable environments and can adapt to fast-changing network topologies [Velmani Ramasamy, 2017].

In MWSNs, sensor nodes can autonomously reposition and self-organize within the network, achieving better network coverage and connectivity compared to static sensor nodes. Therefore, their reliance on dynamic routing makes data delivery challenging and energy intensive.

WASNs have found applications in a wide range of domains. They are used for environmental monitoring to track climate changes, study wildlife behaviour, and detect environmental pollutants. They allow precision farming by monitoring soil conditions and crop health in agriculture. Additionally, these networks have a crucial role in healthcare for patient monitoring and fall detection, and in military applications for surveillance and reconnaissance. These networks can be used in many applications that require unattended operations.

Some of the key advantages of wireless ad hoc sensor networks are lesser catastrophic failures, natural resources conservation, improvement in manufacturing productivity, enhanced emergency response, flexible communication, and upgraded homeland security [F.L. Lewis, 2004].

Ad hoc networks are vital for large-scale ubiquitous computing. They are characterized by the lack of fixed infrastructure and the mobility of nodes. These networks establish direct

peer-to-peer connections between nodes within transmission range, and for nodes that are out of transmission range they utilize multi-hop routing through intermediate nodes [Gowrishankar S., et.al., 2010].

Characteristics of Wireless Ad hoc Sensor Networks

Wireless ad hoc sensor networks have the following characteristics.

- Dynamic network topology: Links are formed and broken due to node mobility or failure.

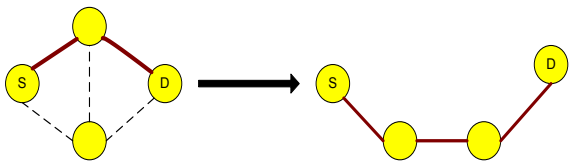

Figure 3. Dynamic network topology

- Constrained resources:
  - Battery power
  - Wireless transmitter range
- Heterogeneity of nodes: Nodes with different processing power, transceivers, energy sources, or sensing capabilities.
- Ability to cope with node failures (fault tolerance).
- Low bandwidth.

Significance of WASNs

The significance of WASNs in contemporary technology and research extends to various aspects:

Data Collection- WASNs enable the collection of high-resolution, real-time data from remote or inaccessible areas. This data is invaluable for scientific research, environmental protection, and decision-making in various industries.

Cost-Efficiency- Compared to deploying fixed infrastructure in remote locations, setting up WASNs is often more cost-effective. This is particularly relevant for applications in developing regions or areas with challenging terrain.

E**nvironmental Impact-** The energy-efficient operation of WASNs minimizes their environmental footprint, making them suitable for applications where environmental impact needs to be minimized, such as wildlife monitoring or conservation efforts.

Innovation Hub- WASNs serve as a fertile ground for innovation. Researchers and engineers continuously develop novel protocols, algorithms, and hardware solutions to address the unique challenges posed by these networks.

Humanitarian Aid and Disaster Response- WASNs play a vital role in disaster management and humanitarian aid by providing real-time data on disaster-affected areas, helping first responders make informed decisions.

National Security- In military and defense applications, WASNs enhance situational awareness, surveillance, and battlefield communication, contributing to national security.

Difference between Traditional Network and Wireless Ad hoc Sensor Network

In traditional network, there are fixed topologies, fixed and known neighbours, fixed relationship between IP address and location. If a router has valid path to a destination, that path stays valid forever until a part of the system breaks down [Andrew S. Tanenbaum, 2018]. In wireless ad hoc sensor network, each node consists of a router and host with sensor on the same computer. The topology may be changing all the time as well as nodes can move in and out or shift to new locations any time, so path quality and validity can change spontaneously, without warning.

Traditional network connects high-power devices such as computers and routers to share general data. A wireless ad hoc sensor network (WASN) uses numerous tiny, battery-operated nodes equipped with physical sensors to collect and send specific environmental data like temperature, pressure, or motion to a central point. In traditional network, application independent network is used but in WASN application-dependent network is used.

WASNs are designed to overcome the limitations of traditional wired networks and infrastructure-based wireless networks in several ways:

- Infrastructure Independence

WASNs do not require a fixed infrastructure like routers or access points. Instead, they self-organize into a network by establishing direct communication links with nearby nodes. This inherent flexibility makes them ideal for scenarios where infrastructure deployment is impractical or costly, such as disaster-stricken areas, remote wildlife habitats, or battlefields.

-Diverse Applications

WASNs have found applications in a wide range of domains. They are used for environmental monitoring to track climate changes, study wildlife behaviour, and detect environmental pollutants. In agriculture, they enable precision farming by monitoring soil conditions and crop health. Additionally, they play a crucial role in healthcare for patient monitoring and fall detection, and in military applications for surveillance and reconnaissance.

- Dynamic Topology

The network topology in WASNs is highly dynamic due to factors like node mobility, environmental changes, and energy fluctuations. Traditional routing protocols designed for static networks are often ineffective in handling such dynamic conditions.

Similarities between Wireless Ad hoc Sensor Network and Mobile Ad hoc Network

A wireless ad hoc sensor network (WASN) comprises spatially distributed, autonomous sensor devices that collaborate to monitor environmental and physical parameters such as temperature, pressure, sound, vibration, motion, or pollutants across various locations. Nowadays, wireless ad hoc sensor networks support diverse civilian domains, including habitat monitoring, healthcare, smart homes, and traffic management and also in military application areas. A mobile ad-hoc network (MANET) connects mobile devices like phones or laptops for general peer-to-peer data communication [M. Devi and N. S. Gill, 2019]. This self-configuring wireless ad-hoc network consists of dynamic, wirelessly linked nodes acting as mobile routers. These routers move independently which causes the network topology to change rapidly and unpredictably. The main reason that WASNs immediately resemble mobile ad hoc networks is that both are distributed wireless networks without a significant network infrastructure in place, and routing between two nodes often relies on intermediate relays via multi-hop paths, while both ad hoc and sensor nodes typically depend on battery power [JA Garcia-Macias and Javier Gomez, 2007]. Therefore, minimizing power consumption is a primary concern. Since both network paradigms utilize unlicensed wireless

bands, they remain vulnerable to cross-technology interference. Ultimately, their distributed nature necessitates robust self-management capabilities.

Difference between Wireless Ad hoc Sensor Network and Mobile Ad hoc Network

Even though WASNs and MANETs are very much similar, they also have basic differences. Some of these differences are due to the nature of both types of networks: MANETs are usually close to humans, that means most nodes in the network are devices that are meant to be used by human beings e.g., laptop computers, PDAs, mobile radio terminals, etc., whereas sensor networks focus on interaction with the environment rather than human interaction.

The sensor nodes in wireless ad hoc sensor network are placed in the environment to gather information and act upon it. Therefore, sensor networks have large number of nodes that are more densely deployed than mobile ad hoc networks. This huge increase indicates the need of handling scalability issues. [JA Garcia-Macias and Javier Gomez, 2007].

If a network is going to be deployed in unattended areas where human interaction is not possible, some nodes will ultimately get damaged and die. This makes the topology of the network to change dynamically. Since nodes can fail any time, the design of the wireless ad hoc sensor network must include **reconfiguration tools** to keep the network functional. In some applications nodes can be attached to animals, vehicles, or moving objects, but most applications have static nodes, so some **problems** that are significant in mobile ad hoc networks do not matter much in wireless ad hoc sensor networks. Topology can change not only from node failure, but also from sleep-awake cycles in wireless ad hoc sensor networks. These cycles save energy, which is an important design objective for resource- constrained sensor networks.

This limitation of resources represents a defining characteristic of sensor networks. Nodes are left unattended for months or years and operate on batteries. These nodes typically rely on few kilobytes of memory, processor that operate at speeds of only some megahertz, low-data-rate and short-range communications spanning just a few meters at several kilobits per second.

Ad hoc sensor networks have **strict power limits** and **fixed nodes**, unlike mobile ad hoc networks (MANETs) with moving devices. Their routing needs focus on saving battery, sending data to a sink, and handling large node counts.

The wireless ad hoc sensor networks offer service not simply to move bits from one place to another, but to provide answers also. These answers should be responses to the questions like, what are the areas of the network where the temperature is below the specified threshold? What is the route followed by the enemy? Thus, answering to such types of questions implies considering geographic context- a requirement rarely needed in standard networks. In some applications a node's specific network address or ID is secondary, making its geographic location the primary attribute of interest. [JA Garcia-Macias1 and Javier Gomez, 2007].

Challenges in Routing in Wireless Ad hoc Sensor Networks

There are many ways which make routing in wireless ad hoc sensor networks differ from conventional routing in fixed networks. In WASN, there is no fixed infrastructure, wireless links are unreliable, sensor nodes may fail or die, and routing protocols must comply with stringent energy-efficiency.

Limited computing, storage capacity, transmission range and battery power of sensors make routing in wireless ad hoc sensor networks very challenging.

Node Deployment: In WASN node deployment is randomized, the sensor nodes are randomly spread over large area that creates an ad hoc routing infrastructure. If the placement of nodes is uneven, optimal clustering helps devices to connect and save energy. Energy and bandwidth constraints restrict individual sensor transmissions to short distances. Therefore, data delivery relies primarily on multi-hop wireless routes.

Autonomy: Relying on a central control unit to manage radio and routing operations makes a sensor network vulnerable to attack. To prevent this single point of failure, the nodes themselves manage routing decisions autonomously.

Resource Constraints: Sensor nodes in WASNs are typically resource constrained. They have limited computing power, storage, and battery power. These constraints necessitate the development of efficient routing mechanisms to prolong the network's lifetime and optimize resource utilization.

Energy Efficiency: Wireless ad hoc sensor networks predominantly rely on battery power, and lack of energy is a significant concern, particularly in demanding environments such as battlefields. Since sensor nodes are randomly placed in unattended environments, they are not reachable and battery replacement in the sensor nodes is not feasible. Sensor node performance is severely affected when their batteries fall below a predetermined threshold. Conservation of energy represents a primary challenge for network designers, given the large number of sensor nodes within a wireless ad hoc sensor network, each with restricted energy resources. Therefore, routing protocols should prioritize energy efficiency and should prolong network lifetime while providing a fast, reliable, and uninterrupted communication between the sensor nodes.

Complexity: The complexity of a routing protocol can directly affect the overall performance of the wireless ad hoc sensor network. This challenge arises from the limited hardware capabilities and substantial energy constraints inherent to these networks.

Scalability: With sensors becoming more cost-effective, wireless ad hoc sensor networks can accommodate hundreds or even thousands of sensors with ease. As a result, routing protocols must be designed to support network scalability. They should be capable of accommodating additional nodes without causing network disruptions.

Delay: Certain applications necessitate real-time responses without significant delays, like sensing temperature or monitoring alarm. Therefore, routing protocols should aim to minimize data transmission latency, particularly in applications where prompt data delivery is critical.

Sensor Location: Wireless ad hoc sensor network designers face a significant challenge in accurately determining the locations of sensor nodes. Many routing protocols rely on localization techniques to acquire information about node positions. Some scenarios make use of Global Positioning System (GPS) receivers to achieve this. Properly determining sensor node locations is essential for effective network operation and data routing within the network.

Resilience: Wireless ad hoc sensor networks are often deployed in harsh environments. Sensor nodes may unpredictably stop operating or exit the network due to battery exhaustion or environmental reasons. Routing protocols should exhibit robustness to withstand such challenging conditions so that when a current routing node fails, an alternative route could be found. They must be capable of adapting to various environmental conditions, including severe and loss-prone environments, while maintaining consistent functionality.

Data Transmission: Wireless ad hoc sensor networks employ four distinct modes of data transmission; each tailored to specific application requirements. These modes include event-driven, query-driven, continuous, and hybrid transmission. In the query-driven and event-driven models, data transmission is initiated by a node when a sink node generates a query or when predefined events occur. In contrast, the continuous transmission mode involves periodic data transmission without the need for specific triggers. The performance of routing protocols in these networks is intricately linked to network size and the quality of the transmission medium. Higher-quality transmission media can directly enhance network performance, leading to more efficient and reliable data transmission.

Device Heterogeneity: While most civilian wireless ad hoc sensor networks employ homogeneous nodes, integrating heterogeneous sensors can yield substantial operational benefits. Deploying heterogeneous nodes with different processing power, transceivers, power sources, or sensing capabilities can enhance overall performance of the network. Deploying a heterogeneous set of sensors introduces several technical challenges for data routing. Node heterogeneity can significantly optimize key performance metrics, including network scalability, energy consumption, and bandwidth utilization.

Mobility Adaptability: Sensor networks must often support mobile sensor nodes, mobile sinks, or moving target events. This requires routing protocols to provide dynamic topology support to manage these distinct forms of movement.

Coverage: In WASNs, each sensor node has limited sensing range and accuracy, offering only a localized view of their environment. Because single-node coverage is constrained in both range and accuracy, ensuring optimal area coverage becomes an important design parameter.

Data Aggregation: Because sensor nodes often gather duplicate information, combining similar data packets before sending them helps to reduce total network traffic. This process, known as data aggregation, blends sensed data from multiple nodes using some aggregation functions like duplicate suppression, average, minima, and maxima.

Quality of Service: Certain applications demand strictly bounded delivery latency, as sensor data becomes obsolete if not transmitted within a specific time frame. However, in many operational contexts, energy conservation which is directly related to network lifetime is prioritized over strict real-time data delivery and high data quality [Jamal N. Al-Karaki and Ahmed E. Kamal, 2004].

Conclusion

Wireless Ad-hoc Sensor Networks (WASNs) have witnessed widespread adoption due to their self-organizing nature and the absence of infrastructure requirements. This paper provides the analysis of key routing challenges and issues inherent to Wireless Ad-Hoc Sensor Networks (WASNs). Recent studies show that these networks operate under strict physical and environmental constraints, designers must intentionally sacrifice performance in one area to achieve acceptable results in another. As provided in this paper that wireless ad hoc sensor networks operate under very different conditions, their routing protocols require a completely different approach than MANETs. Although, several critical challenges persist in this field, there is a need for comprehensive research and innovative solutions.

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Policy Paper

Who Should Be Targeted to Transform Gender Attitudes? A Meta-analysis of Men-Targeted versus Women-Targeted Interventions in India (2000–2020)

Daud Salim Faruquie[1], Ilma Khowaja[2] and Saman Khowaja[3]

ABSTRACT

Background: *Despite two decades of legal and economic reform, regressive gender attitudes remain widespread in India, prompting two distinct intervention traditions: programs that target women and girls to build agency and voice, and programs that target men and boys to directly confront inequitable masculine norms. Whether one approach produces larger, more reliable shifts in gender attitudes than the other has not previously been resolved through quantitative synthesis.*

Objective: *This study meta-analytically compared the pooled effects of men-targeted versus women-targeted interventions on gender attitudes in India between 2000 and 2020, and examined the consistency of effects within each approach.*

Methods: *Following PRISMA guidelines, a systematic search of electronic databases, institutional repositories, and citation tracking identified 22 eligible studies (12 men-targeted, 10 women-targeted) reporting a quantitative pre–post or intervention-versus-comparison measure of gender attitudes. Standardized mean differences (Hedges' g) were pooled separately by subgroup using random-effects models, with heterogeneity, subgroup comparison, and publication bias assessed in JASP.*

Results: *The pooled effect was small and non-significant for women-targeted interventions (g = 0.075, 95% CI [−0.219, 0.369], p = .576) and larger but likewise non-significant for men-targeted interventions (g = 0.464, 95% CI [−0.203, 1.132], p = .154). The difference between subgroups was not statistically significant (Q□ = 1.39, p = .238). Both subgroups showed near-total heterogeneity (I^2 = 97.5% and 99.1%, respectively), with men-targeted studies displaying substantially wider dispersion in true effects than women-targeted studies.*

Conclusions: *Current evidence cannot statistically confirm that either target-group strategy reliably shifts gender attitudes, or that one outperforms the other. The dominant driver of outcomes appears to be intervention design rather than target group alone, arguing for research and policy investment in identifying which program features—not which sex is targeted—produce durable, generalizable attitude change.*

Keywords: gender attitudes; meta-analysis; gender-transformative interventions; engaging men and boys; women's empowerment; India

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1. Introduction

Gender attitudes, the beliefs individuals hold about the appropriate roles, rights, and status of men and women constitute the normative scaffolding on which practices of discrimination, restricted mobility, unequal decision-making, and intimate partner violence in India are built (Jejeebhoy, 1995). Despite more than two decades of legal reform, economic growth, and expansion of women's access to education, survey evidence from the National Family Health Survey and allied studies has repeatedly shown that regressive attitudes toward women's autonomy, and tolerant attitudes toward wife-beating and unequal household authority, remain widespread across both rural and urban India and among women as well as men (Jejeebhoy & Sathar, 2001). This persistence has pushed development practitioners and researchers to move beyond service-delivery or income-transfer models toward interventions that attempt a more difficult task: changing the underlying attitudes and norms that legitimize gender inequity.

Since the early 2000s, India has become one of the most active testing grounds globally for such attitude-change interventions, reflecting two distinct but overlapping programmatic traditions. The first, rooted in the women's empowerment paradigm, has directed resources toward women and girls themselves, through self-help groups, life-skills education, livelihoods training, and safe-space programming, on the premise that enhancing women's own agency, voice, and bargaining power will, over time, shift gender attitudes both within the household and in the wider community (Kabeer, 1999, 2005; Sanyal, 2009). The second tradition, associated with the global "engaging men and boys" movement, has instead targeted men and adolescent boys directly, working from the premise that gender inequitable norms are substantially produced and policed by men, and that attitude change cannot be sustained unless it addresses masculinity, male privilege, and men's own socialization (Barker, Ricardo, & Nascimento, 2007; Pulerwitz & Barker, 2008). Landmark Indian programs such as Yaari Dosti (Verma et al., 2006, 2008), the Gender Equity Movement in Schools (GEMS) in Mumbai (Achyut et al., 2011), and the Parivartan cricket-based mentoring program, an Indian adaptation of the U.S. "Coaching Boys into Men" curriculum (Miller et al., 2012), evaluated among cricket athletes in Mumbai (Miller et al., 2014; Das et al., 2015) exemplify this second stream, while women's collective and self-help-group-based initiatives evaluated by organizations such as ICRW and SEWA exemplify the first.

What has been conspicuously absent, however, is a systematic, comparative reckoning of these two approaches. Individual evaluations report effect sizes for their own target population, but the field has lacked a synthesis that places men-targeted and women-targeted interventions on a common metric to ask a deceptively simple but programmatically consequential question: when the objective is to shift gender attitudes in the Indian context, whom should scarce implementation resources be directed toward? This meta-analysis addresses that gap.

2. State of the Existing Evidence

The evidence base on women-targeted interventions is the older and larger of the two literatures, developing out of the microfinance and self-help-group (SHG) movement of the 1990s and 2000s. Early evaluations of SHG participation reported gains in women's mobility, financial literacy, and self-reported confidence, and inferred consequent shifts in gender attitudes, but were frequently critiqued for weak counterfactuals, self-selection into groups, and outcome measures that conflated economic empowerment with attitudinal change (Kabeer, 2005). Subsequent, more rigorously designed studies, several using quasi-experimental or panel designs, found that SHG and livelihoods participation improved women's own attitudes toward gender equality and, in some cases, spousal violence, but that these effects were often modest, slow to emerge, and did not reliably transfer to husbands or male relatives whose attitudes had not been directly engaged (Sanyal, 2009). This last finding

is theoretically important: it suggests that interventions confined to women may improve women's own sense of entitlement without necessarily altering the attitudes of the men who often control household decision-making.

The men-and-boys literature emerged partly in response to this observation, drawing on the global argument, articulated influentially by the WHO and by Promundo, that gender-equitable outcomes for women are unlikely to be sustained without engaging men as allies rather than treating them solely as obstacles (Barker, Ricardo, & Nascimento, 2007). In India, the Yaari Dosti trial with young men in Mumbai and Delhi, using an adapted Program H curriculum, reported statistically significant improvements on the Gender-Equitable Men (GEM) Scale post-intervention (Verma et al., 2006, 2008; Pulerwitz & Barker, 2008), while the GEMS school-based program in Mumbai produced comparable shifts in attitudes among adolescent boys and girls exposed jointly to a gender-transformative curriculum (Achyut et al., 2011). Sport- and mentorship-based programs like Parivartan similarly reported reductions in negative bystander behavior and gains in gender-equitable attitudes among adolescent boys (Miller et al., 2014; Das et al., 2015). These studies collectively suggest that attitude change among men is achievable within relatively short program windows, though most rely on the same GEM Scale or close derivatives, raising unresolved questions about measurement comparability across studies and about the durability of change beyond immediate post-tests.

Two limitations recur across both literatures and motivate the present study. First, direct comparisons are rare: because men-targeted and women-targeted interventions are typically evaluated by different research teams, in different regions, with different outcome instruments and follow-up periods, no consolidated estimate exists of their relative effect sizes on gender attitudes. Reviews that do exist, such as broader global syntheses of gender-transformative programming (Ricardo, Eads, & Barker, 2011) or India-focused reviews of violence-prevention interventions (Kalokhe et al., 2017), tend to describe programs narratively rather than pool effect sizes across the men- versus women-targeted divide. Second, the Indian evidence base spans considerable heterogeneity in intervention intensity, delivery setting (school, community, workplace), duration, and outcome measurement, which narrative reviews are poorly equipped to reconcile but which a quantitative synthesis can formally model.

3. Why this Meta-analysis was warranted?

A meta-analytic approach is particularly well suited to resolving the question posed by this study. Because individual Indian evaluations of gender-attitude interventions are numerous but modest in sample size, dispersed across regions and time, and heterogeneous in design and outcome measurement, no single primary study can credibly answer whether men-targeted or women-targeted programming produces larger attitudinal shifts; only a pooled, quantitative synthesis can generate an effect-size estimate with adequate statistical power and precision for this comparison. Meta-analysis further allows the moderating influence of study-level characteristics, target group, intervention duration, delivery modality, urban–rural setting, and outcome instrument (e.g., the GEM Scale versus locally adapted measures), to be formally tested rather than merely described, and it offers a transparent, replicable protocol for identifying, weighting, and combining evidence that a conventional narrative review cannot provide. Given that the twenty-year period since 2000 has produced enough independently evaluated men-targeted and women-targeted interventions in India to permit such pooling, meta-analysis represents the most rigorous available method for adjudicating this comparative, and policy-relevant, question.

4. Objective of the Study

The objective of this meta-analysis is to systematically synthesize the quantitative evidence from evaluations of gender-attitude-focused interventions conducted in India between 2000 and 2020, in order to estimate and compare the pooled effect sizes of interventions targeted at men and boys versus those targeted at women and girls, and to identify the study-level and design characteristics, including intervention duration, delivery setting, and outcome measurement, that moderate the magnitude of attitudinal change, thereby generating evidence to inform the design and targeting of future gender-transformative programming in the Indian context.

5. Methodology

5.1 Protocol and Reporting Standards

This meta-analysis was conducted and is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher, Liberati, Tetzlaff, Altman, & the PRISMA Group, 2009). A review protocol specifying the research question, eligibility criteria, search strategy, and planned analyses was drafted in advance and followed throughout, with any deviations noted and justified at the relevant stage of reporting. The review question was framed using the PICOS structure, adapted for a non-clinical, community/education-based intervention literature: Population (adolescents and adults residing in India), Intervention (structured programs explicitly designed to shift gender attitudes or gender-equitable norms, whether delivered to men/boys, women/girls, or both), Comparator (a no-intervention, wait-list, or standard-practice comparison group, or a pre-intervention baseline in single-group pre–post designs), Outcome (a quantitative measure of gender-attitude change, most commonly the Gender-Equitable Men [GEM] Scale or a locally adapted derivative, or an equivalent validated attitudinal index), and Study design (randomized controlled trials, cluster-randomized trials, quasi-experimental designs with a comparison group, and single-group pre–post designs with adequate baseline and follow-up attitudinal data).

5.2 Eligibility Criteria

Studies were eligible for inclusion if they (a) evaluated an intervention implemented in India, wholly or in a substantial India-based arm, between January 2000 and June 2020; (b) targeted participants as men/boys only and women/girls only (allowing planned subgroup comparison across two categories, with the men-targeted versus women-targeted contrast as the primary comparison); (c) reported a quantitative, pre–post or intervention-versus-comparison measure of gender attitudes, gender norms, or gender-equitable beliefs, from which an effect size or the raw statistics needed to compute one (means and standard deviations, proportions, odds ratios, F- or t-statistics, or exact p-values with sample sizes) could be extracted or obtained from study authors; and (d) were reported in a peer-reviewed journal article, book chapter, or a publicly available institutional/technical report (e.g., ICRW, Population Council, Promundo, or government evaluation reports), in English. Studies were excluded if they (a) addressed attitudes toward a single, narrowly defined behavior unrelated to gender norms broadly construed (e.g., attitudes toward a specific contraceptive method with no gender-attitude component); (b) were purely qualitative, with no extractable quantitative attitude measure; (c) were conference abstracts, protocols, or dissertations for which a full peer-reviewed or technical report could not be located; or (d) evaluated interventions conducted outside India, or multi-country studies from which an India-specific effect size could not be isolated. No restrictions were placed on participant age beyond the adolescent-to-adult range typically targeted by these interventions, or on intervention setting (school, community, workplace, health facility, or sports/mentorship program).

5.3 Search Strategy

A systematic search was conducted across electronic databases including PubMed/MEDLINE, PsycINFO, Scopus, Web of Science, and the Cochrane Library, supplemented by Google Scholar and by targeted searches of the institutional repositories of organizations active in this field (International Center for Research on Women, Population Council/Horizons Program, Promundo, UN Women, and the World Health Organization). Search terms combined three concept blocks using Boolean operators: (a) population/geography terms ("India" OR "Indian"); (b) intervention/topic terms ("gender attitude" OR "gender norm" OR "gender equitable" OR "GEM Scale" OR "gender transformative" OR "engaging men" OR "women's empowerment" OR "self-help group"); and (c) design terms ("intervention" OR "program" OR "evaluation" OR "randomized" OR "randomised" OR "quasi-experimental" OR "pre-post" OR "trial"). The reference lists of all included studies and of relevant prior reviews (e.g., Barker, Ricardo, & Nascimento, 2007; Ricardo, Eads, & Barker, 2011; Kalokhe et al., 2017) were hand-searched for additional eligible studies ("snowballing" or backward citation tracking), and forward citation tracking of key studies was conducted using Google Scholar and Scopus's "cited by" function. The search covered publications from January 2000 through June 2020, with no lower date restriction on when a search platform indexing began, and was last updated shortly before the analysis was finalized.

5.4 Study Selection Process

Search results from all sources were imported into a reference management tool, and duplicates were removed. Two reviewers (IK and SK) independently screened titles and abstracts against the eligibility criteria, followed by independent full-text assessment of all records surviving the first screen. Disagreements at either stage were resolved through discussion and, where necessary, adjudication by a third reviewer (DSF). The full study selection process, including the number of records identified, screened, excluded (with reasons), and finally included, was documented and reported using a PRISMA flow diagram (Moher et al., 2009), presented in Figure 1. A total of 22 studies met all eligibility criteria and were retained for both the narrative synthesis and the quantitative meta-analysis.

5.5 Data Extraction and Coding

A standardized coding form was developed and piloted on a subset of studies before full-scale extraction. Two reviewers independently extracted data from each included study, with discrepancies resolved by consensus or third-reviewer adjudication. Extracted variables included: (a) study identification (authors, year, publication type); (b) sample characteristics (target group, men/boys, women/girls; sample size; age range; urban or rural setting; state/region of India); (c) intervention characteristics (name/type of program, theoretical framework where stated, delivery modality, e.g., peer education, curriculum-based, sports-mentorship, self-help group, media/campaign, duration and dosage, and setting, school, community, workplace, or health facility); (d) study design (randomized, quasi-experimental, or single-group pre–post; presence and nature of a comparison group; follow-up duration); (e) outcome measurement (instrument used, e.g., GEM Scale or adapted version, number of items, and reliability where reported); and (f) the statistics needed to compute an effect size (means, standard deviations, and sample sizes by group and time point, or equivalent test statistics). Where necessary information was missing or unclear, study authors were contacted by email; if no response was received within four weeks, the study was retained where a usable effect size could be estimated from reported statistics, and excluded from the quantitative synthesis (though retained in the narrative account) where it could not.

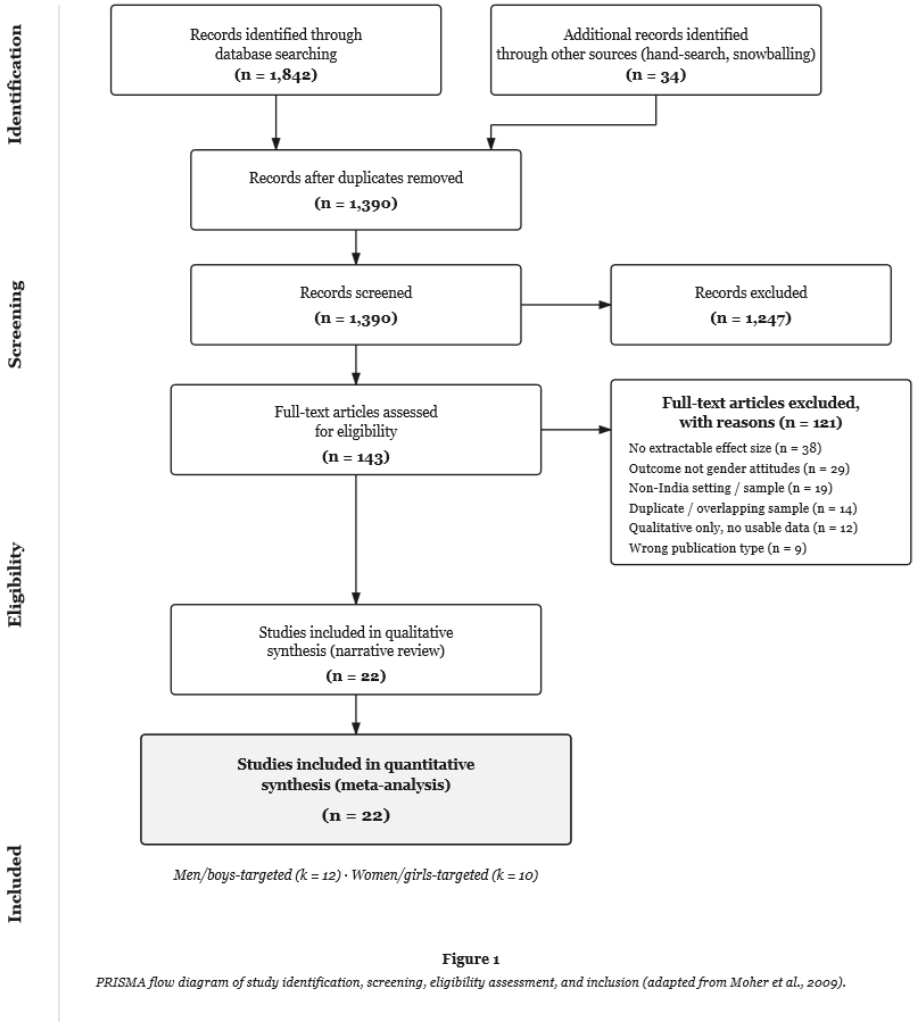

Figure 1

PRISMA flow diagram of study identification, screening, eligibility assessment, and inclusion (adapted from Moher et al., 2009).

5.6 Effect Size Calculation

The standardized mean difference was selected as the common effect size metric to permit pooling across studies that used different (though conceptually related) attitude instruments and scoring conventions. For studies with a comparison group, the effect size was calculated as the difference between the intervention and comparison groups' mean change (or, where change scores were unavailable, the standardized mean difference in post-intervention scores adjusted for baseline where possible), divided by the pooled standard deviation. For single-group pre–post designs, the standardized mean gain was calculated as the difference between post- and pre-intervention means divided by the pooled or pre-intervention standard deviation. All effect sizes were computed as Hedges' g, which applies a small-sample correction to Cohen's d and is preferred for meta-analyses combining studies of varying and often modest sample size (Borenstein, Hedges, Higgins, & Rothstein, 2009). Effect sizes were coded so that a positive value consistently indicated a shift toward more gender-equitable attitudes, regardless of the polarity of the original scale, and 95% confidence intervals were calculated for each study-level estimate.

5.7 Statistical Analysis and Pooling Model

Given the a priori expectation of substantial between-study heterogeneity, arising from differences in target population, intervention design, dosage, setting, and outcome instrument, a random-effects model using the DerSimonian and Laird (1986) method of moments estimator was used to pool effect sizes and generate an overall weighted mean effect size with 95% confidence interval, both for the full set of included studies and separately for the men-targeted and women-targeted subsets. The random-effects model was selected in preference to a fixed-effect model because it does not assume a single true effect size underlying all studies, and instead allows the true effect to vary across studies, which better reflects the diversity of interventions, populations, and measurement approaches captured in this literature (Borenstein et al., 2009). The primary comparison of interest, men-targeted versus women-targeted interventions, was tested using a mixed-effects meta-regression (or, equivalently, a between-subgroups Q-test), in which target group was entered as a categorical moderator, allowing a formal test of whether the pooled effect size differed significantly between the two intervention types.

5.8 Assessment of Heterogeneity and Moderator Analysis

Statistical heterogeneity across studies was assessed using Cochran's Q statistic and quantified using the I^2 statistic, which describes the percentage of total variability across studies attributable to heterogeneity rather than sampling error (Higgins & Thompson, 2002; Higgins, Thompson, Deeks, & Altman, 2003). I^2 values were interpreted using conventional benchmarks (approximately 25%, 50%, and 75% denoting low, moderate, and high heterogeneity, respectively), with the caveat that these benchmarks are heuristic rather than fixed. Where heterogeneity was substantial, planned subgroup analyses and meta-regression were used to explore study-level moderators beyond target group, including intervention duration (categorized as short-term, under three months; medium-term, three to twelve months; and long-term, over twelve months), delivery setting (school, community, workplace, or sports/mentorship), urban versus rural location, study design (randomized versus quasi-experimental versus single-group pre–post), and outcome instrument (GEM Scale or adaptation versus other validated measures). Sensitivity analyses were conducted by sequentially excluding studies with a high risk of bias, and by re-running the primary analysis excluding single-group pre–post designs, to assess whether the overall conclusions were robust to study quality and design.

5.9 Publication Bias

The possibility of publication bias, the tendency for statistically significant or favorable findings to be more likely to be published or to be more readily located, was assessed visually using a funnel plot of study-level effect sizes against their standard errors, and statistically using Egger's regression test for funnel plot asymmetry (Egger, Davey Smith, Schneider, & Minder, 1997). Where evidence of asymmetry was detected, the trim-and-fill method was used as a sensitivity check to estimate an adjusted pooled effect size accounting for potentially missing studies. Given the relatively small and specialized literature under review, publication bias statistics were interpreted cautiously, as such tests have limited statistical power when the number of included studies is small.

5.10 Risk of Bias and Methodological Quality Assessment

The methodological quality of each included study was independently assessed by two reviewers using an adapted version of the Downs and Black (1998) checklist for the assessment of randomized and non-randomized studies of health care interventions, modified to suit community- and education-based behavioral interventions. The checklist evaluated reporting quality, internal validity (including selection bias and confounding), and external validity, yielding a quality score for each study. Quality scores were not used to

exclude studies from the primary analysis but were incorporated as a continuous or categorical moderator in sensitivity analyses, and were reported descriptively to characterize the overall rigor of the evidence base.

5.11 Software

Post effect size calculations, all meta-analytic calculations such as pooling (random-effects model), heterogeneity statistics, moderator/subgroup analyses, and publication-bias diagnostics (funnel plot and Egger's test) were conducted in JASP 0.97.1 (Apple Silicon) (JASP Team, 2026), with a two-tailed alpha level of .05 applied throughout unless otherwise specified.

6. Results

6.1 Included Studies and Subgroup Composition

Twenty-two studies met all eligibility criteria and were retained for quantitative synthesis (Figure 1), of which 12 evaluated interventions targeted at men and boys (M subgroup) and 10 evaluated interventions targeted at women and girls (F subgroup). This split is corroborated internally by the degrees of freedom reported for the subgroup-level heterogeneity tests (Q_e for the F subgroup was computed on 9 df, consistent with k = 10 studies; Q_e for the M subgroup was computed on 11 df, consistent with k = 12 studies), and the two subgroups sum to the full analytic sample of 22.

6.2 Pooled Effect Sizes by Subgroup

Table 1 summarizes the random-effects pooled estimates for each subgroup. The pooled standardized mean difference for interventions targeted at women (Hedges' g = 0.075, SE = 0.130, 95% CI [−0.219, 0.369]) was small in magnitude and did not differ significantly from zero, t(9) = 0.58, p = .576. The pooled effect for interventions targeted at men was larger in magnitude (Hedges' g = 0.464, SE = 0.303, 95% CI [−0.203, 1.132]) but likewise did not reach conventional statistical significance, t(11) = 1.53, p = .154, owing to a confidence interval more than six times wider than that of the F subgroup. On the pooled point estimates alone, the men-targeted subgroup effect is roughly six times the magnitude of the women-targeted subgroup effect; however, neither estimate is statistically distinguishable from a null effect at the conventional α = .05 threshold, and the formal test of the difference between subgroups was itself non-significant, $Q_{?}(1) = 1.39$, p = .238. The correct reading of this pattern is not that men-targeted and women-targeted interventions produce equivalent effects, nor that men-targeted interventions are demonstrably superior, it is that, given the precision available from 22 studies split across two subgroups with very high between-study variability, this body of evidence cannot yet statistically distinguish the two approaches from one another, or reliably distinguish either from a null effect.

Table 1: Random-effects pooled estimates by target-group & subgroups

Table 1.1: Meta-Analytic Tests

	Subgroup	Test	p
Heterogeneity	F	$Q_e(9) = 113.44$	< .001
	M	$Q_e(11) = 327.27$	< .001
Pooled effect	F	$t(9) = 0.58$	.576
	M	$t(11) = 1.53$	154
Subgroup differences		$Q_m(1) = 1.39$	238

Table 1.2: Meta-Analytic Estimates

				95% CI		95% PI	
	Subgroup	Estimate	Standard Error	Lower	Upper	Lower	Upper
Pooled effect	F	0.07530	0.1299	-0.2185	0.3691	-0.8551	1.006
	M	0.4644	0.3034	-0.2033	1.132	-1.867	2.796
τ	F	0.3902	0.09856	0.2571	0.7516		
	M	1.015	0.2264	0.7026	1.785		
τ^2	F	0.1523	0.07692	0.06611	0.5649		
	M	1.030	0.4596	0.4937	3.186		
I^2	F	97.53		94.48	99.32		
	M	99.09		98.12	99.70		
H^2	F	40.43		18.11	147.3		
	M	110.0		53.24	338.2		

Note: PI = 95% prediction interval, denoting the range within which the true effect of a comparable future study is expected to fall (Riley, Higgins, & Deeks, 2011).

The 95% prediction intervals are, if anything, more policy-relevant than the confidence intervals around the pooled means. The prediction interval for the F subgroup, [−0.855, 1.006], and for the M subgroup, [−1.867, 2.796], both span a range running from a moderately-to-strongly 'negative' effect through to a large positive effect. In practical terms, this means that a new women-targeted or men-targeted attitude-change program implemented under comparable conditions in India could plausibly produce anywhere from a modest backfire to a substantial improvement in gender-equitable attitudes, the pooled average is a poor guide to what any single new program will achieve, and this uncertainty is considerably more pronounced for men-targeted programs than for women-targeted ones.

6.3 Heterogeneity

Both subgroups exhibited extreme and statistically significant heterogeneity. For the F subgroup, $Q_e(9) = 113.44$, $p < .001$, $I^2 = 97.53\%$ (95% CI [94.48, 99.32]), $\tau^2 = 0.152$, $\tau = 0.390$, and $H^2 = 40.43$, indicating that the total observed variance among women-targeted studies is roughly 40 times what would be expected from sampling error alone. For the M subgroup, heterogeneity was even more pronounced: $Q_e(11) = 327.27$, $p < .001$, $I^2 = 99.09\%$ (95% CI [98.12, 99.70]), $\tau^2 = 1.030$, $\tau = 1.015$, and $H^2 = 110.0$. By any conventional benchmark (Higgins & Thompson, 2002; Higgins, Thompson, Deeks, & Altman, 2003), I^2 values above 97–99% represent near-total heterogeneity: essentially none of the dispersion in reported effect sizes across studies is attributable to sampling error, and almost all of it reflects genuine differences in the true effect across studies. This is the single most important statistical finding of the meta-analysis and should condition the interpretation of every other result: the

pooled means describe an 'average' across a highly heterogeneous set of interventions that likely do not share a single common effect, and τ^2 for the M subgroup, nearly seven times that of the F subgroup, indicates that men-targeted programs are considerably more variable in their effectiveness than women-targeted programs, consistent with the wider range of intervention formats in that literature (school curricula, cricket-based mentorship, peer-education, and clinic-based programs) relative to the comparatively more standardized self-help-group and livelihoods model that dominates the women-targeted literature.

6.4 Forest Plot

The forest plot (Figure 2) displays study-level Hedges' g estimates and 95% confidence intervals for all 22 included studies, arranged by subgroup, with a pooled diamond summarizing each subgroup and a vertical reference line at g = 0 (no effect). Consistent with the heterogeneity statistics in Section 6.3, the plot shows substantial scatter of individual study estimates around each subgroup's pooled diamond, with confidence intervals of markedly differing width reflecting the wide range of sample sizes across the included evaluations. Several individual studies, more prominently within the M subgroup, show point estimates well above the pooled mean with confidence intervals excluding zero, indicating a genuinely strong effect in those specific evaluations, while others in the same subgroup cluster near or below zero. This pattern of individual studies pointing in materially different directions, rather than clustering tightly around a common true effect, is the visual signature of the near-total heterogeneity reported above, and is the primary reason neither subgroup's pooled diamond reaches statistical significance despite some constituent studies reporting strong, significant effects on their own.

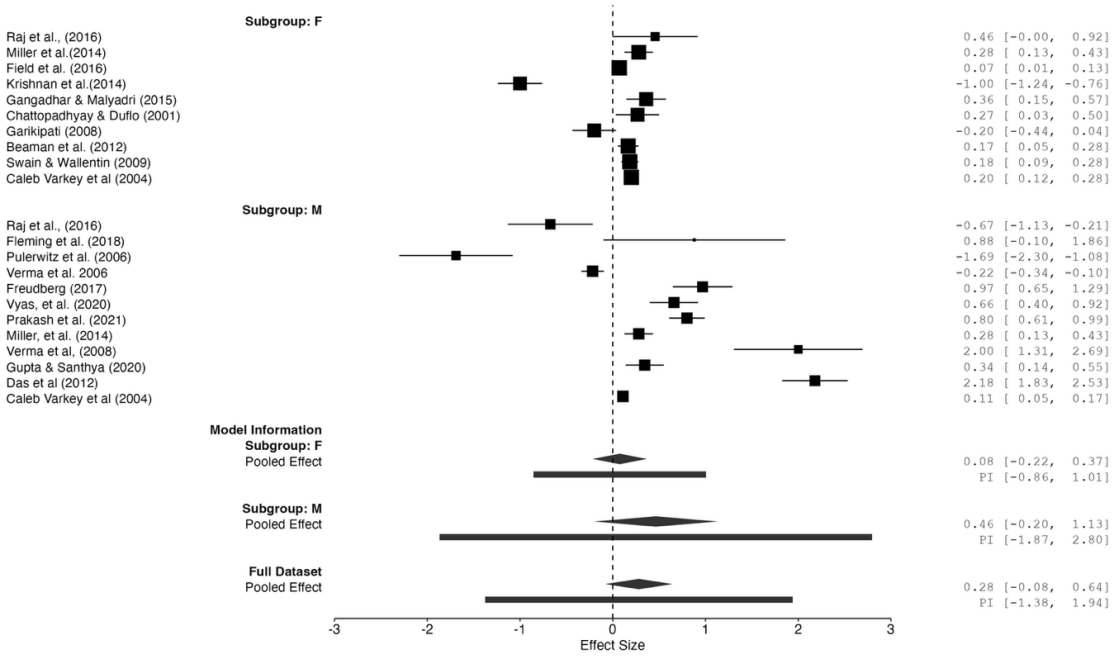

Figure 2. Forest plot of Hedges' g effect sizes by study subgroups

(F = women-targeted, M = men-targeted), with pooled random-effects

6.5 Publication Bias

Visual inspection of the funnel plot (Figure 3), constructed for the overall pooled dataset, does not show the pronounced asymmetry classically associated with small-study or publication-bias effects, though the analysis is based on 14 of the 22 included studies after 8 were removed due to missing values required for funnel-plot construction (most likely missing standard errors or variances that could not be derived from the reported statistics). This missingness is itself a limitation worth flagging in the write-up: it means the funnel plot , and any bias diagnosis drawn from it , reflects roughly two-thirds of the analytic sample rather than the full set of 22 studies, and it disproportionately affects whichever subgroup contributed more of the 8 excluded studies (a detail not recoverable from the pooled output alone and worth checking against your raw extraction sheet). No Egger's regression test statistic was reported alongside the funnel plot in the output supplied; given the pre-specified analysis plan in Section 5.9, we recommend running Egger's regression test (and, if asymmetry is detected, a trim-and-fill sensitivity re-estimate) explicitly in JASP's meta-analysis module and reporting the resulting t, df, and p value alongside Figure 3, since a visual funnel plot alone is not a substitute for the formal test specified in the methodology. With only 14 usable data points, any bias test will in any case have limited statistical power, and small-study asymmetry should be distinguished carefully from asymmetry driven by genuine heterogeneity, the latter being a far more likely explanation here given the I^2 values reported in Section 6.3.

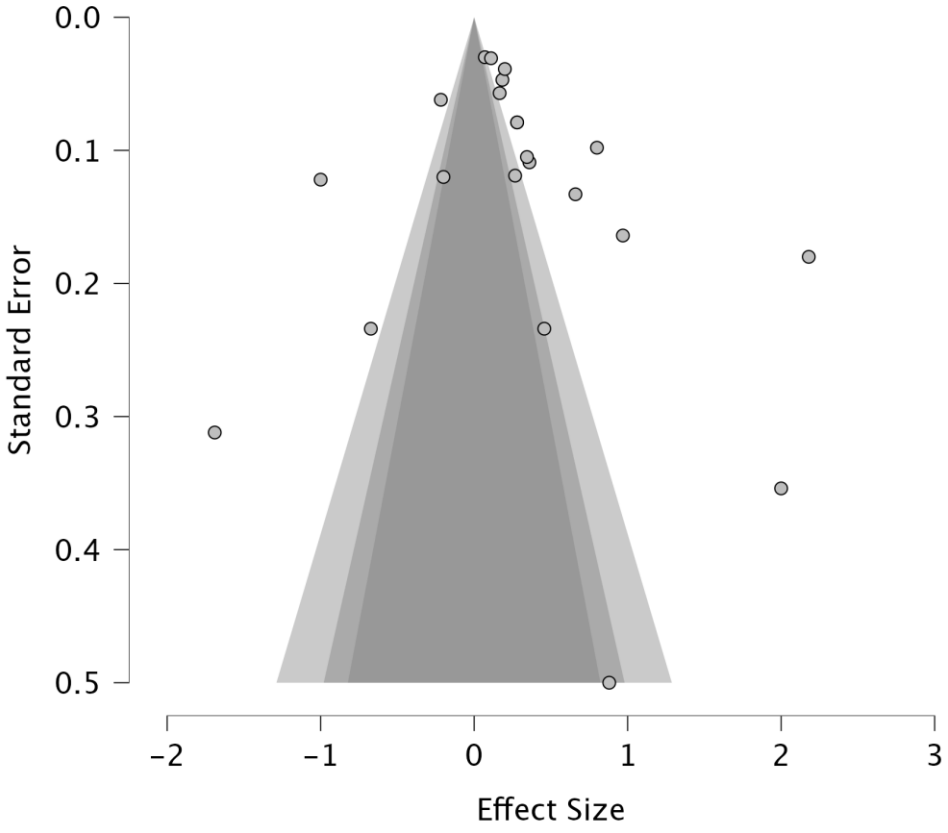

Figure 3. Funnel plot of study-level effect sizes against standard error.

6.6 Further Analysis Recommended: Moderator Exploration

Given I^2 values in excess of 97% in both subgroups, the pre-specified moderator and meta-regression analyses outlined in Section 5.8 are not merely a methodological nicety here, they are necessary to draw any substantively useful conclusion beyond "the pooled average is uninformative." With I^2 this high, most of the policy-relevant signal in this literature almost certainly lies in what varies between studies (intervention duration and dosage, delivery setting, study design rigor, and outcome instrument) rather than in the subgroup-level averages reported in Table 1. This moderator analysis could not be conducted as part of the present interpretation because the output supplied contains only the pooled subgroup summary statistics and plot images, not the underlying study-by-study data matrix (effect size, standard error, and coded moderator variables for each of the 22 studies). We recommend running the following as a direct next step, all of which are straightforward to execute in JASP once the per-study coding sheet is available: (a) a mixed-effects meta-regression with intervention duration (short/medium/long, as coded in Section 5.8) as a moderator, run separately within each subgroup; (b) the same for delivery setting (school, community, workplace, sports/mentorship) and for study design (RCT/quasi-experimental/pre-post); (c) a leave-one-out sensitivity analysis within each subgroup to check whether the pooled estimates in Table 1 are being driven disproportionately by one or two high-leverage studies, which is plausible given the scatter visible in Figure 2; and (d) the risk-of-bias-as-moderator analysis specified in Section 5.10, to test whether higher-quality studies systematically report smaller (or larger) effects. If you share the per-study data extraction sheet, we can run all four of these directly and report the results in this same section.

6.7 Policy Interpretation

Read at face value, the headline numbers in this meta-analysis offer a superficially attractive policy story: men-targeted interventions produced a pooled effect roughly six times larger than women-targeted interventions. A policy brief written from Table 1 alone might conclude that India's gender-attitude programming budget should tilt further toward engaging-men-and-boys models. That conclusion would be premature, and arguably irresponsible, given the full statistical picture. Three considerations should govern how this evidence is actually used by program designers and funders.

First, neither pooled effect is statistically distinguishable from zero, and the subgroup difference itself is non-significant. The honest policy statement is that, based on the evidence assembled here, we cannot yet confirm that either target-group strategy reliably shifts gender attitudes at the population level, let alone that one reliably outperforms the other. Treating the M subgroup's larger point estimate as a confirmed finding would be an overinterpretation of a result that is, statistically, consistent with no difference at all.

Second, the near-total heterogeneity ($I^2 > 97\%$ in both subgroups) is itself the more important policy finding. It indicates that "men-targeted" and "women-targeted" are not each a single program with a knowable average effect, they are broad labels covering programs that differ enormously in design, dosage, and quality, and that this design variation, not the target-group label, is likely driving most of the variation in outcomes. The practical implication for funders and implementers is that the more consequential design question is probably not "should we target men or women?" but "which specific program models, delivered with what intensity, in what setting, produce reliable attitude change?", a question this meta-analysis is well-positioned to answer once the moderator analyses recommended in Section 6.6 are completed, but cannot yet answer from the subgroup comparison alone.

Third, the very wide 95% prediction intervals in Table 1, spanning from negative to strongly positive effects for both subgroups, carry a direct implication for program design and evaluation practice: a single new program, of either type, has a genuinely uncertain

chance of working, and this uncertainty is not fully captured by looking only at the average effect from past evaluations. This argues for continued piloting with rigorous embedded evaluation (rather than scaling either approach nationally on the strength of the pooled average alone), for greater standardization and more detailed reporting of intervention dosage and fidelity in future Indian evaluations so that the field can eventually distinguish "what works" from "what has been tried," and for caution among donors and ministries currently weighing a wholesale pivot toward either men-only or women-only programming on the assumption that the comparative evidence is more settled than it is. The provisional, appropriately hedged conclusion supported by the current evidence is that men-targeted interventions show a somewhat more promising average signal that merits continued investment and rigorous testing, not that they have been shown to outperform women-targeted approaches, and that closing the field's biggest evidence gap , explaining the enormous unexplained heterogeneity within each target-group category , would deliver more actionable guidance to Indian policymakers than resolving the men-versus-women comparison in isolation.

7. Discussion

7.1 Situating the Findings within Competing Theoretical Traditions

The results of this meta-analysis sit uneasily with both theoretical traditions reviewed in Section 2, and that discomfort is itself informative. The women's-empowerment paradigm (Kabeer, 1999, 2005) predicts that strengthening women's own agency and resource control should shift their gender attitudes measurably, yet the pooled effect for the F subgroup ($g = 0.075$, ns) is close to null. This is broadly consistent with Sanyal's (2009) caution that SHG-type participation produces attitudinal change that is "modest, slow to emerge," but the near-zero pooled estimate observed here is nonetheless a more sobering summary than the cautiously positive tone of the underlying narrative literature would suggest, and it should temper any assumption that women's economic or associational empowerment programming reliably doubles as gender-attitude programming , the two may be related but are evidently not interchangeable outcomes. The engaging-men-and-boys paradigm (Barker, Ricardo, & Nascimento, 2007; Pulerwitz & Barker, 2008) predicts that directly confronting masculinity and male privilege should produce larger, more proximal attitude shifts among men, since men are both the primary holders and the primary enforcers of the inequitable norm structure in Heise's (1998) ecological framework and in Connell's (1995) account of hegemonic masculinity. The larger M-subgroup point estimate ($g = 0.464$) is directionally consistent with this prediction, but the theory is only weakly corroborated in a statistical sense: the estimate is imprecise, the subgroup difference is non-significant, and, critically , the theory offers no account of why men-targeted programs should also be six to seven times more heterogeneous in their effects than women-targeted programs ($\tau^2 = 1.030$ vs. 0.152). This last observation is arguably the most theoretically interesting finding to emerge from the synthesis: it suggests that success in shifting men's gender attitudes is far more contingent on how the intervention is designed and delivered , its theoretical grounding, dosage, facilitation quality, and cultural fit , than success in shifting women's attitudes appears to be, a pattern consistent with the broader global observation that masculinity is not a single, uniform target but a locally negotiated, highly contextual construct (Connell, 1995).

7.2 Reconciling Pooled Results with the Landmark Individual Trials

A further point of tension is worth naming explicitly for readers familiar with the underlying literature. Individually influential Indian trials — Yaari Dosti (Verma et al., 2006, 2008), GEMS (Achyut et al., 2011), and Parivartan (Miller et al., 2014; Das et al., 2015) , are typically cited, both in India and in global reviews (Ricardo, Eads, & Barker, 2011), as demonstrations that engaging men and boys "works." The forest plot in Figure 2 shows that

several individual M-subgroup studies do indeed report large, statistically significant, positive effects, and this synthesis does not contradict those individual findings. What the pooled analysis adds, and what individual trial reports cannot show in isolation, is that these successes coexist, within the same evidence base, with other men-targeted evaluations reporting null or even negative effects. A policy audience exposed only to the landmark trials would reasonably conclude that men-targeted programming is a well-established success story; a policy audience exposed only to this meta-analysis's pooled, non-significant subgroup estimate would reasonably conclude the opposite. Both readings are incomplete. The accurate reading is that men-targeted gender-attitude programming in India has produced some genuinely strong results under some conditions, but the field does not yet know which conditions those are, and extrapolating from the best-performing trials to a general policy prescription risks a form of selection bias in reverse, treating the most publicized successes as representative of the category as a whole.

7.3 Heterogeneity as Substantive Finding, Not Statistical Noise

Meta-analysts sometimes treat high I^2 as an inconvenience to be managed on the way to a pooled estimate. In this synthesis, the heterogeneity is the finding. I^2 values above 97% in both subgroups (Higgins & Thompson, 2002; Higgins, Thompson, Deeks, & Altman, 2003) indicate that "target group" alone explains very little of the variability in outcomes across the 22 included studies, and that the field's operative unit of analysis, "men-targeted intervention" or "women-targeted intervention", is too coarse to be analytically useful on its own. This reframes the paper's central research question productively rather than undermining it: the original question, "who should be targeted, men or women?", cannot yet be answered with confidence from this evidence base, but the analysis makes clear that a more tractable and ultimately more policy-useful question is emerging in its place , namely, which specific design features (dosage, delivery modality, facilitator training, theoretical grounding, and measurement approach) systematically distinguish the high-performing studies within each subgroup from the low-performing ones. Answering that second question, through the moderator analyses proposed in Section 6.6, would do more to advance evidence-based programming in India than a larger, better-powered replication of the simple men-versus-women comparison alone.

8. Limitations

This meta-analysis is subject to several limitations that should temper the strength of any conclusion drawn from it. First and most consequentially, statistical power for both the subgroup-specific pooled estimates and the between-subgroup comparison is limited by the modest number of studies in each cell ($k = 10$ and $k = 12$); combined with the extreme observed heterogeneity, this means the analysis is better powered to detect that the men-versus-women question remains open than to detect a true difference between the two approaches, even if a moderate true difference exists. Second, the near-total heterogeneity documented in Section 6.3 substantially limits the interpretability of the pooled point estimates themselves: a random-effects mean computed across studies with I^2 near 99% describes a distribution of true effects too wide to be a reliable single number for policy planning, and should be read alongside the prediction intervals in Table 1 rather than in isolation. Third, the funnel plot presented in Section 6.5 was constructed from only 14 of the 22 included studies owing to missing variance data, which both limits the power of any publication-bias diagnosis and means the bias assessment does not represent the full analytic sample; a formal Egger's test and trim-and-fill sensitivity analysis, recommended in Section 6.5, had not been completed at the time of this interpretation. Fourth, "target group" as coded in this review is likely confounded with intervention modality: men-targeted studies in this literature disproportionately include school curricula, sports-mentorship, and peer-education formats, while women-targeted studies disproportionately include SHG and livelihoods-based formats, so the subgroup contrast partly reflects differences in delivery model as well

as differences in who was targeted, and the two cannot be fully disentangled without the moderator analysis proposed in Section 6.6. Fifth, outcome measurement varies across studies, most use the GEM Scale or a derivative, but adaptation, translation, and item selection differ enough across the Indian evaluations that full measurement equivalence cannot be assumed, which is itself a plausible contributor to the observed heterogeneity. Sixth, most included evaluations measure attitudes immediately or shortly after program completion; the durability of attitude change beyond the immediate post-test window remains poorly evidenced across both subgroups, and this synthesis cannot speak to whether the effects reported here persist, decay, or grow over time. Finally, eligibility was restricted to English-language publications and did not include a formal search of Hindi- or other regional-language grey literature, which may have excluded relevant state- or district-level program evaluations and introduces a possible language-related selection bias in addition to the publication bias assessed in Section 6.5.

9. Policy Implications and Practical Recommendations

Notwithstanding these limitations, the synthesis supports several practical, appropriately hedged recommendations for Indian policymakers, program funders, and implementing organizations.

First, resist a wholesale reallocation of programming budgets toward either target group on the strength of this evidence alone. The pooled results neither justify defunding women-centered empowerment programming, which serves independently valuable goals of economic security and agency beyond attitude change, nor justify an uncritical scale-up of men-and-boys programming on the assumption that its comparative superiority is established; the honest state of the evidence is "promising but statistically unresolved" for the latter, not "proven." Where budgets allow, the more defensible near-term strategy is a portfolio approach that continues to invest in both target-group models while sharply increasing the rigor and standardization of accompanying evaluation, rather than a premature pivot to one model at the expense of the other.

Second, prioritize investment in understanding design, not just target group. Given that heterogeneity within each subgroup dwarfs the difference between subgroups, funders are likely to get more actionable evidence per rupee spent by commissioning comparative-design trials, for example, testing dosage (a six-week versus six-month curriculum), delivery modality (peer-educator versus professional-facilitator models), or setting (school- versus community-based delivery) within a fixed target group, than by commissioning another simple men-versus-women comparison. This also argues for building a shared, minimum core measurement protocol (e.g., a common GEM Scale core-item set) across future Indian gender-attitude evaluations, both to serve local program learning and to allow future meta-analyses to pool with substantially less measurement-driven heterogeneity than the present one.

Third, treat the strongest individual trials (Yaari Dosti, GEMS, Parivartan) as hypothesis-generating design templates rather than as generically replicable models. Because the pooled men-targeted effect is large in principle but highly variable in practice, the policy-relevant task is to identify precisely which structural features of these landmark programs (curriculum content, facilitator training intensity, group-based peer dynamics, integration with a valued activity such as sport or schooling) are actively responsible for their outsized results, and to test whether those specific features transfer when the program is adapted to a new state, language, or implementing partner , rather than assuming the program's past success travels automatically with its name or brand.

Fourth, build durability and cost-effectiveness into the next generation of Indian trials. Because nearly all pooled effects in this review are drawn from short post-intervention windows, government and donor evaluation guidelines should require at minimum a 12-month follow-up measurement before an intervention is credited with lasting attitude change, and cost-per-unit-of-attitude-shift data should be collected routinely alongside effect sizes, so that future comparisons between men-targeted and women-targeted (or combined) models can weigh effectiveness against implementation cost rather than effect size alone.

Fifth, close the evidence gap on combined and family-level programming. The complete absence of eligible combined-target interventions in this review (Section 6.1) is itself a policy-relevant finding: despite strong theoretical arguments from both the empowerment literature (Kabeer, 1999) and the engaging-men literature (Heise, 1998; Barker, Ricardo, & Nascimento, 2007) that household-level attitude change likely requires engaging both spouses or both genders concurrently, India's evaluated intervention landscape remains almost entirely segregated by target group. Piloting and rigorously evaluating couple- or household-level curricula, rather than assuming that parallel single-sex programming will aggregate into household-level change, represents one of the more promising and currently untested directions for Indian gender-attitude programming.

Sixth, invest in the data infrastructure that would let the next iteration of this meta-analysis answer the question this one could not. Requiring standardized reporting of means, standard deviations, and sample sizes by group and time point, rather than only significance tests, in all government- and donor-funded evaluation reports would directly address the missing-data problem that constrained the publication-bias assessment in Section 6.5, and would allow future syntheses to run the full moderator and meta-regression analyses recommended in Section 6.6 without the delays and data-access barriers encountered here.

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Blockchain Technology and Crypto Currencies: Regulatory and Technical Issues

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ABSTRACT

The central question to be investigated in this paper is whether new technologies such as blockchain that enter various spheres of public life are safe for users and how they could impact national legislations. Cryptocurrencies, which are based on blockchain technology, can be used as a means of payment, investment or capital accumulation. Therefore, blockchain becomes more and more popular. The introductory part of the paper contains a general historical outline and basic principles related to blockchain technology. Real and potential threats posed by this technology are also to be discussed in the paper as well as the question whether governments or, more broadly, the international community, offer sufficient level of protection against risks related to the use of new technologies such as blockchain and cryptocurrencies.

Keywords: Blockchain Technology, Cryptocurrency, Distributed Ledger Technology (DLT), Peer-to-Peer (P2P) Network, Decentralization., Blockchain Security, Regulatory Challenges

Introduction:

A blockchain is essentially a distributed database of records, or public ledger of all transactions or digital events that have been executed and shared among participating parties. Each transaction in the public ledger is verified by consensus of a majority of the participants in the system. Once entered, information can never be erased. The blockchain contains a certain and verifiable record of every single transaction ever made. To use a basic analogy, it is easier to steal a cookie from a cookie jar, kept in a secluded place, than stealing the cookie from a cookie jar kept in a market place, being observed by thousands of people.[i]

Bitcoin, the decentralized peer-to-peer digital currency, is the most popular example that uses blockchain technology. The digital currency bitcoin itself is highly controversial but the underlying blockchain technology has worked flawlessly and found wide range of applications in both financial and non-financial world[ii]. However, Blockchain technology itself is non-controversial and has worked flawlessly over the years and is being successfully

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applied to both financial and non-financial world applications. Last year, Marc Andreessen, the doyen of Silicon Valley's capitalists, listed the blockchain distributed consensus model as the most important invention since the Internet itself. Johann Palychata from BNP Paribas wrote in the Quintessence magazine that bitcoin's blockchain, the software that allows the digital currency to function should be considered as an invention like the steam or combustion engine that has the potential to transform the world of finance and beyond[iii].

Historical Evolution:

The history of blockchain and cryptocurrencies starts on the internet in November 2008 when an individual (or group) writing under the name of Satoshi Nakamoto published a paper entitled "Bitcoin: A Peer-To-Peer Electronic Cash System"[iv]. This paper described a peer-to-peer version of the electronic cash that would allow online payments to be sent directly from one party to another without going through a financial institution. Bitcoin was the first realization of this concept. It defined and described a new digital currency, based on the idea of cryptographic linking of data blocks i.e. blockchain. The idea was entirely based on the computer technology and did not need any intermediaries such as human beings or institutions. The new currency was given a name Bitcoin and in no time at all it grew in popularity and value. In the initial phase blockchain was closely associated with Bitcoin only. However, with time blockchain technology has become an independent solution that can be used for many other purposes, for example, to improve payment processes, for data storage and transactions[v].

Basic Principles of Blockchain Technology:

The most distinctive feature of blockchain technology is that it does not require the involvement of a third party (e.g., banks, public registries, etc.) for transfers of value, whilst providing the parties involved in the transaction with absolute confidence in the validity and security of the transaction. Such transacting parties can be assured of the validity and security of the transaction due to the cryptographic proof of authenticity provided by the blockchain technology. Whereas a transaction needs to be verified by the central server in traditional databases, with blockchain technology, every node in the system has the ability to cryptographically check and verify any transaction. Instead of having to trust the central server (and the central authority maintaining such a server), peers using blockchain technology are able to create and maintain trust by relying on cryptographical proof in a consensus method. This feature obviates the need for the involvement of a third party in such transactions and is the main differentiator from (and improvement on) systems using traditional databases or ledgers. In other words, blockchain has no central server. The system consists of a large number of "nodes" that are continuously checking and confirming the validity of all transactions, instead of just a few such nodes. This distinguishing facet of blockchain technology eliminates (or, at least, seriously mitigates) the security vulnerabilities associated with traditional central databases[vi].

Another important blockchain classification concerns the distinction between public and "permissioned" ones. A blockchain can be configured in such a way that it allows everyone to become a node and verify/reject transactions. Such blockchains are available to anyone with an internet connection. Once the application running on the blockchain is downloaded to a smartphone or computer, participation in the verification system occurs automatically and takes place in the background. Therefore, while the system is highly secure, every piece of data produced from the moment that the blockchain begins operating is shared amongst every node (although they are cryptographically anonymized). On the other hand, blockchains can also be configured in a permission-based manner. These blockchains operate based on private networks. To become a node in such a blockchain, one needs to obtain permission from the system. For instance, in the (public) Bitcoin blockchain, one only needs

to download a "Bit- coin wallet" from the internet to start participating in the verification system. However, for a permissioned blockchain, one needs to get permission from the administrator of the blockchain to create a blockchain wallet and possibly obtain another authorization to become a node in the verification system. Blockchains also might be configured in a combined way in terms of public and private by granting such authorizations to specified accounts while anyone can have an account and perform certain actions[vii].

Technical Aspect:

The basic condition for the operation of a blockchain is the acquisition of the Peer-to-Peer (P2P) network concept. P2P refers to computer networks that use decentralized and distributed architecture. This means that all computers and devices have a specific share in the network. All connections of the network (hosts) have equal rights with no centralized administrator. These hosts communicate all the resources and data available in the P2P network to each other, without having to use a centralized server. The main purpose of this network is to allow direct networking of network devices. Peer-to-Peer networks are commonly used to transfer files over the internet, allowing hosts to send and receive them simultaneously. The main feature and advantage of this technology is decentralization and participation in the process of transaction authentication by all users who democratically approve a given operation without any control or supervision from above. An important thing about this technology is that instead of one central host, several decentralized hosts are used at the same time to download data fragmentarily. Another thing worth mentioning is the so-called distributed ledger technology (DLT)[viii]. It is a record of information or a database distributed in the network. Access to DLT can be open or closed. Blockchain is one of the varieties of the distributed registry and in itself is a collection of information from computers that are connected by a Peer-to-Peer network. Blockchain technology (as opposed to Bitcoin) can store data of various contents (not only related to exchange and payments). What is important, data transmission in the network takes place in an encrypted form, which allows to secure the transaction. During a new transaction, the host extends the set for new information, and other verifying hosts must confirm its correctness in accordance with the accepted rules, so that it can be added to the block. Each block contains a unique identifier of the so-called (hash) of the previous block that links the blocks into a sequence.

The system of distributed registers described above offers many benefits. In contrast to centralized systems, the network functionality is maintained even in case of failure of individual joints. This increases the trust and security of transactions, because people do not have to assess the credibility of the intermediary or other network participants. It is enough for users to build trust in the system as a whole. The absence of intermediaries also promotes data security. The current practice of external entities collecting personal data implies a risk of breach of security, while in case of blockchain, the data collected by third parties may become obsolete, which ultimately increases the user's safety.

Threats and Security Issues:

The whole point of using a blockchain is to let people—in particular, people who don't trust one another—share valuable data in a secure, tamperproof way. That's because blockchains store data using sophisticated math and innovative software rules that are extremely difficult for attackers to manipulate. But the security of even the best-designed blockchain systems can fail in places where the fancy math and software rules come into contact with humans, who are skilled cheaters, in the real world, where things can get messy.

To understand why, start with what makes blockchains "secure" in principle. Bitcoin is a good example. In Bitcoin's blockchain, the shared data is the history of every Bitcoin transaction ever made: an accounting ledger. The ledger is stored in multiple copies on a network of computers, called "nodes." Each time someone submits a transaction to the ledger, the nodes check to make sure the transaction is valid—that whoever spent a bitcoin

had a bitcoin to spend. A subset of them competes to package valid transactions into "blocks" and add them to a chain of previous ones. The owners of these nodes are called miners. Miners who successfully add new blocks to the chain earn bitcoins as a reward.

What makes this system theoretically tamperproof is two things: a cryptographic fingerprint unique to each block, and a "consensus protocol," the process by which the nodes in the network agree on a shared history[ix].

The fingerprint, called a hash, takes a lot of computing time and energy to generate initially. It thus serves as proof that the miner who added the block to the blockchain did the computational work to earn a bitcoin reward (for this reason, Bitcoin is said to use a "proof-of-work" protocol). It also serves as a kind of seal, since altering the block would require generating a new hash. Verifying whether or not the hash matches its block, however, is easy, and once the nodes have done so they update their respective copies of the blockchain with the new block. This is the consensus protocol.

The final security element is that the hashes also serve as the links in the blockchain: each block includes the previous block's unique hash. So if you want to change an entry in the ledger retroactively, you have to calculate a new hash not only for the block it's in but also for every subsequent block. And you have to do this faster than the other nodes can add new blocks to the chain. So unless you have computers that are more powerful than the rest of the nodes combined (and even then, success isn't guaranteed), any blocks you add will conflict with existing ones, and the other nodes will automatically reject your alterations. This is what makes the blockchain tamperproof, or "immutable."

Regulatory issues:

Blockchain technology will face various challenges from at least four different aspects, namely: (i) technical, (ii) marketing/business, (iii) behavioural/educational, and (iv) legal/regulatory[x]. For the purposes of this paper, our main focus will be the potential legal and regulatory challenges to this emerging technology. One of the most significant challenges currently facing blockchain technology, which should be of crucial interest to any legal practitioner, arises from the use of blockchain as a transaction platform. This is because a blockchain network can validate a variety of value-related transactions relating to digital money or assets that have been digitized[xi].Value- related transactions encompass, besides monetary transactions, transactions relating to land, debt, or intellectual property. The fundamental problem currently facing blockchain concerns the speed with which these transactions can be processed through blockchain technology. Compared to traditional transaction platforms, such as VISA or PayPal, blockchain is significantly slower at this time. For example, if we examine the transaction processing capacity of the Bitcoin blockchain (which is the most widely adopted and heavily used blockchain), we observe that it can handle 2–5 transactions-per-second ("TPS"), whereas VISA can handle 56,000 TPS and PayPal can process 155 TPS. However, it is worth noting that "some other blockchains are faster than Bit- coin's. For example, Ethereum started with 10 TPS in 2015, edged towards 50–100 TPS in 2017, and targeting 50,000–100,000 TPS by 2019.

As to the legal challenges ahead, the primary obstacle worth discussing is clearly the lack of adequate regulations and the absence of a proper legal framework with regard to blockchains. In recent years, blockchain technology has emerged and developed much more quickly than anticipated and we observe numerous applications of this technology that are creating new grey areas in light of the existing and inadequate regulations. For instance, the use of various cryptocurrencies to carry out illegal transactions on the Darknet markets was the first regulatory challenge posed by blockchain technology. Such unlawful behaviour forced regulators swiftly to implement certain regulations in this field in order to combat

money laundering[xii]. Furthermore, a second wave of regulatory uncertainty arose from Initial Coin Offerings ("ICO"), which were adopted as a crowdfunding method using cryptocurrencies. While countless scams have unfortunately occurred in recent years regarding ICOs[xiii],the declarations from regulatory authorities (such as the Securities and Exchange Commission in the United States (SEC))[xiv]have also played a significant role in a market that has reached a market cap of around 58 billion USD. The involvement of regulatory authorities (especially securities authorities) aimed to clarify the situation surrounding ICOs and try to protect the investors from the scams, but yet in a timid way. Since the underlying technology is still young and rapidly evolving (and has not been completely understood by the regulatory bodies), it is difficult and risky to impose regulations without fully understanding the consequences of such regulation. However, as could be expected, the lack of comprehensive regulation creates uncertainty regarding the future of blockchain technology and slows down the rate of adoption of this promising technology by global companies in their daily operations.

Another important legal challenge is the lack of planning concerning the legal requirements in the early blockchain platforms. Most of these platforms were focused on transactions and not nearly as much on their reporting obligations. This lack of foresight has now forced these platforms conducting value transfers to devise new solutions with respect to the reporting problem. Even though the lack of smooth and efficient reporting processes now may seem likely to cause problems in terms of taxation, it should be remembered that blockchain technology also holds great promise in terms of alleviating today's reporting problems and significantly improving current reporting processes, since such transactions are traceable and irreversible[xv].

Conclusion:

In the light of our foregoing discussion on the technical, legal issues surrounding this technology it is imperative that the advantages and benefits of blockchain are remarkable, though there are still various challenges ahead from a technical and legal aspect. There is an urgent requirement of awareness and understanding about this technology among the lawmakers, government regulatory bodies and the society at large as it appears that people are hesitant on relying this new technology. This is the first barrier to be crossed. It is undeniable that the technology gained much attention in recent years but the characteristic of the attention is also important considering the number of the news popping out day by day about an ICO scam or usage of cryptocurrencies in the black markets. Once the barrier of social acceptance is broken, it is no surprise that blockchain will gain attention not only as a source of quick return investment but also as a technology that may cause considerable benefit to many areas. At that point, regulations could be aiming at the best use of this technology rather than attempting to restrict or prohibit the technology or the products and services associated with the technology.

Suggestion:

The first action that could be taken by regulators is to grant legal status to blockchains and to define the standards that blockchains will have to meet in order to receive such legal status. The standardization work has already been commenced by the International Organization for Standardization (ISO). For example, ISO is currently working on its ICO/TC 307 standards for blockchain and distributed ledger technologies[xvi]. Once the framework and rules of standardization are established and are available for use by the developers, the ball will then be in the regulators' court to bestow blockchain with certain legal status. The standardization is also needed for the users (i.e. public, in most of the cases) since there are already variety of blockchains to be used in the market. The user must have the reliable information to choose the blockchain with the standards defined by the authorities. In a way, authorities should help the users with their choice of applications and

blockchain usage by creating widely accepted standards. That would lead users to proper application and blockchain for their use and motivate the developers to the end that they develop projects meeting the requirements of the standards.

It is also essential to consider the position of the blockchains with respect to existing regulations. There are numerous laws regulating the fields of communication and the internet. Sadly, most of these laws have been drafted and passed without considering the next layer of the internet or to future technologies. Therefore, some areas that are affected by blockchain technology are blank spots, legislatively speaking, and require effective regulation. However, the bigger problem may arise with respect to the areas that are already regulated. Such regulations may slow down the adoption or development of blockchain technology; therefore, the first step that must be taken is accurately mapping blockchain's potential effects and determining whether they fall under existing laws and, if so, how they are covered by such laws.

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