

Empowering Rural Women Entrepreneurs Through Solar Drying Systems: A Social Business Approach to Food Security

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Abstract

This study proposes an integrated strategy to address food insecurity by empowering rural women entrepreneurs through the adoption of solar-drying technology. Rural farmers in Bangladesh frequently experience unstable prices and seasonal food shortages due to insufficient storage, limited transportation facilities, and post-harvest wastage. While sun drying is cost-effective, it often results in contamination, insect infestation, and inconsistent drying, leading to a loss of nutritional value. Solar drying ensures more efficient and reliable food preservation. This study applies the principles of social business to examine how women use solar drying to create sustainable micro-enterprises. The proposed model integrates capacity building, financial access, and market linkages to enhance women's entrepreneurial skills. This study examines the connections among women's entrepreneurship, renewable energy, and food security through an extensive literature review. The findings indicate that women's food preservation businesses generate income and employment, boost household nutrition, enhance climate resilience, and foster inclusive rural development. By embedding solar drying technology into food entrepreneurship and women's economic participation, this research supports sustainable food systems aligned with the Sustainable Development Goals. The study gives practical advice for leaders, development practitioners, and social business creators seeking to design fair, climate-ready, and sustainable food security interventions.

Keywords: Food Security, Renewable Energy, Social Business Model, Sustainable Development Goals, Women Entrepreneurship.

Introduction

Addressing food security remains a multifaceted development issue in Bangladesh. The World Food Program (WFP) reported that nearly 24 percent of the population was food-insecure, among them 47% were low-income, 9% were medium-income, and less than 3% were high-income households (1). Economists argue that food insecurity in Bangladesh arises not necessarily from food scarcity, but from entitlement failure. Entitlement failure occurs not just from food scarcity but also from changes in food distribution or access. Factors like inflation, speculation, and social/political issues such as discrimination, corruption or conflict can make food unaffordable or inaccessible to the poor. Therefore, despite efforts to boost agricultural output, Bangladesh grapples with substantial post-harvest losses, curtailing impoverished communities' access to nutritious food and exacerbating food insecurity.

Persistent food deficits within households, stemming from poverty and limited resources, result in chronic food insecurity. On the other hand, transient food insecurity arises from unexpected shortages due to factors such as import deficits, climatic variations, supply constraints, and price hikes (2). Moreover, the cost of agricultural supplies and conveyance expenses inflate food prices, limiting people's access to food. The key elements of food security, including food availability, accessibility, proper utilization, and stability over time, are widely acknowledged in practical applications, research, and policymaking (3). Moderate or severe food insecurity affected nearly one-third of rural areas (31.9%), followed by urban periphery (29.9%) and urban areas (25.5%). Globally and in all regions, food insecurity is consistently higher among women than men (4). Energy security is fundamental to achieving

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sustainable food production and ensuring prolonged food security, particularly in rural areas, where approximately 70%–80% of the population experiences food insecurity (2). Improving energy access in underserved communities would enhance different components of the food supply chain, such as trade, storage, and packaging, thereby reducing food insecurity (5). In Bangladesh, ensuring cost-effective and sustainable food preservation methods is crucial for rural communities. However, conventional technologies reliant on electricity or fossil fuels pose challenges as a broad segment of society lacks access to these resources. Given the context, appropriate technologies that align with local resources and needs are essential. Therefore, providing farmers with locally adapted agro-processing technologies (e.g., solar energy) and affordable, renewable energy solutions is imperative to enhance food security.

Furthermore, rural women can engage in entrepreneurship by drying food during surplus seasons. Providing solar dryers to women entrepreneurs, along with necessary credits, training in operation and maintenance, and market access, can be instrumental in alleviating food insecurity during lean seasons. In addition, increased incomes for women help reduce rural poverty, improve women's employment and empowerment, and contribute to family health and well-being through dietary improvements. Using solar dryers also supports renewable energy, which in turn contributes to a more sustainable environment.

A social business operates with a clear social mission, addressing pressing issues such as unemployment, poverty, climate change, environmental degradation, gender inequality, and access to necessities like food, education, and healthcare etc. It does so through a sustainable entrepreneurial approach. For example, ASA and Grameen Shakti, NGOs in Bangladesh, are providing solar-based technologies to rural women with necessary credit and training facilities. Hence, this paper will explore the diverse landscape of social business models adopted to enhance food security and women's empowerment, drawing evidence from Bangladesh and other global contexts. By utilizing renewable energy sources, this analysis will explore how these models foster local food systems, improve

market access, enhance nutritional outcomes, particularly for vulnerable populations and contribute to achieving the Sustainable Development Goals (SDGs) (6). While existing literature focuses on food security, this study uniquely connects social business and women's entrepreneurship through renewable energy solutions.

Status of Women in Bangladesh and Importance of Women Entrepreneurship

Gender research suggests that women face significant deprivation and discrimination in access to resources and earnings (7-9). Barriers in the labor market, for example, low levels of literacy, lack of awareness, inadequate political representation, socio-economic deprivation, entrenched social norms, religious constraints, and inequities in partnerships, particularly in rural areas, hinder women's progress (10, 11). Cultural practices like purdah confine women to domestic responsibilities or home-based labor, restricting their broader labor market engagement. Rural women encounter unique challenges: their economic activities primarily revolve around household tasks, and mobility constraints imposed by patriarchal norms limit their opportunities (12).

Women comprise nearly half of the population, yet their employment engagement rate is only 36.3% (9). They account for over 10% of all entrepreneurs in Bangladesh, with many involved in the informal sector, which provides 50-75% of total employment in developing countries (13). The informal sector allows easy market access, requiring fewer skills, less stringent registration, and minimal start-up capital (14, 15).

The food industry is the second most-favored-sector among women entrepreneurs in rural areas (16). This preference is driven by low entry barriers, availability of local resources, and alignment with traditional roles in food preparation. Opportunities range from small-scale food processing to large agribusiness ventures. According to Statista Market Insight, the Bangladeshi food market is projected to reach US\$149.90 billion by 2024, with a compound annual growth rate (CAGR) of 9.28% from 2024 to 2028 (16). Growth is driven by urbanization, rising incomes, a growing middle class, and government support for agricultural development.

Despite the promising market outlook, data on women entrepreneurs in the food sector is insufficient, hindering understanding of their contributions and the barriers they face. Factors like limited access to finance, lack of training, and socio-cultural constraints hinder women's entrepreneurial activities. More targeted policies and programs are needed to support women entrepreneurs in scaling their businesses and integrating into the broader market.

Harnessing women's entrepreneurial capacities not only promotes women's empowerment but also has the potential to improve food security, particularly in rural areas. This is especially crucial for the informal food sector, where women can leverage their cooking skills to generate income. Additionally, it allows women to work flexible hours, operate home-based businesses, and cater to local community needs, thereby enhancing their economic independence and contributing to household food security (17-19). Further research is needed to gather detailed data on women's involvement in the food industry. This can inform the development of supportive measures, such as financial assistance, capacity-building programs, and policy interventions, building a conducive ecosystem for women entrepreneurs in the food sector.

Understanding Food Security and Its Dimensions

Food security denotes the state in which everyone consistently has both physical and economic access to adequate, healthy, and safe food that meets their nutritional needs and food choices, for a healthy and active life. This concept is supported by four key dimensions: food availability, accessibility, utilization, and stability (8).

Availability hinges on domestic production or imports.

Accessibility requires adequate means or entitlements to obtain food.

Utilization depends on balanced diets, nutrient-rich foods, and clean-water.

Stability ensures continuous food availability.

While food availability and access have improved in Bangladesh, the consumption of nutritious food still falls below standard levels (8, 20). Providing Bangladeshi farmers with the necessary knowledge and tools for resilient farming is essential (20).

A report by the World Health Organization

highlighted that in 2015, 600 million people in developing countries were affected by food borne-diseases, claiming 420,000 lives each year, among them 125,000 children who never reach their fifth birthday (21, 22). The study suggested that many developing nations still need to enhance their infrastructure to manage chemical, biological, and physical hazards that significantly threaten the food supply chain (21).

Based on the past studies, this paper presented a comprehensive framework illustrating the various components of food security and insecurity as shown in Figure 1 (23). This framework breaks down food security into key elements such as availability, access, utilization, and stability. Furthermore, food security will be ensured through optimal handling of the food supply chain. Most developing nations have failed to ensure food safety due to a lack of training in hygiene standards, poor infrastructure and support, informal or home-based environments, and lack of refrigeration and they operate within unregulated local markets. This diagram clarifies the complex relationship between food security, nutrition, and health, highlighting the need to address all components to ensure a healthy population. Proper food security leads to adequate nutrition, which in turn supports good health and prevents diseases. Conversely, food insecurity results in malnutrition, which can cause a range of health issues and diseases.

Bangladesh's rankings in global food security indices highlight ongoing struggles with hunger and food access. In the 2022 Global Food Security Index, it ranked 80th out of 113 countries, scoring 54.00, reflecting widespread food insecurity (24). Nearly half of the population lacks consistent access to sufficient, nutritious food, with low-income communities especially vulnerable due to economic shocks, climate change, and rising prices. The 2023 Global Hunger Index, which ranked Bangladesh 81st with a score of 19.0, further highlights the nation's struggle (25). While categorized as "moderate hunger," this ranking point to persistent issues of undernourishment, child wasting, and child stunting. The moderate score signals that Bangladesh faces obstacles in ensuring adequate caloric intake and nutrition for its people, especially vulnerable groups such as women and children.

Seasonal food scarcity is also very common in flood

and monga-affected areas. "Monga" is seasonal food insecurity prevalent in ecologically vulnerable and economically weak areas of north-western Bangladesh. It primarily stems from a lack of employment and income before the aman rice harvest, particularly affecting rural poor households reliant on agriculture for their income. A study by PKSf showed that the percentage of households that consumed three full meals decreased from 40.6% to 4.44% during monga (8, 26).

The study also finds that male-headed households generally experience greater food security compared to female-headed households (27). This disparity reflects broader societal norms in which men typically have greater access to resources than women. Women, especially those leading their families, are often more vulnerable and disadvantaged in our social context. Thus, empowering women entrepreneurship is expected to play a vital role in ensuring food security.

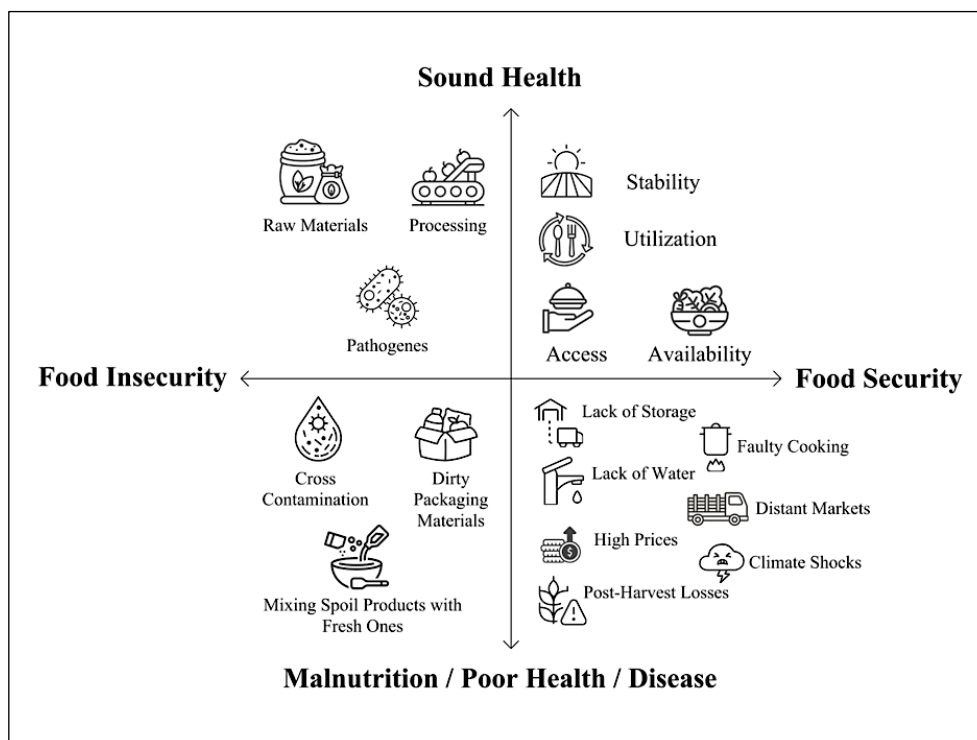


Figure 1: Food Safety, Nutrition and Food Security

The Intersection of Women Entrepreneurship and Food Security

In Bangladesh, women constitute more than half of the agricultural workforce and are primarily responsible for food production on homestead grounds (28). They perform a critical function by influencing household members' food security and nutrition through food processing and preparation, and by maintaining family hygiene and health. Furthermore, women's health and nutrition affect future generations.

Empowering women is essential for curbing malnutrition, as they manage household nutrition, prepare and process food, and ensure family health and hygiene. Women's entrepreneurship enhances women's economic empowerment by ensuring access to resources like assets, credit, irrigation,

decision-making, and advisory services. Food entrepreneurship not only ensures the availability of various seasonal foods in the off-seasons but also gives additional income for the women. Additionally, access to food and water enhances their capacity to improve household nutrition and overall family well-being. Thus, women's economic empowerment directly enhances households' food and nutritional security.

Studies indicated that women entrepreneurs are increasingly interested in agricultural businesses like livestock farming, home gardening, horticulture, and fisheries to supplement family income (29). Entrepreneurial training in livestock and crop production, mixed farming, fishing, and agricultural processing is crucial for sustainable food production and stable earnings for farm-based social entrepreneurs (30). Women

entrepreneurs contribute significantly to sustainable food production by managing family businesses and engaging in on-and off-farm activities such as poultry and dairy farming, and running vegetable shops (31). These activities boost household income and improve food security by providing nutritious food. However, their potential is limited by insufficient access to capital, training, and markets. Social businesses can play a positive role by providing entrepreneurship opportunities, market access, credit, and training.

The remaining sections of the paper will explore the theoretical foundations and methodologies. It will also analyze the current status of women and the critical need to develop women's entrepreneurship. Furthermore, the paper will present evidence on how women's entrepreneurship can enhance food security and propose a social business model on the impact of renewable energy, women's empowerment and food security. Finally, the study will conclude with practical implications.

Theoretical Underpinnings

This study proposes a social business model to promote women's entrepreneurship and boost food security through renewable energy. Drawing on existing literature, the study examines the status of women in rural communities, focusing on empowerment, labor participation, nutrition, and food security. By establishing a clear connection between women's entrepreneurship and food security, the study relies on secondary sources, including statistical reports, databases, and relevant literature reviews, to substantiate its findings.

Figure 2 shows that the intersection of various theories provides a comprehensive approach to support women entrepreneurs in overcoming structural barriers and enhancing food security. Feminist theories highlight the strong necessity for gender parity in political and legal rights. Building on this, past study underscores the significance of providing women with enhanced access to productive resources to strengthen their bargaining power within households (32). The deprivation argument further elucidates how

societal norms restrict women's access to schooling, industry experience, networking, and capital, thereby hindering their entrepreneurial success (10). Human capital theory links the lack of investment in women's education and training to limited career advancement, while cultural and disadvantage theories explain how cultural differences and labor-market disadvantages contribute to women's reduced success in business (10, 33). Agency theory complements these perspectives by focusing on balancing the interests of women entrepreneurs (agents) with those of key stakeholders such as governments, NGOs, and communities (principals) (34, 35). This alignment helps to create supportive incentive structures, monitor progress, and foster community engagement, ensuring that women entrepreneurs can effectively contribute to and benefit from enhanced food security.

Furthermore, resource-based theory (RBT) provides a framework for identifying and leveraging critical resources to empower women entrepreneurs (36). By focusing on the development and strategic use of unique resources, such as technology, financial capital, skills, and knowledge, RBT fosters sustainable competitive advantages that lead to increased food production, improved food availability and access, and better nutritional outcomes. "Ecosystem of support" approach to women's economic empowerment combined resources, agency, and outcomes or voices (37). It argued that access to and control over resources make women resilient during shocks, agency helps women identify and pursue their goals, and voices enable women entrepreneurs to negotiate for gender equality.

Integrating these theoretical frameworks underscores the multifaceted barriers women face and the necessity for comprehensive strategies to promote gender equality, support women entrepreneurship, and enhance food security. By aligning interests through agency theory and leveraging resources via RBT, stakeholders can develop and implement effective policies and programs that empower women, drive economic growth, and achieve universal food security. Figure 2 provides integrated theoretical framework of women entrepreneurship and food security.

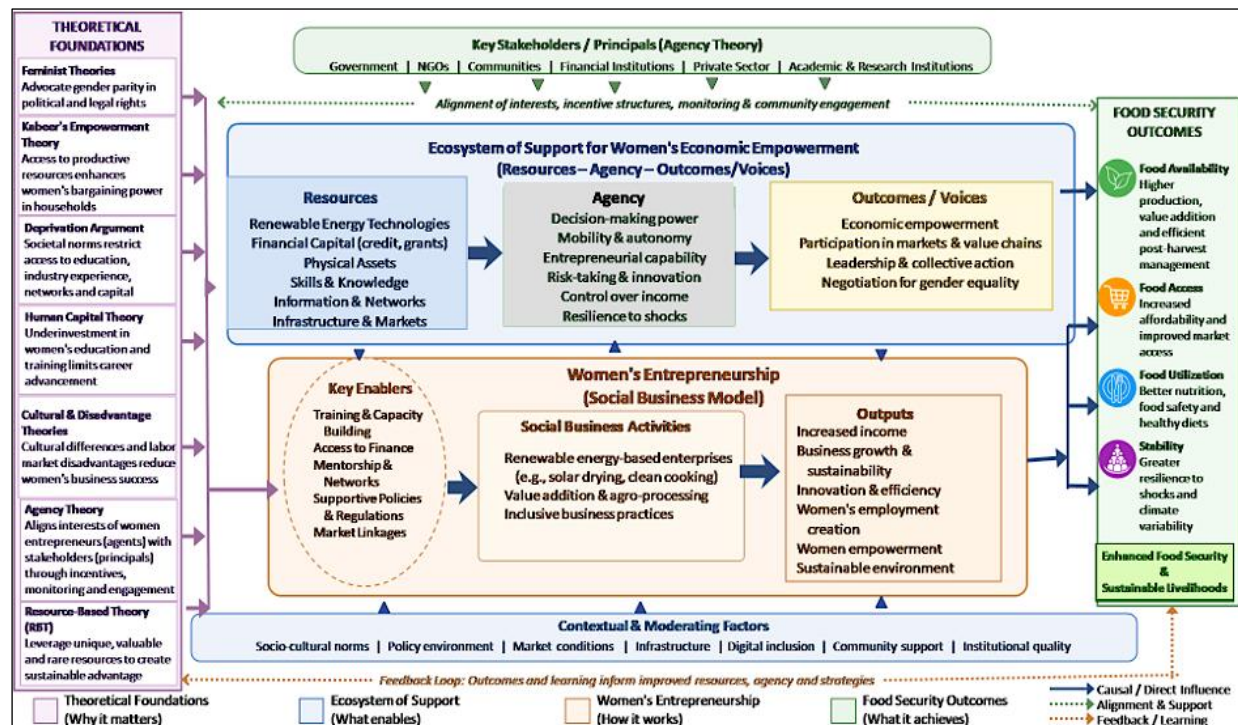


Figure 2: Theoretical Framework

Methodology

Research Approach

This study employed a comprehensive literature review and case study analysis to explore the relationship between women's entrepreneurship, renewable energy, and food security. This approach provided a detailed understanding of the existing knowledge base and practical examples of successful initiatives.

Data Collection

The data collection methodology involved an extensive literature review and case study analysis. The literature review drew on a variety of sources including academic articles, textbooks, and conference proceedings. The key databases used to source relevant literature included Web of Science, ScienceDirect, Scopus, SpringerLink, IEEE Explore, JSTOR, SSRN, and Google Scholar. This broad search ensured a comprehensive understanding of themes such as women's empowerment, entrepreneurship, labor participation, nutritional health, food security, and renewable energy. In addition to academic literature, the study analyzed statistical reports from various reputable organizations, including the Ministry of Agriculture Government of the People's Republic of Bangladesh, Agrilink, WHO, Bangladesh Bureau of Statistics, USAID, World Bank, FAO, and the National Renewable Energy Policy of Bangladesh.

These reports provided valuable quantitative data and insights into the state of women's entrepreneurship and food security.

Furthermore, databases from FAO, World Bank, IFAD, UNICEF, WHO, and WFP were used to gather additional statistical information and research findings. These databases provided extensive data on global and regional trends in food security, nutrition, and the impact of renewable energy initiatives.

The study also included the identification and analysis of successful case studies, with particular focus on rural communities. These case studies illustrated how women's entrepreneurship, supported by renewable energy, had positively impacted food security. By examining these successful initiatives, the study aimed to identify best practices and effective strategies that could be applied in other contexts.

Overall, this research methodology provided broad and multifaceted insights into the interplay among women's entrepreneurship, renewable energy, and food security, supporting the development of a robust social business model.

Search Strategy and Screening Criteria

A PRISMA 2020-guided screening process was adopted to ensure transparency as shown in Figure 3. In the initial stage of screening, a total of

186 literature from academic databases and other grey literature sources were identified using search keys like 'renewable energy and solar technologies', 'solar dryers and women entrepreneurship', 'food security and renewable energy', 'social business and sustainable development', 'women entrepreneurship and empowerment', 'agricultural innovation and rural development', 'women entrepreneurship and theories', etc. After removing duplicates, 126 documents were screened based on their titles and abstracts. Articles before 2010 and non-relevant

theories / methodologies were excluded from the list. Finally, 71 full-text articles were included for analysis. Among the references, more than half (54%) were published during the most recent period (2021-2026). This indicates a strong emphasis on contemporary research on food security, renewable energy, women's entrepreneurship and sustainable development. Around 31% references were published during 2016-2020, and 15% during 2010-2015, providing theoretical foundation and empirical support for the study as shown in Table 1.

Table 1: Year Wise Classification of Articles Reviewed and Exclusion Criteria

Time Period	Percentage (%)	Exclusion Criteria
2010-2015	15	Before 2010 publication
2016-2020	31	Non-open access article
2021-2026	54	Article in press/ under review
		Not related to research themes/ methods

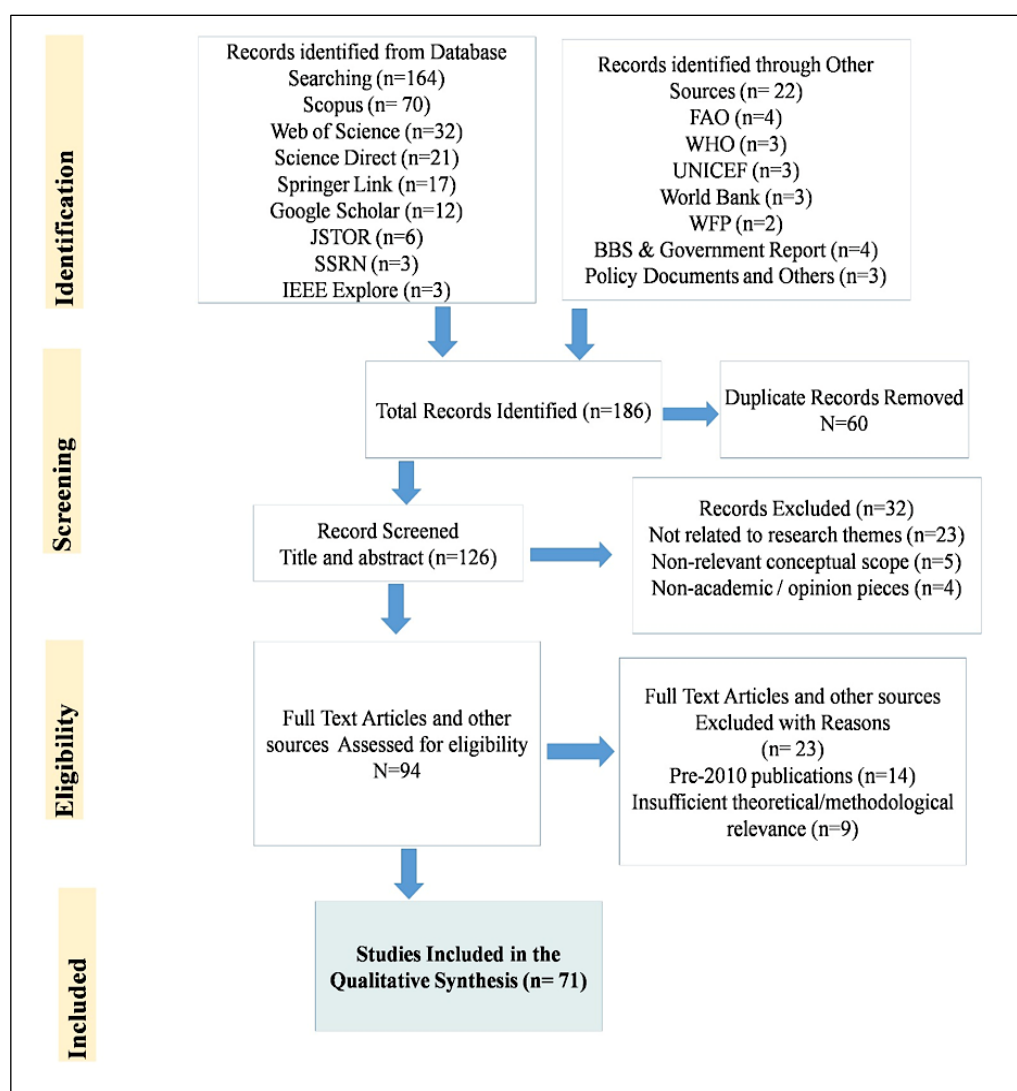


Figure 3: PRISMA 2020-based Flow Diagram of Screening and Selection Process of Reviewed Articles

Results and Discussion

Social Business models and food security

Social businesses are ventures created by social entrepreneurs (38). These entrepreneurs are motivated by a commitment to societal benefit, such as poverty reduction, job creation, climate change mitigation, enhanced food security, and improved access for disadvantaged populations to technology, healthcare, education, and credit facilities (35). In addition to these objectives, social entrepreneurs also pursue financial sustainability. Unlike conventional businesses, social businesses reinvest their earnings into growth, innovation, and the enhancement of their positive impact on society, rather than distributing dividends to shareholders (39). Social businesses operate like traditional firms, offering products and services, engaging with customers, and managing expenses and revenues. However, their primary goal is to maximize social benefit rather than profit. According to Nobel Laureate Professor Muhammad Yunus, a social business is designed to meet a social goal. For example, GrameenDanone, Grameen Veolia Water Ltd., and Grameen Euglena aim to enhance nutrition and improve food security for poor families in Bangladeshi villages (40).

Social enterprises such as the Ashoka Foundation, Aakruti Agriculture, AMUL, Farm2Food Foundation, Star Agri, BRAC Agriculture, and the Grameen Foundation play a vital role in driving agricultural development and economic transformation advancing food security in the agricultural sector (41). Past studies showed that information and communication technology based agricultural program provides knowledge that enhances crop yields, minimizes losses, and increases the incomes of smallholder farmers across Asia, East Africa, West Africa, and Latin America, significantly contributing to food security (42).

In Philadelphia, farmers' markets implement a system that enables low-income community members to access products that are typically sold at higher prices (43). In a similar vein, social entrepreneurs in Singapore operate large-scale integrated agricultural systems, offering a holistic approach to sustainable food production and minimizing the ecological footprint (44).

Studies discovered that training in solar drying techniques can significantly improve food security,

enhance women's food diversity and extending the duration of food availability. The study found that 56% of solar dryer users reported high food availability, in stark contrast to the low availability reported by most non-users (45).

In Vietnam, the "Start Your Business" training program targets women entrepreneurs aiming to establish small businesses. This initiative equips women with the skills and knowledge to create income-generating ventures, contributing to the financial stability of their families. By focusing on women, the program fosters gender equality and empowers women as economic contributors. The training promotes sustainable food production by teaching sustainable practices such as efficient resource management, organic farming, and eco-friendly packaging (36). Several studies highlight the program's positive impact on food security by improving access to nutritious food, stimulating local markets, benefiting the broader economy, and supporting sustainable development (46).

In New York City, urban gardens supported by community initiatives are transforming unused platforms, helping smallholder farmers access real-time market prices and turning agricultural spaces into productive sites, providing fresh produce to underserved neighborhoods while promoting environmental sustainability (47). Likewise, in Kenya, mobile technology advice enhances their productivity and income (48).

In Amsterdam, rooftop farming projects are being developed to better utilize urban spaces, producing local food and reducing the city's carbon footprint (49). Similarly, in Brazil, agroforestry systems are being adopted to integrate trees and shrubs into crop and livestock farming, improving biodiversity, soil health, and farmers' livelihoods (50).

Furthermore, in India, social enterprises are leveraging blockchain technology to ensure transparency and traceability in the food supply chain, thereby ensuring fair prices for farmers and quality assurance for consumers (51, 52). Savitribai Phule Mahila Ekatma Samaj Mandal (SPMESM) in India trained and equipped 200 smallholding female farmers and homemakers to dehydrate locally available, seasonal food using a domestic Solar Conduction Dryer. These dehydrated products were then incorporated into daily cooking to enhance feeding practices and

reduce malnutrition (53). Additionally, in Australia, regenerative farming practices are gaining traction, focusing on soil regeneration, water management, and increased biodiversity to create sustainable and resilient agricultural systems (54). Studies conducted in Bangladesh found that women using BAU-STR drying technology established group enterprises resulting in BDT 80105 average net profit, enhanced empowerment by reducing post-harvest stress, enabling women to invest time in revenue-generating ventures, and social networking, gain food security, and reduce family poverty slightly (55).

The Government of Bangladesh actively encourages women to pursue food entrepreneurship. For example, the "Ekti bari, Ekti Khamar" (one house, one farm) project has

improved small farmers' nutrition and socioeconomic standing. This initiative transformed household farms into comprehensive, productive enterprises, encouraging the cultivation of vegetables, fruits, and other crops, as well as the raising of fish, poultry, ducks, and livestock. This project enhanced women's empowerment and increased their contributions to income-generating activities (11).

Empowering women entrepreneurs in sustainable food production enhances food security through increased income, improved nutrition, and greater investment in health and well-being. Research showed that income is a key indicator of food security in rural areas. Figure 4 shows the intersection of women entrepreneurship and food security (56).

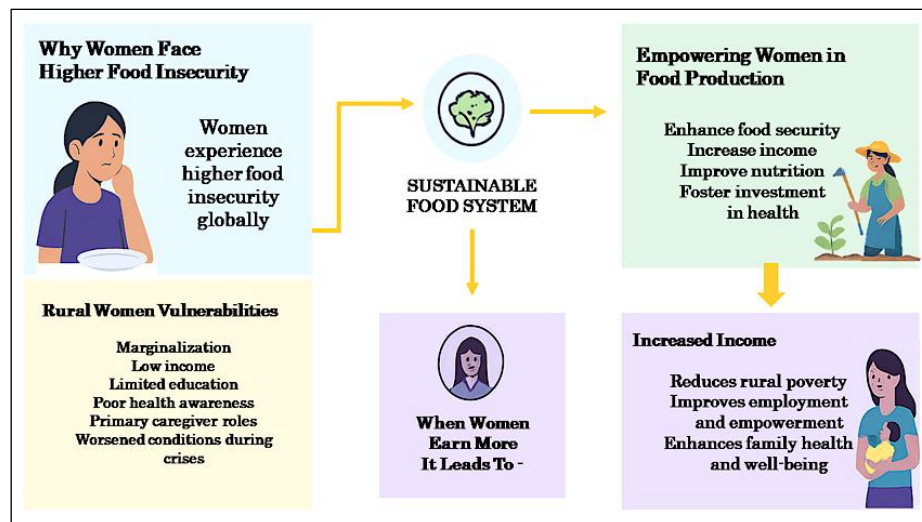


Figure 4: Intersection of Women Entrepreneurship and Food Security

Renewable Energy Solutions and Their Impacts

Energy security is crucial for green food production and sustained food security, particularly in rural settings in where 70%-80% of inhabitants are food insecure (2). Providing energy access to these underserved communities can improve various aspects of the food supply chain, such as food processing, trade, storage, and packaging, thereby reducing food insecurity (5). In Bangladesh, nearly 89% of electricity is generated from natural gas, with the remainder from coal, liquid fuels, and hydropower (57). Renewable energy sources account for just 4.47% of the nation's total energy needs (58). However, governments across the globe are

increasingly turning to renewable energy resources to decrease dependence on conventional fossil fuels (59). Bangladesh's Renewable Energy Policy of 2008 set targets for renewable energy generation at 10% of total demand by 2020, but the country achieved only 1.01% by 2021 (60, 61). New objectives aim for 20% of electricity from renewable sources by 2030, and 30% by 2040 (61).

While open-sun drying is commonly used in rural areas to dry agricultural products, it can result in significant losses of product triggered by fungal infestation, insufficient drying, affecting sensory quality, nutritional value, and the presence of rodents, birds, and insects (62). Figure 5 shows that besides sun drying, researchers also mentioned solar tunnel drying, mechanical cabinet

drying, oven drying, and freeze drying. The choice of method depends on factors like cost, especially for small-scale farmers or home-based entrepreneurs. Oven drying, freeze drying, and microwave vacuum drying require controlled

temperatures, humidity, and pressure, making them expensive and less accessible to small farmers (53). Thus, solar drying is the preferred alternative as it is cost-effective and sustainable due to the use of free solar energy.

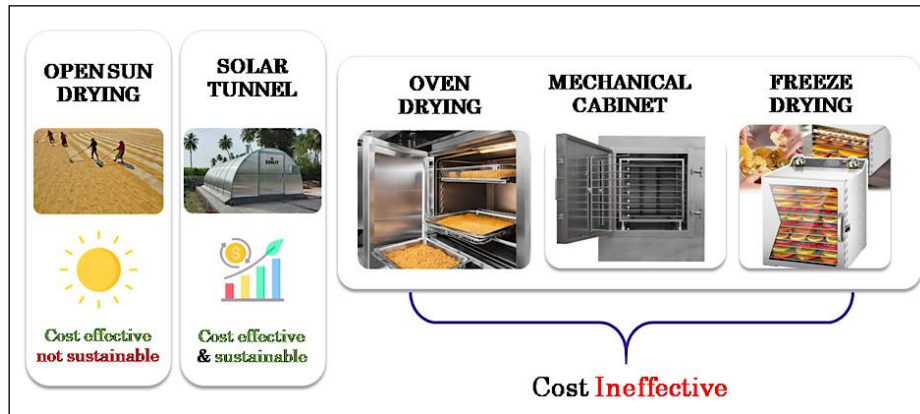


Figure 5: Drying Methods (53)

Researchers found evidence that solar dryers are more effective than open sun drying (63). Studies found that solar dryers enhanced the market competitiveness of the dried food for low moisture, high drying rate, aroma, natural color, high nutritional content, and longer shelf life (64). A study reported that fruits dried in a conventional solar dryer exhibited higher organoleptic quality (65). In the Aurangabad district of India, women using domestic solar-conduction dryers have reported increased empowerment and enhanced food security in the region (53).

Solar dryers also saves electricity, reduces uses of traditional fossil fuels thereby contribute to global energy security, enhance energy diversity, and sustainable environment: i.e., 1352,97 kWh of electricity or 128.18 liter oil was saved during cob maize drying in India, 5604 kWh electricity or 555.06 liter of diesel was used to save each year from potato chips drying in East Africa (66, 67). Researchers also claimed that the solar dryer reduces post-harvest losses (68). Therefore, solar drying presents a viable solution for low-income communities due to its cost-effectiveness and high-quality results.

Grameen Shakti, a social business enterprise in Bangladesh, provides solar energy to rural poor customers through "soft credit" programs, making the technology both affordable and capable of generating income (69). This initiative has significantly contributed to poverty reduction, women's employment, and education by transforming rural life through new income

opportunities (70). Furthermore, Grameen Shakti has empowered numerous disadvantaged rural women by setting up Grameen Technology Centers (GTCs), which offer training in energy technologies and the installation of renewable energy products (71). Recent studies showed that renewable energy has generated more than 12 million jobs globally (23). The solar photovoltaic (PV) industry alone accounts for more than three million positions. Solar thermal heating and cooling industries have added over 819,000 jobs, while solar thermal systems have contributed around 31,000 jobs. Although the USA, China, and the EU are leading in renewable energy investments, other Asian countries are also entering the solar manufacturing sector. Solar energy accounts for the most jobs in the renewable energy sector and has increased employment in developing countries by powering microenterprises, thereby contributing to poverty alleviation. Additionally, solar power is essential for plant and environmental sustainability.

Empowering women entrepreneurs in solar drying sectors requires multifaceted approaches from governments, NGOs, financial institutions, communities, and the private sector. Rural women are often unaware of solar drying technologies. Adopting solar dryers among rural women entrepreneurs may be challenging. Social enterprises, government agencies, NGOs, and international development organizations may promote the adoption of these technologies. There is also concern about the high initial cost of solar

technologies, which may hinder their large-scale adoption. Social enterprises and MFIs may step forward by providing credit to women entrepreneurs based on their needs. These organizations may also implement comprehensive training programs to equip women with the necessary skills in solar drying, maintenance and operation, business management, and marketing. Training should also include financial literacy to help women manage their enterprises effectively. Efforts are also needed to create platforms and networks that connect women entrepreneurs to local, regional, and national markets. Establishing cooperatives or associations can enhance collective bargaining power and improve market access. Advocating for policies that support women's entrepreneurship in the agricultural sector is also required. Policies should focus on incentivizing renewable energy solutions, reducing bureaucratic hurdles, and ensuring women's access to land and resources. Moreover, investing in research to continuously improve solar drying technologies and adapt them to local conditions should be given priority. Collaboration with academic institutions and research centers can drive innovation and ensure that the technologies meet the needs of rural communities. Nonetheless, promoting the adoption of social business models that prioritize

social impact over profit may enhance women's entrepreneurship among rural communities. These models can attract investment and support initiatives to improve food security and empower women. Social enterprises like Grameen Shakti, NGOs, microfinance institutions, Grameen Bank, Micro Industries Development Assistance and Support (MIDAS), government bodies, and international development organizations are expected to support women entrepreneurs by providing access to credit, markets, and essential skill development training.

The use of solar dryers is anticipated to provide a sustainable energy source and mitigate the impact of climate change. Women entrepreneurship, facilitated by these resources, is expected to enhance food security, create employment opportunities, empower women, and improve health and well-being as shown in Figure 6.

In summary, ensuring energy security and promoting renewable energy are essential for achieving sustainable food production and ensuring long-term food security. By adopting cost-effective and sustainable practices like solar drying, communities can improve food preservation, reduce food insecurity, and empower women entrepreneurs, ultimately enhancing the overall well-being and economic stability of rural areas.

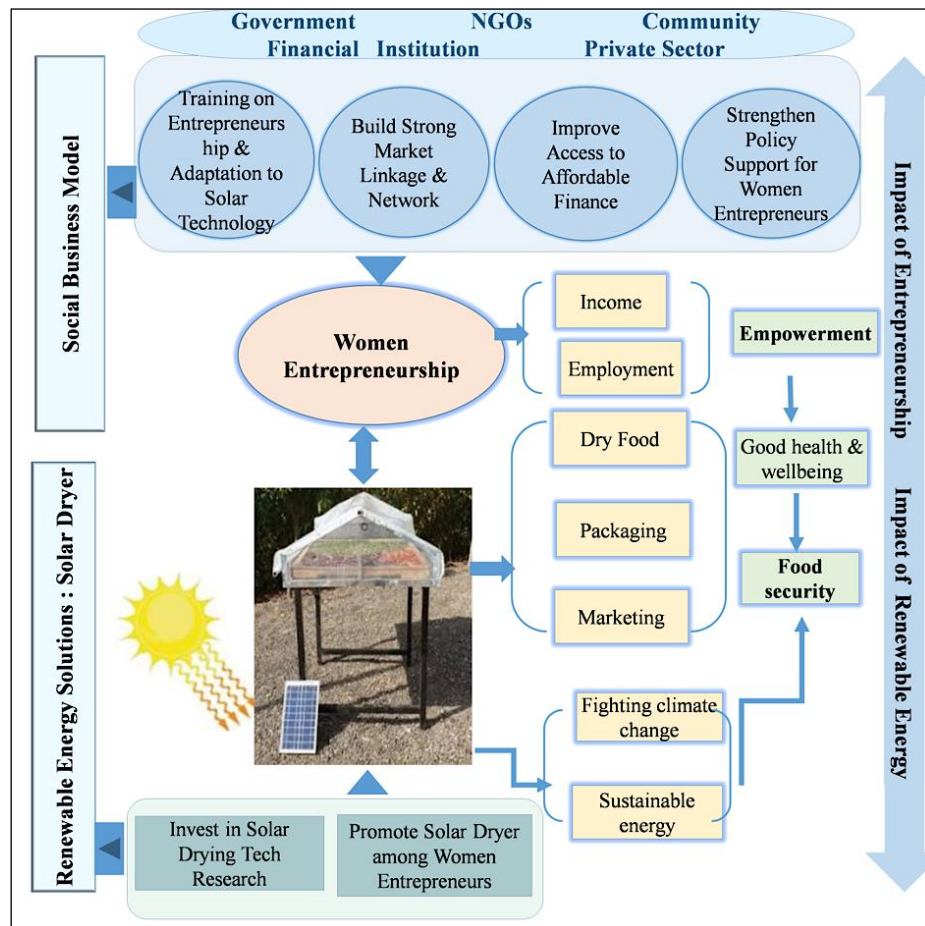


Figure 6: Social Business and Renewable Energy Solutions for Women Entrepreneurs

Figure 7 shows that solar based women entrepreneurship also plays a crucial role in achieving the Sustainable Development Goals (SDGs) set by the UN in 2015, to be completed by 2030. It directly contributes to:

- a) SDG1: Alleviating poverty
- b) SDG2: Fighting hunger
- c) SDG3: Ensuring good health and well-being
- d) SDG5: Achieving gender equality
- e) SDG7: Ensuring universal access to affordable, reliable, sustainable, and modern energy
- f) SDG8: Promoting inclusive and sustainable economic growth and ensuring decent work for all individuals
- g) SDG12: Encouraging responsible patterns of consumption and production
- h) SDG13: Taking urgent measures to address climate change
- i) SDG17: Building partnerships through social business entrepreneurship to implement these actions.

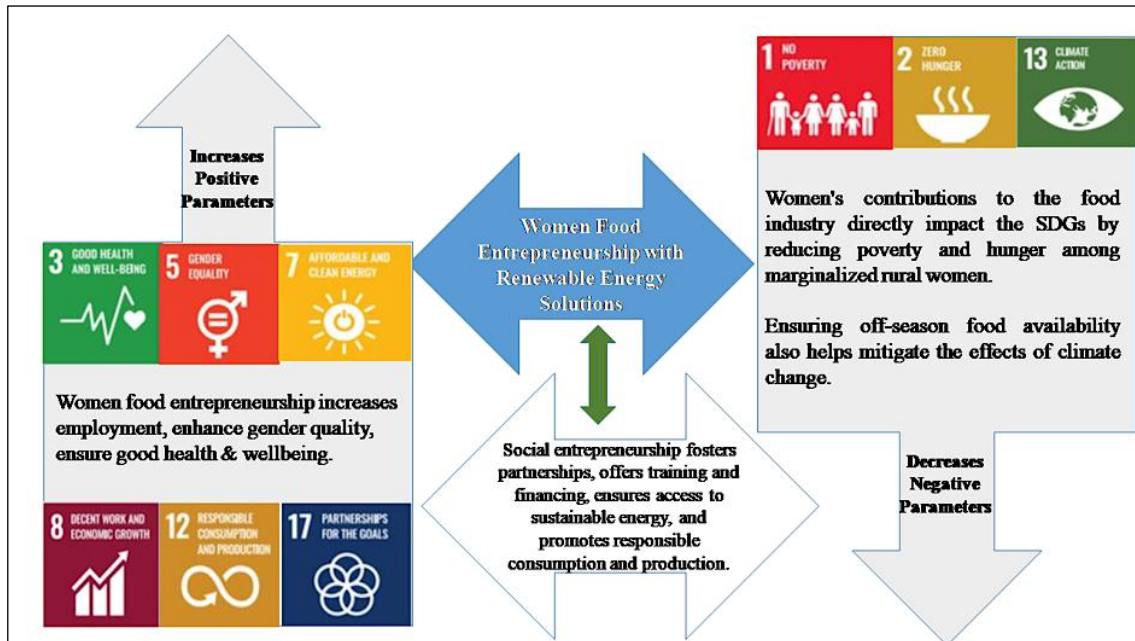


Figure 7: Contribution to SDGs

Conclusion

The study underscores the vital role of empowering women through entrepreneurship to address food security challenges in rural Bangladesh. By integrating solar drying systems, women can effectively preserve agricultural produce, thereby reduce post-harvest losses and ensure a more stable food supply. Solar drying not only maintains the nutritional value of food but also offers a sustainable, cost-effective method for food preservation. Despite the advantages, women face considerable barriers, including limited access to resources, financial capital, and markets, which hinder their full entrepreneurial potential. The social business model proposed in this study aims to address these barriers by providing capacity-building, mentorship, and financial access, thus fostering inclusive growth. This model not only enhances food security but also contributes to women's economic empowerment, ultimately leading to more resilient and sustainable food systems.

However, the study is not free from limitations. There are different types of solar dryers with varying levels of efficiency and outcomes. This study did not examine the impacts of a specific solar dryer but rather focuses on overall impact on entrepreneurship. Future research may work on the impact of a specific type of solar dryer. Moreover, future research may analyze primary data on women entrepreneurs, their

empowerment, and food security.

Abbreviations

GTCs: Grameen Technology Centers (GTCs), IRT: Institute of Research and Training, MIDAS: Micro Industries Development Assistance and Support, PV: Photovoltaic, RBT: Resource-based theory, SERI: Solar Energy Research Institute, SPMESM: Savitribai Phule Mahila Ekatma Samaj Mandal, UKM: Universiti Kembangan Malaysia, WFP: World Food Programme.

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Author Contributions

Farhana Ferdousi: Conceptualization, Manuscript Draft, Yusuf Mahbubul Islam: Conceptualization, Guided in the Overall Manuscript Design, Mofazzal Hossain: Revision, Md Khan Sobayel Bin Rafiq: Literature Review, Policy Implications. All authors have reviewed and approved the submission of this paper.

Conflict of Interest

No conflict of interest exists in the preparation and publication of this manuscript.

Data Availability

All data presented in the paper are taken from secondary sources and are cited accordingly.

Declaration of Artificial Intelligence (AI) Assistance

AI technology is used only for proofreading and English correction, not for conceptualization and writing. All figures included in this study were developed by the authors and few were polished using artificial intelligence (AI) tools. The authors take full responsibility for the content's originality, interpretation and accuracy.

Ethics Approval

This study was conducted using secondary data that are publicly available in journals, reports, and other published sources. No personally identifiable information was collected and processed. However, a formal ethics committee's approval (SEU/IRT/REB/2026/05/20-10) is also taken from the Institution's Research Board, Southeast University.

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