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Zero hunger through agroforestry: Bridging the gap to sustainable development goal 2

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Abstract

Sustainable Development Goal 2 (SDG 2) aims to eradicate hunger, ensure food security, enhance nutrition, and promote sustainable agriculture by 2030. Agroforestry emerges as a promising sustainable land use system with the potential to significantly contribute to the achievement of this goal. This paper presents a systematic review of relevant research papers and secondary literature to assess the role of agroforestry in addressing food insecurity and advancing sustainable agriculture. Through meticulous analysis of diverse research works, it is evident that agroforestry systems offer a multifaceted approach towards achieving zero hunger. These systems not only enhance food production and security but also contribute to environmental resilience and economic stability. Moreover, they provide support to smallholder farmers and enhance ecosystem services, thereby aligning with the broader objectives of sustainable development. By integrating trees and crops, agroforestry presents a sustainable and resilient model for nourishing the growing global population while simultaneously safeguarding the environment. Consequently, agroforestry emerges as a potent tool in the concerted efforts against hunger.

Keywords: Agroforestry, sustainability, food security and zero hunger

1. Introduction

Food security, defined as continuous access to adequate, safe, and nutritious food meeting dietary needs and preferences, is universally recognized as fundamental for individual survival and development (FAO, 1996). It encompasses both the availability and affordability of food, ensuring a balanced intake of macronutrients (energy, protein, fat) and micronutrients (vitamins, minerals). While the Green Revolution notably increased global crop production, it primarily targeted a few staple crops, leading to a reduction in macronutrient deficiencies but not necessarily addressing micronutrient deficiencies. Alarming, one in three people worldwide suffer from hidden hunger, characterized by micronutrient deficiencies (FAO, 2013; Tulchinsky, 2010) ^[16]. Recent reports estimate that 795 million people are undernourished globally, with approximately 2 billion experiencing one or more micronutrient deficiencies (FAO, 2023). Malnutrition, including obesity, remains a significant contributor to the global burden of disease (FAO, 2015). Micronutrient deficits often stem from low agrobiodiversity, limited dietary diversity, increased consumption of low-quality processed foods, and inadequate nutrition education. To achieve Sustainable Development Goal 2 of zero hunger, food production needs to double in the coming decades (FAO, 2018) ^[17]. However, conventional agriculture, while prevalent, has notable adverse effects on the environment and society. The intensification of modern agricultural practices, characterized by a focus on a limited number of crop species, is facing mounting challenges due to ongoing climate change, population growth, dwindling agricultural inputs, soil degradation, and land scarcity (Kumar *et al.*, 2023) ^[31]. Recent evidence suggests that crop yields in many agrarian regions have plateaued or declined (Paramesh *et al.*, 2023) ^[37]. Prolonged use of inorganic fertilizers has adversely impacted soil physicochemical and biological properties, leading to environmental degradation (Albiach *et al.*, 2000) ^[4]. Moreover, agricultural activities contribute significantly to global greenhouse gas emissions, primarily driven by the widespread use of synthetic fertilizers and pesticides. The indiscriminate application of fertilizers, notably nitrogen-based, exacerbates environmental pollution (Davidson *et al.*, 2014) ^[10].

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These challenges underscore the imperative to explore alternative agricultural systems that prioritize underutilized crop species, minimize input requirements, enhance climatic resilience, mitigate environmental harm, utilize marginal lands, and ensure long-term productivity. Diversified food systems offer a holistic approach by integrating improved food production, biodiversity conservation, ecosystem services provision, and enhanced agroecosystem stability and resilience. Agroforestry systems emerge as promising solutions to foster diverse food systems and achieve sustainable food security goals (Barrios *et al.*, 2018; Plieninger *et al.*, 2020)^[5, 38].

The diverse and nutritious food production is the major component of the food security policy, 2013. Agroforestry systems are deliberately designed to maximize the positive interactions between tree and non-tree components encompassing a wide range of practices (Upadhyay *et al.*, 2020; Dutta *et al.*, 2023)^[56, 12]. The fundamental idea behind the practice of agroforestry is that the trees are integral part of natural ecosystems providing a range of benefits in the agricultural domain (Dutta *et al.*, 2023, Castle *et al.*, 2022, Murthy *et al.*, 2016)^[12, 7, 34]. Agroforestry holds significant promise for bolstering food production by optimizing natural resource utilization, reclaiming degraded lands, and conserving resources, thereby mitigating the risk of total crop failure during adverse conditions (Santoro *et al.*, 2020; Dampney *et al.*, 2021)^[43]. Furthermore, its provision of diverse products contributes to ensuring food security by reducing dependence on a single crop. Beyond food production, agroforestry plays a pivotal role in enhancing nutrition, improving the health of rural populations, and securing livelihoods by generating income and employment opportunities (Tiwari *et al.*, 2017; Waldron *et al.*, 2017; Sahoo *et al.*, 2020)^[52, 42]. The multifaceted benefits of agroforestry extend to the enhancement of farm productivity through processes such as biological nitrogen fixation, nutrient cycling, and improving soil physicochemical properties, thereby increasing moisture availability (Rolo, 2022; Quandt, 2021)^[41, 39]. Importantly, agroforestry systems stand out for their minimal input requirements, increased climatic resilience, lower environmental impact, ability to utilize marginal lands, and capacity to sustain long-term production (Kamara *et al.*, 2019)^[28]. Hence, this paper seeks to explore the pivotal role of agroforestry in achieving food security and zero hunger while concurrently addressing climate change mitigation, enhancing environmental resilience, and promoting biodiversity conservation. Through a critical review of scientific findings, it aims to elucidate the multifaceted contributions of agroforestry towards supporting sustainable agricultural production.

2. Methodology

2.1 Data collection

This study utilized an extensive desktop review methodology to collect relevant research papers and secondary literature on agroforestry systems worldwide. The data collection process involved finding and extracting scholarly articles, reports, and publications from various academic databases and repositories. Sources such as Google Scholar, ResearchGate, ScienceDirect, Springer, Elsevier and Academia were employed.

2.2 Search strategy

The search strategy was formulated to ensure the inclusion of studies directly related to agroforestry practices, their impacts on zero hunger, food security, and related socioeconomic and environmental aspects. Keywords such as “SDG 2:Zero hunger” “Food and Agriculture” “Food security and sustainability,”

“Agroforestry and SDG 2,” “Agroforestry for zero hunger,” “Food security through agroforestry,” “Agroforestry sustainable agriculture,” “Agroforestry rural development,” “Agroforestry poverty alleviation,” “Agroforestry nutritional security,” “Agroforestry socioeconomic impacts,” “Agroforestry environmental benefits,” “Agroforestry climate resilience,” “Agroforestry sustainable livelihoods,” “Agroforestry and smallholder farmers,” “Agroforestry biodiversity benefits,” “Agroforestry ecosystem services,” “Agroforestry and agricultural productivity,” “Agroforestry for sustainable development,” “Agroforestry land management,” and “Agroforestry integrated farming systems.” were used. These terms were used singly and in different combinations to capture a wide range of literature pertinent to the goals of the study.

2.3 Inclusion and exclusion criteria

The inclusion criteria for selecting secondary literature in this study were systematically established to ensure the relevance and quality of the sources collected. Only published research papers, articles and reports written in English were included. Likewise, in order to preserve the review's thematic coherence, material unrelated to agroforestry systems or their impact on ending hunger and ensuring food security was omitted. From the chosen sources, 57 research papers that satisfied the inclusion criteria were taken out. The information on agroforestry systems worldwide was extracted from these papers through a thorough review and analysis process. Consequently, the study adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure a thorough and comprehensive review process. The reviewed paper framework analysis process is outlined in Fig. 1.

3. Results

3.1 Concept of zero hunger

A key component of the 2030 Sustainable Development Goals set forth by the UN, is the goal of achieving Zero Hunger, which calls for a radical restructuring of the world's food systems. Zero hunger aims not only to guarantee adequate food production but also to ensure fair access to safe and nutritious food for everyone (Benson, 2021; Otekinrin, 2023)^[6, 36]. Zero Hunger (SDG 2) is closely interconnected with all other SDGs, highlighting a web of interdependence that emphasizes the importance of these relationships. SDG 2 focuses on eradicating hunger and malnutrition, promoting sustainable agriculture and improving the livelihoods of smallholder farmers, especially in developing countries. According to UNDP report (2012), food secure community has better growth, development and productivity rate than those who plagued by severe hunger or are malnourished. Furthermore, food security also advantageous for the nation's economic expansion (Labadarios *et al.*, 2009)^[32]. The United Nation General Assembly Economic and Social Council's preliminary report showed that only 12% of the 140 SDG targets are on track, 50% are thought to be off track and 30% are either stagnant or have regressed below the 2015 measure (UNGA Economic and Social Council, 2023). Therefore, in order to realize the SDG 2 in span of remaining six years, sustainable agricultural practices are essential.

3.2 Agroforestry for achieving zero hunger

There are four pillars of food security namely availability, accessibility, utilization and stability. Agroforestry systems with its diverse nature and multiple benefits helps in achieving these pillars in the following ways:

3.2.1 Agroforestry for increasing food availability

Agroforestry have ability to increase food availability by directly providing tree foods along with staple crop production for increased macronutrient and micronutrient intake compared to monoculture (Agroforestry network, 2018). Agroforestry systems also help in increasing farmers income through the sale of tree products and surplus staple crops along with various supporting and regulating services (Singh *et al.*, 2017; Soto-Pinto *et al.*, 2022) ^[48]. A variety of trees within farmland and adjacent natural forest remnants, when available, sustains populations of pollinator species like insects and birds, crucial for the cultivation of numerous crops (Garibaldi *et al.*, 2013) ^[19]. All the agroforestry approaches may not be universally applicable, but they can be modified to meet location-specific requirements through the variety of possibilities derived from traditional practises (Kumar, 2006) ^[30]. The practises must be focused on providing farmer-based, environmentally sound solutions in particular, so that quality food is available to the farmers all the time. In the near future, more attention should be paid to incentives that encourage investments in agroforestry and the creation of tree crop products driven by the market.

3.2.2 Agroforestry for reducing problems associated with food accessibility

Access refers to the state when every home has access to adequate means to buy food in enough variety, quality and quantity for a healthy diet. Therefore, tackling food insecurity and malnutrition requires an increased focus on food quality (Gordon *et al.*, 2017) ^[21]. Agroforestry systems, are perhaps the most poignant examples of diverse food systems for achieving sustainable food security. Agroforestry systems can reduce problems associated with food accessibility by providing products that are usually restricted by market access. By practicing different agroforestry system various dietary products are available in farmers own fields which make access to food easy for them (Sudomo *et al.*, 2023). Other than this farmer can derive various commercial products from agroforestry system such as fiber, timber, resin, gum, spices and stimulants etc., which can be sold in market. Income derived from selling various products can be used to buy food from the market (Mellisse *et al.*, 2017) ^[33]. Usually, traditionally cultivated crop species and varieties typically boast higher levels of nutrients, protein and fibers in comparison to conventional, high-yielding crops (Jamnadass *et al.*, 2013) ^[27]. These indigenous varieties have traditionally been gathered from forests by local indigenous communities, but this practice is increasingly becoming endangered due to deforestation and habitat destruction (Seneviratne *et al.*, 2015) ^[46], as well as shifting farmer preferences and market demands. Hence, agroforestry is a potential avenue for reintegrating local knowledge and conservation of these species and varieties while concurrently cultivating other crops in order to improve the food accessibility.

3.2.3 Agroforestry for improving food utilisation

It indicates the capacity of an individual to utilise food in a way that satisfies all physiological needs. Over 2.7 billion people worldwide rely on traditional fuels such as firewood, charcoal and dung for cooking (IEA, 2011). The majority of these individuals reside in rural areas across developing Asia and sub-Saharan Africa. They form a significant portion of the one billion-strong global agricultural workforce, with 500 million being smallholder farmers responsible for 80% of food production in these regions (Nwanze, 2011) ^[35]. A considerable number also belong to the 980 million individuals enduring

extreme poverty in rural settings worldwide. In India, approximately 70% of energy consumption relies on fuelwood. Poverty affects women and men disparately, particularly in developing nations where women face pronounced deprivation, partly due to limited access to clean energy options (Kiptot and Franzel, 2012) ^[29]. Biomass energy predominates in most rural households, with women from low-income households spending more time gathering firewood compared to those from wealthier households. In regions with declining vegetation cover, women and children trek long distances in search of firewood (Sharma *et al.*, 2016) ^[47]. On farm trees in agroforestry produce fuelwood for cooking food and save time of farmers especially those in the developing countries who needs to walk miles just to collect firewood (Hagos *et al.*, 2020) ^[24]. Furthermore, raising trees on the farm land reduce the pressure on the natural forest. Agroforestry reduces the need for harmful pesticides and herbicides that affect food safety, by providing organic matter ascribable to leaf litter production which decompose to produce high SOC content along with this tree component in agroforestry create microenvironment and reduce volatilization of different nutrients in the soil (Gupta and Sharma 2009; Sirohi and Bangarwa, 2017; Zahoor *et al.*, 2021) ^[47, 49].

3.2.4 Agroforestry for achieving food stability

When food is available, accessible and utilized on sustainable basis for long term it ensures food stability (FAO, 2009) ^[15]. It includes stability in terms of food, income and economic resources. Additionally, it's critical to reduce external risks through actions and implementations that increase household resilience, such as price volatility, natural disasters, climate change, conflicts and epidemics (Aborisade and Bach, 2014; Guine *et al.*, 2021) ^[1, 22]. These measures include environmental protection, the insurance against drought and crop failure and the sustainable use of natural resources like soil, water and land. Agroforestry provides food from different species during periods of food scarcity, ensuring consistent income through product diversification and reducing the risks of focusing on one or few crops (Cialdella *et al.*, 2021; Sarveswaran *et al.*, 2023) ^[9, 45]. The worth of multipurpose tree species to farmers is not merely due to their diverse outputs but also due to their perennial and long-term sustainability. Most, if not all, agroforestry systems aim to maintain or increase production of preferred commodities as well as productivity of the land. Agroforestry can improve productivity in many different ways. These include, increased output of tree products, improved yields of associated crops, reduction of cropping system inputs, and increased labour efficiency (Raj *et al.*, 2014; Agnoletti *et al.*, 2022) ^[40, 2]. Agroforestry also provides a unique opportunity to combine the alike objectives of climate change adaptation and biodiversity conservation. It has the ability to enhance the resilience of the system for coping with the adverse impacts of climate change thus reduce the chances of total crop failure. Although agroforestry systems are not primarily designed for carbon sequestration, but there are many recent studies that substantiate the evidence that agroforestry systems can play a major role in storing carbon in aboveground as well as below ground biomass in the form of root, necromass and soil organic carbon (Jesus *et al.*, 2023, Murthy *et al.*, 2016) ^[11, 34]. Tree component in agroforestry also improve the physicochemical properties of the soil, create microenvironment to protect the understorey crop from harsh weather condition, play crucial role in water & nutrient cycling and erosion regulation etc. (Sarvade *et al.*, 2014; Chiemela *et al.*, 2018) ^[44]. The trees biomass also provides favourable environment for soil microbes and fauna which in

turn break down the biomass and release plant nutrients (Garima *et al.*, 2021). Thus, agroforestry is an important land use system in order to ensure food security and meeting the sustainable development goals.

4. Constraints in agroforestry implementation and action required

To foster the uptake of agroforestry among farmers, it's crucial to reframe it as an investment opportunity. This entails bolstering farmers' access to vital support services such as technology, credit facilities, extension programs, and insurance options, particularly the provision of comprehensive agroforestry education and training, especially targeting farmers with smaller landholdings. Additionally, there's an urgent need to overhaul any restrictive regulations that impede the implementation of agroforestry practices. Ensuring access to high-quality planting materials is indispensable for the success of agroforestry initiatives. Equally vital is the enhancement of farmers' market access to improve their economic sustainability. Policymaking in this domain should be grounded in the specific requirements and entitlements of both smallholder farmers and those with larger land holdings, taking into account the local context. Moreover, promoting research geared towards the

domestication of diverse tree species and assessing their economic feasibility is pivotal for advancing the adoption of agroforestry systems. This concerted effort towards providing comprehensive support and conducive policy frameworks can catalyze the widespread adoption of agroforestry practices among farmers, thereby fostering sustainable agricultural development. More importantly, intersectoral coordination has to be improved for better policy coherence. The research in agroforestry should be based on the following aspects:

- Which tree-crop combinations exhibit synergistic interactions specific to a given site?
- Which agroforestry systems support healthy and ecologically functional landscapes?
- How can ecosystem service delivery through agroforestry be optimized?
- How agroforestry species will help in mitigating and adapting the climate change?
- Do the adaptation benefits of agroforestry surpass those of alternative land uses?
- In what ways can payments for ecosystem services or carbon offsets help smallholder farmers?
- Which extension methods are most effective for promoting agroforestry systems?

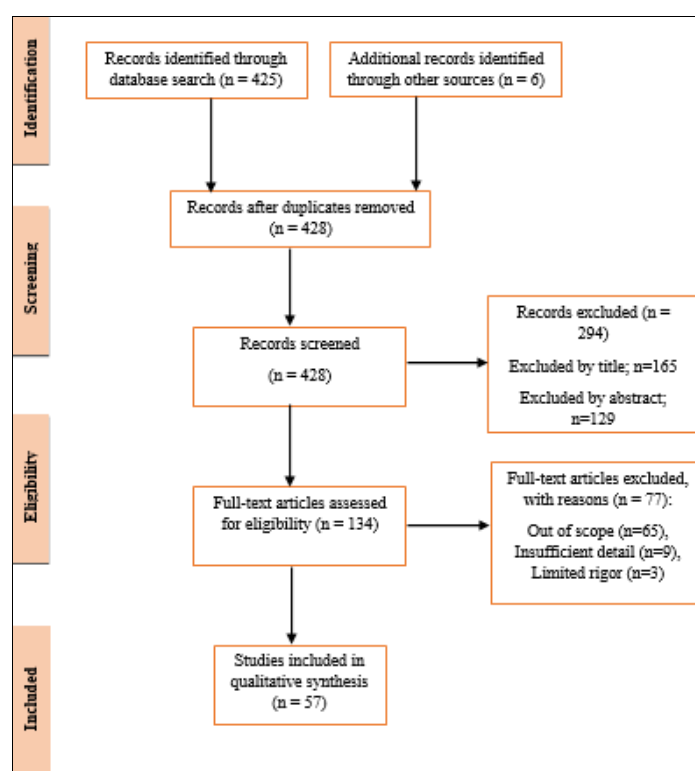


Fig 1: PRISMA flow diagram for literature identification and selection

5. Conclusion

In conclusion, achieving global food security necessitates approximately doubling food production in the forthcoming decades, a challenge exacerbated by the environmental and social detriments associated with conventional agricultural practices. Central to food security is the production of diverse and nutritious food, coupled with efforts to mitigate external risks such as natural disasters, climate change, price volatility, conflicts, and epidemics. Agroforestry emerges as a promising solution to augment food production by conserving resources, rehabilitating degraded lands, and optimally utilizing natural resources. Furthermore, its provision of a diverse array of farm products mitigates the risk of crop failure during adverse

conditions. Moreover, agroforestry plays a pivotal role in enhancing nutrition and health outcomes for rural populations while ensuring livelihood security through the generation of rural income and employment opportunities. As a sustainable land use system, agroforestry stands as the most viable option for addressing food security challenges and realizing the ambition of zero hunger on a global scale.

6. Author's contributions

Mitali Mehta contributed to the contextualization of the theme, data collection, data analysis, study design, formal analysis, visualization, writing the review and editing. Mohd. Hussnain contributed to the contextualization of the theme, writing review

and language editing. All the authors read and approved the final manuscript.

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