International Journal of Environment and Climate Change

Volume 13, Issue 8, Page 1847-1856, 2023; Article no.IJECC.101437
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Environmental Sustainability and Food Security of Traditional Agricultural Practices in India: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2023/v13i82138

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/101437

Review Article

Received: 09/04/2023
Accepted: 11/06/2023
Published: 17/06/2023

ABSTRACT

This synthesis consolidates current research on sustainable agriculture and its pivotal role in enhancing food security, conserving biodiversity, and mitigating climate change. Sourced from a wide array of references, it accentuates exercises such as organic farming, agroforestry, and diversified farming systems as cornerstone approaches, sustainable agriculture. The potential of

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these practices is also explored, highlighting the carbon sequestration capacity of agroforestry systems, the environmental advantages of organic farming over conventional methods, and the implications of diversified farming systems on food security. However, sustainable agriculture still confronts numerous challenges, especially regarding the environmental repercussions of pesticide use and the barriers hindering the adoption of sustainable farming practices. The substantial role of traditional agricultural practices, which often reflect fundamentals of sustainability and resource preservation, is also underscored. The transformative impact of integrated aquaculture-agriculture systems on small-scale farms in Southern and Southeastern Asia is with Farmer Field School experiences worldwide. Critically, the synthesis acknowledges the daunting task of feeding a burgeoning global population and the environmental ramifications of land utilization. Synthesis concludes by asserting that future research and policy must perpetually focus on these issues, aiming to generate innovative strategies for sustainable agriculture and to bolster the resilience of farming systems in the face of climate change.

Keywords: Sustainable agriculture; traditional farming practices; agroforestry; organic farming; food security.

1. INTRODUCTION

Agriculture, admitted as the backbone of the Indian economy, accounts for 16-17% of the country's GDP and employs about 60% of the labor force, emphasizing its significance in socio-economic aspects [1]. India's agricultural landscape is higly diverse, both in terms of crops grown and the farming systems employed, ranging from modern mechanized practices to traditional methods deeply rooted in local indigenous knowledge [2]. India takes pride in being the largest global producer of several crops such as spices, pulses, and it also ranks second in the production of carbohydrates sources such as rice and wheat; fruits and vegetables, fruits, and vegetables [3]. Despite these accomplishments, the Indian agricultural sector grapples with various challenges, including dependence on erratic monsoons, soil degradation, and the low efficiency of conventional farming practices, along with the looming threat of climate change [4].

In the face of growing population pressure and limited natural resources, the dual challenge of maintaining environmental sustainability and ensuring food security is becoming increasingly pressing [5]. Environmental sustainability in agriculture refers to the responsible management of natural resources, minimizing harmful impacts on the environment while preserving biodiversity and ecosystem services [6]. On the other hand, food security, as defined by the United Nations' FAO, is the condition when all people at all times have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life [7]. The relationship between these two concepts is vital because agricultural activities have significant environmental impacts, while food production and distribution are greatly influenced by environmental conditions [8].

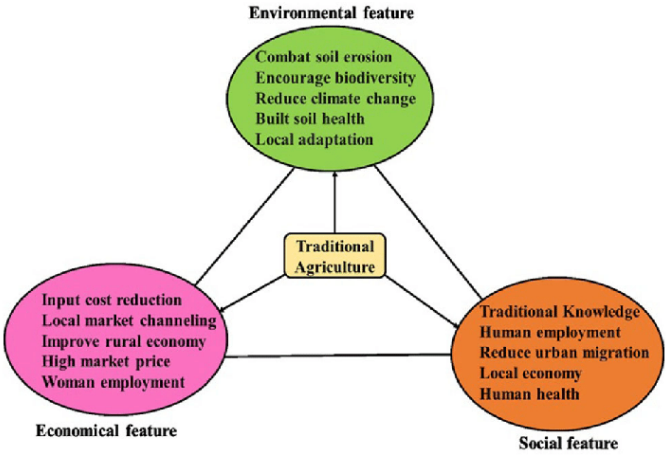

Fig. 1. Sustainability potential of traditional agriculture

Traditional agricultural practices, based on indigenous knowledge and shaped by the local socio-cultural and ecological context, have demonstrated their potential for promoting environmental sustainability and food security [9]. Traditional farming systems such as agroforestry, terracing, multi-cropping, and organic farming can minimize negative environmental impacts by enhancing soil health, conserving water, reducing chemical inputs, and maintaining biodiversity [10]. Concurrently, these practices contribute to food security by promoting crop diversity, enhancing resilience against climate shocks, and fostering local food sovereignty [11]. This paper aims to critically review the role of traditional agricultural practices in India in promoting environmental sustainability and food security. It will explore the potential benefits, challenges, and opportunities associated with these practices, offering insights for policy, research, and exercise.

2. TRADITIONAL AGRICULTURAL PRACTICES IN INDIA

Traditional agricultural practices in India have evolved over centuries, based on local ecological conditions and sociocultural practices. Vedic scriptures dating back to 1500–600 BCE reference agricultural practices, indicating that India's farming traditions have a long-standing history [12]. India, with its diverse climate and geography, hosts a wide range of traditional farming systems, each suited to its unique environmental conditions. For instance, in the northwestern states of Punjab, Haryana, and parts of Uttar Pradesh, a system of wheat and rice rotation is traditional, primarily due to the fertile Gangetic plains and availability of irrigation [13]. In contrast, the terraced farming system has been widely adopted in the hilly and mountainous regions of Himachal Pradesh and Uttarakhand, taking advantage of the natural slope for efficient water management [14]. The coastal regions, such as West Bengal, Orissa, and parts of Kerala and Tamil Nadu, have a long history of integrated rice-fish farming, which optimizes resource use by combining rice cultivation with fish rearing [15]. In the rain-fed regions of central and southern India, farmers have traditionally relied on mixed cropping and agroforestry systems, which enhance resilience against climate variability [16].

2.1 Common Traditional Farming Systems and Methods

Several traditional farming systems in India are recognized for their potential contribution to environmental sustainability and food security.

1. Organic Farming: This practice eschews synthetic inputs, emphasizing natural soil fertility management, crop rotation, and biological pest control. Sikkim has been declared India's first organic state, where farming without synthetic fertilizers and pesticides is the norm [17].
2. Agroforestry: Agroforestry integrates trees, crops, and sometimes livestock on the same land, promoting biodiversity, soil conservation, and livelihood diversification. This system is prevalent across different regions of India, including the dry regions of Rajasthan and the rain-fed regions of Madhya Pradesh and Chhattisgarh [18].
3. Multi cropping: This practice involves growing two or more crops simultaneously in the same field, enhancing land use efficiency, pest control, and crop diversity. It is widely practiced in diverse agro-ecological zones of India [19].

2.2 Current State of Traditional Farming Practices in India

In recent years, there has been a resurgence of interest in traditional farming practices due to their potential benefits for sustainability and food security. However, these practices are facing various challenges. Rapid urbanization, modern agricultural technologies, and market-oriented farming have led to the erosion of traditional knowledge and farming systems [20]. The transition towards sustainable farming systems is hindered by economic and institutional constraints, including lack of access to credit, markets, and extension services [21].

Despite these challenges, several initiatives are underway to revitalize traditional farming practices. The Government of India's National Mission for Sustainable Agriculture recognizes the role of farming systems in sustainable agricultural development and promotes their adoption through various programs [22]. Community-based initiatives, such as the traditional seed exchange programs in Odisha and the indigenous rice conservation efforts in Assam, are also contributing to the revival of traditional farming practices [23].

Table 1. Different traditional agricultural practices performed in India

S. No	Traditional Agricultural Practices	Characteristic Features	Performing Community	State
1	Forest Gardening	Selection of superior species incorporated in home garden	Mostly forest tribal	Almost entire India
2	Rice fish culture	Aquaculture along with rice farming in lower plots	Apatanis tribes	Arunachal Pradesh
3	Aquaforestry	Cultivating fish and prawn in saline water, growing coconut and other trees on pond bunds	Coastal population	Coastal areas of Andhra Pradesh
4	Shifting cultivation	Burning forest land to release nutrients for cultivation of annual and perennial crops	Nishis, Karbis, Kacharis	Northeast India
5	Kanabandi	Building barriers with small pieces of dead wood or vegetation to check wind velocity	Local farmers of arid region	Rajasthan
6	Terraces or bun cultivation	Slope and valley cultivation for improved crop production and moisture retention	Khasis, Jaintias, and Garos	Meghalaya
7	Badi cropping system	Home gardening practice for soil fertility maintenance	Baiga tribes	Madhya Pradesh
8	Live bunding/vegetative bunding	Planting bushes and grasses between field bunds for soil conservation	Local farmers	Uttar Pradesh
9	Livestock panning and fallowing	Using livestock for panning and fallowing fields to improve fertility	Aheer and Gadaria	Madhya Pradesh and Uttar Pradesh
10	Utera cropping system	Sowing the next crop before harvesting to utilize soil moisture	Baiga tribes	Madhya Pradesh
11	Alder-based farming system in Jhum cultivation	Cultivating Alder (Alnus nepalansis) in jhum cultivation for soil moisture retention and nutrient fixation	Indigenous tribes	Nagaland
12	Farming below the sea level	Creating biobuds to regulate flooding and salinity in agriculture	Farmers of coastal area	Kerala
13	Kaipad (rice-fish farming)	Rice cultivation from April to October, prawn/fish farming from November to April	Farmers of coastal area	Kerala
14	Pannendu Pantalu	12-crop system with millets, pulses, oil crops, and vegetables grown on a single piece of land	Most of the farmers	Andhra Pradesh
15	Homesteads (Kyaroo)	Growing tree species for fuel, fodder, and timber along with livestock, poultry, and fish	Most of the farmers	Himachal Pradesh and Jammu and Kashmir
16	Zabo System	Impounding water for forest, agriculture, animal husbandry, and pisciculture	Chakhesang tribe	Nagaland
17	Sanda practice (double transplanting)	Rice nursery transplanted twice in a cropping season for water management	Local farmers	Uttar Pradesh

Table 2. Yield assessment of various staple food crops in traditional versus modern agricultural practices

Agriculture Practice	Country	Cultivated Crop(s)	Description
Zero tillage	Indo-Gangetic Plains	Rice-Wheat	Up to 200-500 kg/ha increase was found in wheat yield with no-tillage practice than conventional practice under a rice-wheat cropping system
Conservation agriculture	Odisha, India	Maize and Cowpea	A 3-year combined practice of reduced tillage, cover crop, and intercropping (maize and cowpea) was performed. No significant increase was found in the yield of maize, but a considerable increase was found in intercrop cowpea.
Conservation agriculture	Keonjhar district	Maize, Cowpea, and Mustard	Maize and intercrop of cowpea followed by mustard crop. Farmers gained a profit of 754 USD/ha in reduced tillage-intercropping compared to modern practices (227 USD/ha)
Mixed cropping	China	Rice	Farmers cultivated four rice varieties on a 3000 ha landscape. More than 89% increase in yield and 44% less blast attack of pests were found compared to monocropping without the use of pesticide
Small ruminant-integrated farming	Santa Cruz, Laguna	Coconut	Sheep and goat grazing integrated with coconut farming (1991-1994) increased net profit from 60 to 356 USD
Food crop and rubber plantation	Butamarta, Indonesia	Food crops and Rubber	The farming of food crops and rubber with integrated livestock system (one cow, three goats, and 11 chickens) enhanced profit from 68 to 161 USD
Agroforestry	Haryana, India	Barley	Plant species like *Prosopis cineraria*, *Azadirachta indica*, *Acacia albida*, and *Tecomella undulata* positively enhanced the productivity of *Hordeum vulgare* (barley). Plantation of *P. cineraria* improved average yield of grain by 86% compared to conventional cultivation
Agroforestry-based cultivation	Sahel, Sahara desert	Maize and Applering Acacia	*Applering acacia* (*Faidherbia albida*) with other trees enhanced the production of maize from 1 to 3 ton/ha compared to monocropping
Agroforestry-based agriculture	Rajasthan, India	Wheat, Barley, Gram	Agroforestry of different leguminous plant species and mulching of leaves improved microbial density, C, N, and P contents towards non-plant cultivation
Optimized farming practices	Southern Italy	Durum wheat	Crop rotation minimized the use of nitrogen fertilizer and reduced GHG emission. It enhanced per kg of wheat production compared to modern agriculture

3. ROLE OF TRADITIONAL AGRICULTURAL PRACTICES IN PROMOTING ENVIRONMENTAL SUSTAINABILITY

3.1 Environmental Benefits of Traditional Farming Systems

Traditional agricultural practices in India present several environmental benefits.

1. Reduction in Synthetic Inputs and Environmental Pollution: Traditional practices generally use fewer synthetic inputs than conventional farming, often relying instead on organic matter, local resources, and biological pest management [24]. This can reduce soil, water, and air pollution from chemical fertilizers and pesticides, contributing to a healthier environment and reducing public health risks [25].
2. Preservation of Biodiversity and Ecosystems: Traditional farming systems like agroforestry and multi-cropping promote biodiversity by hosting a variety of plant and animal species [16]. Biodiversity supports ecosystem functions and services, such as nutrient cycling, pest control, and pollination, which are vital for sustainable agriculture [26].

3. Adaptation and Mitigation to Climate Change: By improving soil health, conserving water, and enhancing agro-ecosystem resilience, traditional farming systems can help adapt to climate change [27] and [28].

3.2 Comparison of Traditional and Conventional Farming Practices in Terms of Environmental Impact

Comparatively, traditional farming practices tend to have lower environmental impacts than conventional methods. Conventional agriculture, characterized by high-input monocultures, has been associated with numerous environmental issues, including soil degradation, water pollution, biodiversity loss, and greenhouse gas emissions [29]. On the other hand, traditional practices, such as organic farming, agroforestry, and multi-cropping, have shown potential in mitigating these impacts [30].

It's important to note that traditional farming systems are diverse, and their environmental impacts can vary depending on the specific practices, local conditions, and management intensity [6].

Case Studies Illustrating the Environmental Sustainability of Traditional Practices

1. The Apatani tribal farming system in Arunachal Pradesh integrates rice cultivation with fish farming in the same field. This system has been recognized by the FAO as a Globally Important Agricultural Heritage System due to its sustainability, biodiversity conservation, and adaptation to the local environment [3].
2. In the desert state of Rajasthan, farmers have developed unique water harvesting systems, such as the 'khadin' system, which allows for sustainable agriculture in an arid climate. These systems demonstrate the potential of traditional knowledge for water conservation and climate resilience [31].

4. ROLE OF TRADITIONAL AGRICULTURAL PRACTICES IN ENHANCING FOOD SECURITY

Food security is a multifaceted concept defined by the Food and Agriculture Organization as a state "when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" [7]. The four pillars of food security are:

1. Availability: The supply of sufficient quantities of food of appropriate quality.
2. Access: The ability of individuals to acquire appropriate foods for a nutritious diet.
3. Utilization: The proper biological use of food, requiring a diet providing sufficient energy and essential nutrients, potable water, and adequate sanitation.
4. Stability: The ability to access adequate food at all times and not risk losing access to food due to shocks (e.g., economic or climatic crises) or cyclical events (e.g., seasonal food insecurity) [32].

4.1 Contribution of Traditional Farming to Food Security

Traditional farming practices can significantly contribute to food security in multiple ways.

1. Diversification of Food Crops and Dietary Diversity: Traditional farming systems, such as agroforestry and multi-cropping, often involve the cultivation of diverse crop species, contributing to dietary diversity and nutritional security [16].
2. Localized Food Production and Self-sufficiency: Traditional farming systems tend to be locally adapted and can contribute to local and regional food self-sufficiency, reducing dependency on external food supplies [33].
3. Resilience of Traditional Systems to Climate and Economic Shocks: Traditional farming systems, with their emphasis on diversity, local resources, and ecological balance, can be more resilient to climate variability and economic shocks, enhancing the stability dimension of food security [34].

4.2 Comparison of Food Security Outcomes in Traditional and Conventional Farming Systems

Compared to conventional farming systems, traditional farming systems may have potential advantages for food security. For instance, diversification strategies inherent in traditional

systems can provide a variety of nutrients, thus supporting dietary diversity and nutrition security [35]. In contrast, conventional agriculture often focuses on a limited number of staple crops, which can compromise dietary diversity [36].

It is essential to acknowledge that food security outcomes depend not only on agricultural systems but also on socioeconomic factors, including income, market access, and social safety nets [32].

4.3 Case Studies Highlighting the Food Security Benefits of Traditional Practices

1. In the tribal areas of Odisha, traditional mixed farming systems, including the cultivation of millets, pulses, and vegetables, have been shown to enhance dietary diversity and nutrition security [37].
2. In Kerala, the traditional homegarden system, combining various crops, fruit trees, and livestock, contributes to household food self-sufficiency and income generation [38].

5. CHALLENGES AND OPPORTUNITIES IN PROMOTING TRADITIONAL AGRICULTURAL PRACTICES

5.1 Social, Economic, and Institutional Barriers to the Adoption and Continuation of Traditional Farming Systems

Despite the benefits of traditional agricultural practices, their adoption and continuation face several challenges.

Socially, traditional farming may be viewed as backward or less prestigious compared to modern farming, influencing farmers' decisions [39]. Economically, traditional systems may face issues such as lower productivity in terms of yield per unit area, lack of access to markets, and limited financial support compared to conventional farming [34]. Institutionally, there can be a lack of policy support, training, and research for traditional farming practices [33].

5.2 Technological and Policy Interventions to Support Traditional Farming Practices

Both technological and policy interventions can support traditional farming practices.

Technologically, advances in agroecological research can enhance the productivity and resilience of traditional systems. For instance, integrating improved seed varieties, organic fertilizers, and biological pest control methods can help optimize traditional farming systems [6].

Policy interventions can include incentives for environmentally friendly practices, support for organic certification, investment in rural infrastructure, and reforms in agricultural education and research to incorporate agroecological principles [40].

5.3 Role of Community-Based Initiatives, Knowledge Sharing, and Farmer Cooperatives

Community-based initiatives, knowledge sharing, and farmer cooperatives can play a crucial role in promoting traditional farming practices.

For example, farmer field schools and participatory research programs can facilitate knowledge exchange and capacity building for sustainable farming [41]. Farmer cooperatives can support localized food systems, facilitate access to markets, and provide a platform for collective bargaining and resource sharing [42].

5.4 Future Prospects and Directions for Traditional Agricultural Practices in India

Looking ahead, there are promising prospects for traditional agricultural practices in India. With growing recognition of their environmental and food security benefits, there is potential for scaling up these practices through a combination of research, policy, and community action.

However, it is essential to address the barriers to their adoption and ensure that they meet the needs and aspirations of farmers. In addition, integrating traditional wisdom with modern science and technology can offer innovative solutions for sustainable and resilient food systems [43].

6. CONCLUSION

Sustainable agriculture is vital for ensuring food security and biodiversity conservation, as well as combating climate change. Various practices, including organic farming, agroforestry, and diversified farming systems, have shown

promising results in different parts of the world. However, challenges such as the impact of pesticides on the environment and the adoption of sustainable farming practices persist. Research and policy need to continue to focus on strategies for overcoming these barriers and enhancing the resilience of farming systems to climate change. The study and preservation of traditional agricultural practices can also provide valuable insights into sustainable resource management. Ultimately, achieving global food security while preserving our environment requires a multi-pronged and globally coordinated approach.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/101437