Chapter

# Agroecological Approach to Farming for Sustainable Development: The Indian Scenario

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## Abstract

Agroecology is the application of ecological principles to agricultural systems and practices and the application of social justice principles to whole food systems. Agroecological farming, an unfamiliar concept to those who treat agriculture and ecology as separate subjects, refers to farming for producing food, employment and economic benefits in addition to cultural, social and environmental services and benefits. Additionally, agroecology empowers farming communities, as the key agents of change, and addresses the root cause of problems of unsustainable agricultural systems in an integrated way and provides holistic and long-term solutions to transform the food and agricultural systems. As agroecology is at the forefront of transforming farming and food system sustainability, the present chapter specifically explores the state of Indian traditional farming agroecosystems, evidence collected under the ongoing Indian UNEP-GEF project "Mainstreaming agricultural biodiversity conservation and utilization in agricultural sector to ensure ecosystem services and reduce vulnerability". We discuss traditional Indian farming in view of FAO's 10 principles of Agroecology which is key to help policymakers, practitioners and stakeholders, in planning, managing and evaluating agroecological transitions.

**Keywords:** agroecology, agrarian reforms, traditional Indian agroecosystems, agroecological transitions, sustainable agriculture

## 1. Introduction

Agroecology, barely recognized a decade ago within official circles, has taken a central stage now in global discussions on food system, environment, and development [1–7]. Agroecology offers an alternative and viable strategy for transforming food systems to deliver fair outcomes for farmers, society, and the environment [8]. Its holistic view of agroecosystems facilitates ecological and social levels of coevolution, structure, and function [8]. In particular, agroecology is acquiring a new relevance on reconstructing the post-COVID-19 agriculture, one that is able to avoid widespread disruptions of food supplies in the future by territorializing food production and consumption of healthy and sustainably produced foods [9].

The Food and Agriculture Organization (FAO) of the United Nations asserts that agroecology can help alleviate hunger and poverty as well as contribute to meeting other sustainable development goals [3]. Agroecological practices such as crop diversification, intercropping, agroforestry, mixed crop-livestock systems, soil

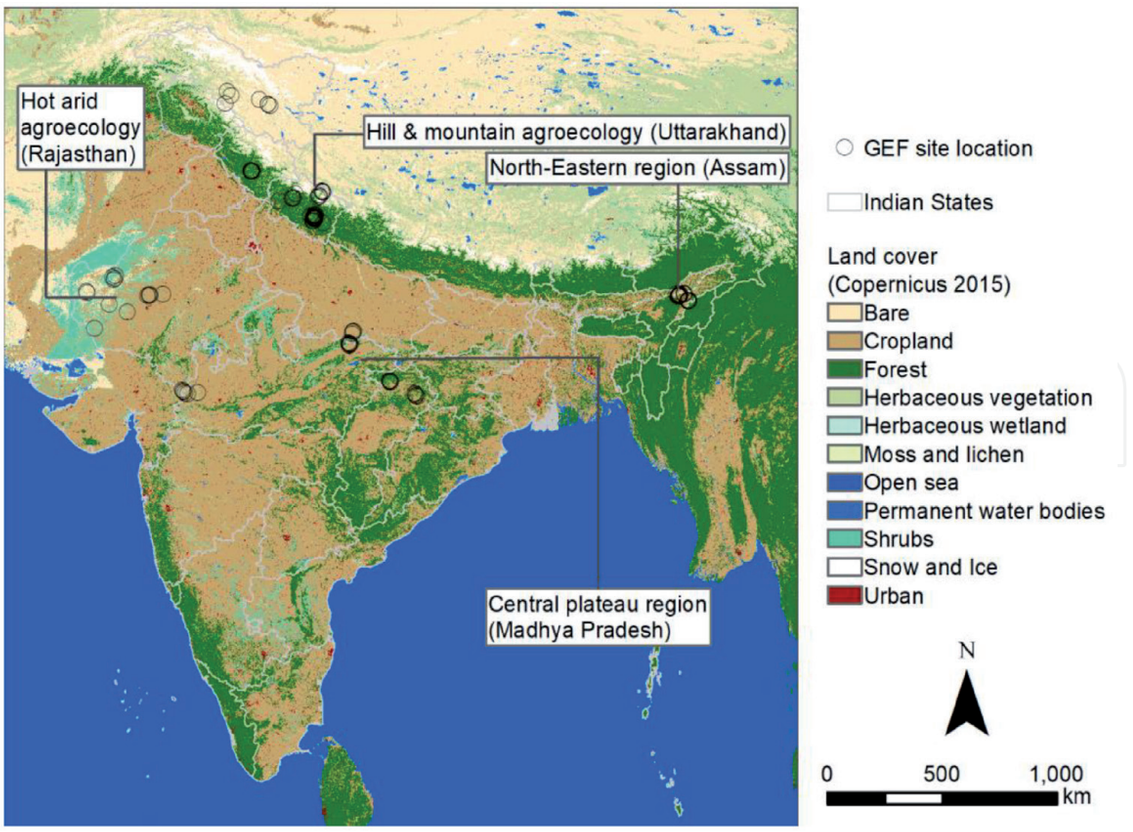


**Figure 1.**
*The four unique agroecosystems of India being studied presently under the UNEP-GEF project and the extent of agricultural area in India.*

management measures, and farmer-to-farmer networks have been reported to have positive food security and nutrition outcomes [7]. To facilitate the adoption and transition towards agroecological production systems, various efforts have helped to condense and integrate the various principles and elements put forward as key enablers of agroecology as a social movement and science [2, 6, 10, 11, 12].

Here, we use the FAO [11] approved 10 Elements of Agroecology to identify how traditional Indian farming systems contribute to each element and discuss the knowledge gaps and next steps needed to further advance adopting these principles in the Indian context. We mobilize the evidence collected from the UNEP GEF project "Mainstreaming agricultural biodiversity conservation and utilization in agricultural sector to ensure ecosystem services and reduce vulnerability". The project's evidence comes from four contrasting agroecosystems (**Figure 1**) specifically selected to cover unique crops and associated diversity adapted to diverse agricultural practices, weather pattern and socioeconomic systems. The UNEP-GEF project will directly support India's contribution to the CBD's Strategic Plan and the Aichi Targets adopted at the 10th Conference of the Parties (CoP) of the CBD, by working with farmers to document existing cultivars, and trial and scale crop diversification strategies (as one of agroecology principles) to enhance agronomic, ecological, and social outcomes [13]. Overall, we aim to offer a fundamentally different vision of the way India can produce and consume food, while contributing to the creation of equitable food systems.

## 2. Traditional world agriculture and the Indian agroecosystems

More than half of the world's cultivated land is still farmed by traditional and subsistence methods [11, 14]. This type of farming is usually better adapted to

local conditions and has been benefitted from centuries of cultural and biological evolution. Small holder farmers have inherited or developed such complex farming systems that have helped them meet their subsistence needs for centuries, even under adverse environmental conditions with scarce and locally available resources, without depending on purchased inputs. In traditional subsistence farming, nearly all of the crops or livestock raised are used to maintain the farmer and the farmer's family, leaving little, if any, surplus for sale or trade.

The small holder farmers have designed practices that optimize productivity in the long term rather than maximize it in the short term [15]. Inputs originate locally and the farm work is performed by family labours or animals that are fuelled from local sources. Smallholder farmers, working within these energy and spatial constraints, have learned to recognize and use locally available resources for agricultural production [16]. Traditional farmers are innovative, and often manage and value a plethora of products and characteristics of the farming system (e.g. resilience, food availability), beyond the yield of only one commodity. The productivity comparisons between Green Revolution and traditional agriculture systems have, therefore, been misleading and biased. In order to remedy deficiencies in modern agriculture, many scientists in developed countries are now showing enhanced interest in traditional agriculture, especially in small-scale mixed crop systems. The wealth of traditional farmers' practical experiential knowledge needs to be transferred to farming system productions before it is lost forever.

India represents nearly 7–8% of the recorded species and is one of the 17 recognized mega-diverse countries of the world, with a large landmass and varied ecosystems [17]. It represents four of the 36 globally identified biodiversity hotspots, designated by Conservation International [18]. Besides, there are 22 recognized agrobiodiversity hotspots [19] that harbor the diversity of native and naturalized crops, their wild and weedy relatives, and crop associated biodiversity in agroecosystems.

The smallholder farming in all recognized agrobiodiversity hotspots of India is mainly subsistence and highly labour-intensive. Agriculture, however, is still the biggest land use and the biggest employer in India. Nearly 55% of the population rely on agriculture and allied activities for their livelihood [20]. Smallholder and marginal farmers account for 86.2% of all farmers in India.

## 3. The 10 elements of agroecology and the traditional Indian farming scenario

The 10 elements of agroecology emanated from the FAO regional seminars on agroecology and are intended to help guide countries to transform their food and agricultural system. The elements have been grouped under three categories as shown in **Figure 2** [11]. These 10 Elements of Agroecology are interlinked and interdependent, and are a guide for policymakers, practitioners and stakeholders in planning, managing and evaluating agroecological transitions, as an analytical tool.

Kumar [21] provides an insight into the agrarian history of pre-green revolution India and the reasons contributing to the adoption of "productivity-oriented" green revolution agriculture, largely unaddressed in the contemporary literature. Das [22] defines it as a tragedy that the green revolution model of agricultural development has made such headway that it is almost impossible to do away with the concept and practice of 'increasing production' of all sectors of agriculture at the cost of the environment, economy, ecology, nutrition, diversity, etc. A country with a tradition of paddy rice and millet cultivation adopted a new agricultural development strategy based mainly on wheat. The multi-crop model existing in different

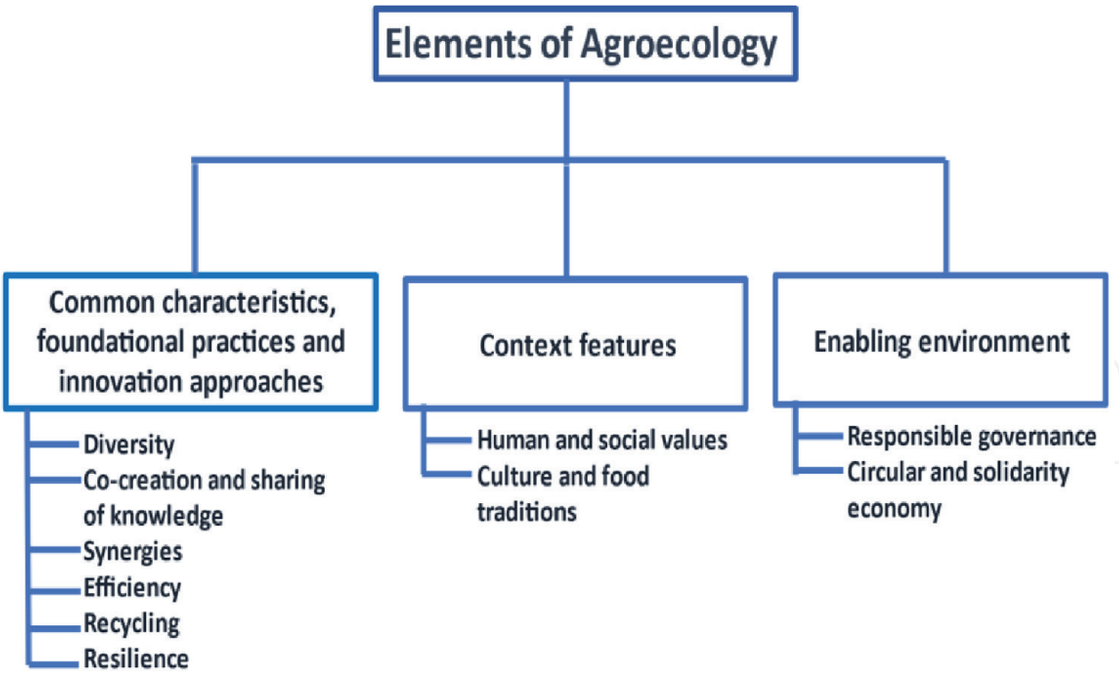


**Figure 2.**
*The 10 elements of agroecology from FAO [11].*

agroecological conditions has been neglected at the cost of environment and socio-economy, adopting a monocrop model heralded by the green revolution. The green revolution increased agricultural production around the world with the planting of mainly high yielding wheat and rice varieties that depended on applications of synthetic fertilizers, pesticides, irrigation and enhanced farm mechanization. The Green Revolution in India started in the late 1960s and with its success India attained food self-sufficiency within a decade.

The blind adherence to increasing food production without considering trade-offs or synergies with other outcomes is now being challenged [21], and enabling India to envision alternative futures that address the needs of farmers, society and nature. The self-sufficiency in two cereals, wheat and rice, in India came at the cost of another form of dependence - the import of rock phosphate for fertilizers and petroleum for irrigation pumps and tractors. Dependence on these non-renewable and fast depleting sources of energy and minerals also made agriculture a carbon-emitting sector impacting the climate. The country did not stop being vulnerable; it became vulnerable to a different set of interests. With this, deeper ecological and existential questions have emerged [22].

In the following sections, we use data collected on the UNEP-GEF project to investigate how well FAO's elements of agroecology are embedded into traditional farming landscapes in the four agroecologically contrasting regions of India, described above (**Figure 1**). This includes data collected through exploratory surveys with farmers across four representative agroecosystems based on participatory focus group discussions and observational surveys, between 2017 and 2020 [23, 24]. Farmer surveys indicate that about 80% of households have crop-livestock mixed farming across the four Indian agroecosystems, while the remaining 20% are engaged either in crop production or livestock production alone (**Table 1**). Livestock, therefore, are integral sector of all traditional farming agroecosystems. Farmers indicated that the purpose of crop production is mainly for home consumption (subsistence) and only the surplus produce is for sale.

| **Main agricultural activity (response of mean % households)** | |
|---|---|
| 1. Mainly crop production | 8.52 |
| 2. Mainly livestock production | 10.60 |
| 3. Mixed (crop and livestock) | 80.88 |
| **Purpose of crop production (response of mean % households)** | |
| 1. Producing only for sale | — |
| 2. Producing mainly for sale with some own consumption | 8.32 |
| 3. Producing mainly for own consumption with some sales | 68.84 |
| 4. Producing only for own consumption | 22.84 |

*Sourced from: Bisht et al. [23].*

**Table 1.**
*Main agricultural activity and purpose of crop production in traditional Indian farming agroecosystems.*

### 3.1 Diversity

Biological diversity is essential to life, providing the raw material for evolution and strengthening ecological stability. This also applies to crop diversity as without it, crop improvement is impossible [25]. Traditionally, farmers worldwide, have been selecting, improving, developing, protecting and using a wide range of species adapted to the often harsh or difficult pedo-climatic conditions through ingenious practices, unfortunately, these knowledge, practices and species are disappearing fast [26]. The novel agroecosystem designs appropriate to smallholder farmers are reported to have been modeled on successful traditional farming systems [27].

Deploying and protecting currently available biodiversity in production landscapes, contributes to a range of production, socio-economic, nutrition and environmental benefits. Diversification has been a common and key to agroecological transition ensuring food and nutrition security and sustainable management of natural resources in all the traditional Indian agroecosystems researched in the recent past [23, 24]. Traditional production systems in India are highly diverse, characterized by polyculture farming; crop-livestock small-scale mixed farming; greater farmer household production and dietary diversity; use of traditional agriculture innovation practices, etc. The benefits of diversification extend to human diets. Consuming a diverse range of food resources are important in contributing macro- and, micro-nutrients and, other bioactive compounds to human diets [28]. On-farm conservation have been reported to result in a number of interlinked elements that supports agricultural biodiversity as part of a dynamic system [29].

Multiple strategies exist to diversify production systems. For example, agroforestry systems organize crops, shrubs, and trees of different heights and shapes at different levels or strata, increasing vertical strata with different habitat and resources [30] for biodiversity, climate mitigation and yields. Intercropping combines complementary species to increase spatial diversity. Crop rotations, often including legumes, increase temporal diversity and soil fertility by fixing nitrogen. Crop-livestock systems in all agroecosystems rely on diversity of local breeds adapted to specific environments, that also largely contribute to household cash economy and soil fertility and labour relief [31]. Similarly, traditional fish polyculture farming systems follow the same principles to maximizing diversity [32].

In the project sites, in average, traditional systems at the community level maintain three varieties per crop (**Table 2**). Surprisingly, 55% of land is occupied by rare landraces (i.e. traditional variety) despite the current lack of economic or social

| Crop diversity variables | Diversity measure | Diversity estimates* |
|---|---|---|
| Crop species diversity | Species richness | 16.0 |
| Within- species (genetic) diversity | Cultivar richness | 47.8 |
| Area share of common landraces | Share of cropland (%) | 46.0 |
| Area share of rare landraces | Share of cropland (%) | 54.0 |
| Loss of species diversity | Species lost as a share of all known crop species** (%) | 20.0 |
| Loss of genetic (within species) diversity | Cultivars lost as a share of all known crop cultivars** (%) | 7.0 |

**Diversity estimates were made per village, as a unit of study, based on 2–3 core villages each across four representative agroecosystems of the GEF project (Sourced from: Bisht et al. [24].*
***Information on known crop species and cultivars is based on exploratory surveys.*

**Table 2.**
*Major staple food crop species and within-species (genetic) diversity in traditional farming agroecosystems.*

recognition of these conservation efforts. The crop landrace species and varietal diversity remains high, although 20% of species and 7% of varieties are considered locally extinct. Crop species and varietal diversity has been maintained with the active intervention of local farmers. The traditional landraces differing in morphological characteristics, offer farmers other valued benefits including taste, texture, cooking quality, resistance to biotic/abiotic stresses and others besides yield per se. For example, in the project sites, we found each agroecosystem has a unique crop/species combination for multiple uses including food, but also medicinal, incense and perfume which have a cultural and social value (**Table 3**).

Crop diversity loss and agroecosystems homogenization have major consequences for provision of ecosystem system services as well as food system sustainability [33]. Agroecology can help reverse these trends by managing and conserving agrobiodiversity, and responding to the increasing demand for a diversity of products that are eco-friendly and nutritious. The 'fish-friendly' rice produced from rice ecosystems, particularly in tropical and subtropical Asia including India, can be cited as an example here, which values the diversity of aquatic species and their importance for rural livelihoods [34].

Conservation is especially important in the case of disappearing, specially adapted varieties, calling for renewed efforts to support farmers as custodians of biodiversity and genetic resources [35]. Hence, the importance of policies for agroecological transition that enables, recognize and strengthen the collaboration between holders of indigenous knowledge and mainstream scientific research. This close collaboration will facilitate co-producing knowledge that will guide locally relevant and adapted interventions for preserving diversity in the field, and landscapes and for food, nutrition, ecosystem services and resilience [36].

UNEP [37] outlines some of the key issues for consideration by policymakers to ensure the continued engagement of farmers in conservation and the use of agrobiodiversity. Recognizing better the role of farmers as libraries of traditional knowledge, custodians of natural resources and providers of nutritious foods and ecosystem services reflected in a better social status and quality of life could be a good starting point to encourage farmers to continue farming. This requires the support of policymakers, for developing the mix of mechanisms or incentives that will make farming an appealing, respected and well valued profession and way of

| Agroecosystem | Main crops | Main tree/shrub agroforestry species |
|---|---|---|
| **Hill & mountain**  | Rice (*Oryza sativa*), wheat (*Triticum aestivum*), minor millets (ragi, *Eleusine coracana*; barnyard millet, *Echinochloa frumentacea*); foxtail millet, *Setaria italica*), black-seeded soybean (*Glycine max*), urd bean (*Vigna mungo*), horsegram (*Macrotyloma uniflorum*), mustard (*Brassica* spp.), sesame (*Sesamum indicum*), pseudocereals (amaranths, *Amaranthus* spp.; buckwheat, *Fagopyrum* spp.), miscellaneous vegetables, temperate fruits, etc. | Main agroforestry species for high quality fiber are drooping Fig (*Ficus semicordata*), *Grewia oppositifolia*, *G. asiatica* etc., and for edible fruits are European nettle tree (*Celtis australis*,) *Grewia oppositifolia*, *G. asiatica*, Elephant ear Fig (*Ficus auriculata*), wild Fig (*F. palmata)*, drooping fig (*F. semicordata*), willow-leaf fig (*F. nemoralis)*, wild Himalayan pear (*Pyrus pashia*), etc., beside several others. |
| **Hot arid**  | Pearl millet (*Pennisetum glaucum*), mung bean (*Vigna radiata*), sesame (*Sesamum indicum*) and cluster bean (*Cyamopsis tetragonaloba*) | Screw bean (*Prosopis cineraria*), *Ziziphus nummularia,* wild Caper bush (*Capparis decidua*), gum arabic tree (*Acacia senegal*). |
| **Central tribal plateau**  | Rice (*Oryza sativa*), wheat (*Triticum aestivum*), pigeon pea (*Cajanus cajan*), mung bean (*Vigna radiata*), urd bean, soybean (*V. mungo*) | Forestry species: gum arabic tree (*Acacia nilotica*), river tamarind (*Leucaena leucocephala*), English beechwood (*Gmelina arboria*), North Indian rosewood (*Dalbergia sissoo,* Pongame oiltree (*Millettia pinnata*), and as fruit trees: Malabar plum (*Syzygium cumini*), common guava (*Psidium guajava*), drumstick tree (*Moringa oleifera*), Indian gooseberry (*Phyllanthus emblica*), custard apple (*Annona reticulata*), jackfruit (*Artocarpus heterophyllus*). |

| Agroecosystem | Main crops | Main tree/shrub agroforestry species |
|---|---|---|
| **North-eastern region**  | Rice (*Oryza sativa*), tea (*Camellia sinensis*), vegetables, sugarcane (*Saccharum officinarum*), jute (*Corchorus olitorius*), cotton (*Gossypium* spp.), black gram (*V. mungo*), lentil (*Lens culinaris*) green gram (*V. radiata*), gram (*Cicer arietinum*), pigeon pea (*Cajanus cajan*), linseed (*Linum usitatissimum*), castor (*Ricinus communis*), sesame (*Sesamum indicum*), rapeseed & mustard (*Brassica* spp.), banana (*Musa* spp.), papaya (*Carica papaya*), orange (*Citrus* spp.), pineapple (*Ananas comosus*), areca nut (*Areca catechu*), coconut (*Cocos nucifera*), chili (*Capsicum* spp.), turmeric (*Curcuma longa*), ginger (*Zingiber officinale*), potato (*Solanum tuberosum*), sweet potato (*Ipomoea batatas*), etc. | Agar *(Aquilaria agallocha*), areca nut (*Areca catechu)*, needlewood tree (*Schima wallichii*), java cassia (*Cassia nodosa*), kassod tree (*Cassia seamea)*, white siris (*Albizzia procera*), betel (*Piper betel*), long pepper (*P. longum*), bamboos (*Bambusa* spp.), canes, timbers and other shade trees. |

*Sourced from: Bisht et al. [24].*

**Table 3.**
*Main agroforestry species of the different Indian farming agroecosystems and multiple uses (fibers, food, fodder, medicinal, wood, incense/perfume).*

living. For example, payment for ecosystem services (PES) can compensate farmers for the services and conservation efforts they provide, beyond food. Similarly, market signals that makes cheaper traditional and nutritious food, against highly subsidized and less nutritious food can also incentivize the production, consumption and profitability of traditional/indigenous crops, this off course should be in tandem with nutritional programs that highlight the nutritional, ecological, agricultural and cultural value of traditional foods. Investing in conservation, protection and use of agrobiodiversity in field and plates is an urgent need across countries for enabling and facilitating agroecological transitions and production systems that provide nutritious food and ecosystem services. Investing, therefore, where the most agricultural biodiversity occurs, subsistence farming, is an important low-risk option.

### 3.2 Co-creation and sharing of knowledge

In traditional Indian farming contexts, we find limited responsiveness of modern science to societal needs [24]. The gap between experts' knowledge and traditional innovations in actual farming situations were more pronounced when sustainability issues are being considered. Sustainability of traditional smallholder farming, therefore, requires a holistic approach and an interdisciplinary research

style. The need of a new knowledge base has been strongly felt for transition towards more sustainable agriculture [38]. Farmers greatly value local experiential knowledge which is not being optimally used and a better strategy to integrate various forms of knowledge is needed [39].

Incorporating farmers' experiential knowledge with formal agricultural knowledge is still being debated [40], as the agricultural knowledge system has always been very closely connected to the modernisation process in agriculture,

| **Management areas and various management actions based on farmers' indigenous knowledge (IK)** |
|---|
| • **Biodiversity conservation** |
| ○ Management of domesticated and wild farm biodiversity |
| ○ Local community-level on-farm and off-farm vegetation management including forestry resources |
| ○ Managing biodiversity in sacred groves/sacred landscapes |
| ○ Cultivation of medicinal plants. |
| • **Adaptation to climate change** |
| ○ The multiple and diversified livelihood skills of farmers is a source of resilience in times of uncertain weather and climate change. |
| ○ Maintaining species and genetic diversity in fields provide a low-risk buffer in uncertain weather and the diversity in production landscapes is considered a necessity rather than a choice. |
| • **Agroforestry** |
| ○ Indigenous knowledge on traditional agroforestry offers opportunities to farmers for sustainable management of resources and support socio-ecological and socio-economic benefits. |
| ○ The traditional/cultural knowledge embedded within the rural communities in different agroecosystems is the inherent identity that is unique and diverse in all respects to traditional agroforestry management and conservation. It is reflected in their cultivation system, ethnobiology and health and nutrition management. |
| • **Traditional medicine** |
| ○ Use of herbal medicines was reported by native farming communities of all Indian agroecosystems. Traditional medicines are used to cure different ailments. Herbal formulations were administered either internally or applied externally depending on the type of ailment. |
| • **Customary resource management** |
| ○ Traditional knowledge, innovations and practices duly supported by spiritual beliefs and customary laws are developed and nurtured over many generations. The natural resource-based livelihood of native communities enable them to live within the natural limits of specific territories, areas or resources upon which they depend for livelihoods and wellbeing. |
| • **Applied anthropology** |
| ○ Indigenous knowledge and institutions are contributing to more culturally appropriate and sustainable development. It is also based on the realization that native communities are not only more keenly aware of their needs than are outside development agencies but that those needs are culturally defined, demanding a substantive rather than a formal appreciation. |
| • **Impact assessment** |
| ○ Indigenous knowledge can assist bring awareness about potential impact of a project and steps taken to prevent adverse effects to the existing environment but there are currently no guidelines on how indigenous knowledge should be integrated into impact assessments. |
| • **Natural disaster preparedness and response** |
| ○ Indigenous knowledge can be transferred and adapted to other communities in disaster management, it encourages community participation and empowers communities in reducing disaster risk. |
| *Sourced from: Bisht et al. [24].* |

**Table 4.**
*Farmers' experiential knowledge and various management actions related to mainstreaming biodiversity in production landscapes.*

the 'scientification' of agriculture [41]. The science-based model advocating yield maximization, for example, often fail in actual farming situations and farmers normally find that experts' knowledge is of limited practical value [42–44]. This gap between theory and practice becomes even more pronounced when sustainability issues need to be considered and calls for a new mode of working that enables scientists to optimize knowledge within and for different local conditions. In order for agriculture to become sustainable and resilient, there is need of knowledge networking that facilitates knowledge exchanges, joint learning which facilitates the generation and innovation of new and more integrated solutions [39].

Agricultural innovations respond better to local challenges when they are co-created through participatory processes. Data on farmers' experiential knowledge and various management actions related to mainstreaming biodiversity across the four UNEP-GEF project production landscapes are presented in **Table 4**, collected through participatory focus group discussion meetings with farmers from 2 to 3 core villages in each of the four representative agroecosystems. This shows that in traditional systems farmers' experiential knowledge to agriculture cannot be seen in isolation, rather a whole range of interlinked management areas are as important.

Native farming communities in all Indian agroecosystems are especially vulnerable to weather uncertainties and climate change [24]. The community level climate change adaptation plans are often rooted in Western scientific knowledge, largely ignoring traditional farmer innovations. Incorporating indigenous knowledge into Western science-based climate change adaptation plans is, therefore, an untapped opportunity for the policymakers to integrate into climate change adaptation plans and legislate accordingly.

Farmers' knowledge is considered a better resource for managing ecosystems [45] that gives an insight on designing social systems that mesh better with ecosystems. The differential farming styles are forms of adapting to diversity within local ecosystems. Farming styles are an outcome of 'co-production', that is the ongoing interplay and mutual transformation of the social and the technical [46], including evidently local ecosystems.

As agroecology depends on context-specific knowledge, hence agroecological practices should be tailored to fit the environmental, social, economic, cultural and political context [11]. The co-creation and sharing of knowledge at multiple levels (i.e. farmers, states, ecoregions, countries) plays a central role in the process of developing and implementing agroecological innovations to address challenges across food systems including adaptation to climate change. Currently, media can facilitate fast and massive knowledge interchange with a larger reach than traditional extension officers. Hence, co-evaluating agroecological practices (i.e. extension officers, universities, research institutions and farmers) across agroecological zones and social-economic context through simple online videos and tutorials verified and curated is a new strategy at its infancy for facilitating knowledge integration and farmer-to-farmer learning at the new pace and scale that is needed. Through the co-creation process, agroecology cross-pollinate traditional knowledge and global scientific knowledge.

### 3.3 Synergies

The IAASTD [47] concluded that the future of agriculture lies in biodiverse, agroecological based farming systems that can meet social, economic and environmental goals while maintaining and increasing productivity. Agroecology is therefore increasingly recognized as the way forward for agriculture, capable of delivering productivity goals without depleting the environment and disempowering communities. The value of various ecosystem services to agriculture

is enormous and often underappreciated [48, 49]. Agroecosystems also produce a variety of ecosystem services, such as conservation of biodiversity, regulation of soil and water quality, carbon sequestration, and cultural services [50]. On the other hand, depending on management practices, agriculture can also be the source of numerous disservices, including loss of wildlife habitat, nutrient runoff, sedimentation of waterways, greenhouse gas emissions, and pesticide poisoning of humans and non-target species [51].

The trade-offs that may occur between provisioning services and other ecosystem services and disservices should be evaluated in terms of spatial scale, temporal scale and reversibility. As more effective methods for valuing ecosystem services become available, the potential for 'win-win' scenarios increases. Under all scenarios, appropriate agricultural management practices are critical to realizing the benefits of ecosystem services and reducing disservices from agricultural activities [47]. Building synergies enhances key functions across food systems, supporting production and multiple ecosystem services.

Agroecology pays careful attention to the design of diversified systems that selectively combine annual and perennial crops, livestock, trees, soils, water and other components on farms and agricultural landscapes to enhance synergies in the context of an increasingly changing climate [11].

Building synergies in food systems delivers multiple benefits. By optimizing biological synergies, agroecological practices enhance ecological functions, leading to greater resource-use efficiency and resilience. Intercropping with pulses in traditional farming landscapes saves about USD 10 million in nitrogen fertilizers globally every year through biological nitrogen fixation [52] and substantially contributes to soil health, climate change mitigation and adaptation. Crop-livestock integration in traditional farming systems also highlights synergies as about 15 percent of the nitrogen applied to crops comes from livestock manure [53]. Integrated rice systems, in Asia, combine rice cultivation with the generation of other products such as fish, ducks and trees. The total area of land available for rice cultivation in India is about 43 million hectares (ha), of which an estimated 20 million ha is suitable for adoption of the rice-fish integration system, mainly in rainfed medium lands, waterlogged lands etc. By maximizing synergies, integrated rice systems significantly improve yields, dietary diversity, weed control, soil structure and fertility, as well as providing biodiversity habitat and pest control [54].

At the landscape level, synchronization of productive activities in time and space is necessary to enhance synergies between social and nature rhythms. Pastoralism and extensive livestock grazing systems manage complex interactions between people, multi-species herds and variable environmental conditions, building resilience and contributing to ecosystem services such as seed dispersal, habitat preservation and soil fertility [55, 56]. In India, the beauty of pastoralist ways of life lies in their ability to convert the marginal resources in dry and arid regions; cold mountain meadows, and other regions to productive resources such as milk, meat, wool, and manure with marginal inputs.

While agroecological approaches strive to maximize synergies, trade-offs also occur in natural and human systems. Managing trade-offs is an endless process and innate characteristic of sustainable production systems, hence the urgent need of getting good at anticipating, managing and meditating trade-offs. Agroecology emphasizes the importance of partnerships, cooperation and responsible governance, involving different actors at multiple scales to promote synergies within the wider food system, and best manage trade-offs.

In India, a good example of actively seeking for synergies is the agroecological system of farming millets, in water deficient Tamil Nadu [57]. They ought to take into account not only water use, but also the whole gamut of political and ecological

| Agricultural inputs used in traditional farming agroecosystems* | |
|---|---|
| Use of farmer varieties or traditional landraces (%) | 80.5 |
| Use of purchased inputs (%) | |
| • Seeds | 11.3 |
| • Inorganic Fertilizer | 6.3 |
| • Pesticides | — |
| Use of improved mechanized modern farming practices (%) | 10.0 |
| Area share of crops that have non-food uses (%) | 6.3 |

**Percent of households in a village, as a unit of study. In total 2–3 villages each in four representative agroecosystems of the GEF project sites were surveyed.*
*Sourced from: Bisht et al. [24].*

**Table 5.**
*Characteristics of inputs used in traditional Indian farming agro-ecosystems.*

issues that are connected to farming such as public procurement, land reform, minimum support price, subsidized credit, agricultural extension services, and so on. The publicly procured millet output is distributed through the public distribution system, government schools, and through the network of Amma canteens in the state. Amma canteens is a food subsidization programme, a first of its kind scheme, run originally by the Government of Tamil Nadu state in India. Its success has been an inspiration for many other states of India including Odisha, Karnataka and Andhra Pradesh, who subsequently proposed similar schemes.

### 3.4 Efficiency

Agroecological systems improve the use of natural resources, especially those that are abundant and free, such as solar radiation, atmospheric carbon and nitrogen. Innovative agroecological practices produce more using less external resources. **Table 5** lists the inputs used in traditional Indian farming landscapes from across the UNEP-GEF study sites. Use of external resources or purchased inputs is minimal in traditional agroecosystems.

Increased resource-use efficiency is an emergent property of agroecological systems that carefully plan and manage diversity to create synergies between different system components. A key efficiency challenge, for example, is that less than 50 percent of nitrogen fertilizer added globally to cropland is converted into harvested products and the rest is lost to the environment causing major environmental problems [11, 58].

By enhancing biological processes and recycling biomass, nutrients and water, traditional farming communities are able to use fewer external resources, reducing costs and the negative environmental impacts of their use. Reducing dependency on external resources will ultimately empowers farmers by increasing their autonomy and resilience to natural or economic shocks. Agroecology thus promotes agricultural systems with the necessary biological, socio-economic and institutional diversity and alignment in time and space to support greater efficiency. Nonetheless, technological, social and digital innovations remain a critical need for offering farmers timely information and reducing labour constraints in already heavily overworked farmers.

### 3.5 Recycling

More recycling means agricultural production with lower economic, social and environmental costs. In all traditional subsistence Indian agroecosystems, farming

is organic by default with negligible use of inorganic fertilizers and pesticides. Organic farming is primarily aimed at cultivating the land and raising crops in such a way, as to keep the soil alive and in good health by use of organic wastes and avoiding use of synthetic inputs (such as inorganic fertilizers, pesticides, hormones, feed additives etc.). The organic cultivation rely to the maximum extent feasible upon crop rotations, crop residues, animal manures, forest litter and other off-farm organic waste, and biological system of nutrient mobilization and plant protection. The default organic agriculture in all Indian agroecosystems is a unique production management system which promotes and enhances agroecosystem health, including biodiversity, biological cycles and soil biological activity, and this is accomplished by using on-farm agronomic, biological and mechanical methods in exclusion of all synthetic off-farm inputs.

Recycling can take place at both farm-scale and within landscapes, through diversification and building of synergies between different components and activities. Agroforestry systems, for example, that include deep rooting trees can capture nutrients lost beyond the roots of annual crops [59].

Crop–livestock systems of all traditional Indian agroecosystems, promote recycling of organic materials by using manure for composting or directly as fertilizer, and crop residues and by-products as livestock feed. Integrating livestock plays a key role in nutrient cycling, accounting substantially of the economic value of all non-provisioning ecosystem services. Recycling organic materials and by-products offers great potential for agroecological innovations.

### 3.6 Resilience

Enhanced resilience of farmers, communities and ecosystems is key to sustainable food and agricultural systems. It is a well-accepted fact now that the high external input agriculture of India, with the spread of green revolution paradigm and technology, is unsustainable and has placed enormous strain on natural resource base of the economy. India's agrarian issues are being discussed widely in policy circles and media but the solutions proposed by policy makers hardly seem to be addressing the deep structural malaise that has set in at the core of India's agrarian economy [60]. In the north-western India, the core green revolution area is experiencing, massive groundwater depletion, high land degradation, decline in the levels of soil organic matter, soil erosion, loss of soil fertility without mentioning the countless impacts on human health and wellbeing. By revisiting India's agrarian history and outlining the circumstances under which the green revolution model was adopted, Kumar [21] has sought to challenge the blind adherence of high productivity agriculture that are likely to open up ways to address the future needs of the country.

The search for solutions to problems that plague Indian agriculture must begin with fundamentally questioning the green revolution paradigm. Taking agroecology as its core, the alternative path calls for making a decisive shift from a production/economic-centric approach of the green revolution paradigm towards an ecosystem/social-centric approach for resilient farming system.

High crop species and varietal (within-species or genetic) diversity provides resilience by contributing to production stability and by enabling long-term adaptation. Intercropping of varieties with varying water-use efficiencies stabilized yield in a drought-prone environment. Adaptation to long-term environmental changes may reflect both phenotypic plasticity and continued evolution [61]. Maintaining evolutionary processes ensures the generation of new combinations of genes in response to stresses and climatic variability [62]. Cultivation of varietal mixtures may confer enhanced resilience to biotic and abiotic stresses [63, 64]. Crop yield

increased by 2.2 percent overall were reported in cultivar mixtures with more functional-trait diversity in comparison to monoculture in a study examining the relationship between intraspecific diversity and yield in cultivar mixtures [65]. Cultivar mixtures also showed higher yield stability than monocultures, especially in response to annual weather variability over time.

Enabling agroecological adoption in India requires, therefore, promoting and safeguarding the free access of farmers to a range of diverse varieties will improve the resilience of production systems [66] by maintaining and supporting seed-exchange systems, and associated traditional knowledge. Farmers' traditional knowledge, preferences and practices, and social networks strongly influence the stress-prone and marginal production systems by enhanced use of genetic resources [67–69]. Informal seed-exchange systems are especially effective at maintaining high diversity, and participation in social networks has been demonstrated to facilitate access to genetic resources that can aid farmers in coping with crop failures, drought and environmental uncertainties [70]. On a landscape scale, diversified agricultural landscapes have a greater potential to contribute to pest and disease control functions [71].

### 3.7 Human and social values

Protecting and improving rural livelihoods, equity and social well-being is essential for sustainable food and agricultural systems. Across diverse settings, the traditional agricultural "living landscapes", created by native peoples and local communities are the results of the dynamic interaction of people and nature over time. These landscapes, rich in agrobiodiversity as well as inherent wild biodiversity and cultural and spiritual values, embody human ingenuity and are continually evolving [72]. These landscapes and their associated management systems have much to teach us about sustainability and resilience in the face of global change.

Agroecology places a strong emphasis on human and social values. Agroecological approaches empower communities to overcome poverty, hunger and malnutrition by building autonomy and adaptive capacities to manage their agroecosystems. Agroecological approaches also promote human rights, such as the right to good and healthy food, and stewardship of the environment so that future generations can also live in prosperity.

Agroecology also seeks to address gender inequalities by creating opportunities for women or other minorities often left behind or ignored. Women make up almost half of the agricultural workforce in India. Besides household food security, nutrition and health, women also play a vital role in conservation and sustainable use of biological diversity. Their contribution, however, remain unrecognized making them economically marginalized and vulnerable to violations of their rights [73].

**Table 6** highlights the role of women as agricultural workforce and contribution of women in household cash income in different farming agroecosystems. Self-help groups (SHG) is bringing women together under a common platform. In addition to their farming skills, women are learning stitching, embroidery, patchwork, weaving, food-processing (making use of their locally available resources), handicrafts, etc. Women enjoy the learning opportunity as well as the quality time spend together. Working for few hours a day for certain days (7–10) in a month, the women associated with the group are earning a decent amount, which represents in average about 10% of the household cash income. Participating in the SHG has helped them to gain self-respect and increase their say in decision making of family matters. Agroecology can, therefore, help open spaces for women to become more autonomous and empower them at household, community levels and beyond – for instance, through participation in producer groups. Women's participation is essential for agroecology and women are frequently the leaders of agroecology projects.

| Agroecosystems | Agriculture workforce | | Contribution of women SHG to HH cash income (%) |
|---|---|---|---|
| | Men (%) | Women (%) | |
| Hill & mountain agroecology (Uttarakhand) | 36 | 62 | 15 |
| Arid desert (Rajasthan) | 56 | 78 | 7 |
| Central plateau region (Madhya Pradesh) | 54 | 80 | 8 |
| North-eastern region (Assam) | 51 | 72 | 12 |
| Mean | 49.3 (±9.0) | 73.0 (±8.1) | 10.5 (±3.7) |

*Sourced from: Bisht et al. [24].*

**Table 6.**
*Agriculture workforce in different agroecosystems and contribution of women self-help groups (SHGs) to household (HH) cash income.*

In many places around the world, rural youth face a crisis of employment. Agroecology provides a promising solution as a source of decent jobs. Agroecology is based on a different way of agricultural production that is knowledge intensive, environmentally friendly, socially responsible, innovative, and which depends on skilled labour. Meanwhile, rural youth around the world possess energy, creativity and a desire to positively change their world. What they need is stable, good and long-term support and opportunities.

**Table 7** indicates probable areas where enhanced job opportunities at community level exist in small-holder Indian farming. As a bottom-up, grassroots paradigm for sustainable rural development, agroecology empowers people to become their own agents of change.

### 3.8 Culture and food traditions

By supporting healthy, diversified and culturally appropriate diets, agroecology contributes to food security and nutrition while maintaining the health of ecosystems.

The food we eat plays a huge role in our ability to keep our physical, mental, emotional and psychological health in balance. Further, it is being greatly recognized now that without mental health there can be no true physical health. In spite of nutrition transition trends, it is widely acknowledged that the traditional farming agroecosystems rich in crop and livestock diversity and use of wild harvested foods, the food traditions are still prevailing in the life of rural households to a greater extent. This is indeed heartening that the traditional food habits are still playing a great role in contemporary food habits of the traditional Indian farming communities; therefore, the possibility of reversing the trends in favor of dietary diversification from dietary simplification looks promising with enabling policies [74].

Culture and food traditions play a central role in society and in shaping human behavior as agriculture and food are core components of the human heritage. However, in many instances, our current food systems have created a disconnection between food habits and culture. This disconnection has contributed to a situation where hunger and obesity exist side by side, in a world that produces enough food to feed its entire population. Almost 800 million people worldwide are chronically hungry and 2 billion suffer micronutrient deficiencies [75]. Meanwhile, there has been a rampant rise in obesity and diet-related diseases; 1.9 billion people are overweight or obese and non-communicable diseases (cancer, cardiovascular disease, diabetes) are the number one cause of global mortality, a pattern also followed in India [76, 77].

| Probable areas | Job opportunities and policy support required |
|---|---|
| Organic farming | • Production of organic agricultural inputs.<br>• Post-harvest farm - to - market supply chains.<br>• Linking organic farming to marketing interventions.<br>• Infrastructure development like cold stores to avoid post-harvest losses. |
| Agro-ecotourism | • Linking ecotourism to traditional farming landscapes.<br>• Developing herbal farms, food parks, biodiversity parks, sacred grooves, fish farms, wild life parks, rural game parks in agricultural landscapes near to ecotourism sites.<br>• Training the local youths in hospitality management and environmental education. |
| Women-centric jobs, viz. embroidery, tailoring, weaving, patchwork, applique, handicraft, etc. | • Creating women-centric jobs by forming Self Help Groups (SHGs).<br>• Requisite skill development and making available all need-based equipment/resources at subsidized rates. |
| Management of Common Property Resources (CPRs)/ agroforestry species/ community forests | • Nursery raising and planting of agroforestry species.<br>• Planting diverse tree species and maintaining diverse economically important species at CPRs . |

*Sourced from: Bisht et al. [23].*

**Table 7.**
*Probable areas/sectors where job opportunities at community level exist in small-holder Indian farming.*

Agroecology seeks to cultivate a healthy relationship between people, culture and food by rebalancing traditions and modern food habits. Cultural identity and sense of place are often closely tied to landscapes and food systems. As people and ecosystems have evolved together, cultural practices and indigenous and traditional knowledge offer a wealth of experience that can inspire agroecological solutions. For example, India is home to an estimated 50 000 indigenous varieties of rice [78]- bred over centuries for their specific taste, nutrition and pest-resistance properties, and their adaptability to a range of conditions. Culinary traditions are built around these different varieties, making use of their different properties. Taking this accumulated and tasty body of traditional knowledge as a guide, agroecology can help realize the potential of territories to sustain their peoples.

## 3.9 Responsible governance

Agroecology calls for responsible and effective governance to support the transition to sustainable food and agricultural systems. **Table 8** indicates areas where largely default organic production of traditional Indian farming agroecosystems can be liked to "localized" marketing interventions through enabling marketing support. Transparent, accountable and inclusive governance mechanisms are necessary to create an enabling environment that supports producers to transform their systems following agroecological concepts and practices. Promoting community supported agriculture (CSA); linking traditional farming with school feeding (MDM) and public procurement programmes; market regulations allowing for branding of differentiated agroecological produce, and subsidies and incentives for ecosystem services, etc. are some areas where a strong political will and policy support is required for sustainable farming and food systems.

| Linking organic farming to market-oriented initiatives | Actions at community level and policy support |
|---|---|
| Community Supported Agriculture (CSA) initiatives | • Facilitate forming village-level farmer cooperatives.<br>• Consolidation and pooling of farm land for collective farming.<br>• Awareness campaigns for popularizing the nutritional superiority of organically grown native crops among urban consumers.<br>• Mobilizing urban consumers become CSA members. |
| Linking organic food to school meal (MDM) programmes | • Empowering the local district administrations to make changes to menu of MDM served in government schools to suit the local tastes.<br>• Divert a substantial Ministry of Human Resource Development (MHRD) budget for local purchasing of native healthy food for MDM directly from small-holder native farmers. |
| Enhanced market access and value chain development for local plant food resources | • Make food-based approach as major initiative for household nutrition and health.<br>• Where there is no secure market for raw produce, build capacity of farmers for processing/packaging to enhance benefit from localized sale. |

*Sourced from: Bisht et al. [23].*

**Table 8.**
*Linking organic farming to marketing interventions, community level actions and policy support.*

**Promoting Community-Supported Agriculture (CSA) Initiatives:** In small holder Indian farming, CSA initiatives are considered a better approach for sustainable agricultural development [23]. Hence, CSA can gain and play a larger role on satisfying the local/regional nutritional and food needs, where consumers are becoming more concerned about the environment, health, and animal welfare, due to food scandals related to the industrialized and globalized food systems [79–81]. Also, alternative production systems such as organic agriculture, are distancing from its original ideology due to the high industrialization and long supply chains [82, 83]. Therefore, new and alternative arrangements bringing farmers and consumers closer together and shortening supply chains, like farmers' markets, farm shops, subscription box schemes, and CSA are supporting sustainable farming and consumption [84, 85].

Reinforcing solidarity, direct human relationships, mutual trust, small scale, and respect for the environment and life overall is key in the new economic and sustainable models [86]. Most CSAs were initially based on vegetable production but a wide range of other agricultural produce is increasingly being covered now [87]. Therefore, the agroecological transition should strengthen and bring closer farmers and consumers to return to both production and food sovereignty, where farmers and consumers are empowered, autonomous, happy and where farmer's key role in culture and society valued and recognized [88].

**Linking traditional agriculture with school meal (MDM) programme:** A crucial step in enhancing the nutritional standards of MDM in traditional farming agroecosystems of India, would be through the introduction of nutritionally rich local crops in the MDM menu [23].

Structured demand guarantees large yet predictable sources of demand to smallholder or marginal farmers, thereby giving them income security. A cooperative model would be better as farmers would retain bargaining power in the supply chain. As for local schools in villages, the cooperatives themselves could supply the commodities based on the requirement, which is how it works in Brazil [89]. However, there is need of ensuring strict monitoring at every stage of procurement

and payment. For a school meal scheme to be a success for both children and farmers, like Brazil's PNAE, existing structural loopholes in both the education and agricultural sectors have to be plugged [90]. Eventually, such contracts could also be extended from school meals to include public colleges, offices and hospitals.

**Enhanced market access and value chain development for local plant food resources:** Enhanced "localized" market access and value chain development for local plant food resources can be an important initiative, making traditional agriculture in Indian agroecosystems sustainable [23]. The native crops from traditional farming areas have a greater potential for value chain development and other marketing interventions. There is enough scope for development of local and distant markets in which traditional varieties command a price premium. With enhanced awareness about the nutritional importance of local crops in the community, in well-functioning markets, the native crop landraces can be competitive and have enough potential to provide commercial opportunities fetching a premium price (**Table 9**).

**Off-farm employment for rural youth at community level:** Farm and non-farm employment opportunities at community level for rural youths is considered very vital to bring sustainability in agricultural production [23]. Policies that help to generate part-time, farm and non-farm employment at community level in rural areas can, therefore, help sustain small farms. Organic farming; agro-ecotourism; women-centric self-help groups (SHGs) for several non-farm jobs viz. embroidery, tailoring, weaving, patchwork, applique, handicraft, etc., and community managed agroforestry/forestry interventions can generate enough jobs for rural youths for year-round employment. Non-farm income already accounts for a significant proportion of household income in rural India [91]. Hence, the Mahatma Gandhi National Rural Employment Guarantee Act (MNREGA) of India, aimed at enhancing livelihood security in rural areas at the community level for reducing out-migration of rural youth in search of off-farm employment elsewhere, but the scheme often failed due to misappropriation and subversion of funds in many states [24].

**Promoting food-based approach towards community nutrition and health:** Food-based approach towards community nutrition and health under overall eco-nutrition framework, needs to be promoted [92–94]. An econutrition model has been suggested for a healthy human nutrition that can be best achieved by an

| Agroecology | Organic crops with high marketing potential |
|---|---|
| **Hill & mountain** | Common bean (*Phaseolus vulgaris*), soybean (local black-seeded, *Glycine max*), black gram (*Vigna mungo*), horse gram *(Macrotyloma uniflorum*), finger millet (*Eleusine coracana*), barnyard millet (*Echinochloa frumentacea*), buckwheat (*Fagopyrum* spp.), amaranths (*Amaranthus* spp.), aromatic (including *basmati*) and red rice (*Oryza sativa*). |
| **Hot arid** | Coriander (*Coriandrum sativum*), fennel (*Foeniculum vulgare*), fenugreek (*Trigonella foenum-graceum*), mung bean (*Vigna radiata*), pearl millet (*Pennisetum glaucum*), sesame (*Sesamum indicum*). |
| **Central tribal plateau** | Sharbati wheat (*Triticum aetivum*); durum wheat (*Triticum durum*), pigeonpea (*Cajanus cajan*); Kodo-Kutki (*Paspalum scrobiculatum* and *Panicum sumatrense*); Basmati/aromatic rice (*Oryza sativa*), and organic cotton grown in different parts of central plateau region are in great demand nationally/ internationally. |
| **North-eastern region** | Joha (aromatic) rice (*Oryza sativa*), ginger (*Zingiber officinale*), turmeric (*Curcuma longa*), chili (*Capsicum* spp.), oranges (*Citrus* spp.), black pepper (*Piper nigrum*) and pineapples (*Ananas comosus*). |

*Sourced from: Bisht et al. [24].*

**Table 9.**
*Organically grown crops with high marketing potential grown in some Indian agroecosystems.*

approach to agriculture that is biodiverse. Integrating environmental and human health, focusing especially on the many interactions between agriculture, ecology, and human nutrition are being explored [95, 96]. A more radical transformation of agriculture will be required for development of sustainable agriculture by ensuring that ecological change in agriculture is only possible with comparable changes in the social, political, cultural, and economic arenas that help determine agriculture.

An inter-disciplinary collaboration is required to define priority research questions to co-deliver economic, environmental and health goals [97]. Food-based solutions to hunger, malnutrition and poverty are of global concern and must be addressed if food and nutrition security is to be achieved in a sustainable manner [98]. According to the HLPE [99], "A sustainable food system (SFS) is a food system that delivers food security and nutrition for all in such a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised".

**Promoting indigenous food sovereignty:** Food sovereignty prioritizes local and national economies and markets and empowers peasant and family farmer-driven agriculture, artisanal fishing, pastoralist-led grazing, and food production, distribution and consumption based on environmental, social and economic sustainability [100].

In traditional Indian agroecosystems, without any formal interventions, food sovereignty exists de facto. Re-introduction of indigenous food production practices will help restore food sovereignty to native communities [101]. The food sovereignty initiatives, world over, are community-led. There are reports that many tribal communities in USA, for example, are regaining control of their food supply, they are growing traditional foods and collaborating with the federal government to retain rights for hunting and gathering [102].

The subsistence farming agroecosystems of India are expected to set the stage for future research that demonstrates how the local foods contribute to a sustainable agriculture–food–nutrition strategy. In India, there is no formal awareness about indigenous food sovereignty movements and no formal partnerships with native farming communities doing their part to address the challenges linked to ensuring indigenous food sovereignty. Formal Food Sovereignty Alliances need to put the traditional farming communities at the centre of decision-making on policies, strategies and natural resource management [103, 104].

### 3.10 Circular and solidarity economy

Circular economy is based on the principles of eliminating waste, continued use of resources and regenerating natural systems [105]. The solidarity economy refers to a wide range of economic activities that prioritizes social profitability over purely financial profits.

As per a recent tentative estimate by an Environmental Research and Action Group "CHINTAN" (*www.chintan-india.org/sites/default/files/2019–09/ Food%20 waste%20in% 20 India.pdf*), about 40% food produced in India is wasted. Despite adequate food production, it has been reported by the UN that about 190 million Indians remain undernourished. It is further estimated that the value of food wastage in India is around ₹92,000 crores (13,000 million USD) per annum. These are some bleak statistics, but they help us realize the magnitude of the problem of food waste, as much as inequity, in India. A substantial food waste along the food chain, accounting for more than 30% of the agricultural production, is also a big concern at the global level [106].

Prioritizing local markets and supporting local economic developments by creating virtuous cycles, agroecology seeks to reconnect producers and consumers through

a circular and solidarity economy [107]. Agroecological approaches help create more equitable and sustainable markets by promoting fair solutions based on local needs, resources and capacities. Shorter food circuits strengthen better producer-consumer linkages. It can increase the incomes of food producers while maintaining a fair price for consumers [107]. These include new innovative markets [108, 109] alongside more traditional territorial markets, where most smallholders market their products.

Regenerative agriculture is already gaining momentum in India. Application of circular economy principles is likely to make agricultural production more regenerative, creating a more diverse and resilient food system; preserving the integrity of the natural systems, and supporting rural livelihoods and incomes [110].

A broad range of circular economy opportunities exists for India to consider when shaping the future of its food system and agricultural activities until 2050. By capturing these opportunities, India could build a food and agricultural system that leverages the current small-farm structure to create a network of farmers, symbiotic in their practices and committed to regenerative approaches.

With on-going COVID-19 pandemic, it has forced us to revisit the way we tend to modify our agricultural practices. We need to sustain out food and nutritional security, farming with new technological developments vis-à-vis traditional agroecological methods need to be merged. In short, learnings from the past need to be married with the present practices while eyeing the future.

Kumbamu [111] critically examines and analyses place-based as well as network-based strategies of alternative development organizations that claim to be building sustainable social and solidarity economies (SSE) in the political context of neoliberal globalization. While the Indian state and market forces are actively promoting the neoliberal agri-food system, alternative development organizations are working with farmers to build the SSE based on the principles of democracy, inclusiveness, reciprocity, cooperativism, and socioecological sustainability. Using a case study approach, the article analyses how SSE initiatives are aiming to reclaim control over the local agri-food sector. Specifically, the article examines how community development organizations mobilize farmers based on the principles of agroecology and the politics of seed and food sovereignties.

## 4. Conclusion

Agroecosystem management is at a crossroads today. The challenge that modern agriculture is presently facing is not to increase productivity but to strengthen the resilience of our food production in the face of ever increasing stress on the system. The major long-term trends and challenges faced, as highlighted in the FAO [75] report, will determine the future of food security and nutrition, rural poverty, the efficiency of food systems, and the sustainability and resilience of rural livelihoods, agricultural systems and their natural resource base.

With the present global climate change and the dwindling natural resource base, it will be difficult to continue growing food in a way that will support the future human generations. This is where agroecology comes in, which is the foundation of sustainable agriculture and the best path forward for feeding the world. Agroecology provides robust set of solutions to the environmental and economic problems for design and management of sustainable farms.

The agroecological approach specifically aims to transform agriculture to build locally relevant food systems that strengthen the economic viability of rural areas based on short marketing chains, and both fair and safe food production.

Increasing dependence on hazardous pesticides and other purchased chemical inputs will degrade soil, pollute water and threaten the essential ecological services

to agriculture. By shifting farming policies and practice to embrace agroecology, we can create a food system - one rooted in productivity, resilience, equity and sustainability to sustain this and future human generations.

Traditional farming practices as adopted by small holder Indian farming communities in different agroecosystems showcase a better way forward that recognizes multifunctional dimensions of agroecological approaches to agriculture including use of locally available resources and indigenous knowledge and practices. The de facto organic biodiverse agriculture of different traditional Indian production landscapes demonstrates a bottom-up, grassroots paradigm for sustainable rural development empowering native farmers to become their own agents of change. This has power to protect and improve rural livelihoods, equity and social well-being, considered essential for sustainable food and agricultural systems.

As agroecology requires a whole-systems approach based on traditional knowledge, alternative agriculture and local food system experiences, blending modern science with farmers' experiential knowledge is considered important for enabling agricultural innovations. Agricultural innovations respond better to local challenges when they are co-created through participatory processes. The local food movement and year-round employment opportunities for rural youth are key components to help bring about the much needed transformation to agroecological farming and food systems. Making agriculture more environmentally, socially and economically sustainable will, in turn, lead to overall rural development, critical to shifting India's rural farmers out of poverty.

## Acknowledgements

The authors thank the project partners and the farmer households of different farming agroecosystems for effectively interacting and sharing valuable information on traditional farming and native food systems under the UNEP-GEF project "Mainstreaming agricultural biodiversity conservation and utilization in agricultural sector to ensure ecosystem services and reduce vulnerability in India (Project Code: A 1265)' being executed jointly by Alliance of Bioversity International and CIAT, and the Indian Council of Agricultural Research (ICAR).

## Conflicts of interest

The authors declare no conflict of interest.

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