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Review Article

Traditional Food Production Systems of Arunachal Pradesh: Clue or Conundrum for Sustainable Food System Transition

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ABSTRACT

Food systems are at the core of sustainable development. Despite global efforts to eliminate hunger and malnutrition, about 670 million people will be undernourished on our planet in 2030, which necessitates a food system transition in a way that respects "planetary boundaries". The transformation of the food system aims to provide just and equitable livelihoods, as well as to make food production, processing, and sales as local and sustainable as possible, which requires innovation adoption along the entire food value chain. Arunachal Pradesh is equipped with many traditional food production systems and there is a need to revitalize these given the emerging challenges on the food front. The Apatani eco-cultural landscape, the mixed species homegarden system, various ethnic foods, wild edibles, and entomophagy are predominant in the state. But many of these are experiencing existential challenges. The low agricultural productivity in the state and the increasing human population further compound this problem. To feed the growing population and reduce food waste- a major contributor to greenhouse gas emissions-a multi-pronged approach for conserving traditional food production systems and adopting intensive production strategies for non-traditional ones is required. Furthermore, foodstuffs such as wild fruits, vegetables, and edible insects should be collected in a way that is environmentally sound and resilient, and domestication of wild plants and farming of edible insects may be attempted to prevent the endangerment of these resources in the wild.

Keywords: Domestication, Food system transformation, Greenhouse gases, Insect farming, Local food production

INTRODUCTION

Food systems are complex structures that encompass all components and actions involved in the production, processing, supply, preparation, and utilization of food, as well as the institutional and market mechanisms that regulate them and the effects of those activities on the socioeconomic and environmental spheres [1]. It also spans a variety of policy sectors, including agriculture, environment, and health, and performs a range of social functions such as food security, welfare, and environmental conservation at local, regional, national, and global levels [2], implying a range of trade-offs. Food systems are at the core of the Sustainable Development Agenda 2030, as they integrate food security and human nutrition, ecosystem services, climate change mitigation and adaptation, and rural prosperity [3]. According to Agroforestry Network, nine out of the 17 Sustainable Development Goals (SDGs), which seek to promote social, environmental, and economic sustainability, are convergent around land-use, particularly food systems [4,5]. To maintain and advance human welfare as well as the planet's capacity for resilience, it is essential to have an effective food system that provides sustained nutrition and food security for everyone [6].

South Asia's contemporary food systems are, however, dysfunctional. There have been substantial setbacks, such as hunger, poor diet quality, unfairness, and threats to the environment. Diet-related poor health outcomes, Greenhouse Gas (GHG) emissions, environmental degradation, biodiversity loss, and food losses and waste are foremost concerns [7]. These problems are further amplified by long-term drivers of change, such as climate change, urbanization, population growth, and

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consumerism [8,9]. The COVID-19 pandemic has aggravated progress in achieving some of the United Nations Sustainable Development Goals (SDGs 2 and 3) and the Russia-Ukraine conflict has further compounded the global food crisis [10,11].

Many food systems are already vulnerable as they are unable to absorb or adapt to the stresses and shocks, and the magnitude, frequency, and intensity of such stresses will only increase in the ensuing decades [12]. The recent Global Food Policy Report thus highlighted the need for a food system transition to regain the lost ground for achieving the SDGs by 2030 and to benefit both people and the environment. According to Schmidt-Traub, et al., we may ‘‘fix the broken food system’’ by evolving integrated approaches that concurrently focus on “Efficient and resilient agriculture systems, Conservation and restoration of biodiversity, and Food security and healthy diets” [13]. Strengthening local agricultural capacities and local food production systems at the family and community levels is critical for sustainable food and nutritional security [14]. Local food initiatives strive to produce, process, and sell as many of their products locally as they can and the consumer is also aware of or given access to information about the food's origin and production.

Food production and waste are responsible for 21%-37% of GHG emissions and contribute to many other types of environmental degradation threatening the Earth’s systems. Specific emissions from food systems include methane from enteric fermentation in ruminant animals and rice paddies, carbon dioxide from land-use changes, transport, and processing, and nitrous oxide from fertilizer and compost applications [15]. Climate change also has a 30% impact on agricultural yield growth, with over 500 million small farms around the world being the most negatively impacted [16].

There is a need to develop sustainable agricultural practices to ensure food security, given the perception that contemporary farming practices are not sustainable and climate change impacts are threatening food security. The government of Arunachal Pradesh, in 2021, has adopted the “Pakke Tiger Reserve 2047 Declaration on Climate Change Resilient and Responsive Arunachal Pradesh”, which aims to promote climate-resilient development in the state (https://arunachalforests.nic.in/). Climate resilient agriculture is a central plank of the Pakke declaration. This paper attempts to provide an overview of the prospects of food system transition in the state of Arunachal Pradesh with special reference to the roles traditional food production systems play in providing food security to the people, reducing GHG emissions, and conserving agrobiodiversity.

LITERATURE REVIEW

Dominant features of the food production systems in Arunachal Pradesh

The gap between food grain production and requirement in the Northeastern Region (NER), an important biogeographic region of India, was 2.21 million tons in 2011 and it is widening year after year [17]. Despite this, the states of Arunachal Pradesh, Manipur, and Nagaland showed a surplus in food grain production, but paradoxically lifted 86.81, 84.47 and 149.97 million tons of food grains from the central pool in 2010-2011 to meet the demands, in turn, raising serious concerns about the legitimacy of the dataset [18]. The crop productivity indicators imply poor agricultural productivity for Arunachal Pradesh. Lower agricultural production and productivity in the state are probably because of the non-induction of improved and fertilizer-responsive crop varieties and the non-adoption of better crop management practices. Nonetheless, the state aims to transform its agricultural activities into commercial ventures to increase the farmers' incomes in the future (https://agri.arunachal.gov.in/).

A characteristic feature of the farming systems in Arunachal Pradesh is the "organic by default" status, where more than 80% of the crops produced are grown without the use of chemical fertilizers and other agrochemicals. Fertilizer use in Arunachal Pradesh is particularly low. During 2015-2016, the combined use of $N+P_2O_5+K_2O$ was a modest 0.56 kg ha−1, with no value reported for the year 2017-2018. The corresponding figures for the country, however, were 92.33 kg ha^{-1} and 128.02 kg ha^{-1}, respectively [19]. Making use of the circumstance, the state aims to transform its traditional organic agriculture into "organic agriculture by design with the backing of state organic policies". It also aspires to become the country's and South East Asia's organic hub by 2030, with a vision to achieve food and nutritional security by 2022 and a 25% surplus by 2030 (https://agri.arunachal.gov.in/).

There are many traditional, mixed (transitional), and modern food production systems in Arunachal Pradesh based on the food environment and food supply chains [1]. These traditional local food production systems sustained the local populations since time immemorial. Such local foods are produced at a short distance from the consumer and have fewer links in the food chain and may involve direct sales from the farmer or producer (such as farm gate sales or delivery services), free distribution within the community, or even sales through local stores (or at a market or food event) with little direct interaction between the farmer or producer.

The traditional land-use and food production systems, which abound in the state, are rich in agro biodiversity-a key factor that sustains food and nutritional security. People consume many plant and animal species, implying the need to maintain agrobiodiversity. According to Maikhuri et al, as many as 134 species are consumed in the state [20]. The state is also provided with an enormous genetic diversity for most crops, which could be exploited for bucking its low agricultural productivity pattern.

Major local food production systems

Although the food chain's power dynamics have changed and the consumer’s preferences have shifted to include more processed foods, more meat, and more dairy products, the local food production systems are still popular in Arunachal Pradesh and in the entire NER and the prominent ones with implications for food security and agro biodiversity conservation are briefly described in the ensuing section.

The Apatani system of integrated rice and fish production

Among the various cultural groups in northeast India, the Apatani tribe residing in the Ziro valley (aka. Apatani valley) in the Lower Subansiri district in the central western part of Arunachal Pradesh practice the unique Apatani system of wet-rice cultivation and land management, which is known for its sustainability. Unlike other tribal communities in NER that mainly practice shifting cultivation, the Apatani tribe depends on this system of rice cultivation, which involves organically growing 16 varieties of rice in waterlogged fields along with fish [21]. The Apatani system is designed and managed by the village institutions where land-use is regulated by traditional land laws, in which the property is owned by individuals, kinship groups, or communities through inheritance or acquisition. Rice is cultivated on lands receiving adequate rainfall or having enough stored water. Millets and maize are grown, together with vegetables such as pumpkin, bottle gourd, cucumber, beans, potato, and ginger, on rain-fed lands.

The Apatani system has evolved over centuries of cultural and biological transformations and it represents the accumulated knowledge and insights of cultivators who have interacted with adverse environments, without access to external inputs, capital, or technical skills. Its unique water management system involves strong community participation aimed at the equitable sharing of water resources. Stream water from near the forest in the foothills is collected through the main canals on the periphery of the valleys and distributed through a network of small canals so that every plot is supplied with irrigation water for rice-cum-fish culture. Water distribution is regulated by a nominated committee, which ensures equitable distribution and is empowered to resolve any conflicts arising in the matter. Terraces, made along the contour, at the higher elevations are interconnected using small bamboo pipes; pine pipes (split, hollowed-out trunks) of larger diameter are used in the lower reaches. Bio-fencing of *Phragmites sp., Ligustrum sp.*, etc. is common. Barriers of *Pinus wallichiana*, Castanopsis sp., or bamboo species (*Phyllostachys bambusoides*) are also established for soil and water conservation, making it an innovative agroforestry practice.

The soil nutrient status of the Apatani fields is maintained by recycling agricultural wastes, paddy straw, rice husk, ash, weeds, etc. Paddy stubbles (60 cm or 70 cm long) are left in the field at harvesting, and the same is burnt in situ subsequently. Field weeds and biodegradable wastes from the homesteads (vegetable waste, poultry, and piggery waste) are also incorporated into the soil. Burnt bice husk after milling is applied in the field prior to irrigation. The household's wastewater is also drained to the irrigation canals providing a good source of nourishment for the crop. Livestock grazing after rice harvest (November-March) is widespread and their excreta invariably enrich soil fertility. In addition, the decomposed leaf litter from the forest floor is collected through separate pipes connected to the main canal so that it goes on to the plots. Fish excreta are another source of plant nutrients.

Fish forms an important part of the diet of the Apatanis and fetches subsidiary incomes too. Capture fisheries systems involving the naturally available *talinguyi* (*Channa sp.*) and *papinguyi* (*Puntius sp.*) fishes in the paddy fields were practiced earlier. The concurrent paddy-fish culture of common carp (*Cyprinus carpio*), however, is popular now in the waterlogged rice fields [21]. The smallholder farmers also undertake livestock production to augment food production, diversify and increase farm income, and exploit the under-utilized resources [22]. This practice of paddy-fish culture has the potential of becoming commercially vibrant if the people and the government work toward its development.

The Apatani system is characterized by its potential for optimum utilization of available natural resources, low soil erosion, and onsite soil nutrient conservation. There is less reliance on exogenous inputs-fertilizers, agrochemicals, feeds, energy, etc. By-products and residues originating in one component of the system become inputs for another "productive" activity, thus reducing waste and making the system sustainable. Given these unique attributes, the Apatani Cultural Landscape of Ziro valley has been proposed as a UNESCO World Heritage site (https://whc.unesco.org/en/tentativelists/5893/).

Homegardens and other agroforestry systems

Tropical homegardens, one of the oldest forms of managed land-use systems, are widespread in the NER (Figure 1).Homegardens are an adjunct to the house, where select trees, shrubs, and herbs are cultivated for edible products and cash income, as well as for a diverse range of outputs that have both production and service values including aesthetic and ecological benefits. The range of homegarden products includes fruits, nuts, vegetables, medicines, resins, firewood, and the like. Much of the homegarden produce is consumed at home or freely distributed within the community. A small portion may also be sold in the local markets to earn cash income. However, data on the relative proportion of homegarden products sold in the market or consumed at home are not available.

Figure 1: A multispecies homegarden in Namsai district of Arunachal Pradesh

Homegardening has been a way of life for millennia and is still essential to the local subsistence economy and food security of the people of Arunachal Pradesh. Homegardens represent multispecies, multistrata systems and are often regarded as the "epitome of sustainability". High species diversity is an intrinsic feature of the homegardens in Arunachal Pradesh, as elsewhere [23]. But they have received relatively little scientific attention in the state and are frequently being converted into tea gardens lately.

The Apatani tribal farmers have developed an integrated "bamboo+pine homestead agroforestry system" over the years. The potential role of bamboo+pine homestead agroforestry appears to be the supply of materials for housing, fencing, and the construction of sacrificial altars during festivals, handicraft production, food, and medicines, providing cash income, and protecting the soil from erosive forces. The pine trees included in the system help in better nutrient cycling and the pine needles are also used for soil mulching. The bamboos additionally provide many cultural ecosystem services (e.g., spiritual values as a divine tree). Integrated bamboo+pine agroforestry in Ziro Valley has been a vital feature of the local landscape and is also protected and managed through community action with little or no exogenous inputs or technologies [24].

Other traditional land-use systems

An exceptional feature of the Arunachal Pradesh landscape is the abundance of bamboo resources, which constitute the lifeline of the entire NER (Figure 2). Numerous bamboo species are found throughout the state at various altitudes, and they are used for a variety of applications (building construction, fencing, culinary, spiritual, etc.). According to estimates by Hore et al, and Biswas et al, approximately 7770 km^{2}, or 9.3% of the state's geographical area, is covered by 41 species of bamboo [25,26]. Most ethnic cultures are also infused with bamboo. Bamboos are integrated with diverse kinds of arable and horticultural crops, forming an array of bamboo-based agroforestry systems (AFS), providing a range of ecosystem services.

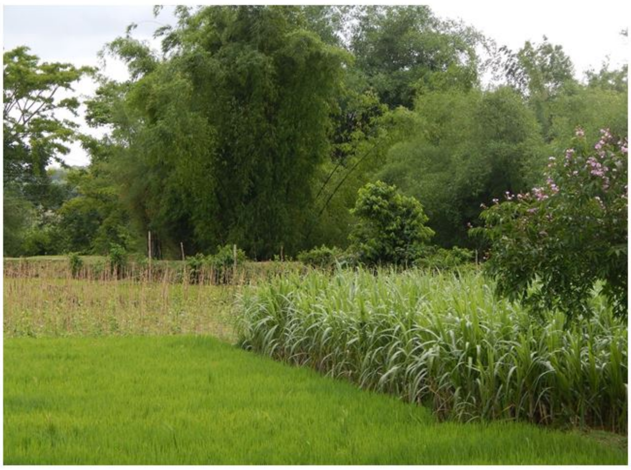

Figure 2: Bamboo resources on the farmlands of Tripura, India. Arable crops like corn is seen in the foreground.

Different cultural groups of NER also have developed unique agricultural practices (e.g. stable systems, fallow systems, and homegardens), which utilize different ecological niches [27].For example, at Balijan, in the foothills of Arunachal Pradesh, the Nishis practice slash-and-burn agriculture (jhum) systems with a 10–20-year cycle length, though longer and shorter cycles are also seen in the region [20]. The long fallow periods provide an opportunity for soil fertility recuperation, making the system sustainable.

In Monpa and Brokpa villages, the farming systems involve the forest tree called paisang (*Quercus griffithii*). The paisang tree leaves play a important role in sustaining the traditional cropping systems of the Monpa people. Indeed, the Monpa practice integrated farming involving diverse arable crops, oilseeds, vegetables, spices, home-gardens, poultry, and livestock under rainfed conditions. Instead of chemical fertilizers, which are not affordable, they depend exclusively on the dry paisang leaves and pine needles for mulching and as manure. Crop rotation of cereal crops with legumes (black gram, field pea, French bean, and soybean) to improve soil fertility through biological nitrogen fixation is also widespread. The Monpa farmers (usually women) exchange (barter) the leaves and agricultural products for yak-based and sheep-based food products from the yak herders, Brokpa. Paisang is also a culturally important keystone tree that supports the livelihoods of both Monpa and Brokpa and is conserved by individuals as well as the community [28]. Wet rice cultivation is also done in the low-lying valleys by the Nishis, the Karbis, and the Chackmas (Maikhuri and Ramakrishnan 1991).

Collection of wild edibles

The tribals, by and large, depend on nature for meeting their basic needs and many traditional practices have evolved in and around the forests to supply essential goods. The native inhabitants of Arunachal Pradesh, which includes 26 major tribes and more than 110 sub-tribes, collect wild fruits, vegetables, and medicinal plants (Figure 3), for their life support systems and livelihood security. Both above ground (young shoots, petioles, leaves, stems, seeds, fruits, barks) and below ground (rhizomes, tubers, and roots) components are part of the tribal recipes, which, however, vary from tribe to tribe, and are eaten either raw or cooked. Apart from meeting the dietary requirements for protein, fat, vitamins, sugar, and mineral requirements, wild edible plants, especially some wild fruits are considered an important part of the culture of indigenous people and they are medicinally important too (e.g., *Averrhoa carambola*, *Dillenia indica*, *Mahonia nepalensis*, *Pyrus sp.*, *Terminalia chebula*, *Ziziphus mauritiana*, etc.). Fruits such as *A. carambola*, *Elaeocarpus floribundus*, *Myrica esculenta*, *Z. mauritiana*, etc. are also processed and preserved as pickles.

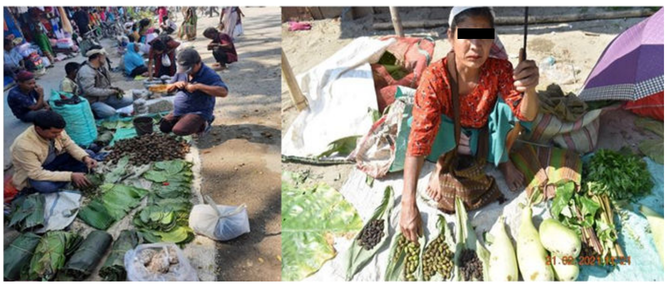

Figure 3: Wild and cultivated fruits, nuts, and vegetables in the Namsai market.

The extraction of plant resources for vegetables, fruits, nuts, spices, and medicines is a daily activity for many tribal people, and value addition through the preparation of extracts for revenue-generating is done at times. However, non-judicious collection and utilization have led to the overexploitation of these resources in the wild, which calls for the need to create awareness among the tribal people on aspects relating to sustainable harvest and value addition of these non-timber forest products. Domestication of wild fruits and vegetables is yet another dimension of this. However, no efforts have been made in this direction until now.

Edible insects and insect farming

Insects are "fast emerging as a viable food and feed group with mass production gaining some popularity globally" [29]. According to FAO, more than 1900 insect species are used as a part of the diets of around 2 billion people across the globe [30]. However, 92% of the edible insect taxa are wild-harvested, with 6% semi-domesticated and only 2% cultured [31]. Many tribal communities in NER consume insects as part of their diets and consider them a delicacy. For example, the Adi tribe uses 53 species of insects belonging to 24 families and 8 orders while the Apatani tribe uses 49 species of 21 families and 8 orders [32]. Food insects are chosen by members of the various tribes according to their traditional beliefs, tastes, and regional and seasonal availability. Depending on the species, only certain, but sometimes all, developmental stages are consumed, either roasted or boiled.

Insects constitute nutritionally rich food and offer other health benefits too. Micronutrients like iron, zinc, magnesium, manganese, phosphorus, selenium, and zinc are abundant in insects (FAO 2021). Regarding the bioavailability of certain micronutrients, there is, however, currently inadequate knowledge. Although Rumpold and Schlüter described the nutritional profile of 236 edible insects and reported that they are "rich in protein (dry matter), dietary fibre, and beneficial fatty acids", information pertaining to the edible taxa of Arunachal Pradesh, or for that matter the NER is Insufficient [33]. Furthermore, there are wide variations in the nutritional makeup of many edible insects. The nutrient content and nutritional quality of edible insects are also influenced by substrate quality, the stage of development at which they are harvested, and the environmental variables [34,35].

Even though eating insects as part of the diet has historically been a part of the NER culture, because of the influence of western culture, particularly on younger generations, eating insects is now seen as unpleasant and primitive, and as a result, this practice is dwindling. Furthermore, with the habitat loss associated with natural resource degradation, rapid human population growth, and increasing "westernization," the traditional wisdom of NER tribals relating to insect use is at risk of being lost.

Insect farming for human and animal consumption, however, is emerging as a potential practice in many regions of the world now [29]. Unlike in the past when edible insects were primarily collected from the wild, insects are now considered appropriate and desirable species for farming due to their "high fecundity, excellent feed conversion efficiency, and rapid growth rates," and suitability for culturing in compact, modular spaces under rural and urban settings [36]. Furthermore, there are many environmental benefits associated with this practice. For instance, in comparison to livestock, insects produce much less GHG emissions e.g., pigs emit 10 to 100 times more GHG per kilogram of weight than mealworms [29,30]. Compared to conventional protein sources, the production of edible insects also has high land-use efficiency; i.e., to produce one kilogram of edible insect protein compared to that of one kilogram of protein from pigs or cattle, 2 to 10 times less agricultural area is required [37,38]. The feasibility of an insect species for mass production, however, depends on several criteria: fast growth, ability to grow quickly in simple-to-maintain environments, consuming inexpensive and locally abundant feed substrates, and withstanding high densities without cannibalism [39]. Although there is scope for edible insect farming in the NER, such enterprises are yet to emerge [40].

CONCLUSION

Sustainable food system transition, focusing on the diversity of foods as well as reductions in waste generation and GHG emissions from the food supply chain, is imperative for achieving SDGs. It calls for greater reliance on the local food systems fostered by the ethnic groups. With 26 major tribes and 110 sub-tribes, Arunachal Pradesh is endowed with a great diversity of traditional land-use and food production systems, as well as ethnic cuisines. Sustainability is an intrinsic feature of these traditional land-use systems, e.g., the Apatani integrated rice-fish production system, the mixed species home-gardens, and the bamboo-based agroforestry. Given the low agricultural productivity in the state, presumably because of the low percolation of modern technologies, these local food production systems hold promise. They not only rely on locally available resources but also conserve species diversity *ex situ*. Practices like entomophagy, which is dwindling as a result of forest destruction, degradation, habitat loss, and sociocultural shifts, and the collection of wild edibles such as fruits, tubers, and leafy vegetables, which are being overharvested resulting in the depletion of natural populations, are also significant. Potential solutions include farming edible insects and domesticating wild fruits and vegetables.

While preserving the traditional land-use systems, simultaneous attempts are necessary to augment agricultural productivity as well. Efficient land management and sustainable use of non-traditional agro-ecosystems assume significance in this respect and it requires research and innovations, which will act as a catalyst for the much-needed food system transformation, especially in situations of great uncertainty such as the pandemic and climate change. Efficient utilization of available energy along with land and other resources may trigger increased rice production to feed the ever-increasing population and to meet other social and economic goals. Environmental and climate outcomes of food systems are also important in the food system transition. Curbing GHG emissions, especially for achieving net-zero food system emissions, are imperative and the local food production systems are generally characterized by low GHG emissions and high carbon sequestration rates.

Future research may focus on the diversity of the traditional food production systems of Arunachal Pradesh (ethnic foods and wild edibles) and the existential challenges they encounter. Evaluating their nutritional value, culinary applications, and conservation status is a case in point. There is also a need to examine the insect species commonly consumed by the tribals, their nutritional attributes, and the cultural perceptions associated with entomophagy, besides, evolving sustainable harvesting techniques. Given the decreasing natural resource base, the conservation of wild fruits, vegetables, and edible insects, assumes significance. Domestication of wild edible plants and edible insect farming to prevent their endangerment in the wild may be given priority. Ensuring environmental sustainability, equitable distribution, and evaluating the effects of population increase on food security in the region are imperative to satisfy the demands of a growing population. Food waste being an important source of greenhouse gas emissions, developing solutions to reduce food waste at various stages of the food value chain, such as production, processing, distribution, and consumption, is essential.

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