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# Evidence that cultural food practices of *Adi* women in Arunachal Pradesh, India, improve social-ecological resilience: insights for Sustainable Development Goals

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## Abstract

**Introduction:** Sustainable use of biocultural diversity can help achieve Sustainable Development Goals (SDGs) in many ways. The tribal communities of bio-culturally rich Northeastern India rely heavily on local food resources and knowledge for livelihood security. In this study with *Adi* women of East Siang district, Arunachal Pradesh, India, we aimed to understand (i) access and use patterns for biocultural plants and animal species from diverse ecosystems and (ii) species diversity and conservation strategies deployed by *Adis*. We employed a novel participatory approach called “recipe contest” to mobilize *Adi* women from 15 randomly selected remote and transitional villages. Data collected through interviews, focus group discussions and transect walks from 75 women, were analyzed using qualitative and quantitative methods.

**Results:** We found that traditional local food was linked intricately with women’s knowledge, access patterns, and socio-cultural institutions. From an end-user perspective, remote *Adi* villages had more widespread use of plant species (14 as food; 34 as food-cum-ethnomedicine and 13 as income-generating species) and animal (17) as food in remote than in transitional villages. Further, there were significant differences ( $p < 0.000$ ; 0.244 and 0.000, respectively) across the social groups for use of plant- and animal-derived food and ethnomedicine. Among different land use systems (i.e., *Jhum* lands, home gardens, and *morang* forests), the highest diversity for food plant was found in home gardens while that for food-cum-ethnomedicinal plants and animal species was observed in *morang* forests. *Adi* women apply traditional agronomic, cultural, and harvest strategies, based on local knowledge and institutions and varying with social systems, to conserve their key local resources. Significant correlations ( $r = 0.63$  to  $0.92$ ) were seen between conservation and use of food and animal species. Traditional knowledge on these aspects was linked intricately to the socio-cultural milieu and is transmitted inter-generationally through various social institutions.

**Conclusions:** Cultural food practices, crucial to social-ecological resilience and livelihood security of *Adi* and similar indigenous communities confronting global environmental challenges, need to be mainstreamed with relevant policies for achieving some targets of SDGs.

**Keywords:** *Adi* women, Arunachal Pradesh, Conservation, Diverse ecosystems, SDGs, Traditional food species

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## Introduction

Human-environment interactions shape socio-cultural and ecosystem diversity in several ways (Marten 2001). Social-ecological diversity, in turn, helps determine intrinsic relations between food-based cultures and livelihood patterns (Pretty et al. 2009). Learning about local biodiversity-based traditional food systems requires continuous acquisition and integration of knowledge from diverse sources (Turner and Turner 2004; Reyes-García et al. 2009). Such knowledge varies with eco-cultural diversity and local strategies for accessing food-based resources (Singh et al. 2010). In the recent past, erosion of traditional food and related cultural knowledge, and the importance of characterizing, validating, and promoting this knowledge has been stressed, particularly relating to impacts on peoples' nutrition and health (Kuhnlein 2005; Kuhnlein et al. 2013; Turner 2005). Mainstream society can learn from traditional knowledge holders to better understand and strengthen location-specific adaptive practices for sustaining biocultural diversity and reducing land degradation (Pretty et al. 2009).

Women are generally considered more knowledgeable than men regarding the ecology and conservation practices of plants used as food and ethnomedicine (Merétika et al. 2010), since they need this knowledge for ensuring family food security (Ellena and Nongkynrih 2017). In mountainous regions in particular, where subsistence economies prevail, strategies for food production and sustenance are major responsibilities of women (Singh et al. 2017), who possess significant knowledge of harvesting, processing, and use of food and ethnomedicine (Magni 2016). Women in general also play an important role in intergenerational transfer of traditional knowledge (TK), thus ultimately assuring food and livelihood security, as well as careful observation and testing of particular foods (Turner and Clifton 2009; Turner and Spalding 2013). Women's knowledge of processing and sustaining food and nutritional resources varies with socio-cultural systems (Gupta 1996).

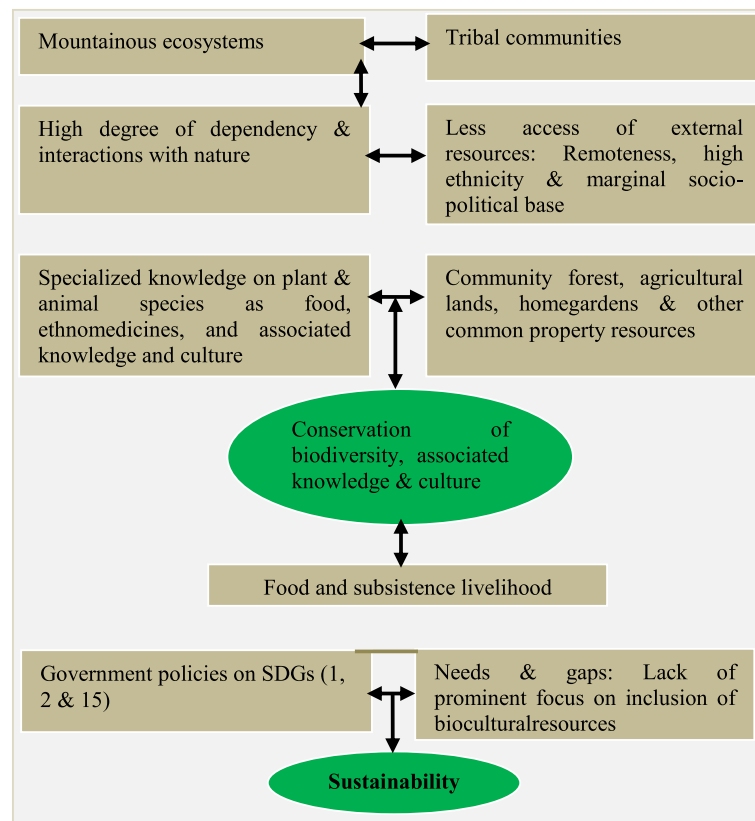
Arunachal Pradesh (Ar P), a state in northeastern India, occupies 7.7% of the total geographical area of the country and is one of the biodiversity hot-spots of the world (Myer et al. 2000). It harbors a large proportion of India's flora [(8000 species) (Rao 1994)], with about 4% (2526 plant species) being endemic (Nayar 1996). Community forests—which include forests under clan control, cultivated and non-cultivated floras in *jhum* land (slash and burn agriculture), and home gardens—play a pivotal role in conservation of indigenous biodiversity and securing food and livelihoods for local communities (Ramakrishnan 2007). In Ar P, the women often take the lead in managing TK, and in development, care, and well-being of families and their food systems. However, in most conservation programs for biodiversity of

India—including Ar P—the roles of women and their knowledge for strengthening and promoting community survival are often not acknowledged (Mishra et al. 2009). An understanding of women's roles and the ways in which they uphold TK—either in harvesting or adding cultural value to plants and animals used as food and ethnomedicine—and in conservation of related biodiversity is critical to achieving some of the SDGs (Sustainable Development Goals) in India. This study focuses on the *Adi* women of Ar P relating to understand (i) access of culturally valuable local plant and animal species from diverse ecosystems for use as food and ethnomedicine and (ii) assessing species diversity and location-specific traditional conservation strategies.

## Conceptual framework

Tribal communities living in remote locations of India, particularly of mountainous ecosystems differ from those of more settled and manipulated landscapes in terms of available resources and socio-cultural and political resource base (Joshi 1989) (Fig. 1). These economically marginal communities, unable to access external resources, have developed ecosystem-based knowledge systems (Gupta et al. 1999; Subramanian and Pisupati 2010), to survive and maintain biocultural diversity (Toledo 1999). Over time, they have also evolved culturally and ecologically responsive strategies for adapting to multiple stressors (Davidson-Hunt et al. 2012). Identifying these strategies can provide meaningful insights for policymakers attempting to develop place-based approaches to land and resource use, and meeting targets of SDGs, especially for biocultural hot-spots (Maffi 2010; UNESCO 2019). Based on insights from Toledo (1999), Maffi (2010), and Davidson-Hunt et al. (2012), we conceptualized *Adi* biocultural resources as “a plant-animal-cultural continuum contributing to resilience and sustainable livelihoods”.

Development approaches relating to food and environmental security for those having predominant biocultural resource bases require a different lens for understanding people's worldviews and practices for sustainability (Davidson-Hunt et al. 2012). The Indian government has prepared a stakeholder framework to meet the SDG targets (particularly goal 1, “No Poverty”; goal 2, “Zero Hunger”; and goal 15, “Life on Land”) (Aayog 2017). Scrutiny of this framework, however, shows a lack of focus on SDGs on ensuring biocultural resources and inclusion of *bottom-up* perspectives from marginal and tribal communities. Schleicher et al. (2018) stress the importance of biocultural diversity in understanding the constraints of such peoples and their priorities and agendas. We have conceptualized biocultural knowledge as how tribal communities assign cultural values to local plant and animal species used as traditional foods and



**Fig. 1** Conceptual framework on biocultural resources helping to sustain food security and subsistence livelihood, and contributing to the Sustainable Development Goals

how they apply their knowledge to access, use, and conserve these species in diverse ecosystems (Fig. 1). We assumed that inclusion of insights from the biocultural resources conserved by more nature dependent and marginal communities (in our case *Adi*) in making strategies on SDGs can provide multiple-scale outcomes helpful in addressing the challenges of SDGs (Fig. 1).

In this study, we documented *Adi* food species, their origins, use as food and/or ethnomedicine, and importance in local culture including beliefs, festivals, and marriage (Maffi 2010). We also documented *Adi* women's traditional management practices, growing and maintaining local species in particular land use types (Fig. 1). We first present *Adi* women's use and access patterns for local plant and animal species as food, ethnomedicine, and income provisions and how these vary in remote and transitional villages. We then highlight similarities and differences in food species and document how different traditional agronomic and cultural practices can strengthen conservation of these species within different social systems. Finally, we highlight connections between culture, learning (biocultural dimensions), and food species conservation. We discuss probable determinants shaping the key trends reflected

in our results, and suggest how policy and planning agencies can gain insights to strengthen some targets of SDGs relevant to fragile mountainous ecosystems.

## Research methodology

### Study area

Arunachal Pradesh (Ar P) state of India (26° 28' and 29° 30' N, 90° 30' and 97° 30' E) covers an area of 83,743 km<sup>2</sup>. The entire state is mountainous, with altitudes ranging from 200 to 6,400 m above sea level. The climate is humid at lower elevations; the valleys are covered by swampy rain-forest, particularly in the eastern section. Altogether, the state's forest cover is 81.22%. Forests comprise 10.03% of India's total forest cover (DoEF 2010). Most of "unclassified" forests in Ar P are *morang* (community owned). Forests in and around *jhum* lands are managed by particular clans/tribes (Singh et al. 2018).

Ar P is home to 26 tribes and about 110 ethnic groups. The *Adi* (also known as *Abor*) are a major collective tribe living in West Siang, East Siang, Upper Siang, Upper Subansiri, and Dibang Valley districts. The *Adi* have distinct customs, dialect, and life-ways (Danggen 2003). Their economy is primarily agrarian, revolving predominantly around *jhum* and wet rice cultivation.

Their staple foods include rice, maize, millets, and forest-based traditional food products. Women collect culturally important plants from diverse ecosystems for their food, ethnomedicine, marketing, firewood, and other needs. Men hunt wild game from *morang* community forests, including for feasting on cultural occasions such as festivals and weddings (Singh et al. 2010). A traditional measure of a family's wealth is the possession of "*mithun*," a native ox (*Bos frontalis*). Folk dances are performed as part of important rituals, during festivals and other occasions, generally accompanying serving of traditional foods.

### Research design

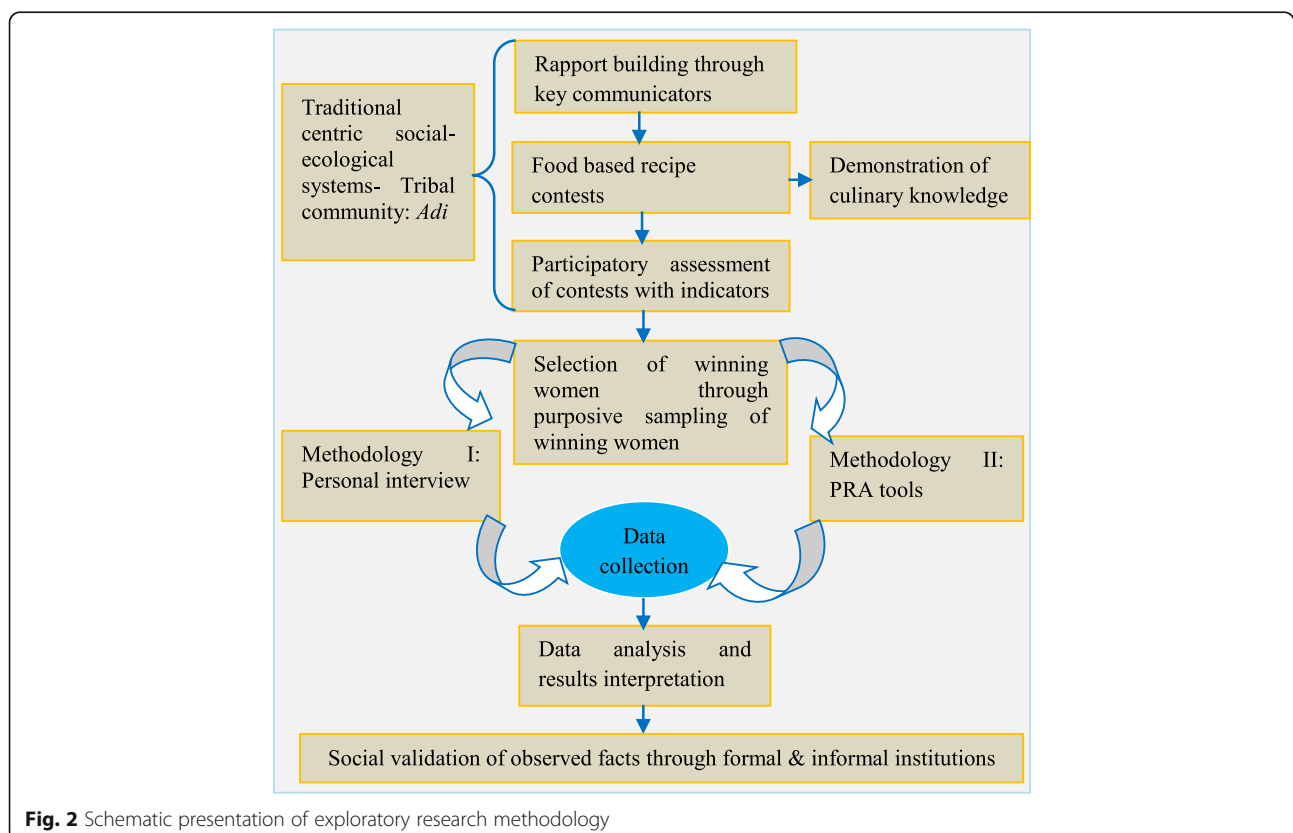
Exploratory research design is widely applied in assessing human-environment interactions to develop a better understanding of how people perceive and use local resources for their well-being (Cuthil 2002). The purpose of this research was to explore the culturally valuable plant and animal species being used as food and/or ethnomedicine and for income generation, and how they are being conserved by the *Adis*. We used an exploratory research design (Roscoe 1975) involving both conventional social-ecological tools and unique participatory approaches (Wagner and Alexander 2013) to accomplish the study objectives (Fig. 2).

### Sampling of study area

We applied a mixed method of sampling to the study area (Onwuegbuzie and Collins 2007). At the outset, we approached each village community, building rapport with key village communicators (customary chief, elders, cultural experts and hunters) to describe our study objectives. The study was carried out within three purposively selected circles (State Government administrative units): Pasighat and Mebo of East Siang, and Maryang of Upper Siang. This purposive selection was based on *Adi*'s ethnicity, high dependency on local bioresources, remoteness of the region, high level of diversity and endemism of plant resources (both terrestrial and aquatic), and communal nature of the local resources. Within each circle, five villages (a total of 15 from three circles) were selected randomly. Seven of these were relatively remote and 8 were transitional, being situated closer to towns.

### Recipe contest: participatory methodology for sampling participants

In each sampled village, a participatory recipe contest (traditional food competition) was organized among *Adi* women, being publicized about 15 days prior to the event. Potential women participants were informed about the event with the help of a team, consisting of *Gaon Burha* (customary chief of an *Adi* village), elders



**Fig. 2** Schematic presentation of exploratory research methodology

and hunters of selected villages. The contest allowed us to explore, fairly readily, each village's relative diversity of culturally important plant- and animal-based traditional food (Singh and Singh 2013). On a fixed date, interested women presented dishes prepared from local plants and animals in village *mosup* (community hall) (Fig. 3), along with plant samples and dried parts of animals (stored already). Their plant samples were identified by plant taxonomists of the Botanical Survey of India, Ar P and zoological resources were identified by wildlife experts, with the help of hunters and the participating women.

The number of participants in the selected villages varied from 15 to 35. The plant- and animal-based foods were assessed by a team consisting of 4–5 elderly women, *Gaon Burha* (~ 4; 60 from 15 villages) and study team members. Assessment categories included local species used as food, traditional cooking methods applied, learning sources (parents, grandparents, or other

members of community), and knowledge about the ecosystems from which species were accessed. Each category was assigned a potential high score of "1"; thus, a species fulfilling all criteria would be assigned a maximum score of "4." Based on the highest mean scores (scores assigned from village food expert and scientists added together) obtained by women for their total foods presented in the "recipe contest," first, second, and third prizes were awarded, with two additional consolation prizes. The winners received their awards at a public gathering in each village, and the proceedings were broadcasted by All India Radio, Pasighat (East Siang district). Based on scores obtained in the contest, a total of 35 women were finally selected randomly (based on the equal probability to each participant of being selection) from remote villages and 40 from transition villages. Thus, we interviewed a total of 75 women (five from each village) for recording study observations (see Additional file 1: Table S1).



**Fig. 3** An *Adi* woman displaying diversity of traditional food prepared from local plant and animal species (photo by Ranjay K. Singh)

### Data collection through interviews

Our interview schedule with open-ended questions was based on a local literature search and scopic study (Orchard et al. 2016) conducted earlier (Singh and Adi 2010), allowing us to become familiar with the local context. We applied a combination of data collection approaches, both qualitative (use and access patterns of species, agronomic practices and cultural dimensions) and quantitative (diversity of plant species, conservation practices and income). The interview schedule was first applied in a pilot test with 5 *Adi* women in a non-sampled area to assess the reliability of our questionnaire and make any needed improvements in questions and language (see Additional file 1: Table S2). Throughout the study a local guide assisted us in our documentation, and the women participants were interviewed in the *Adi* dialect. On average, interviews were conducted in segments over 1–2 days per woman, with a total of about one week of interviewing for each village.

### Data collection through participatory tools

Transect walks were done with elders and sampled respondents to identify land use types. Visits to various food production and conservation areas (*jhum* lands, home gardens, *morang* community forest, and aquatic bodies under common property resources) were made, with the support of village elders (4 per village), who helped in our assessments during the recipe contests, recording and validating the different food species (see Additional file 1: Table S3). Focus group discussions helped to document complex aspects such as changes in food systems over time, cultural dimensions and a deeper sense of ecological aspects of food species. Participant observations with some respondents helped to document agronomic and harvesting practices and connections between festivals and traditional foods. Participatory audio recording helped to cross check data taken through interviews and FGD (see Additional file 1: Table S4).

### Measurement of major variables

Learning modes were assessed in terms of number of socio-cultural institutions (e.g., family and indigenous institutions) through which respondents acquired local knowledge of plant and animal species. Land use systems (home gardens, *jhum* land, *morang* community forest and water stream or community river) determined scores assigned to a species: 1 for species conserved in home gardens (less in area), 2 for those in *jhum* land (moderately higher in area), and 3 for species conserved in *morang* forests or water streams (highest in area). The conservation of each species was considered based on their cultivation within a particular land use type or how the *Adi* women allowed them to grow naturally

(prefixing cultural value). The food species included in this study were classified based on the purpose of use and access from different land use types. Use, as a variable, was quantified by assigning a score of “1” if a species was used by less than 50% of respondents, followed by “3” (51–75%) and “5” (76–100%). This score also helped in assessing significance of difference between two social groups about species used for diverse purposes. Similar patterns were followed in species used both in food and ethnomedicines, and those used as animal-based food.

### Criteria for selection of species for economic and livelihood aspects

Data were collected for 13 of the most popular ethnobotanicals and their overall economic value was assessed using the following criteria: (i) most frequently used in foods, (ii) easy availability, (iii) conservation in various habitats, (iv) economic value in local market, and (v) adaptive capacity for climatic, ecological, and socio-institutional stresses.

### Data analysis and statistics

A thematic technique was applied to determine patterns and trends in particular aspects of the data (Stringer et al. 2017). Diversity indices of species found in different land use systems were calculated drawing on insights from Coddington et al. (1996), Camargo (1997), Nagera (2002) and Eguia-Aguilara et al. (2005). The indices were computed using PAST software (Hammer et al. 2001). STAR statistics (version 2.0.1) (IRRI 2013) was applied to compute the Spearman correlation between usage and conservation of species. The significance of difference between usage of plant and animal food species and income of women from remote and transitional villages was tested applying *t* test. Other data, including use percentage, income, and agronomic practices, were analyzed using descriptive statistics in a spreadsheet. Key results obtained were shared back with the study respondents to socially validate our conclusions.

## Results

### Use and accessibility of food species

#### Plant food species

Fourteen plant species were identified as key ingredients in the foods prepared by *Adi* women. The percentage of use of plant species as food varied from as low as 50.4% for *dilap* (*Allium hookeri*) to the highest at 97.7%, for *onger* (*Zanthoxylum rhetsa*) in remote villages (Table 1). These two species were used relatively less in transitioning villages (55.8 and 25.0%, respectively). *Marshang* (*Spilanthes acmella*) was the second most used species in remote villages (94.6%), while *ongin* was used highly (65.0%), followed by *marshang*, by the respondents of

**Table 1** Major local plants species used in foods

Local name	Botanical name	Parts used <sup>a</sup>	Habitats <sup>b</sup>	Use % <sup>c</sup>	
				Rural	Transitioned village
<i>Lai saag</i>	<i>Brassica</i> sp. L.	Leaf	JL and HG	65.9	50.5
<i>Dilap</i>	<i>Alleum hookeri</i> L.	Whole plant	JL and HG	50.4	25.0
<i>Epek-tangum</i>	<i>Bidens pilosa</i> L.	Leaf	JL and HG	87.5	40.5
<i>Onger</i>	<i>Zanthoxylum rhetsa</i> (Roxb.) DC.	Leaf	JL, HG, and MCF	97.7	55.8
<i>Ongin</i>	<i>Clerodendrumcole brookianum</i> Walp.	Leaf	JL, HG, and MCF	93.9	65.0
<i>Marshang</i>	<i>Spilanthes acmella</i> L.	Leaf	JL, HG, and MCF	94.6	58.0
<i>Kopi</i>	<i>Solanum khasianum</i> C.B. Clarke	Fruits	JL and HG	80.5	47.0
<i>Koppir</i>	<i>Solanum spirale</i> Roxb.	Fruits	JL and HG	60.3	41.4
<i>Paput</i>	<i>Gnaphalium affine</i> D. Don	Leaf	JL and HG	59.1	20.2
<i>Mamang</i>	<i>Physalis minima</i> L.	Leaf	JL and HG	58.4	15.0
<i>Fayong</i>	<i>Polygonum chinensis</i> Meissn.	Leaf	JL and HG	68.9	10.5
<i>Nayang</i>	<i>Erigeron Canadensis</i> L.	Leaf	JL, HG, and MCF	91.2	35.7
<i>Tangum</i>	<i>Bidens pilosa</i> L.	Leaf	JL and HG	68.6	19.0
<i>Gende</i>	<i>Gynura crepidioides</i> Benth	Leaf	JL and HG	86.8	38.4
Statistics			$t$ value = 5.36, $p < 0.000$		

JL *Jhum*-land, HG home gardens, MCF *Morang* community forest

<sup>a</sup>Plant parts data: 11 species as leaves (78.57%), 2 species each as fruit (14.28%), 1 species as whole plant (7.14%)

<sup>b</sup>Species data: JL and HG = 10 species (71.42%); JL, HG, and MCF 4 species (28.57%)

<sup>c</sup>Multiple percentages

transition villages. Overall, women from remote villages used a greater percentage of local plant species as food than their counterparts of transition villages and these two groups varied significantly ( $t = 5.36$ ,  $p < 0.000$ ). Out of 14, most of the species were used in the form of leaves (78.57%) and fruits (14.28%) across the social systems. The majority (71.42 %) of the food plant species were accessed from *jhum* lands and home gardens, and the remainder from a set of three land use systems: *jhum* lands, home gardens, and *morang* community forests (28.57%).

#### **Food plant species with ethnomedicinal values**

We identified 33 plant species used as both food and ethnomedicine for treating certain diseases and disorders (Table 2). *Namdung* (*Perilla ocyroides*) was recorded to be a highly used dual purpose species (for stomach disorders and supplementary food for pregnant women) by *Adi* women of remote villages (97.5%), but somewhat lower among women of transition villages (58.5%). *Gende* (*Gynura crepidioides*) was the second most used species, for both remote and transitional *Adi* women (96.6% and 41.5%, respectively), for curing sickness. Overall, based on a total of 33 species, the dependency of women from remote villages on use of plants as food and ethnomedicine was significantly greater than those of their transitional village counterparts ( $t = 5.11$ ,  $p < 0.000$ ). Leaves (45.45%) and fruits (27.27%) of these species were the most usable parts across both the social

systems. Home gardens were the most accessed land use system (45.45%), followed by *jhum* lands (24.24%) and *morang* community forests (30.30%) for dual purpose species.

In terms of medicinal species, some like *kekir* or ginger (*Zingiber siangensis*) and *oik* (*Pouzolzia hirta*), were used for coughs and colds, and for treating snake bites and improving lactation among mothers, respectively. However, their use varied between remote (85.5%) and transition villages (57.8%). Some local medicinal species were also sometimes prescribed by professional doctors, according to our interviewees. For example, *ongin* (*Clerodendrum colebrookianum*) is recommended for controlling diabetes and high blood pressure (35.8 % in remote and 39.8% in transitioning villages). Similarly, the green leaves of *onger* (*Zanthoxylum rhetsa*), rich in antioxidants (Bhardwaj et al. 2005), are used in controlling dysentery and diarrhea (66.8 % in remote and 45.7% in transitioning villages). *Onger* leaves are also cooked with pork and other meats (as are other leafy vegetables), to improve the taste and reduce the incidence of potential parasitic diseases like tapeworm infestation (Yadav and Tangpu 2009).

#### **Animal-based food species**

A total of 17 wild animal, fish and insect species were found to be traditional *Adi* foods (Table 3). *Ngopi* (*Labeo dero*) and *ghongha* (*Lymnaea* sp.)/snails (various indigenous species) were used by almost every woman (100%) in remote villages, while having relatively lower use (60.5 and

**Table 2** List of major ethnobotanicals used as food-cum-ethnomedicine by the *Adi* women

Local name	Botanical name	Part used <sup>a</sup>	Habitats <sup>b</sup>	Disease/disorders/ailments	Percentage of use <sup>c</sup>	
					Remote villages	Transitioned villages
<i>Amta</i>	<i>Hibiscus sabdariffa</i> L.	Flowers and leaves	JL	Diarrhea and dysentery	95.2	21.0
<i>Bangko</i>	<i>Solanum spirale</i> Roxb.	Leaves and fruits	JL	High blood pressure and diabetes	94.6	32.5
<i>Kordoi</i>	<i>Averrhoa carambola</i> L.	Fruits	MCF	Jaundice	24.2	8.0
<i>Champa</i>	<i>Dillenia indica</i> L.	Peel of fruit with small fishes	MCF	Stomach pain	22.4	6.5
<i>Dipatalo</i>	<i>Campylandra aurantiaa</i> Baker	Rhizomes	MCF	Tonic in stomach disorders	93.5	47.6
<i>Doni-homgkang</i>	<i>Plantago erosa</i> Wall	Leaves	MCF	Improving digestion	19.8	7.5
<i>Fayong</i>	<i>Polygonum nepalens</i> Meissn	Leaves	HG	For sick persons	87.5	36.0
<i>Gende</i>	<i>Gynura crepidioides</i> Benth	Leaves	HG	For sick persons	96.6	41.5
<i>Haryo</i>	<i>Eryngium foetidum</i> L.	Stem and leaves	HG	Headache and madness	87.2	39.7
<i>Kadokaro</i>	<i>Drymaria diandra</i> Bl	Fruits	MCF	Gastric problem	86.2	40.5
<i>Kekir</i>	<i>Zingiber siangensis</i>	Rhizome	MCF	Cough and cold, wound healing, and in snake bites	85.5	57.8
<i>Koppi</i>	<i>Solanum torvum</i> Swartz	Fruits	HG	Gas and indigestion	80.2	60.0
<i>Koppir</i>	<i>Solanum khasianum</i> Clarke	Fruits	HG	Gas and indigestion	79.5	62.0
<i>Kulu</i>	<i>Musa sapientum</i> L.	Fruits	MCF	Swollen feet and skin disorders	27.9	9.5
<i>Lalada</i>	<i>Zingiber</i> sp. Roscoe	Rhizome	HG	Cough and cold, wound healing	80.4	43.8
<i>Mamang</i>	<i>Physalis minima</i> L.	Leaves	HG	For sick person	78.2	47.6
<i>Namdung</i>	<i>Perilla ocymoides</i> L.	Seeds	JL	Stomach disorders and supplementary food for pregnant women	97.5	58.5
<i>Nayang</i>	<i>Erigeron canadensis</i> L.	Leaves	JL	For sick persons	27.3	9.5
<i>Oik</i>	<i>Pouzolzia hirta</i> Hassk	Leaves	HG	Improving lactation	68.4	33.2
<i>Onger</i>	<i>Zanthoxylum rhetsa</i> Roxb.	Leaves	HG	Stomach disorders and high blood pressure	66.8	45.7
<i>Ongin</i>	<i>Clerodendrum colebrookianum</i> Walp.	Leaves	HG	Controlling high blood pressure and diabetes	65.8	39.8
<i>Paput</i>	<i>Gnepalium affine</i> D. Don	Leaves	HG	For getting quick energy	59.2	28.5
<i>Rouri</i>	<i>Piper sylvaticum</i> Roxb.	Leaves	HG	Sick person	65.9	30.0
<i>Rukdik</i>	<i>Thelypteris glanduligera</i> Kunze	Leaves	MCF	Muscle pain	34.2	14.9
<i>Rumdum</i>	<i>Blumea fistulosa</i> Roxb.	Leaves	MCF	Diarrhea	32.5	7.8
<i>Sajna</i>	<i>Moringa oleifera</i> Lam.	Pods and leaves	HG	control muscle pain and diarrhea	30.2	12.5
<i>Satabayom</i>	<i>Solanum indicum</i> L.	Fruits	HG	Diabetes	77.8	51.4
<i>Sirang</i>	<i>Castanopsis kurzii</i> Hance	Fruits	JL	Alleviating scurvy, gas trouble, and toothache	34.6	13.7
<i>Talab</i>	<i>Allium</i> sp. L.	Bulbs	HG	Improving digestion	75.4	49.5
<i>Tangmeng</i>	<i>Mussaenda roxburghii</i> Hook. f.	Leaves	MCF	Stomach disorders	47.9	30.0
<i>Tangum</i>	<i>Bidens pilosa</i> L.	Leaves	JL	Sick persons	39.2	12.5
<i>Teetbaigan</i>	<i>Solanum kurzii</i> Brace	Fruits	JL	Improving digestion	38.7	14.5
<i>Toko-patta</i>	<i>Livistona jenkinsiana</i> Griff.	Fruits	JL	Gastric problems	37.4	18.0
Statistics				$t$ value = 5.11, $p < 0.000$		

*JL* Jhum lands, *HG* home gardens, *MCF* Morang community forest

<sup>a</sup>Leaf parts data: Leaves = 15 (45.45%); fruits = 9 (27.27%); flower, peel, seeds, stem, bulbs, and pods = 6 (18.18%); rhizomes = 3 (9.09%)

<sup>b</sup>Habitat data: JL = 8 species (24.24%), HG = 15 species (45.45%); MCF = 10 species (30.30%)

<sup>c</sup>Multiple responses



**Table 3** Major animal species used in foods<sup>a</sup>

Local name	Zoological name	Habitats <sup>b</sup>	Cultural dimensions		Use % <sup>c</sup>
			Remote villages	Transitioned village	
<i>Kebungs</i>	Malayan giant squirrel (MGS) <i>Ratufa bicolor</i> Layard in Blyth <sup>c</sup>	MCF	Used as dowry and cultural food during <i>aran</i> festival	66.6	29.5
<i>Chuha</i>	<i>Rattus rattus</i> L./ <i>Niviventer fulvescens</i> Gray	MCF	Used as food in <i>solung</i> , <i>aran</i> festivals, and marriage	65.8	22.4
<i>Lomadi</i>	<i>Vulpes bengalensis</i> Shaw	MCF	Used during grand celebrations after hunting	67.4	11.2
<i>Porcupine</i> <sup>e</sup>	<i>Hystrix hodgsoni</i> Gray	MCF	Part of summer festivals and ethnomedicines	47.2	19.4
<i>Jangalisuar</i>	<i>Sus scrofa</i> L.	MCF	Used during <i>solung</i> , <i>aran</i> , and <i>mopin</i> festival	43.1	23.4
<i>Bug-nyul</i>	<i>Viverricula indica</i> É. Geoffroy Saint-Hilaire	MCF	As above	41.9	29.7
<i>Bhalu-biraf</i>	<i>Arctictis binturong albifrons</i> F. G. Cuvier	MCF	As above	42.5	33.2
<i>Kala bhaluf</i>	<i>Selenarctos thibetanus laniger</i> Pocock	MCF	Used during marriage	40.8	11.4
<i>Neur</i>	<i>Herpestes auropunctatus</i> Hodgson	MCF	Part of dowry	39.1	20.4
<i>Kekkakhane-walamoosa</i>	<i>Herpestes urva</i> Hodgson	MCF	Part of dowry	46.4	23.8
<i>Mithun</i>	<i>Bos frontalis</i> Lambert	MCF	Part of dowry, indicators of social prestige	48.9	35.8
<i>Gandhi pug</i>	<i>Aspongopus nepalensis</i> Westwood	MCF	Used in several <i>Adi</i> ceremonies	43.8	14.5
<i>Run-kung</i>	<i>Oecophylla smaragdina</i> Fabricius	Water stream and CPR	Used as food and applied in curing malaria	42.3	11.2
<i>Ngopi</i> <sup>f</sup>	<i>Labeo dero</i> Hamilton	Water stream and CPR	Used as medicines in skin diseases and kept as fermented food	100	60.5
<i>Ghongha</i> <sup>h</sup>	<i>Lymnaea</i> sp. P. Rashad and other species also	Water stream and CPR	Considered to be helpful in improving vitality	100	55.4
<i>Sidhari</i>	<i>Puntius</i> sp. Hamilton	Water stream and CPR	Fresh and fermented use in parties	98.5	63.8
<i>Chelwa</i>	<i>Chelwa labuwa</i> Hamilton	Water stream and CPR	As above	96.6	60.5
Statistics			$t$ value = 2.05, $p < 0.024$		

MCF *Morang* community forest, CPR common property resources<sup>a</sup>Data pertaining to animals species reported in the table were collected by hosting FGD (focus group discussions) with elder women<sup>b</sup>Habitat data: MCF = 12 species (70.58%); water stream and CPR = 5 species (29.41%)<sup>c</sup>Multiple percentages<sup>d</sup>Red-bellied squirrel (RBS) *Callosciurus erythraeus*, hoary-bellied squirrel (HBS) *C. pygmyrithus*, and the Himalayan striped squirrel (HSS) *Tamiops maccllellandi* are also found there and used occasionally<sup>e</sup>Other than using in meat, the gall bladder is used for curing malaria<sup>f</sup>Other than using in meat, bones are used for some rituals and cultural functions<sup>g</sup>This indigenous breed of fish is used for curing some skin diseases. It is most commonly fish used in fermentation and giving to seek and old person<sup>h</sup>Used in food and its shell is used to make edible lime

55.4%) in transition villages. *Sidhari* (*Puntius* sp.) and *chelhwa* (*Chela laubuca*) fish were the second and third most used food species: 98.5 and 96.6% use, respectively, among the women of remote villages, and 63.8 and 60.5% among women of transitional villages. Among insects, the *gandhi-pug* (*Aspongopus nepalensis*) was used more widely as food (43.8%) in remote villages than in transitional villages (14.5%). These animal-based food species were integral parts of various *Adi* socio-cultural dimensions (festivals, marriage, and ethnomedicines). Overall, their use as food was significantly higher in remote than transitional villages ( $t = 2.05, p < 0.024$ ).

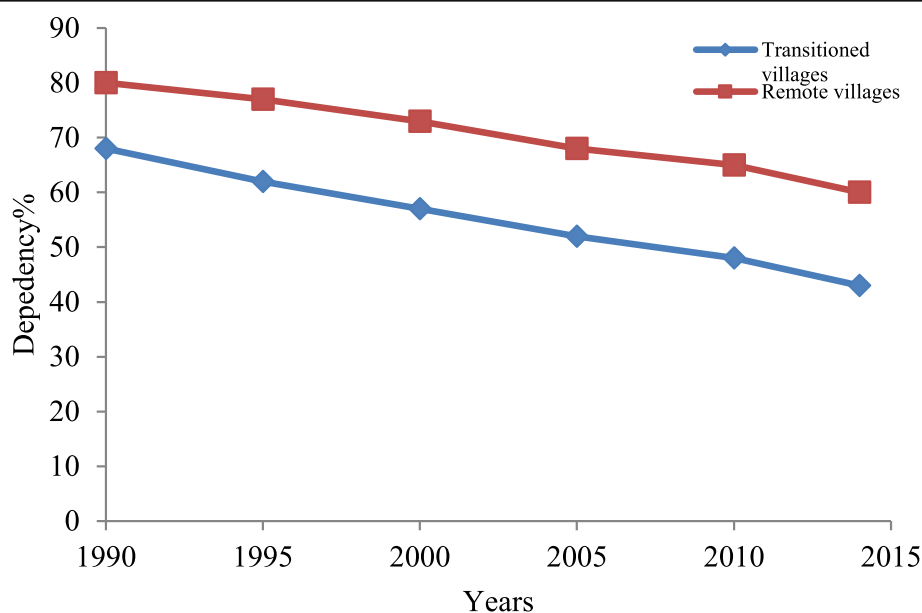
Most of the terrestrial animal species across the two community types were accessed from *morang* community forest (being hunted by the men and provided to the women) (70.58%), while aquatic species, caught by both men and women, came from freshwater streams and community rivers (common property resources) (29.41% use). Proximity to *morang* forest and other common property resources enables the *Adi* of remote villages to hunt listed species more frequently than in transitioning villages. In addition, women living nearby *jhum* lands, especially in remote communities, were able to use local landraces of rice (local variety *amkel* and *geku*) for making fermented rice and taken with fish, animal, and ethnobotanical products.

#### Dietary shift from traditional to “convenience” foods

Some of forest-based foods harvested and used by *Adi* women have made the transition from being considered hardship fare to being delicacies fit for social and cultural celebrations. Examples include *ongin*

(*Clerodendrum colebrookianum*), *onger* (*Zanthoxylum rhetsa*), *kopi* (*Solanum torvum*), *koppir* (*Solanum khasianum*), and *bangko* (*Solanum spirale*). Nevertheless, the use of forest-based foods has decreased over time (Fig. 4). The majority of respondents (79.8%) noted a higher abundance of deer, rabbits, boar, and forest rodents in the 1970s and earlier. With ever-growing population, changing land use pattern, acculturation, and an erosion of traditional conservation values, the populations of these wild animals have generally declined. Women reported that the *jhum* lands, following the cutting of trees, have become drier than in the recent past, and described numerous declines over the past few decades in wildlife abundance and in plant-based traditional foods around the settlements, especially in the transitional villages.

Use of some fiber species in food was greater among *Adi* women of remote areas. For example, only 5–7 fiber-rich species were used by *Adi* women of transitional villages, whereas in remote locations use of 20–25 such species were documented. In transitional villages, people were consuming only 20–25% boiled foods, with diets rich in fried and fast foods (30–40%), whereas in more remote locations mostly boiled food without spices and marketed oil were consumed. In remote communities, fat was mainly obtained from hunted animals, and plants like *sayong*, *kekir*, *onger*, and *dilap* were used as spices and flavoring the food. Women of transitional villages use purified table salt (chemically sodium chloride without trace minerals), while in remote areas, women used natural salts and ash (produced from burning snail shells); presumably rich in both sodium chloride and other minerals.



**Fig. 4** Dependency percentage of *Adi* on forest-based traditional foods over the year near town and in remote villages

### Role of plant species in food and income security

We identified, in all, 13 economically important species harvested by *Adi* women for income, markedly reduce their dependency on external resources (Table 4). These species are adapted to multiple stressors including climatic (flood), ecological (e.g., soil acidity), and institutional (poor accesses of formal institutions and organized market). These species become particularly significant at times when low-lying areas are hit by floods/flash floods, and supplies of marketed foods are curtailed. These species are available in different seasons and vary in economic value, from as low as INR 45/kg to INR 200/kg. However, women of remote areas fetched relatively lower returns from their sale compared to those from transitional village women having access to town markets. For example, the highest difference in market price between remote and transitional villages (109.67%) was recorded for *lalada* (*Zingiber* sp.), while lowest was for *rouri* (*Piper sylvaticum*) (42.86%) (Table 4). There was a significant difference ( $t = 2.94$ ,  $p < 0.003$ ) for the overall market price of 13 species between these two women's groups.

These species were accessed primarily from *jhum* lands (53.84%) and combinations of *jhum* lands, home

gardens, and *morang* community forests (23.08%). The *Adi* women of remote villages—often having more family members to collect these local species from different ecosystems—sell them at lower prices to women living near towns. These women augment the diversity of food plants to some extent from their own land use systems, and diversify market demand by assigning different grades (e.g., single species, mixture of two species, mixture of 3–6 species, and mixture of sometimes 7–12 species) to the plant products, according to customer preferences and the price these mixtures bring. The women of transitional villages earned an average of INR 60,000 to 80,000 (US\$ 943.1 to 1100) per year by selling such local plants, while women of remote villages earned less (INR 35,000 to 50,000; US\$ 487.74 to 696.77).

### Species diversity, and agronomic and cultural practices for conservation

#### Diversity and similarity indices of *Adi* food species

The Shannon index revealed that with species richness of 8, the diversity ( $H$ ) of food plants was higher in home gardens (2.08) with similarity index ( $1-D$ ) of 0.88, followed by *jhum* lands ( $H = 1.79$ ;  $1-D = 0.83$ ). Across

**Table 4** Economically important ethnobotanicals used by *Adi* women for food and income

Local name	Scientific name	Habitat <sup>a</sup>	Seasonal availability	Economic value in INR <sup>b</sup> per kg		Difference %	Role in adaptations
				Remote villages	Transitioned village		
<i>Koppi</i>	<i>Solanum torvum</i>	JL and HG	April to September	70.0	38.0	84.21	A dependable food during flood <sup>c</sup>
<i>Koppir</i>	<i>Solanum khasianum</i>	JL and HG	April to September	65.0	31.0	109.67	As above
<i>Onger</i>	<i>Zanthoxylum rhetsa</i>	JL, HG, and MCF	Year round	75.0	40.0	87.50	Used year round. Stored after drying for off-season use
<i>Pumpkin</i>	<i>Cucurbita moschata</i>	JL	April to August	45.0	20.0	125.00	Easily cultivable
<i>Lalada</i>	<i>Zingiber</i> sp.	JL and HG	May to October	120.0	50.0	140.00	Medicinal and used as cash crop
<i>Kekir</i>	<i>Zingiber siangensis</i>	JL	May to October	200.0	100.0	100.00	Medicinal and used as cash crop
<i>Poi</i>	<i>Basella rubra</i>	JL and HG	April to August	50.0	32.0	56.25	A dependable food during flood
<i>Dhekia saag</i>	<i>Diplazium esculentum</i>	JL and MCF	May to September	60.0	32.0	87.50	As above
<i>Marshang</i>	<i>Spilanthes acmella</i>	JL, HG, and MCF	April to August	45.0	28.0	60.71	Compatible to grow anywhere
<i>Ongin</i>	<i>Clerodendrum colebrookianum</i>	JL, HG, and MCF	May to October	100.0	55.0	81.82	Medicinal and can be used year round. Can be stored after drying for off-season use
<i>Kalmu</i>	A creeper	JL and HG	May to September	65.0	35.0	85.71	Easy in growing and no inputs are required
<i>Rouri</i>	<i>Piper sylvaticum</i>	JL and HG	May to September	60.0	42.0	42.86	Easy in growing and no inputs are required
<i>Adi dhania</i>	<i>Eryngium foetidum</i>	JL and HG	April to November	100.0	55.0	81.82	Used as substitute for many vegetables. Can be stored after drying for off-season use
Statistics			$t = 2.94$ , $p < 0.0035$			Overall 89.69%	

JL, *Jhum*-land; HG, home gardens; MCF, *Morang* community forest

<sup>a</sup>Habitat data: JL = 2 species (15.38%); JL and HG = 7 species (53.84%); JL, HG, and MCF = 3 species (23.08%)

<sup>b</sup>1 USD = 71.76 INR

<sup>c</sup>Since these species are grown at higher altitude in mountainous ecosystems, that is why the flood does not affect these species

these two land use systems, with species richness 14 (Chao-2 =  $34.62 \pm 26.23$ ), the diversity was 2.64 with a similarity index of 0.93 (Table 5). With regard to plant species used for both food and ethnomedicine, the diversity (2.71) with species richness 15 was again highest in home gardens, with similarity index of 0.93 as compared to *morang* community forest ( $H = 2.40$ ;  $1-D = 0.78$ ), having 11 species, and *jhum* lands ( $H = 1.95$ ;  $1-D = 0.86$ ) with 7 species. Across the three land use systems, with species richness of 33 (Chao-2 =  $101.5 \pm 148$ ), the diversity was 3.50, and the similarity index 0.03. In case of animal-based food species, with species richness 12, the *morang* community forest demonstrated higher diversity index (2.49) with similarity value of 0.92 than those of 5 species being accessed from aquatic bodies. With species richness 17, we noted species diversity 3.85 with Chao-2 value  $45.49 \pm 38.29$ . Overall, the species diversity was higher in animal species (3.85), followed by dual-purpose plant species (food and ethnomedicines) (3.50) and species used only for food (2.64). The Berger-Parker index revealed that proportional abundance of species for food and for dual purpose (food and ethnomedicine) was higher in *jhum* lands as compared to other land use systems. In case of animal species used as

food, Berger-Parker index (0.20) was greater for species accessed from aquatic body.

#### **Agronomic practices**

We found that a great majority (90.7%) of women from remote villages practiced mixed cropping along with relay cropping (62.5%) as traditional agronomic practices. These numbers were fewer among their counterparts in transitional villages (40.6% and 8.5%, respectively). The intended outcomes of these practices were to enhance soil fertility, to strategically use residual soil moisture and to avoid ecological and climatic risks associated with particular species (Fig. 5). Controlled burning (82.4%), applying activator material (62.5%) (elephant and deer excreta) to enrich soil fertility, and active seed dispersal (69.2%) were key agronomic strategies for women of remote rural areas. The activator material also helped break seed dormancy of uncultivated species and enhanced plant productivity. They were not used by women in transitional villages, and the other practices were less frequent (20.4%). Similar trends across community types were seen for vegetative propagation, diversifying harvests, applying special planting techniques, and selective harvesting of plant species to enhance plant populations and species diversity. Creation

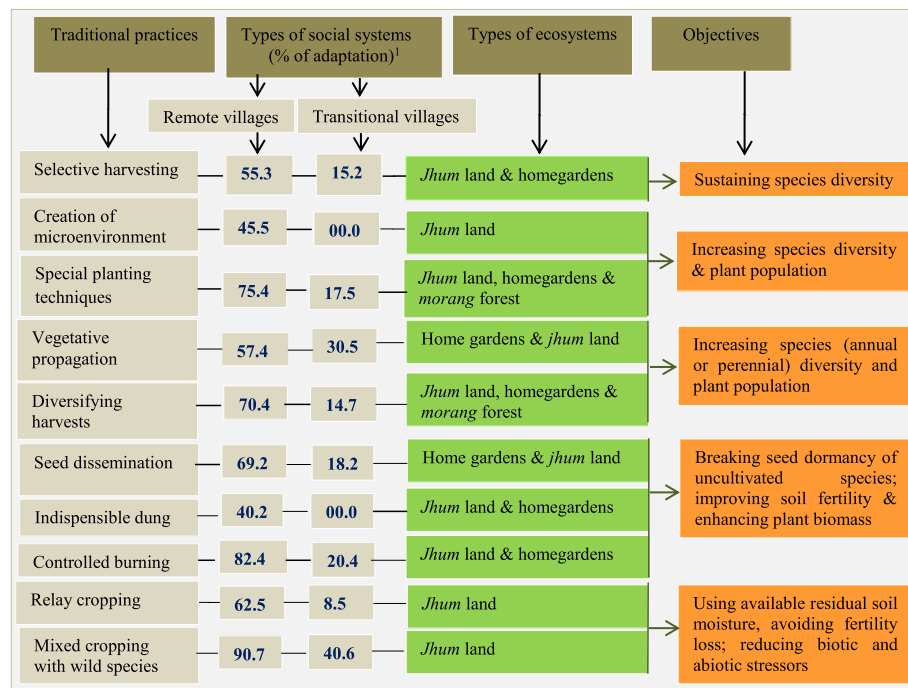
**Table 5** Shannon diversity and similarity indices of bio-culturally important food species of *Adi*

Major use	Diversity and similarity indices			
	<i>Jhum</i> lands	Home gardens/aquatic bodies <sup>a</sup>	<i>Morang</i> community forests	Across the ecosystems
<b>A. Food</b>				
<b>A.1 Plant species</b>				
Species richness	6	8	NA	14
Shannon diversity ( $H$ )	1.79	2.08	NA	2.64
Simpson dominance ( $1-D$ )	0.83	0.88	NA	0.93
Berger-Parker index	0.17	0.13	NA	0.08
Chao-2	-	-	-	$34.62 \pm 26.23$
<b>A.2 Animal species</b>				
Species richness	NA	5	12	17
Shannon diversity ( $H$ )	NA	1.61	2.49	3.85
Simpson dominance ( $1-D$ )	NA	0.80	0.92	0.98
Berger-Parker index	NA	0.20	0.08	0.02
Chao-2	-	-	-	$45.49 \pm 38.29$
<b>B. Food and ethnomedicine</b>				
Species richness	7	15	11	33
Shannon diversity ( $H$ )	1.95	2.71	2.40	3.50
Simpson dominance ( $1-D$ )	0.86	0.93	0.78	0.97
Berger-Parker index	0.14	0.07	0.09	0.03
Chao-2	-	-	-	$101.5 \pm 148$

Note: NA indicates that there were no species recorded in that particular land use

Looking to the assumptions of diversity indices (sample size and number of species for each category), pooled data (across the social systems) were used to draw this table

<sup>a</sup>Aquatic bodies cover water stream in community forest and river tributaries (under community ownership)



**Fig. 5** Traditional agronomic practices adapted by *Adi* women to enrich plant species diversity and enhance ecological sustainability. <sup>1</sup>Figure is based on pooled data of FGDs conducted in each village

of micro-environments (e.g., using exhausted edges of bamboo groves, and digging trenches and lining them with *sisar* tree wood) (45.5%) to increase species diversity and plant populations was an uncommon practice among women of remote villages and not practiced at all among women of transitional villages. All these traditional practices varied across the ecosystems surveyed (*jhum* land, *morang* forest, and home gardens) (Fig. 5).

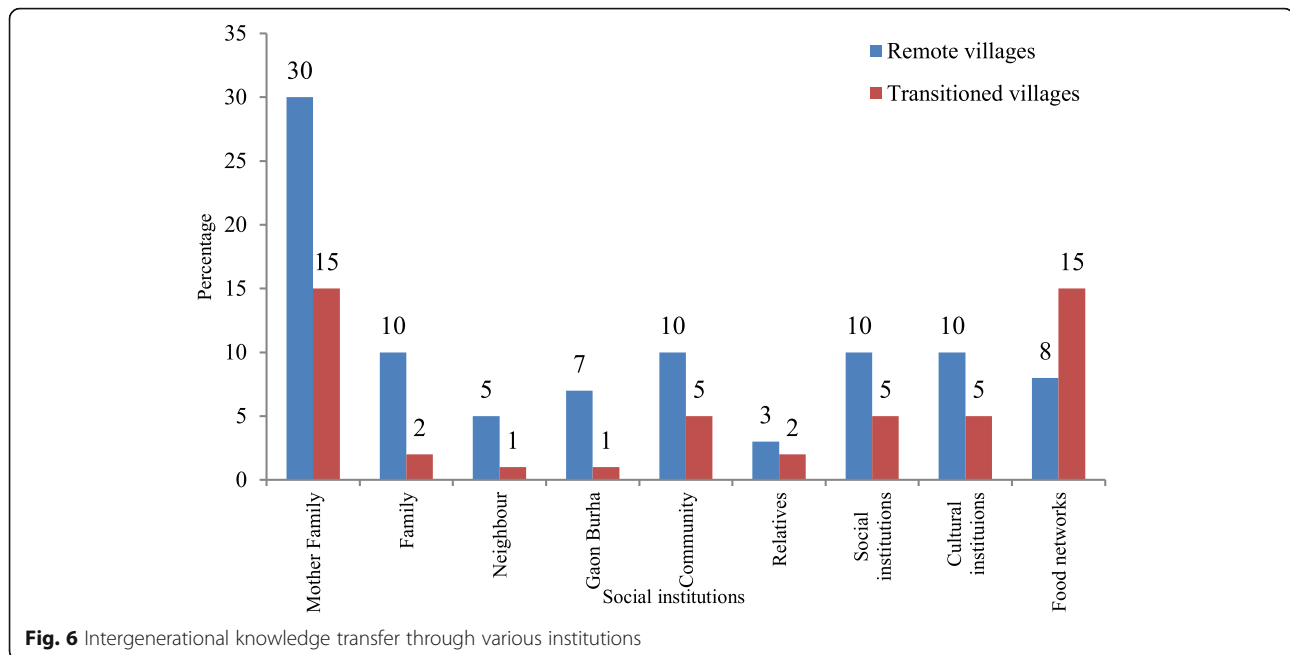
#### Food-based knowledge learning

Acquiring knowledge about a particular food and its component species requires incremental experiential learning and practice, which *Adi* women have achieved with the support of various institutions and means (Fig. 6). In remote settlements, family, community, and socio-cultural institutions (*relep*, an informal institution of women, and *Kebang*, headed by *Gaon Burha*) were major venues of food knowledge transfer, whereas in transitional villages food networks were more prominent. Mothers were a valuable source of learning about cultural foods for both the social groups, although the relative importance of these modes of learning varied considerably across both systems.

#### Sociocultural and institutional practices on animal- and plant-based foods

The women of remote settlements held beliefs that foster conservation of the traditional food species, less so

for their transitional village counterparts (see Additional file 1: Table S5). For example, unlike 70.1% of the remote village participants, only 18.2% of transitional village participants reported that certain fish species are not given to children, due to a belief that this would cause them to urinate in bed, even after they had grown up. Similarly, 89.8% of remote village women, but only 35.0% of transitional village women, maintained that *mithun* (*Bos frontalis*)—a semi-wild animal—is culturally precious and must be carefully treated and never killed without a cultural reason. In remote villages, 56.9% of respondents said that when a wife is pregnant, a male hunter should not hunt monkeys, or they would be haunted by evil spirits, whereas only 23.5% of transitional village respondents held this belief. When they are in the forest at times of their wives' pregnancy, hunters must avoid drinking water from forest water streams, using *Colocasia* leaves for drinking, lest their unborn baby would be attacked by evil spirits. This belief was held by 69.4% of women in remote villages but only 27.0% of transitional villages in transitions. In the event of any of tabooed species being used as food (listed in Additional file 1: Table S5) by mistake, *kekir* (a local variety of ginger) is eaten to drive away the resulting evil spirits. Through practicing these beliefs, the demand for harvesting certain plants and animals is minimized for specific periods, particularly in the remote communities.



**Fig. 6** Intergenerational knowledge transfer through various institutions

Some of the *Adi* festivals such as *solung*, *aran*, and *mopin* are especially dedicated for hunting; in particular, over-populated animals (e.g. rodents and squirrels [*kebungs*]) are hunted across the social systems. More families in remote (62.5%) than in transitional villages (28.5%) mentioned that they avoid hunting female game animals (e.g., *kebungs*) or catching fish during their breeding periods and that they varied their hunting locations to avoid overhunting. As a result, bioresources formerly used indiscriminately have now received priority for conservation. In addition, sustainability of local biodiversity is maintained by indigenous institutions, including *Kebang* (led by men) and *Reglep* (led by women). These play a significant role in regulating hunting and fishing, and harvesting of forest resources, with violators being fined.

#### Correlation of use and conservation of species

We found a highly significant correlation between the use and conservation of plant species for both food and ethnomedicine ( $0.924$ ,  $p < 0.000$ ), and the communities gave greater emphasis on conserving these species in diverse ecosystems (*jhum* land, home gardens, and *morang* forests) than for those used only for food ( $0.632$ ,  $p < 0.015$ ) (Table 6). The correlation between use and conservation of animals used for food was also appreciably high ( $0.832$ ,  $p < 0.0005$ ).

#### Discussion

Two key points arise from this research: first, how culturally rich plant and animal species are used and accessed for food, ethnomedicine, and livelihood security

by *Adi* women and secondly, how the insights of *Adi* women in our study can benefit several targets of Sustainable Development Goals (SDGs) and environmental policies in India.

#### Biocultural resources: food and livelihood security

Locally harvested plants and animals are important culturally and nutritionally, enhancing health and livelihood security for *Adi* women and their families. Turner and Clifton (2009) and Maffi (2010) reported that local biodiversity is a backbone for cultural identity and overall livelihood security of indigenous peoples across the globe. We found that *Adi* women from different social backgrounds (i.e., from remote versus transitional communities) did not necessarily use and access food species in the same way. Women of remote communities in general used more local plant and animal species than those of transitional villages. This difference might be due to variations in upbringing, different ways of coping with time and labor constraints in food production, and differing degrees of access to marketed food (Power 2008; Mishra et al. 2009). Different local strategies were applied by *Adi* women in accessing food species from different land use types (Turner 2005; Reyes-García et al. 2009). A number of plant species documented were used for both food and ethnomedicine, and this was particularly notable for the remote areas. Our work supports other research showing that local plants and wild game are generally beneficial for the overall nutrition, health, and well-being of indigenous peoples (Kuhnlein et al. 2013; Samson and Pretty 2006). Gregory (2000), Kuhnlein (1980), Kuhnlein (2005), and Kuhnlein et al. (2013) reported that wild plant

**Table 6** Association between usage and conservation of species

Biocultural usage of species	Sample size	Spearman rank statistic ( <i>r</i> )	Significance ( <i>p</i> value)
Plant species used in food	14	0.632	0.015*
Plant species used both as food and ethnomedicines	33	0.924	0.000**
Animal species used as food	17	0.832	0.0005**

\*\* and \*\*\* indicate significance at 0.05 and 0.001 probability levels, respectively

Data were analyzed for across the systems (remote and villages under transitions). Categorization in rural and semi-rural was not possible due to statistical assumptions of spearman correlation statistics to avoid misleading conclusions

foods are typically higher in calcium, iron, magnesium, and vitamin C, for example, than cultivated plants. Further, Gregory (2000) suggested that wild fish has less fat, and in particular, less saturated fat, than farm-raised fish. On a worldwide scale, the potential of local species that can be employed as staple foods or in medicinal treatments is very high (Bartlett et al. 2007). While this is especially true for people of remote areas still little affected by planned knowledge, use of local resources also offers many opportunities for enhancing the well-being of town and city dwellers. We found a distinct change in *Adi* peoples' food systems over the last few decades, as is occurring in people's food systems worldwide, which have been transformed at an unprecedented rate due to globalization: a phenomenon termed the "nutrition transition" (Kuhnlein 1980; Bartlett et al. 2007; Power 2008).

We found that women living in transitional social systems closer to urban centers had knew less about traditional ways of cultivating, harvesting, and using local food resources from diverse ecosystems, and used fewer of these foods (cf Turner and Turner 2004; Singh et al. 2010). As a result, their resilience to health and environmental risks is expected to magnify from the erosion of biocultural diversity and the shift away from nutritionally rich local foods to marketed foods, which are often high in unhealthy fats and sugars (Turner and Clifton 2009). Irrigated and mono-cropping systems and implementation of PDS (public distribution system) in India (Kothari 1997), along with emergence of new food stocking and distribution patterns (Behera et al. 2016) with the easy availability of commercial and marketed foods, offer seemingly more efficient alternatives for the people living in or nearby towns, who previously used primarily local and uncultivated species (Kothari 1997). The detrimental effects of new and changed globalized diets are reflected not only in the poorer health of individuals, but also in the farming systems and management of local ecosystems (Parks et al. 2005; Nautiyal et al. 2007).

#### **Biodiversity, conservation, and sustainability**

Strategically, the *Adi* access food resources from diverse ecosystems in different seasons and practice a variety of ways that conserve and sustain these resources.

Nonetheless, the variety of foods and the extent of conservation practices vary with social differences, especially in relation to proximity to urban centers. We found a significant correlation between use and conservation of food species. Home gardens (species used for only food), *morang* community forests (species used for both food and ethnomedicines), and common resource areas (aquatic bodies and *morang* community forests) were the major land use types where diversity of species was higher across both remote and transitional *Adi* communities. Conservation strategies were further augmented with traditional agronomic practices, varying from one social system to another. Studies have confirmed that in mountainous ecosystems, local biodiversity being conserved in traditional land use systems contributes significantly to overall biodiversity (Jiang et al. 2003) as compared to the more intensive land use systems where exotic species are grown intensively (Parks et al. 2005).

Cultural practices are governed through beliefs and value systems, and supported by indigenous institutions that shape human behavior in the extraction of plant or animal resources, thus influencing conservation outcomes (Berkes 2017). We found a number of plant species with very high cultural values. Use and conservation of food species governed through cultural practices, socio-ecologically and economically compatible with *Adi* food traditions, might have been enhanced by their location in remote, fragile mountainous ecosystems, and also their need to ensure that local resources from diverse ecosystems are available consistently (cf Charnley et al. 2007). However, recent changes in ecological processes, such as reduction in the *jhum* land cycle due to the increasing human population (Ramakrishnan 2007), conversion of community forests to commercial fields (e.g., fruit orchards), and changes in social norms, are altering the food habits of local community in Ar P (cf Sobrevila 2008). However, the National Biodiversity Strategy Action Plan and Greening India policies, in which women's participation and knowledge are being incorporated in planning and programs on biodiversity conservation (GOI 2019) show promise. The Indian policy of "*Sustaining Himalayan Ecosystems*", which considers land use change and other environmental factors as challenges to biodiversity conservation, may draw

insights from these findings to improve conservation outcomes (GOI 2010).

### Insights for Sustainable Development Goals (SDGs)

Despite the fact that women are creative in adding value to plant and animal species by cultivating and using them as nutritionally rich foods and ethnomedicines, their knowledge has been given little attention in the science and policy initiatives of Ar P (GOI 2007). One target of SDGs, “No Poverty”, calls on giving equal rights and opportunity to vulnerable people, including women, for management of land and other natural resources to enhance resilience against several environmental stressors (UN 2019). A key result would be to provide opportunities for involving such women, with their different concerns and needs, in the “bottom-top” approaches for conservation, development, and overall community well-being (Shimla Declaration 2009). SDG targets two (“Zero Hunger”) and fifteen (“Life on Land”) call on participation of local stakeholders to strengthen policy and actions required to meet food security, biodiversity conservation, and arresting land degradation (UN *ibid*; UNESCO 2016a; UNESCO 2019). Engaging women and using their knowledge about access to food resources and their conservation practices thus become crucial inputs to various agencies in order to meet targets for sustainable development (Turner and Clifton 2009; UNESCO 2016b). Our results also hold practical utility as knowledge and practices for plant and animal biodiversity management reported herein can be used for formulating location-specific conservation and genetic improvement programs (e.g., selection for diverse traits) and agronomic manipulations for halting biodiversity erosion and land degradation. Ironically, despite their efforts in managing land and biodiversity resources in ecologically harsh situations, such tribal communities seldom receive policy attention and attendant benefits like equitable benefit sharing for biodiversity conservation.

Empowerment of *Adi* women through location-specific educational endeavors is vital. Culturally responsive education on traditional foods and associated knowledge will be a prerequisite (Blanchet-Cohen and Reilly 2013) to further strengthen the legacy of conserving biocultural resources with emphasis on achieving SDG targets (especially 1, 2, and 15). For this, women’s roles within the school education system need to be defined to ensure knowledge transfer and research promotion, in order to provide a scientific and technical base for supporting government policies (Kuhnlein et al. 2013; UNESCO 2016a). Motivating younger women, particularly from transitional systems, to learn from their elders about traditional food-related knowledge, and to form self-help groups (SHG) for value addition and income

generation can strengthen the sustainability of biocultural diversity while meeting several SDGs.

### Conclusions and policy implications

Our study has demonstrated that *Adi* women, particularly those living in more remote communities, possess a rich knowledge about nutritionally important local food species and their traditional products. They rely heavily on local plant and animal species accessed from diverse land use systems and conserved using proven traditional practices. We found that 14 different plant species were used as food, 33 as both food and ethnomedicine, and 13 species were one of the major means to generating income. Furthermore, we noticed that 17 animal species also play crucial roles in food and sustaining cultural identity of the *Adis*. The knowledge on integrated strategies applied by *Adi* women for accessing and using food resources was found to improve biocultural diversity and social-ecological resilience. Women respondents from traditional and transitional villages differed significantly with each other for use of plant and animal species for food, ethnomedicine, and income generation, with the former using significantly more number of species. Similarly, women from traditional villages had more knowledge on species conservation practices than their transitional counterparts. Home gardens were the most important source of diverse food plants, followed by *jhum* lands. *Morang* community forests and home gardens displayed more species diversity than other land use systems. Unfortunately, changing life styles and land use patterns have accelerated the erosion of biocultural knowledge; particularly in and around transitional villages. Based on key findings, following recommendations, covering socio-economic and ecological dimensions, can be of considerable relevance to future policy initiatives on sustainable development in fragile mountainous and similar ecosystems:

1. Promotion of reciprocal learning between formal and informal knowledge systems can enhance the adaptive capacity of local communities to cope with emerging social-ecological stressors and provide new avenues to science-policy establishments for improving outcomes vis-à-vis SDGs. Increased participation of custodians of biocultural resources, for example, can improve the local acceptability and outcomes of programs like “Organic Farming Policy” (2005) intended to achieve intertwined objectives of social-ecological resilience and well-being.
2. Emphasis also needs to be placed on promoting local/regional dialects as means for rapid diffusion of biocultural knowledge, especially in areas where social-ecological changes are taking a toll natural capital and livelihoods. For example, creation of “Village Knowledge Banks” in collaboration of



science-policy institutions, while retaining local identities and ownership of resources, can provide localized education and learning platforms, particularly in areas rich in biocultural resources but facing threats.

3. There is a need for relevant provisions in government policies and programs [e.g., mid-day meal and public distribution system (PDS)] for promoting nutritional local food. Consequent increase in demand for the locally produced nutritious food can motivate the communities for strengthening species conservation measures as well as increasing livelihood opportunities.
4. Special empowerment drives need to be launched for the capacity building of disadvantaged women groups (e.g., *Adi* women in our case) through Indian policies on promotion of micro and small industries, food processing and value addition, skill development, and eco-tourism such that they are not only better equipped for livelihood security in face of looming threats but may also contribute to achieving some targets of SDGs and biodiversity conservation policies.
5. Coordinated planning between agriculture (including horticulture), forestry, land development corporations, and housing authorities remains critical to reversing and arresting the adverse impacts of land use changes and erosion in biocultural diversity. Aligning local conservation practices with flagship national programs (e.g., Sustaining Himalayan Ecosystems) can specifically help achieve the SDGs targets of “Zero Hunger” and “Life on the Land”.

## Supplementary information

**Supplementary information** accompanies this paper at <https://doi.org/10.1186/s13717-020-00232-x>.

**Additional file 1.** Characteristics of sampled *Adi* women; major aspects covered in study through pilot testing of interview schedule; visits conducted to various food production/conservation systems (recording and validating species); participatory rural appraisals tools applied in recording data; and beliefs and traditional practices prevalent among *Adi* women relating to wild animals and some plants used in foods.

## Abbreviations

Ar P: Arunachal Pradesh; SDGs: Sustainable Development Goals; TK: Traditional knowledge; SHG: Self-help group

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## Authors' contributions

RKS generated the idea and designed the study, collected and analyzed data, and wrote the article. AK, AS, and PS helped in application of study framework, statistical applications, writing, and reading and revising the manuscript. All the authors read and approved this manuscript.

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## Availability of data and materials

Substantial amount of data generated and analyzed is covered in the paper. Further, additional data have been provided in online resources. However, corresponding author may be contacted in case of any clarifications required on data under report.

## Ethics approval and consent to participate

Not applicable; however, study participants were informed about the objectives of the study prior to their participation, including the expected outcomes in form of print and digital publications. Accordingly, the consent was obtained in oral form from the studied respondents and Community Chief (*Gaon Burha*) of study villages on knowledge and practices (including photo) on food species to be published. This study was approved by the institute of affiliation.

## Consent for publication

Not applicable

## Competing interests

The authors hereby declare that they have no competing interests on this article.

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