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RESEARCH

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The nexus between ecology of foraging and food security: cross-cultural perceptions of wild food plants in Kashmir Himalaya

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Abstract

Background Wild food plants (WFPs) play an important role in the traditional dietary habits of various indigenous communities worldwide, particularly in mountainous regions. To understand the dynamics of food preferences, cross-cultural studies on food plants should be conducted across diverse ethnic groups in a given area. In this context, the current study investigated the use of WFPs by seven different cultural groups in the Kashmir Himalayan Region. In this area, people gather wild plants and their parts for direct consumption, traditional foods, or sale in local markets. Despite this reliance, documentation of the food system, especially concerning WFPs, is notably lacking. Hence, our research aimed to document WFPs, along with associated traditional ecological knowledge, and identify major threats to their long-term sustainability in Division Muzaffarabad.

Methods Through a comprehensive approach involving questionnaires, interviews, focus groups, and market surveys, we gathered data from 321 respondents. PCA was performed to analyze threats and plant use using "factoextra" in R software. Origin Pro was used to create a chord diagram, while R software was used to generate a Polar heat map. Additionally, a Venn diagram was created using Bioinformatics software.

Results The study included 321 informants, of whom 75.38% were men and 24.61% were women. In total, 113 plant taxa from 74 genera and 41 botanical families were reported. Polygonaceae and Rosaceae accounted for the majority (17 species each), followed by Lamiaceae (7 species). Leaves were the most used part as food sources (41.04%), followed by fruits (33.33%). Most of the species are consumed as cooked (46.46%) and as raw snacks (37.80%). A total of 47 plant species were collected and cooked as wild vegetables, followed by 40 species used as fruits. This study is the first to describe the market potential and ecological distribution of WFPs in the study area. Cross-comparison showed that utilization of WFPs varies significantly across the region and communities, including their edible parts and mode of consumption. Jaccard index (JI) value ranged from 5.81 to 25. Furthermore, the current study describes 29 WFPs and 10 traditional food dishes that have rarely been documented in Pakistan's ethnobotanical literature. Climate change, invasive species, expansion of agriculture, and plant diseases are some of the most significant threats to WFPs in the study area.

Conclusions The older age group has more knowledge about WFPs compared to the younger generation, who are not interested in learning about the utilization of WFPs. This lack of interest in information about WFPs among the younger generation can be attributed to their limited access to markets and availability of food plants

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in the study area. Traditional gathering of food plants has been reduced in younger generations during recent years; therefore, it is crucial to develop effective conservation strategies. These efforts not only safeguard indigenous flora, food knowledge, and cultural heritage, but they also contribute to food security and public health by utilizing local wild foods in the examined area.

Keywords Ethnobotany, Ethnoecology, Food security, Himalaya, Kashmir, Wild food plants

Introduction

Wild food plants (WFPs) play a significant role in the livelihoods of many people living in remote areas around the world, notably in offering dependable alternatives when crop production declines or collapses [1–5]. Wild edible plants provide carbohydrates, proteins, fiber, vitamins, and minerals, with a high concentration of vitamins A and C, zinc, iron, calcium, iodine, thiamine, riboflavin, niacin, and folacin. In addition, WFPs are useful for developing novel food crops through domestication and functioning as a genetic resource pool required to increase cultivar yield [1]. Globally, a lot of people rely on plants during periods of severe food shortages following the occurrence of challenges like drought and inadequate harvests because of these essential characteristics, especially in developing nations. Women who are unemployed and live in rural or urban regions are more likely to prepare meals for their families, thus, when there is a decrease in household income, they are more likely to return to using WEPs [6, 7].

In recent years, WFPs has become a research priority for many ethnobotanists, owing to a worldwide interest in documenting ethnobotanical information about neglected WEPs sources [8]. In order to preserve traditional knowledge regarding WFPs for future generations, it is crucial to support research on these plants, as plant biodiversity loss and the cultural adaptation of indigenous peoples threaten this knowledge [9–13]. Numerous studies carried out in mountainous regions over the past 20 years [14, 15] have shown that those places frequently serve as reservoirs for local flora that are disappearing and are important for food security. Other factors have also significantly influenced this legacy in addition to industrialization and globalization, for example, the homogenizing effect of centralization in former Soviet lands has negatively impacted local knowledge related to plants [16]. WFPs have served as an essential part of human diets throughout human history. The modern agricultural revolution, urbanization, and globalization have caused human populations to move farther away from their natural surroundings. Food security is now under risk due to the disappearance of wild edible plants and agricultural practices [17].

A double burden of malnutrition, a shortfall in calories (hunger), is being faced by humanity as the world's population approaches 10 billion by 2050 [18–20]. Global food production must rise in order to meet these challenges, this cannot be done by merely expanding industrial agriculture by converting land, which would harm the environment and contribute to the already declining biodiversity [21, 22]. This is a challenging scenario because, in order to enable the delivery of other goods and ecosystem services that are both directly and indirectly essential to human well-being, it is necessary to assure the sustainable production of healthy food while safeguarding biodiversity. Additionally, in order to prevent disruptions to food production and people's livelihoods caused by climate change, it is important that social adaptation be facilitated [23–25].

An assessment of the current distribution and conservation status of food resources has become urgent to inform science-based policy making, since most analyses lack information on the entire range of food resources consumed worldwide and because global biodiversity is rapidly declining, which limits our ability to find new food sources [26]. Furthermore, protecting food diversity and related Traditional Knowledge (TK) has become a global priority. This is because climate change has had detrimental effects on biodiversity, agricultural output, and food security [27, 28].

Wild food plants (WFPs) have been a vital source of food for people since ancient times, but their relevance in the human diet has declined, first with agricultural development and then more severely with urbanization and industrialization processes [29]. Whereas the complex body of knowledge, understandings, practices, and beliefs that human civilizations established in inextricably linked relationships with their natural setting and that is dynamic and evolving together with social and ecological changes is known as local/traditional ecological knowledge (LEK/TEK) [30]. We think that environmental foodscapes (agroecosystems where foods are generated), culinary techniques and skills, regional recipes, and the social settings around food consumption across a community are all connected to traditional/local food knowledge (LFK). In the past few years, ethnobiologists have compiled knowledge on gathering and utilizing WFPs in various parts of the world [31–33], and with the goal of offering practical resources for

promoting rural development that is sustainable or, in certain cases, even for enhancing food security [34–37].

Pakistan is the sixth most populated country in the world and has a lower middle-class income and approximately 60% of the country's population experiences food insecurity [38], and it continuing to be the 11th most food insecure nation worldwide [39]. Despite the richness of natural resources in Pakistan, this country still faces a food deficit. A report on the global hunger index (GHI) states that the country is dealing with severe problems related to food security [31]. Natural resources are being lost in the Himalayan region as a result of a number of biophysical and social issues in recent years [40]. This has led to a notable reduction in food yield as well as a major loss of ecosystem services, namely in the areas of biomass, water, and soil nutrients [32].

The historic state of Jammu and Kashmir is renowned for its rich plant diversity because of its variations in topography, elevation, and geography [41–43]. In this prospective area of traditional knowledge, there are many different ethnic communities [41, 44] who rely heavily on small-scale pastoralist and horticultural activities and have a strong connection to natural resources for their livelihood. Kashmir is distinguished by its distinct food preparation, languages, clothing, festivals, customs, and communities. Food serves as a primary identification marker, identifying relationships, socioeconomic classes, personalities, and ethnic groups or nationalities, all of which vary over time and space. It is a clear statement of cultural values [45]. Different ethnic communities in Kashmir have distinctive cultural representations [46]. Different plants are used by each of these ethnic groups in their traditional foods.

Documentation of WFPs in the context of the ethnic group and ecological zones of the study area can effectively illustrate the impact of cultural traditions. Furthermore, many ethnobotanical studies have been done to record the dynamics of medicinal plant utilization [14, 41, 42, 47–53], but with no specific large-scale regional study among various ethnic groups with respect to different ecological zones, focusing on WFPs in Pakistan's Kashmir Western Himalaya. The term Local Ecological Knowledge (LEK) refers to practical ecological knowledge. This encompasses the knowledge held and utilized by indigenous people with a long history of resource use, as well as non-indigenous natural resource users [54]. The seven ethnic groups chosen for this study are prominent consumers of WFPs in their everyday lives. They live in a range of ecological zones within the study area, from subtropical to alpine regions, and integrate various plants into their traditional practices. Consequently, their inclusion ensures a thorough representation of WFPs usage across diverse groups and ecological zones. This selection offers an accurate and comprehensive insight into how different communities engage with and rely on these plants, highlighting the actual diversity and importance of WFPs in the region. The primary goal of this study was to document local ecological knowledge about WFPs in order to provide stakeholders with a potentially helpful baseline of data for revitalizing them. The study aimed to: (a) to document traditional WFPs and their associated folk cuisines in the Kashmir Himalayan Region, (b) to evaluate the ecological distribution in various ecological zones and perceived threats to these WFPs, (c) to conduct a cross-cultural comparison among the selected ethnic communities, and (d) to compare the findings with previously reported ethnobotanical literature.

Materials and methods

Study area

Azad Jammu and Kashmir (AJK) is a region in the western Himalayas and is situated between 33°54′-34° 44′ North latitude and 73° 31′-74° 50′ East longitude [41, 42]. It has a border with the Indian state of Jammu and Kashmir, which is divided by the Line of Control. The state's topography is rugged and mountainous, with forested mountain sides and deep valleys cut by various streams and rivers. Azad Jammu and Kashmiris a biodiversity hotspot with diverse agro climatic zones and ecosystems due to a large altitudinal gradient extending from 360 m in the southern Punjab Plains to 6325 m in the north [15, 55]. There are various breathtaking landscapes around the country, showcasing the allure of tumbling rivers, winding streams, and dense woods with glittering flora. A field survey was conducted in three districts of Kashmir: Muzaffarabad, Neelum Valley, and Jhelum Valley. The target region comprises of subtropical forests and alpine meadows with elevations ranging from 971 to 4229 m (Fig. 1). The research area's environment is extreme cold throughout the winter season, with significant snowfall and freezing temperatures as low as -10 °C between November and April. During the summer months of June to August, the average temperature is around 10 °C, however the season is cold and brief. The area receives approximately 1000 mm of precipitation each year, the most of which arrives as snow in winter [14, 42, 47].

Ethnographic and socio-economic variables of AJK

The region's ethnic composition is wide and complex, including Syed, Awan, Rajgan, Khawaja, Gujjar, Bakarwal, and Mughal. Gujjar tribes are distributed throughout the region, with the Syed and Rajgan tribes being the most influential ethnic groups in Division Muzaffarabad, Azad Kashmir. Almost all of the residents are Muslims. Popular languages include Hindko, Gojri, Pahari, and

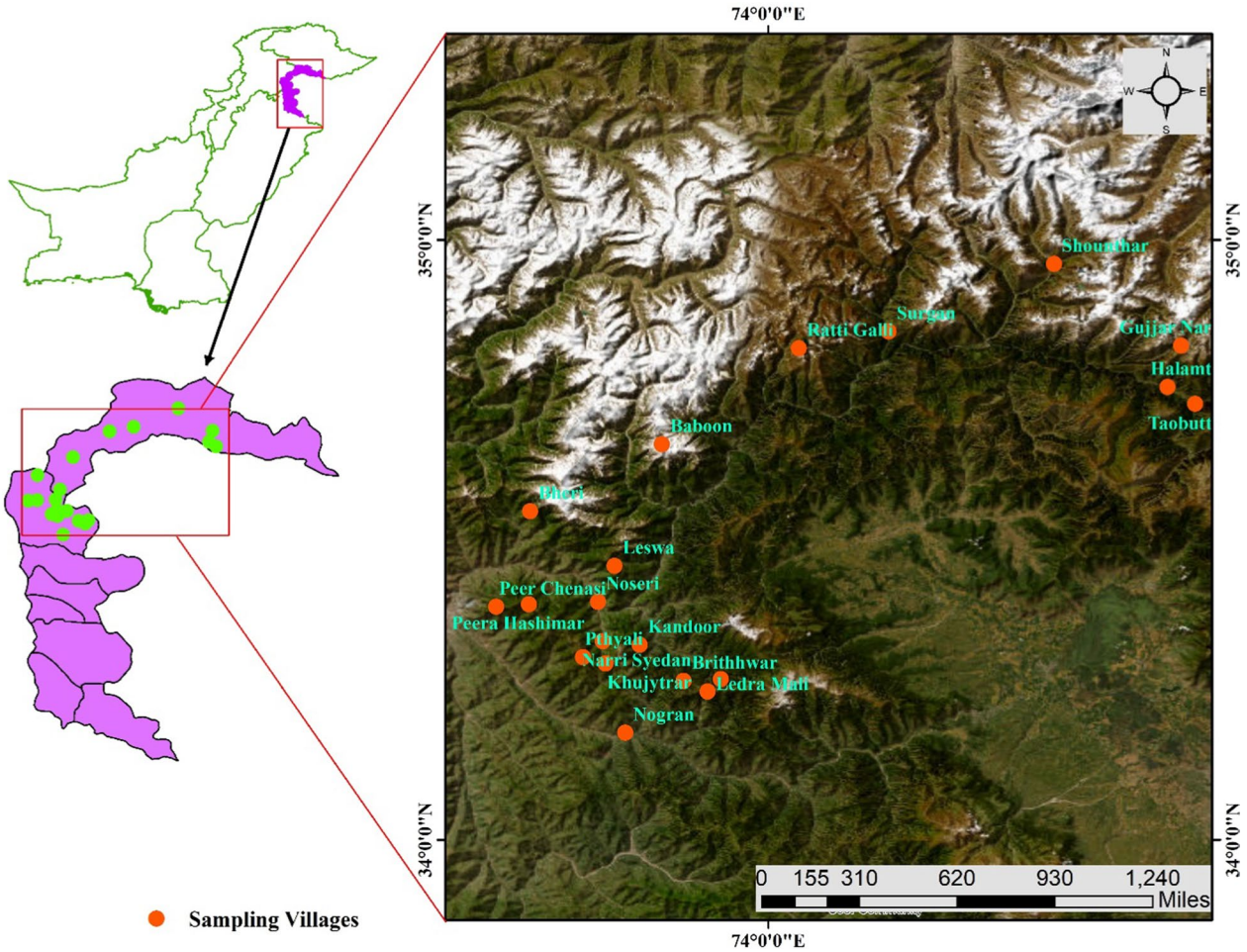

Fig. 1 A map showing the location of the study sites from Kashmir, Western Himalaya

Kashmiri, but a majority are also proficient with Urdu [41]. The majority of the research region is remote, with tough mountainous terrain and a long distance from urban areas. Local residents live in poverty, lack government services, and do not have access to modern healthcare facilities. The roadways and other infrastructure are in poor condition, and many residents are engaged in agriculture, cattle, and their own small businesses. Some are educated and work for the government, while a small number serve abroad. Agriculture is mostly dependent on rain-fed agricultural techniques, with maize being the primary crop in the region. Basic health services are mostly supplied by a few public health dispensaries in the region, but residents at higher altitudes have restricted access to them and rely heavily on herbal medicines to treat most ailments and for nourishment. Elders and health practitioners possess the majority of indigenous ethnomedicinal knowledge [43, 52, 56, 57]. The bulk of the population lives in rural areas, where agriculture and cattle are the primary sources of income. Domestic animal holding among inhabitants of these communities indicates a higher socioeconomic status within a family [15]. Tourism has significantly helped the region's socioeconomic conditions by creating employment opportunities for local people.

Data collection

In the study area, villages and summer pastures were selected using the multistage random selection approach described in the method [58]. The 20 villages and summer pastures selected from the study area included Narri Syedan, Khujytrar, Bheri, Pthyali, Noseri, Ratti Galli, Peer Hashimar, Peer Chenasi, Taobutt, Gujjar Nar, Leswa, Shounthar, Surgan, Baboon, Halamt, Kandoor, Ledra Mali, Sanae Behak, Brithhwar, and Nogran. Between April 2022 and November 2023, field trips were organized to visit each village and summer pasture. Surveys were conducted in the subtropical and temperate zones from April to June each year, spanning a total of 6 months. For the upper temperate to alpine zones, surveys were

carried out from July to September, also covering a total of 6 months. Additionally, WEFPs were collected from various zones during the winter season from October to November each year, amounting to a total of 4 months. Ethnic groups typically gather WFPs from their surroundings as part of their daily diet. The majority of these groups collect WFPs from temperate forests, as well as from subtropical, subalpine, and alpine zones. In the study area, they mainly harvest WFPs during the summer season near their settlements. While some ethnic groups transport wild plants to their gardens, in the alpine zone, local people harvest WFPs directly from their natural habitats, rather than from gardens like those in the temperate and subtropical zones. Interviews have been conducted in accordance with the codes of ethics of the International Society of Ethnobiology and the American Anthropological Association [59, 60]. The study included 321 informants (Table 1, Fig. 2). 75.38% of participants were men, while 24.61% were women. The discussions were carried out in the local languages (Hindko, Pahari, and Gojri) in order to facilitate interaction with the local informants. Participants were asked about the local names, collection seasons, parts used, mode of utilization, recipes, major threats to each species, and the selling or marketing of the WFPs species they have previously obtained and are still collecting [41, 61]. Each interviewee was told verbally that the data acquired would be publicized and shared across the globe, which could benefit them by generating global interest in their traditional knowledge and utilization of food plants, as well as the flora they associate with. The participants represented seven different ethnic groups: Syed, Awan, Rajgan, Khawaja, Gujjar, Bakarwal, and Mughal. Most of the informants were above the age of 35 and below 70 years old. Threats to WFPs are primarily caused by natural and anthropogenic factors. Data on the sustainability and

Table 1 Demographic information of the study area, including stay duration, altitude, ethnicity, religion, occupation, and language

Village/ summer pasture name	Altitude (m)	Ecology	Stay duration (months)	Ethnicity	Religion	Language	No. of male & female interviewed	Occupation
Narri Syedan	1654	Temperate forest	12	Syed	Islam	Hindko	18 M/7F	Farming & Cattle rearing
Khujytrar	2655	Subalpine pasture	4	Syed	Islam	Hindko	13 M/6F	Cattle rearing
Bheri	2794	Temperate forest	4	Gujjar	Islam	Gojri & Hindko	10 M/3F	Farming & Cattle rearing
Pthyali	2647	Subalpine pasture	4	Gujjar	Islam	Gojri & Hindko	12 M/4F	Cattle rearing
Peera Hashimar	3063	Alpine pasture	3	Gujjar	Islam	Gojri & Hindko	10 M/3F	Cattle rearing
Noseri	1073	Subtropical forest	12	Awan	Islam	Hindko	13 M/3F	Farming & Cattle rearing
Peer Chenasi	2819	Upper Temperate Forest	12	Gujjar	Islam	Gojri & Hindko	15 M/4F	Farming & Cattle rearing
Taobutt	2322	Temperate forest	12	Kashmiri	Islam	Kashmiri & Hindko	9 M/4F	Farming & Cattle rearing
Gujjar Nar	3668	Alpine pasture	3	Bakarwal	Islam	Gojri	12 M/5F	Cattle rearing
Ratti Galli	4229	Alpine pasture	3	Bakarwal	Islam	Gojri	10 M/6F	Cattle rearing
Leswa	2371	Upper Temperate Forest		Gujjar	Islam	Gojri & Hindko	13 M/4F	Farming & Cattle rearing
Shounthar	2920	Subalpine pasture	4	Mughal	Islam	Hindko	15 M/3F	Cattle rearing
Surgan	2207	Temperate forest	12	Gujjar	Islam	Gojri & Hindko	12 M/4F	Farming & Cattle rearing
Baboon	3555	Alpine pasture	3	Bakarwal	Islam	Gojri	9 M/3F	Cattle rearing
Halamt	2302	Temperate forest	12	Khawaja	Islam	Hindko	16 M/3F	Farming & Cattle rearing
Kandoor	2147	Temperate forest	12	Gujjar	Islam	Gojri & Hindko	11 M/4F	Farming & Cattle rearing
Ledra Mali	3519	Alpine pasture	3	Mughal	Islam	Hindko	8 M/2F	Cattle rearing
Sanae Behak	2438	Temperate forest	12	Gujjar	Islam	Gojri & Hindko	13 M/4F	Farming & Cattle rearing
Brithhwar	2575	Temperate forest	12	Gujjar	Islam	Hindko	8 M/3F	Farming & Cattle rearing
Nogran	971	Subtropical forest	12	Awan	Islam	Hindko	15 M/5F	Farming & Cattle rearing

Fig. 2 Interviews and group discussions with different ethnic groups, where **a** interview with Bakarwal ethnic group (men), **b** interview with Mughal ethnic group, **c** interview with Bakarwal ethnic group (women), **d** interview with Gujjar ethnic group, **e** group discussion with the local inhabitants, and **f** group discussion with the local inhabitants of various ethnic groups to record the variations among the collected data

long-term existence of WFPs was gathered from the field, where respondents were asked to provide information on potential threats in the study area. Consequently, we collected data on WFP threats through surveys conducted using the group discussion method. During field trips and data collection, we observed that not all plants were in the flowering or fruiting stages. In these instances, we still collected data and revisited the same location during different flowering and fruiting seasons to collect plant specimens. Most of the informants were illiterate. Additionally, these participants had extensive expertise and knowledge of the wide range and utilization of WFPs plants in the study area. All plant specimens were identified by Prof. Dr. Mushtaq Ahmad using the available literature from the Flora of Pakistan (www.efloraofpakistan.com). The plant names were then cross-checked using World Online Flora (www.worldonlineflora.com).

Classification of wild food plants based on mode of consumption

All WFPs were classified into several food categories based on their mode of consumption, as per Thakur et al. [62]. Plants such as *Amaranthus viridius*, *Malva parviflora*, *Chenopodium album*, *Nasturtium officinale*, *Phytolacca latbenia*, *Plantago major*, and *Pteridium aquilinum* were classified as vegetables. Some species, such as *Fragaria nubicola*, *Gaultheria trichophylla*, and *Pyrus pashia*, were classified as fruits, and they were eaten raw. Another category of plants included *Zanthoxylum armatum*, *Mentha longifolia*, and *Juglens regia*, which are used to make sauces, salads, and chutneys. Herbal tea is a beverage made by steeping herbs, flowers, roots, or other plant materials in hot water, whereas herbal drinks are created by using natural substances derived from different parts of plants, such as leaves, stems, roots, fruits, buds, and flowers [63]. Some plants are categorized as herbal teas based on how they are consumed, such as *Abies pindrow, Arnebia benthamii*, and *Bistorta amplexicaulis*. There are also other plants that are classified as herbal drinks, including *Mentha longifolia, Plantago lanceolata*, and *Plectranthus rugosus*.

Jaccard index (JI)

To find similarities or resemblances between indigenous traditional knowledge data and prior ethnobotanical research undertaken in multiple areas of the Himalayas [64], the JI is calculated using the formula:

$$JI = C * 100/(A + B) - C$$

where "A" represents the recorded species in the present investigation, "B" represents the recorded species in the

other area to be compared, and "C" represents the number of species identified in both studies.

Data analysis

Principal component analysis (PCA) was conducted to analyze the threats and plant utilized. The `factoextra` package in R was employed to generate PCA biplots, contribution plots, and eigenvalues, which represent the variance explained by each principal component (Oksanen et al., 2013). A chord diagram illustrating the relationships between modes of preparation, and species was created using Origin Pro software (version 10). For showing the presence and absence of plants in different ethnic groups a Polar heat map was created in R. To visualize the plants across different ecological zones, a Venn diagram was constructed using Bioinformatics & Evolutionary Genomics software (available at http://bioinformatics.psb.ugent.be/cgi-bin/liste/Venn/calculate_venn.htpl) [65].

Results

WFPs and their taxonomic diversity

Overall, 113 folk taxa belonging to 74 genera and 41 botanical families were recorded. A high proportion of these WFPs belong to the Polygonaceae and Rosaceae (17 species each), followed by Lamiaceae (7 species), Asteraceae (5 species), Fabaceae and Solanaceae (4 species each), Plantaginaceae, Moraceae, Poaceae, Malvaceae, Dryopteridaceae, Chenopodiaceae, Berberidaceae, and Amaranthaceae (3 species each) (Fig. 3). The most dominant WFP categories were vegetables (47 species), fruits (40 species), herbal teas (12 species), herbal drinks (9 species), cereal crops (5 species), pickle (chutneys) and sauces (4 species), miscellaneous (3 species), and salad, spice, and condiments (2 species each). Indigenous peoples gathered these species for both their own and their animals' dietary needs (Table 2).

Growth form of the WFPs

The growth form results indicated that the majority of WEFPs are classified into three major categories, such as herbs, trees, and shrubs (Table 2).

Plant parts use

The results of the plant parts used revealed that leaves were identified as the most commonly utilized plant part, accounting for 41.04%. This was followed by fruit (33.33%), aerial parts (10.26%), rhizome (7.69%), bark (2.56%), grains (2.56%), beans (1.71%), seeds (1.71%), the whole plant (1.71%), nut (0.85%), root (0.85%), stem (0.85%), and tuber (0.85%) (Fig. 4).

Mode of consumption

Most of the species are consumed as cooked (46.46%), followed by raw snacks (37.80%), water-boiled (7.87%),

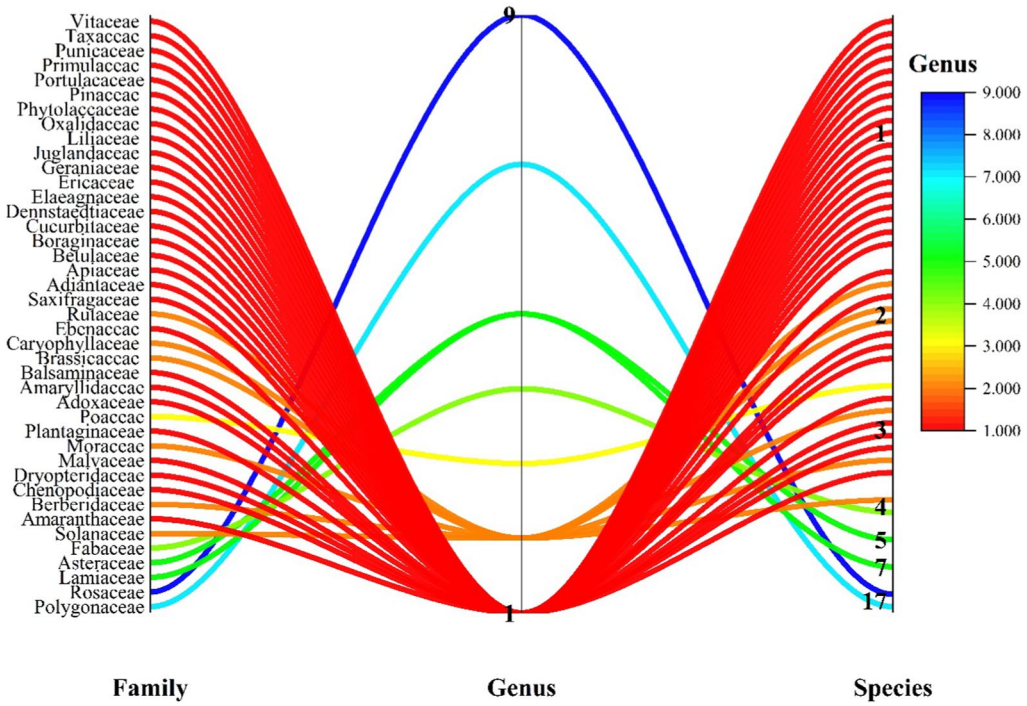

Fig. 3 Alluvial diagram representing the floristic composition of WFPs

Table 2 WFPs based on nutritional values and economic uses by various ethnic groups from Kashmir Himalayas

Taxa/voucher no.	Local name	Family	Life form	Food categories	Part used	Mode of consumption	Recipes	Marketing	Major threats
Abies pindrow (Royle ex. D.Don) Royle K-866	Tung	Pinaceae	T	Herbal tea	Bark	Water-boiled	Bark of the tree is removed, and then the inner soft portion is kept in water for 15–20 min to boil. According to the quantity of water, sugar is added to enhance the taste	–	Fuel wood, Deforestation, Climate change, Debarking, Lightning
Achillea millefolium L. K-867	Dand Jari	Asteraceae	H	Vegetable	Aerial parts	Raw snacks, Cooked	Aerial parts fried in oil with garlic, onion, ginger, tomato, and spices are cooked as vegetable. It is mostly used as a mixed vegetable with *Plantago* and *Polygonum* species during the summer season	–	Grazing
Aconogonum alpiunm Schur K-868	Pancholla	Polygonaceae	H	Vegetable	Leaves	Cooked	Young leaves fried in oil with onions, ginger, and spices are cooked as vegetable among the alpine Bakarwal and Gujjar communities	–	Grazing
Adiantum capillus-veneris L. K-869	Kaakwa	Adiantaceae	F	Herbal drink	Leaves	Infusion	Leaves are ground in water with the help of a pestle and then kept overnight. Locals use that greenish water early in the morning, before breakfast, to overcome many gastric problems	–	Fungal diseases

Table 2 (continued)

Taxa/voucher no.	Local name	Family	Life form	Food categories	Part used	Mode of consumption	Recipes	Marketing	Major threats
Ajuga integrifolia Buch.-Ham. K-870	Jaany Adam	Lamiaceae	H	Herbal drink	Aerial parts	Infusion	Aerial parts are ground in water, then plant material is removed, and the remaining water is taken as an herbal drink	–	Agricultural expansion, Climate change
Allium carolinianum Redouté K-871	Rich Pyaz	Amaryllidaceae	H	Vegetable, Spice, Salad	Whole	Raw snacks, Cooked	Leaves are eaten as salad, used as a vegetable fried in oil with tomatoes and red chilies, and used as a condiment as well	–	Overexploitation
Allium humile Kunth. K-872	Prhe Pyaz	Amaryllidaceae	H	Vegetable, Spice, Salad	Whole plant	Raw snacks, Cooked	Used as a vegetable fried in oil with tomatoes and red chilies, and also as a condiment and salad	–	Overexploitation
Amaranthus retroflexus L. K-873	Ghanyar	Amaranthaceae	H	Vegetable	Leaves	Cooked	Leaves fried in oil with tomatoes, onion, ginger, and spices are cooked as vegetable		Selective harvesting, Invasive species
Amaranthus spinosus L. K-874	Ghanyar	Amaranthaceae	H	Vegetable	Leaves	Cooked	Leaves fried in oil with tomatoes, onion, ginger, and spices are cooked as vegetable	–	Selective harvesting, Invasive species
Amaranthus viridius L. K-875	Ghanyar	Amaranthaceae	H	Vegetable	Leaves	Cooked	Leaves fried in oil with tomatoes, onion, ginger, and spices are cooked as vegetable	–	Selective harvesting, Invasive species
Angelica glauca Edgew. K-856	Choraa	Apiaceae	H	Condiment	Seed	Cooked	Use as condiment	–	Overexploitation
Arenaria serpyllifolia L. K-857	Lalori	Caryophyllaceae	H	Vegetable	Leaves	Cooked	Leaves fried in oil with tomatoes, onion, ginger, and spices are cooked as vegetable	–	Agricultural expansion, Grazing

Table 2 (continued)

Taxa/voucher no.	Local name	Family	Life form	Food categories	Part used	Mode of consumption	Recipes	Marketing	Major threats
Arnebia benthamii (Wall. ex G.Don) I.M.Johnst. K-858	Gaozaban	Boraginaceae	H	Herbal tea	Root	Water-boiled,	Rhizome is boiled in water for 15–25 min, then, with the addition of milk and sugar, taken as an herbal tea	+	Overexploitation, Climate change, Illegal export
Berberis kashmirana Ahrendt K-859	Sumbal	Berberidaceae	S	Fruit	Fruit	Raw snacks	Taken as fruit	–	Climate change, Agricultural expansion
Berberis lycium Royle K-860	Sumbal	Berberidaceae	S	Fruit, Vegetable	Fruit, Leaves	Raw snacks, Cooked	Taken as fruit young leaves are also used as a vegetable	–	Fuel wood, Agricultural expansion
Bergenia ciliata (Haw.) Sternb. K-861	Batpywa	Saxifragaceae	H	Herbal tea	Rhizome	Water-boiled	Rhizome is boiled in water for 20–30 min, then, with the addition of milk and sugar, taken as an herbal tea	+	Overexploitation, Agricultural expansion
Bergenia stracheyi (Hook.f. & Thomson) Engl. K-862	Batpywa	Saxifragaceae	H	Herbal tea	Rhizome	Water-boiled	Rhizome is boiled in water for 20–30 min, then, with the addition of milk and sugar, taken as an herbal tea	+	Overexploitation, Agricultural expansion
Betula utilis D. Don. K-863	Purz/Bhurj	Betulaceae	T	Herbal tea	Bark	Water-boiled	Bark is boiled in water for 10–15 min, then, with the addition of milk and sugar, taken as an herbal tea	–	Deforestation, Fire, Grazing, Lightning, Fuel wood, Debarking, Agricultural expansion
Bistorta affinis Greene K-864	Masloon	Polygonaceae	H	Herbal tea	Rhizome	Water-boiled	Rhizome is boiled in water for 20–25 min, then, with the addition of milk and sugar, taken as an herbal tea	–	Grazing

Table 2 (continued)

Taxa/voucher no.	Local name	Family	Life form	Food categories	Part used	Mode of consumption	Recipes	Marketing	Major threats
Bistorta amplexicaulis (D.Don) Greene K-865	Masloon	Polygonaceae	H	Herbal tea	Rhizome	Water-boiled, Cooked	Rhizome is boiled in water for 20–25 min, then, with the addition of milk and sugar, taken as an herbal tea	+	Grazing, Overexploitation
Capsella bursa-pastoris Medik. K-906	Mirchi	Brassicaceae	H	Vegetable	Leaves	Cooked	Leaves fried in oil with tomatoes, onion, ginger, and spices are cooked as vegetable	–	Grazing
Chenopodium album L. K-907	Bathuaa	Chenopodiaceae	H	Vegetable	Leaves	Cooked	Leaves fried in oil with tomatoes, onion, ginger, and spices are cooked as vegetable	–	Selective harvesting
Chenopodium botrys L. K-908	Bathuaa	Chenopodiaceae	H	Vegetable	Leaves	Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	Selective harvesting
Chenopodium murale L. K-909	Bathuaa	Chenopodiaceae	H	Vegetable	Leaves	Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	Selective harvesting
Cichorium intybus L. K-910	Kaasni	Asteraceae	H	Vegetable	Leaves	Cooked	Leaves are fried in oil along with onion, green chili, turmeric and salt	–	Grazing
Cotoneaster microphyllus Wall. ex Lindl. K-911	Loni	Rosaceae	S	Fruit	Fruit	Raw snacks	Taken as fruit	–	Climate change
Crataegus songarica K.Koch K-912	Arang	Rosaceae	T	Fruit	Fruit	Raw snacks	Taken as fruit	–	Constructions, Agricultural expansion
Cucurbita maxima Duchesne K-913	Choan/Alhan	Cucurbitaceae	Cl	Vegetable	Fruit, Leaves	Cooked	Fruits are fried in oil with tomatoes, red chilies, and used as vegetable		

Table 2 (continued)

Taxa/voucher no.	Local name	Family	Life form	Food categories	Part used	Mode of consumption	Recipes	Marketing	Major threats
Diospyros kaki L.f. K-914	Amlook	Ebenaceae	T	Fruit	Fruit	Raw snacks	Taken as fruit	+	Constructions, Overexploitation, Fuel wood
Diospyros lotus L. K-915	Kala Amlook	Ebenaceae	T	Fruit	Fruit	Raw snacks	Taken as fruit	+	Overexploitation, Fuel wood
Dryopteris filix-mas (L.) Schott K-916	Kunji	Dryopteridaceae	F	Vegetable	Aerial parts	Cooked	Aerial parts are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	+	Overexploitation, Fire, Agricultural expansion
Dryopteris ramosa (C.Hope) C.Chr. K-917	Laangro	Dryopteridaceae	F	Vegetable	Aerial parts	Cooked	Aerial parts are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	+	Overexploitation, Soil erosion, Fire, Agricultural expansion
Dryopteris stewartii Fraser-Jenk. K-918	Kunji	Dryopteridaceae	F	Vegetable	Aerial parts	Cooked	Aerial parts are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	+	Overexploitation, Soil erosion, Fire
Duchesnea indica (Andrews) Teschem. K-919	Sap mewa	Rosaceae	H	Fruit	Fruit	Raw snacks	Taken as fruit	–	Overexploitation
Elaeagnus umbellata Thunb. K-920	Kamkoli	Elaeagnaceae	S	Fruit	Fruit	Raw snacks	Taken as fruit	–	Invasive species, Constructions, Climate change, Agricultural expansion
Fagopyrum dibotrys (D.Don) Hara K-891	Katha	Polygonaceae	H	Vegetable	Aerial parts	Raw snacks, Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	Grazing, Overexploitation
Fagopyrum esculentum Moench K-892	Katha	Polygonaceae	H	Vegetable	Aerial parts	Raw snacks, Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	Grazing, Overexploitation

Table 2 (continued)

Taxa/voucher no.	Local name	Family	Life form	Food categories	Part used	Mode of consumption	Recipes	Marketing	Major threats
Ficus palmata Forssk. K-893	Phagwaari	Moraceae	T	Fruit, Vegetable	Fruit, Leaves	Raw, Cooked	Young leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	+	Fuel wood
Fragaria nubicola Lindl. ex Lacaita K-894	Mywa	Rosaceae	H	Fruit	Fruit	Raw snacks	Taken as fruit	–	Overexploitation
Gagea elegans Wall. K-895	Lyswa	Liliaceae	H	Vegetable	Aerial Parts	Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	Grazing, Climate change
Gaultheria trichophylla Royle K-896	Neeli Boti	Ericaceae	H	Fruit	Fruit	Raw snacks	Taken as fruit	–	Overexploitation, Agricultural expansion, Climate change
Geranium wallichianum D.Don K-897	Ratna	Geraniaceae	H	Herbal tea	Rhizome	Water-boiled	Rhizome is boiled in water for 15–25 min, then, with the addition of milk and sugar, taken as an herbal tea	–	Overexploitation
Impatiens edgeworthii Hook.f. K-898	Bantil	Balsaminaceae	H	Fruit	Fruit	Raw snacks	Taken as fruit	–	Grazing
Impatiens flemingii Hook.f. K-899	Bantil	Balsaminaceae	H	Fruit	Fruit	Raw snacks	Taken as fruit	–	Grazing
Juglans regia L. K-900	Khor	Juglandaceae	T	Nuts, Sauce	Nuts	Raw snacks	Taken as nuts	+	Constructions, Overexploitation
Jurinea dolomiaea Boiss. K-901	Gugal toop	Asteraceae	H	Miscellaneous	Root	Raw snacks, Cooked	Rhizome eaten as raw snacks	–	Overexploitation, Illegal export, Climate change, Habitat fragmentation
Malus pumila Mill. K-902	Syb	Rosaceae	T	Fruit	Fruit	Raw snacks	Taken as fruit	+	Fungal diseases
Malva parviflora L. K-903	Sonchal	Malvaceae	H	Vegetable	Leaves	Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	Grazing, Overexploitation

Table 2 (continued)

Taxa/voucher no.	Local name	Family	Life form	Food categories	Part used	Mode of consumption	Recipes	Marketing	Major threats
Malva sylvestris L. K-904	Sonchal	Malvaceae	H	Vegetable	Leaves	Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	Grazing, Overexploitation
Malvastrum coromandelianum (L.) Garcke K-905	…	Malvaceae	H	Fruit	Fruit	Raw snacks	Taken as fruit	–	No specific
Medicago polymorpha L. K-876	Sinja	Fabaceae	H	Vegetable	Leaves	Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	Grazing
Mentha arvensis L. K-877	Chita Pootna	Lamiaceae	H	Sauce, Herbal drink, Herbal tea	Leaves	Salad, Decoction	Fresh leaves are taken as salad and are also used for herbal tea and herbal drinks	+	Overexploitation, Invasive species, Soil erosion
Mentha longifolia (L.) L. K-878	Pootna	Lamiaceae	H	Herbal drink	Leaves	Decoction	Decoction of leaves is used as a herbal drink	–	Overexploitation, Invasive species, Soil erosion
Mentha spicata L. K-879	Pootna	Lamiaceae	H	Sauce, Herbal drink, Herbal tea	Leaves	Salad, Decoction	Fresh leaves are taken as salad and are also used for herbal tea and herbal drinks	+	Overexploitation, Invasive species, Soil erosion
Morus alba L. K-880	Chita toot	Moraceae	T	Fruit	Fruit	Raw snacks	Taken as fruit	+	Constructions, Plant diseases
Morus nigra L. K-881	Kala toot	Moraceae	T	Fruit	Fruit	Raw snacks	Taken as fruit	+	Constructions, Plant diseases
Myrsine africana L. K-882	–-	Primulaceae	S	Fruit	Fruit	Raw snacks	Taken as fruit	–	No specific
Nasturtium officinale R.Br. K-883	Tara mera	Brassicaceae	H	Vegetable	Leaves	Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	+	Grazing, Soil erosion
Oryza sativa L. K-884	Chawal	Poaceae	H	Cereal crop	Grains	Cooked	Grains are used as a staple food with beans	+	Plant diseases, Invasive species

Table 2 (continued)

Taxa/voucher no.	Local name	Family	Life form	Food categories	Part used	Mode of consumption	Recipes	Marketing	Major threats
Oxalis corniculata L. K-885	Khatkhulda	Oxalidaceae	H	Vegetable	Aerial parts	Raw snacks, Cooked	Eaten as raw snacks and leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	Grazing
Oxyria digyna (L.) Hill. K-886	Khatkhulda	Polygonaceae	H	Vegetable	Aerial parts	Raw snacks, Cooked	Eaten as raw snacks and leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	Grazing, Soil erosion
Phaseolus vulgaris L. K-887	Lobia	Fabaceae	H	Cereal crop	Beans	Cooked	Beans are fried in oil with tomatoes, red chilies, garlic, onion, and ginger and used with cooked rice as a traditional Kashmiri dish	+	Invasive species
Physalis minima L. K-888	….	Solanaceae	H	Fruit	Fruit	Raw snacks	Taken as fruit	–	No specific
Phytolacca latbenia H.Walter K-889	Lubar	Phytolaccaceae	H	Vegetable	Leaves	Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	Overexploitation, Agricultural expansion, Plant diseases
Plantago lanceolata L. K-890	Chamchipatar	Plantaginaceae	H	Herbal drink, Vegetable	Leaves	Infusion, Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	+	Invasive species, Overexploitation
Plantago major L. K-941	Chamchipatar	Plantaginaceae	H	Herbal drink, Vegetable	Leaves	Infusion, Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	+	Invasive species, Overexploitation
Plantago ovata Forssk. K-942	Chamchipatar	Plantaginaceae	H	Vegetable	Leaves	Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	No specific

Table 2 (continued)

Taxa/voucher no.	Local name	Family	Life form	Food categories	Part used	Mode of consumption	Recipes	Marketing	Major threats
Plectranthus rugosus Wall. ex Benth. K-943	Peemaar	Lamiaceae	S	Herbal drink	Leaves	Infusion	Leaves are ground in water, then plant material is removed, and remaining water is taken as an herbal drink	–	Soil erosion
Podophyllum hexandrum Royle K-944	Bankhakri	Berberidaceae	H	Fruit	Fruit	Raw snacks	Taken as fruit	–	Overexploitation, Illegal export
Polygonum aviculare L. K-945	Tarhubra	Polygonaceae	H	Vegetable	Leaves	Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	Overexploitation
Polygonum paronychioides C.A.Mey. K-946	Tarhubra	Polygonaceae	H	Vegetable	Leaves	Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	Overexploitation
Polygonum plebeium R.Br. K-947	Tarhubra	Polygonaceae	H	Vegetable	Leaves	Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	Overexploitation
Portulaca oleracea L. K-948	Bara Kulfa	Portulacaceae	H	Vegetable	Leaves	Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	No specific
Prunus armeniaca L. K-949	Aari	Rosaceae	T	Fruit	Fruit	Raw snacks	Taken as fruit		Fuel wood, Plant diseases
Prunus avium (L.) L. K-950	Alocha	Rosaceae	T	Fruit	Fruit	Raw snacks	Taken as fruit	–	Plant diseases, Soil erosion, Fuel wood
Prunus domestica L. K-921	Aalo bakhara	Rosaceae	T	Fruit	Fruit	Raw snacks	Taken as fruit	+	Fuel wood, Plant diseases
Prunus padus L. K-922	Parth	Rosaceae	T	Fruit	Fruit	Raw snacks	Taken as fruit	–	Fuel wood, Constructions, Plant diseases
Prunus persica (L.) Batsch K-923	Aarun	Rosaceae	T	Fruit	Fruit	Raw snacks	Taken as fruit		Fuel wood, Plant diseases

Table 2 (continued)

Taxa/voucher no.	Local name	Family	Life form	Food categories	Part used	Mode of consumption	Recipes	Marketing	Major threats
Pteridium aquilinum (L.) Kuhn. K-924	Laangro	Dennstaedtiaceae	F	Vegetable	Aerial parts s	Cooked	Aerial parts are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	+	Overexploitation, Fire
Punica granatum L. K-925	Daaro/Jungli Anaar	Punicaceae	T	Fruit	Fruit	Raw snacks	Taken as fruit	–	Fuel wood
Pyrus communis L. K-926	Batang/Naashpaati	Rosaceae	T	Fruit	Fruit	Raw snacks	Taken as fruit	+	Plant diseases
Pyrus pashia Buch.-Ham. ex D.Don K-927	Batangi	Rosaceae	T	Fruit	Fruit	Raw snacks	Taken as fruit	–	Plant diseases
Rheum webbianum Royle. K-928	Chatyal	Polygonaceae	H	Miscellaneous	Stem, Rhizome	Raw snacks, Cooked	Aerial parts are used as raw snacks and young leaves are also used as vegetable	–	Climate change, Overexploitation
Rosa brunonii Lindl. K-929	Chal	Rosaceae	T	Fruit	Fruit	Raw snacks	Taken as fruit	–	Fuel wood, Plant diseases
Rubus elipticus Smith K-930	Graachy	Rosaceae	S	Fruit	Fruit	Raw snacks	Taken as fruit	–	Fuel wood, Agricultural expansion
Rubus fruticosus Lour. K-931	Graachy	Rosaceae	S	Fruit	Fruit	Raw snacks	Taken as fruit	–	Fuel wood, Agricultural expansion
Rubus sanctus Schreb. K-932	Chal	Rosaceae	S	Fruit	Fruit	Raw snacks	Taken as fruit	–	Fuel wood, Agricultural expansion
Rubus ulmifolius Schott K-933	Graachy	Rosaceae	S	Fruit	Fruit	Raw snacks	Taken as fruit	–	Fuel wood, Agricultural expansion
Rumex acetosa L. K-934	Hola	Polygonaceae	H	Vegetable	Leaves	Cooked	Young leaves fried in oil with onions, ginger, and spices are cooked as vegetable		Climate change
Rumex chalepensis Mill. K-935		Polygonaceae	H	Vegetable	Leaves	Cooked	Young leaves fried in oil with onions, ginger, and spices are cooked as vegetable	–	No specific

Table 2 (continued)

Taxa/voucher no.	Local name	Family	Life form	Food categories	Part used	Mode of consumption	Recipes	Marketing	Major threats
Rumex crispus L. K-936	Hola	Polygonaceae	H	Vegetable	Leaves	Cooked	Young leaves fried in oil with onions, ginger, and spices are cooked as vegetable	–	Grazing
Rumex dentatus L. K-937	Hola	Polygonaceae	H	Vegetable	Leaves	Cooked	Young leaves fried in oil with onions, ginger, and spices are cooked as vegetable	–	Grazing, Soil erosion
Rumex hastatus D.Don K-938	Hola	Polygonaceae	S	Vegetable	Leaves	Cooked	Young leaves fried in oil with onions, ginger, and spices are cooked as vegetable	–	Grazing, Soil erosion
Rumex nepalensis Spreng. K-939	Hola	Polygonaceae	H	Vegetable	Leaves	Cooked	Young leaves fried in oil with onions, ginger, and spices are cooked as vegetable	–	Grazing, Soil erosion
Rumex vesicarius L. K-940	Hola	Polygonaceae	H	Vegetable	Leaves	Cooked	Young leaves fried in oil with onions, ginger, and spices are cooked as vegetable	–	Soil erosion
Saussurea costus (Falc.) Lipsch. K-951	Kuth	Asteraceae	H	Miscellaneous	Root	Cooked	Rhizome is used in traditional mixed foods, specifically cooked rice fried in cow's butter in mountainous areas during the winter season	–	Overexploitation, Illegal export, Climate change
Silene conoidea L. K-952	Doobri	Caryophyllaceae	H	Vegetable	Leaves	Cooked	Young leaves fried in oil with onions, ginger, and spices are cooked as vegetable	–	Grazing
Skimmia laureola Franch K-953	Nyra	Rutaceae	S	Condiment	Leaves	Cooked	Taken as condiment	+	Overexploitation, Climate change
Solanum nigrum L. K-954	Kach maach	Solanaceae	H	Fruit	Fruit	Raw snacks	Taken as fruit	–	Grazing, Invasive species

Table 2 (continued)

Taxa/voucher no.	Local name	Family	Life form	Food categories	Part used	Mode of consumption	Recipes	Marketing	Major threats
Solanum tuberosum Bertero ex Walp. K-955	Aalo	Solanaceae	H	Vegetable	Tuber	Cooked	Tubers are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	+	Invasive species, Plant diseases
Solanum virginianum L. K-956	???	Solanaceae	H	Fruit	Fruit	Raw snacks	Taken as fruit	–	No specific
Taraxecum officinale Webb K-957	Hand	Asteraceae	H	Vegetable	Leaves	Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	No specific threat
Taxus wallichiana Zucc. K-958	Barmi/Prungi	Taxaceae	T	Herbal tea	Bark	Water-boiled	Bark is boiled in water for 15–20 min, then, with the addition of milk and sugar, taken as an herbal tea	–	Overexploitation, Climate change, Fuel wood, Constructions
Teucrium royleanum Wall. K-959	Aalba	Lamiaceae	H	Herbal drink	Root	Decoction	Roots are ground in water, then root parts are removed, and the remaining water is taken as an herbal drink		No specific threat
Thymus linearis Benth. K-960	Bunjamain/Chikal	Lamiaceae	H	Herbal tea	Aerial parts	Water-boiled	Aerial parts are boiled in water for 10–15 min, then, with the addition of milk and sugar, taken as an herbal tea		Overexploitation, Climate change
Trifolium repens L. K-961	Sinja	Leguminosae	H	Vegetable	Leaves	Cooked	Leaves are fried in oil with tomatoes, red chilies, and ginger and used as vegetable	–	No specific threat
Triticum aestivum L. K-962	Kank/Gandam	Poaceae	H	Cereal crop	Grains	Cooked	Grains are used as a staple food	+	Plant diseases, Invasive species
Viburnum cotinifolium D.Don K-963	Guch	Adoxaceae	S	Fruit	Fruit	Raw snacks	Taken as fruit	–	Agricultural expansion, Fuel wood

Table 2 (continued)

Taxa/voucher no.	Local name	Family	Life form	Food categories	Part used	Mode of consumption	Recipes	Marketing	Major threats
Viburnum grandiflorum Wall. ex DC. K-964	Guch	Adoxaceae	S	Fruit	Fruit	Raw snacks	Taken as fruit	–	Agricultural expansion, Fuel wood
Vigna radiata (L.) R.Wilczek K-965	Choti Lobia	Fabaceae	H	Cereal crop	Beans	Cooked	Beans are fried in oil with tomatoes, red chilies, garlic, onion, and ginger and used with cooked rice	+	Invasive species
Vitis vinifera L. K-966	Daakh	Vitaceae	Cl	Fruit	Fruit	Raw snacks	Taken as fruit	+	Plant diseases
Zanthoxylum armatum DC. K-967	Timber	Rutaceae	T	Sauce	Seed	Decoction	Fruits are used in the preparation of sauce with a mixture of *Juliens regia* and *Mentha arvensis*	+	Fuel wood, Overexploitation
Zea mays L. K-968	Makaye	Poaceae	H	Cereal crop	Grains	Cooked	Grains are used as a staple food	+	Fungal diseases, Climate change

H = herb, T = tree, S = shrub, Cl = climber, + = presence, — = absence

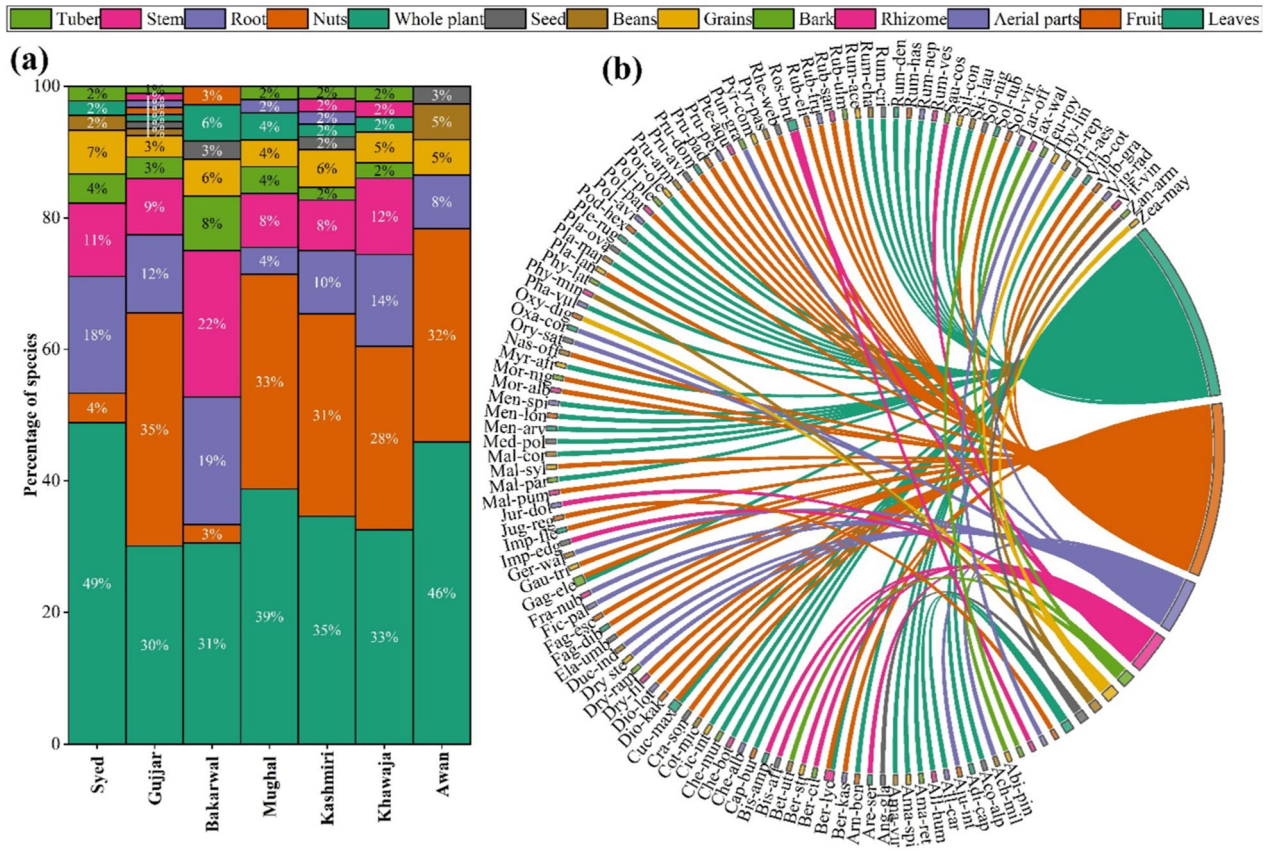

Fig. 4 **a** Percentage of WFPs used among the studied 7 ethnic groups, **b** chord diagram depicting the plant parts used and species names as WFPs

decoctions (3.94%), and infusions (3.94%) (Fig. 5, Table 2).

WFPs used as vegetable

Wild plant species were consumed in different ecological zones of the Kashmir Himalayas during times of food scarcity. Younger parts of plants, such as roots, stems, and leaves, were used in traditional recipes. These plant parts were fried in oil with tomatoes, onion, ginger, and spices, and cooked as vegetables, either alone or in combination with other species. The leaves of the most popular species cooked as vegetables by local participants included *Amaranthus retroflexus*, *A. spinosus*, *A. viridius*, *Chenopodium album*, *C. murale*, *C. botrys*, *Cucurbita maxima*, *Malva parviflora*, *M. sylvestris*, *Nasturtium officinale*, *Oxalis corniculata*, *Plantago major*, *Polygonum plebeium*, *Pteridium aquilinum*, *Solanum tuberosum*, and *Rumex nepalensis.* The species that were dried and stored for the future during the snow periods in the rural mountainous communities included *Amaranthus viridis*, *Phytolacca latbenia*, *Chenopodium album*, *Pteridium aquilinum*, *Dryopteris stewartii*, and *Amaranthus spinosus. Amaranthus viridis*, *Chenopodium album*, *Rumex nepalensis*, and *Polygonum plebeium* were the most commonly used species among the inhabitants of subtropical to alpine local communities in the study area and were thought to be digestive. Their long growing season, wide availability, and distinct flavor make vegetable plants one of the most popular choices among various ethnic groups. *Pteridium aquilinum*, *Malva parviflora*, *Malva sylvestris*, *Phytolacca latbenia*, *Oxalis corniculata*, and *Dryopteris stewartii* are the wild vegetables that are only used among the mountainous and rural communities of temperate to alpine summer pastures. *Rumex nepalensis*, *Trifolium repens*, and *Taraxecum officinale* are the wild vegetable species that were utilized throughout the study area. From March to November, local populations gathered the plant from agriculture fields, scrubland, dry places, shady places, lakes, and summer pastures. The locals of subtropical and temperate zones start to consume vegetables in early March and almost continuously utilize them until November, but on the other hand, subalpine and alpine communities utilize different available wild vegetables from June to October due to snow cover until June and then return to their permanent lower altitude residencies in the months of September to October

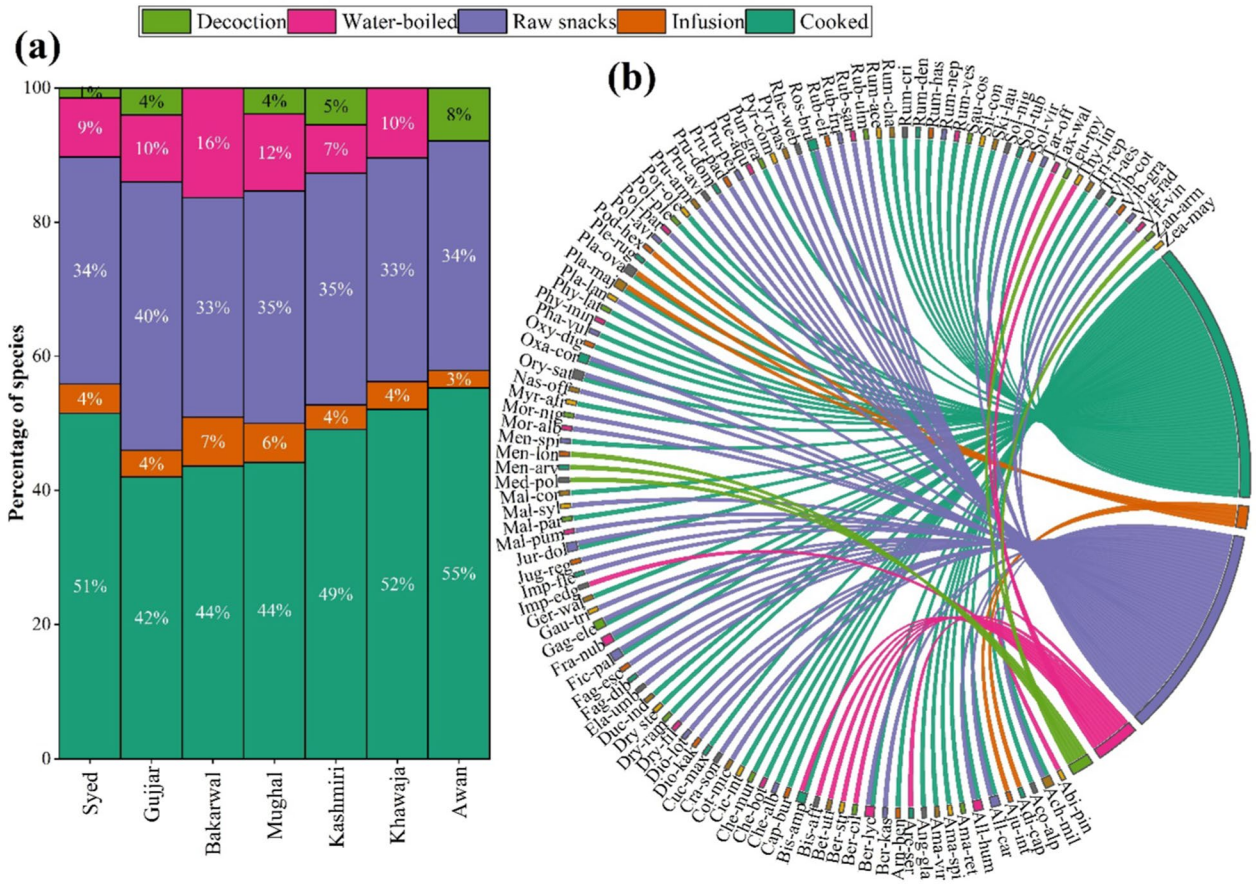

Fig. 5 **a** Percentage of WFPs mode of consumption among studied ethnic groups, **b** chord diagram depicting the WFPs mode of consumption

due to the start of severe coldness and early snowfall in the last weeks of October and early weeks of November. The most common wild vegetables that are available in the market for sale include *Dryopteris stewartii*, *Dryopteris ramosa*, *Amaranthus viridis*, *Cucurbita maxima*, and *Solanum tuberosum* (Table 2).

WFPs used as fruits

Sweet fruits were used as raw snacks by indigenous communities, particularly those who lived a herding lifestyle. A total of 40 WFPs were collected and eaten as fruits. The most important wild fruit species were *Pyrus pashia*, *Pyrus communis*, *Prunus armeniaca*, *Punica granatum*, *Diospyros lotus*, *Ficus palmata*, *Berberis lyceum*, *Elaeagnus umbellata*, *Fragaria nubicola*, *Malus pumila*, *Punica granatum*, *Rubus fruticosus*, and *Viburnum grandiflorum. Malus pumila, Pyrus communis,* and *Prunus armeniaca* were the most common fruit plant species that were collected and utilized almost among the majority of the ethnic groups, and these three species are also available in the market for sale. Some species are restricted to specific ethnic groups or ecological zones, like *Gaultheria trichophylla*, which is only utilized among the Bakarwal ethnic group, and *Malvastrum coromandelianum*, which is consumed only in the subtropical zone of the study area (Fig. 6).

Herbal teas and herbal drinks

In our study species, 21 taxa have been used to prepare drinks such as herbal teas, coffees, decoctions, and herbal drinks. The bark of *Abies pindrow, Betula utilis*, and *Taxus wallichiana* is initially removed, and then the inner soft portion is soaked in water briefly before being boiled to make herbal teas. To improve the taste, sugar is added in proportion to the amount of water. The rhizome of some plants, such as *Bistorta amplexicaulis*, *Arnebia benthamii*, *Geranium wallichianum*, and *Bergenia ciliata*, is boiled in water for 15–25 min, then, with the addition of milk and sugar, taken as an herbal tea. Locals use herbal teas to stay fit and healthy because people in mountainous areas are mostly involved in laborious occupations and coping with the fundamental necessities of life, such as farming and agriculture. After agricultural practices, folks like to drink herbal teas to relieve fatigue.

Fig. 6 **a** *V. vinifera*, **b** *P. communis*, **c** *R. brunonii*, **d** *S. nigrum*, **e** *B. lyceum*, **f** *V. grandiflorum*, **g** *R. sanctus*, **h** *D. lotus*, **i** *P. pashia*, **j** *D. indica*, **k** *M. alba*, **l** *C. microphyllus*, **m** *B. kashmirana*, **n** *T. wallichiana*, **o** *P. hexandrum*, **p** *F. nubicola*

The leaves of *Adiantum capillus-veneris* are crushed in water with a pestle then kept overnight. Locals drink that greenish water early in the morning as an herbal drink before breakfast to relieve a variety of digestive problems. Leaves and aerial parts of some other plant species, like *Ajuga integrifolia*, *Mentha longifolia*, *Mentha arvensis*, *Mentha spicata*, and *Plectranthus rugosus*, are ground in water, then plant material is removed, and the remaining water is taken as an herbal drink. Indigenous communities in the study area use wild plants as herbal drinks to overcome gastrointestinal disorders and to make themselves healthier and more attractive.

Species used for sauces and chutneys

According to informants, chutney is made from just four species. Among the plant species used to make sauces and chutneys were *Mentha arvensis*, *Mentha spicata*, *Zanthoxylum armatum*, and *Juglans regia*. It's interesting to note that all of these species were used both fresh and dried, and they are all aromatic. In order to use these species throughout the year, the locals shade-dried them during the suitable seasons (Fig. 7).

Storage and uses of WFPs during off-seasons

The storing and drying of WFPs is a vital task that offers stability to the food supply throughout year. Local ethnic groups in the area dry vegetables during the summer season, either by leaving them at room temperature or by exposing them to direct sunlight. This is mainly due to the region's hilly terrain and the presence of snow during the winter season, which makes it difficult for local residents to access markets and purchase fresh vegetables. Consequently, these ethnic groups rely on these dried vegetables for sustenance in such circumstances. In the study

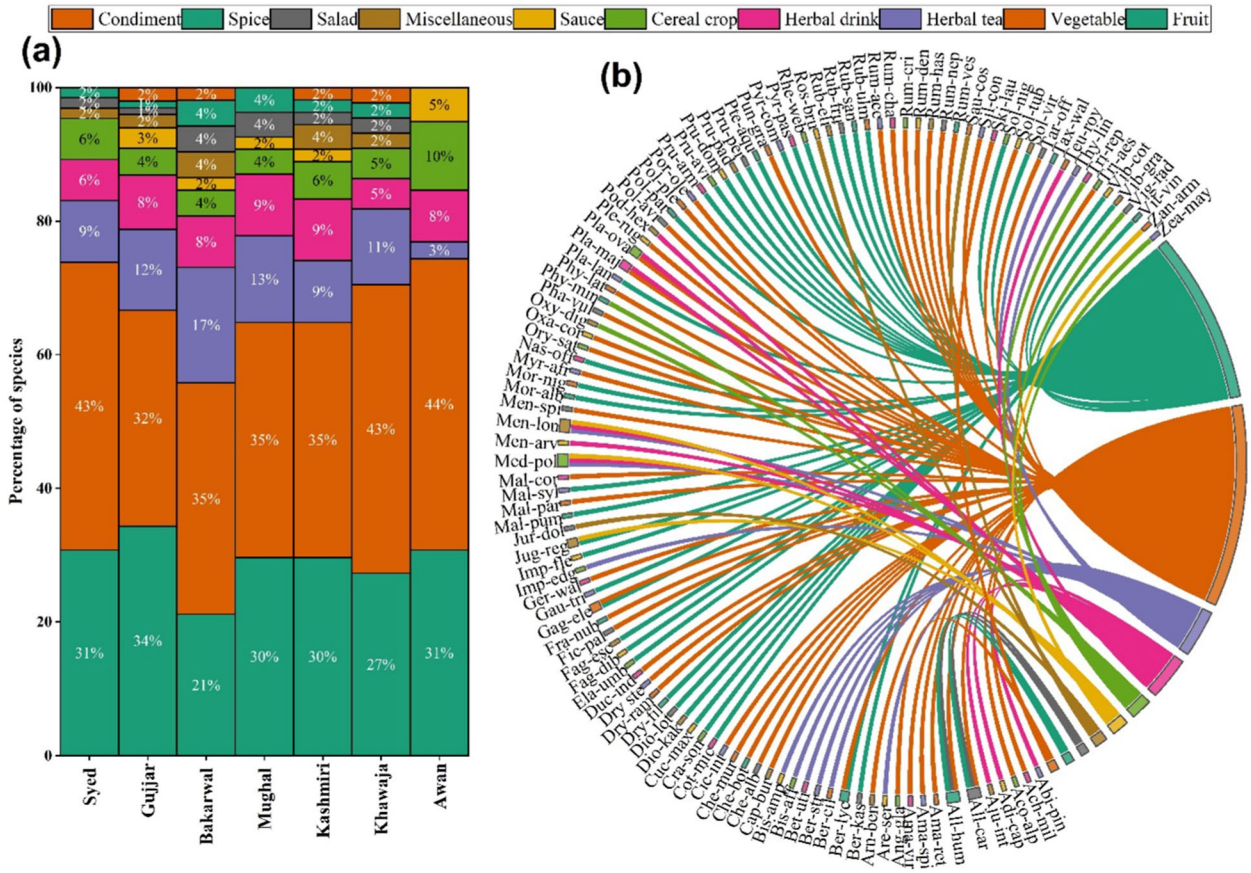

Fig. 7 **a** Percentage of WFPs food category distribution among studied ethnic groups; **b** chord diagram depicting the WFPs food category

area, a number of plants were used during off-Seasons, such as the aerial parts of *Dryopteris stewartii*, *Dryopteris ramosa*, *Amaranthus viridis*, *Pteridium aquilinum*, *Phytolacca latbenia*, *Chenopodium album*, and *Amaranthus spinosus*. Traditional communities collect *Allium humile* and *Allium carolinianum* leaves, which are then used by locals to make local spices or masala. *Pyrus pashia*, *Pyrus communus*, *Prunus armeniaca*, *Punica granatum*, *Diospyros lotus*, and *Ficus palmata* (Anjeer) fruits were dried and utilized during the winter season. Some plant species, such as *Thymus linearis*, *Taxus wallichiana*, and *Bistorta amplexicaulis*, were collected from summer pastures and used by local communities in winter as herbal teas. Traditional communities used *Punica granatum* seeds in sauces and chutneys during off seasons.

Market value of WFPs

To determine the market value of WFPs, we surveyed a local market and a central market, i.e., Muzaffarabad and Neelum. We observed that *Triticum aestivum* (Gandum), *Juglans regia* (Khor), *Malus pumila* (Syb), *Bergenia ciliata* (Butpywa), and *Thymus linearis* (Chikal) are some of the most important edible plants that are on sale in the market for different purposes. The market survey also showed that the current prices vary depending on the quality. Some current pricing for wild edible plants vary by area due to transportation costs for transporting wild edible food plants from one place to another. *Triticum aestivum* (150–250 Pkr. per kg), *Juglans regia* (200–600 Pkr. per kg), *Malus pumila* (150–400 Pkr. per kg), *Bergenia ciliata* (600–1000 Pkr. per kg), and *Thymus linearis* (1000–2000 Pkr. per kg) are sold in various markets of the division Muzaffarabad, including the Madina market in Muzaffarabad. Our results further demonstrated that *Arnebia benthamii* (Gaozuban), *Phaseolus vulgaris* (Lobia), *Saussurea costus* (Kuth), *Solanum tuberosum* (Aalo), *Zea mays* (Makaye), and *Oryza sativa* (Chawal) are highly known edible plant species by all age groups for their socio-economic implications. From all 113 studied species, 37 (32.74%) are available on the market for sale, while 76 (62.25%) are still unavailable. So, from the local perceptions of the indigenous communities, we can also promote the sale of these species that are unavailable in the market to overcome the food insecurity

in developing countries as well as to uplift the socioeconomic conditions of rural communities.

Traditional cuisine recipes of WFPs

Different recipes for preparing WFPs were recorded. Locals used WFPs in a variety of ways, and knowledge of these species and their eating habits was passed down through generations. Depending on the type of plant, several methods were utilized to prepare wild edibles. Small portions of wild vegetables were sliced into pieces and boiled in water.

The raw material was boiled before being fried in butter or oil along with tomato, ginger, onion, garlic, and green chilly to make cooked food. The wild vegetables that were boiled in water and cooked in oil included *Dryopteris stewartii*, *Dryopteris ramosa*, *Amaranthus retroflexus*, *Amaranthus spinosus*, *Amaranthus viridius*, *Chenopodium album*, *Chenopodium murale*, *Chenopodium botrys*, *Cucurbita maxima*, *Malva parviflora*, *Malva sylvestris*, *Nasturtium officinale*, *Oxalis corniculata*, *Plantago major*, *Polygonum plebeium*, *Pteridium aquilinum*, *Solanum tuberosum*, and *Rumex nepalensis*. The most common traditional dish was saag, which was made by cooking various vegetables' green leaves. Saag's main ingredients were *Amaranthus viridius*, *Chenopodium album*, *Plantago major*, and *Polygonum plebeium*, which were boiled in water before being cooked. To prepare traditional saag, their paste was fried in oil or butter with tomato, onion, ginger, garlic, and green chilli, along with spices. On major events and special days, saag was served with maize flour-based bread, lassi (yoghurt drink), and chutney. Another important traditional vegetable known as Katha Saag was prepared specifically by using some specific vegetables, including *Dryopteris stewartii*, *Dryopteris ramosa*, and *Ficus palmata*, in such a way that these plant species were first boiled in lassi (yoghurt drink) for about 30–45 min, then fried in oil or butter with tomato, onion, ginger, garlic, and green chilli, along with spices. This special Katha Saag was mostly utilized along with maize flour-based bread in dysi ghee (animal's butter), lassi, and chutney. Another important local food called Sheera was made by combining maize flour with lassi (yoghurt drink) and dysi ghee (animal butter). Sheera is prepared in such a way that the locals first boil lassi (yoghurt drink) in a kitchen pot at a low temperature for 20–30 min, then add a relevant proportion of maize flour, followed by the addition of dysi ghee (animal butter), and then enjoy eating Sheera with the whole family. Chalithi was another traditional food that was mostly used by women after childbirth, almost for a month after childbirth. This food is used with a combination of some other local foods at regular intervals. The method of preparation of Chalithi was that it was prepared in such a way that first of all, rice was ground with the help of a of a pistle, then soaked for 20–30 min, then fried into dysi ghee (animal butter) at a specific temperature. Then, some kernels of *Juglens regia*, coconut, raisins, and some other dry fruits were added to enhance the taste.

Another traditional rice dish (Phatt) was prepared with the combination root of *Saussurea costus* and local rice in such a way that first of all, the locals wash and clean the rhizome properly, and then it is kept for boiling for 25–40 min. After a proper boil, they add rice to the boiling water, and then after 20–30 min, the locals add dysi ghee (animal butter), and then they enjoy this local food with the whole family. This traditional food was mostly used to overcome the joint problems among the mountainous local communities of the temperate-alpine zone. Recently, the trend of this traditional dish has decreased day by day. Another most popular traditional food among the Gujjar and Bakarwal ethnic groups was the Klaari. The method of preparation of Klaari was that it was prepared with the combination of milk from buffaloes and lassi (yoghurt drink) from cows boiled together for 10–15 min, then cooled and taken as food. The trend of food is also very rare; mostly locals prepare it during their short stay of 2–3 months in summer pastures or alpine meadows. Another most rarely used food was the Anch. This traditional food was prepared with a combination of milk from goats and lassi (yoghurt drink) from buffaloes. This traditional food is prepared and used the same as in Klaari. The most interesting local food, as indicated by the name Moti Roti, was used among the rural communities of Neelum Valley among different ethnic groups. This was prepared in such a way that during kneading the flour, local women kept the flour a little bit hard and then added animal butter, eggs, sugar, or salt. They then cooked that fresh material in the form of bread and took it with the herbal tea that was made from the rhizome of *Bistorta amplexicaulis*. Another very interesting local food is Dary-Behshat. This local cuisine was prepared in such a way that the locals kept the desired quantity of animal butter in a kettle or a boiler, added corn flour, fried it a little bit, added about 200–250 g of jaggery, and then again fried it. After that, locals can also add some dry fruits, and then local women wash their hands with water and make circular bread to eat. Bagori was another traditional local food that was used by the Loan ethnic group of the study area. Bagori was prepared in such a way that first local women boiled the lassi (yoghurt drink), then they kept that boiled lassi in a white cloth and squeezed that cloth in such a way that water (pang) from the lassi ran away, and then the remaining hard portion of lassi was kept in between two weighted stones and kept there for 1–2 days, and then again brought out from

the stones and kept in sunlight to further dry, and then they utilized it as a delicious food.

Ul-Tiki was a traditional food that was recorded from the Shina-speaking linguistic and loan ethnic group of Phulawae. Ul-Tiki was prepared in such a way that during the process of milking from goats, buffaloes, or cows by indigenous women, they did the process of milking in a single milk vessel for about 15–20 times to store the milk froth on the surface of that particular milk vessel and store the bulk of fresh milk in another milk vessel. The locals collect a large quantity of milk froth from the inner surface of the milk vessel, and then they knead it in corn flour and pack it into the bark of *Betula utilis* under the warm ash for about 30–60 min, and finally they utilize it as food (Fig. 8). Many other cultural practices are associated with the local inhabitants of the study area (Fig. 9).

Ecological distribution of WFPs

This study investigated how WFPs were used in various ecological zones by seven different ethnic groups. These zones included subtropical, temperate, subalpine, and alpine. Interestingly, five plant species, namely Oxalis corniculata, Plantago major, Rumex nepalensis, Taraxacum officinale, and Trifolium repens, were found to be distributed across all the ecological zones that were investigated. This comprehensive analysis offers insight on the widespread availability and possible relevance of these plants under a variety of environmental conditions, emphasizing their importance in the diets and cultural practices of the area's ethnic groups. There were only four plant species that were restricted to the subtropical zone. These species were *Zanthoxylum armatum, Rumex chalepensis, Polygonum paronychioides*, and *Malvastrum coromandelianum*. There were 16 plant species that were only collected and restricted to temperate zones. These 16 plant species were *Cichorium intybus, Elaeagnus umbellata, Fagopyrum dibotrys, Fagopyrum esculentum, Medicago polymorpha, Phaseolus vulgaris, Phytolacca latbenia, Prunus padus, Pteridium aquilinum, Rubus ulmifolius, Silene conoidea, Taxus wallichiana, Teucrium royleanum, Viburnum cotinifolium*, and *Vigna radiata*. Only two plant species, *Betula utilis* and *Rumex acetosa*, were restricted and collected from the subalpine zone. There were six6 plant species that were restricted

Fig. 8 Different traditional dishes used among the rural communities of Kashmir Himalayas: **a** local green herbal tea; **b** mix vegetables; **c** freshly prepared corn flour bread (makahe ki roti) by local women; **d** sauce locally known as chutney; **e** butter locally known as dysi ghee; **f** chalithi; **g** lassi (yoghurt drink); **h** homogenizer used by the local women for lassi and ghee production from yoghurt; **i** local halwa; **j** corn flour bread with sauce and yoghurt drink; **k** local dysi variety of rice; and **l** preparation of corn flour bread from wooden fire to enhance the taste

Fig. 9 Different cultural practices among the ethnic groups: **a** traditional house in the summer pasture; **b** mat locally known as Phandi; **c** traditional Bakhari used mostly during the winter season; **d** tandoor; **e** carriage of dry grasses for livestock by a local farmer; and **f** ploughing in the farmland by a local farmer

to alpine zone including *Aconogonum alpiunm*, *Allium carolinianum*, *Arnebia benthamii*, *Bistorta affinis*, and *Gaultheria trichophylla* (Fig. 10).

Major threats

Anthropogenic and naturally occurring factors can be utilized for categorizing the causes of threats to WFPs. Climate change, agricultural expansion, fuel wood, deforestation, selective harvesting, overgrazing, debarking, overexploitation, fire, illegal export, soil erosion, invasive species, and lightning were among the natural and human-induced causes that the informants noted as local threats to WFPs. The ranking effort contributed in identifying the most serious threats to such resources in the study area. Climate change, invasive species, expansion of agriculture, and plant diseases are some of the most significant threats to WFPs in the study area. Some food plants illegally exported in the study area include *Arnebia benthamii*, *Jurinea dolomiaea*, and *Saussurea costus*, and these are also already declared endangered and critically endangered species. The members of the family Rosaceae, particularly fruit species, were facing the threat of plant diseases, according to the local respondents. Tree species such as *Abies pindrow*, *Betula utilis*, and *Taxus wallichiana* were facing threats of deforestation, and debarking for different

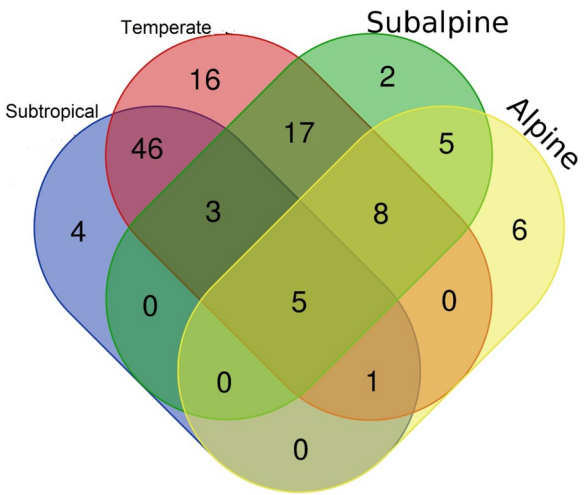

Fig. 10 Ecological distribution of WFPs in different ecological zones

purposes. People started fires, either intentionally or accidently, while looking for newly grown grass in the study area. According to respondents, invasive species were not common in the past, but their invasiveness is rising by the day, contributing to decreased yields of native crops and all other WFPs (Fig. 11).

Cross ethnic comparison

Cross-cultural analysis of WFP gathering among the seven investigated ethnic groups reveals variability and the presence of distinct plant cultural markers. This study explored how people consume wild foods based on choice and cultural availability. Three species (*Rumex nepalensis*, *Taraxecum officinale*, and *Trifolium repens*) overlapped across all ethnic groups. Thirteen plant species overlapped across the 6 ethnic groups. Nine species were overlapped among the 5 ethnic groups. Nineteen plant species were overlapped across the 4 ethnic groups. Twenty-five species were overlapped among the different 3 ethnic groups. Twenty-three species were overlapped across the different 2 ethnic groups. The Gujjar ethnic group gathered and used a wide variety of indigenous plants, totaling 89 species. This was most likely driven by the investigated region's increasing population density, higher social contacts leading to more knowledge, and a move toward occupations closely related to wild food plants. The wide sociocultural differences identified among the ethnic groups analyzed, which differ across different geographical areas within the research area, may contribute to variations in how certain species are used, as reported.

Novelty index

The results of the current study were compared with 20 published articles, especially those focusing on WFPs from the region, as represented in Table 3. Cross-comparison showed that utilization of WFPs varies significantly across the region and communities, including their edible parts and mode of consumption. Jaccard index (JI) value ranged from 5.81 to 25 (Table 3). The highest value of JI was calculated for district Bagh, AJ&K (25.00), and district Neelum, AJ&K (23.40). Both districts located in the geographical boundary of AJ&K. Due to similar environmental conditions, traditions, and geography, the greater JI values showed similar kinds of vegetation in these areas. The lowest value of JI was calculated for Takhte-Sulaiman, Pakistan (5.81). The reported site is in an arid and semi-arid mountainous area with a warm environment, while the present site is in a cold climate representing a temperate to alpine zone. There is significant variation in environment, altitude, topography, and traditions throughout the study area. Only nine similar plants have been documented at the current site due to significant variation, as mentioned earlier.

The current study had a higher degree of similarity in edible part use compared to data from district Bagh, AJ&K (42.5%), followed by district Neelum, AJ&K (32.86%). This is mainly due to the similar geography and vegetation in these areas. The lowest similarity was found in the district of Mastung, Baluchistan (3.18%), followed by Khyber Pakhtunkhwa, North-western Pakistan (3.41%), and the semi-arid region of Punjab, Pakistan (4.57%). The mode of utilization percentage compares how WFPs are used in various ways, such as cooked, sauces, raw, pickled, and sweet recipes, between current findings and previous research. The percentage of similarity in part and mode of utilization was higher in AJ&K

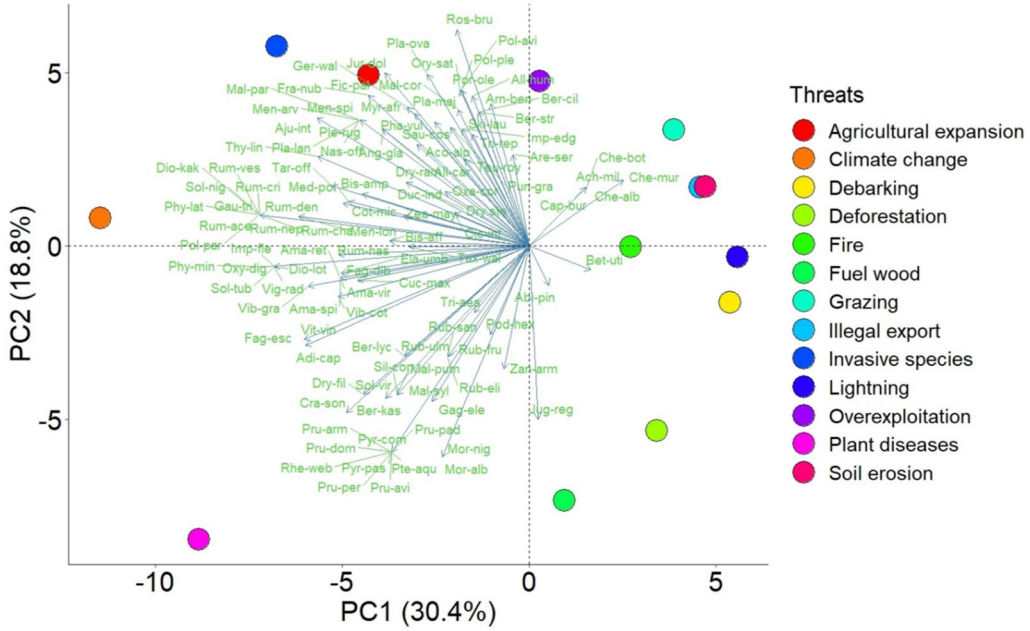

Fig. 11 PCA analysis showing the major threats to WFPs

Table 3 Jaccard index to compare the present study with the published literature of Himalayas show the Novelty aspect of current study

Author citation	Study area	Region	SY	TP	SP	NOP	NOPSU	NOPDU	TSCBA	SEAA	SEOSA	POPSU	POPDU	JI
Kumar et al. [66]	Kishtwar	J&K	2009	50	20	95	17	3	20	34	37	17.89	6.00	13.99
Iqbal et al. [67]	Bagh	AJK	2022	102	43	80	34	9	43	55	61	42.50	8.82	25.00
Amin et al. [68]	Kohistan	Pakistan	2023	64	26	171	18	8	26	22	29	10.53	12.50	17.22
Ijaz et al. [69]	Neelum	AJK	2021	66	17	100	11	6	17	14	21	11.00	9.09	10.49
Abbasi et al. [70]	Lesser Himalayas	Pakistan	2013	45	13	125	6	7	13	12	16	4.80	15.56	8.97
Ahmad et al. [36]	Takhte-Sulaiman	Pakistan	2016	51	9	72	9	4	9	13	11	12.50	7.84	5.81
Abdullah et al. [60]	Hindu Kush Mountain Range	Pakistan	2021	63	26	84	19	7	26	29	31	22.62	11.11	17.33
Abbasi et al. [71]	Lesser Himalayas	Pakistan	2013	35	15	125	11	4	15	19	23	8.80	11.43	11.28
Singh et al. [72]	Bandipora	J&K	2016	111	28	113	17	11	28	34	41	15.04	9.91	14.29
Bhatia et al. [73]	Udhampur	J&K	2018	90	24	88	17	7	24	27	34	19.32	18.89	13.41
Khan et al. [74]	Swat Valley	Pakistan	2015	47	23	95	15	8	23	25	35	15.79	31.91	16.79
Ijaz et al. [75]	Neelum Valley	Pakistan	2022	61	33	70	23	10	33	38	44	32.86	37.70	23.40
Ul Abidin et al. [76]	Khyber Pakhtunkhwa	Pakistan		74	22	233	14	8	22	31	38	6.01	18.92	13.33
Haq et al. [77]	Kashmir	Western Himalaya	2022	127	35	380	21	14	35	41	65	5.53	16.54	17.07
Rashid et al. [78]	AJK	Pakistan	2018	73	23	255	13	10	23	26	35	5.10	17.81	14.11
Ahmad et al. [79]	Pakistan	Pakistan	2016	217	35	250	21	14	35	46	62	8.40	9.68	11.86
Waheed et al. [80]	Punjab	Pakistan	2023	71	14	175	8	6	14	16	17	4.57	11.27	8.24
Rahman et al. [81]	Manoor Valley	Lesser Himalaya	2019	27	13	55	9	4	13	13	15	16.36	33.33	10.24
Bibi et al. [82]	Balochistan	Pakistan	2014	102	15	220	7	8	15	17	19	3.18	6.86	7.50
Sher et al. [83]	Khyber Pakhtunkhwa	Pakistan	2015	126	32	558	19	13	32	35	51	3.41	15.08	15.46

SY = study year, NOP = number of plants, NORP = number of reported plants, NOPSU = number of plants with similar uses, NOPDU = number of plants with different uses, TSCBA = total species common in both areas, SEAA = species enlisted in aligned areas, SEOSA = species only enlisted in the study area, POPSU = percentage of plants with same uses, POPDU = percentage of plants with different uses, JI = Jaccard index

than in other allied areas, mainly due to variations in traditions, cultures, geography, and environmental circumstances between the local communities. Furthermore, various communities in specific regions use the plants in different ways.

Currently, we have reported a variety of traditional food cuisines and wild food plants (WFPs) that have rarely been documented but make up a significant proportion of the local diet in the investigated area. These include vegetables such as *Arenaria serpyllifolia, Fagopyrum dibotrys, Rumex vesicarius, Rumex hastatus, Rumex chalepensis, Polygonum paronychioides, Gagea elegans, Amaranthus retroflexus*, and *Chenopodium botrys*. Fruits that are rarely documented are *Berberis kashmirana, Cotoneaster microphyllus, Gaultheria trichophylla, Rosa brunonii, Vitis vinifera, Myrsine africana, Impatiens flemingii, Impatiens edgeworthii,* and *Prunus padus*. Novel herbal teas in the region include *Abies pindrow, Arnebia benthamii, Bergenia stracheyi, Betula utilis, Bistorta affinis, Geranium wallichianum*, and *Taxus wallichiana*. Additionally, *Plectranthus rugosus* and *Teucrium royleanum* are rarely documented plants used to make herbal drinks. *Vigna radiata* is rarely documented as a bean, and *Skimmia laureola* is rarely documented as a condiment. It should be noted that there are several local traditional food cuisines in the region, such as Chalithi, Sheera, Katha Saag, Bagori, Klaari, Anch, Moti Roti, Dary-Behshat, Phatt, and Ul-Tiki, which are unique and have not been previously documented.

Discussion

WFPs and their taxonomic diversity

Our research focused on the role that WFPs play in maintaining a healthy food chain and promoting balanced nutrition in local communities residing in the Himalayan mountainous region of Kashmir. WFPs should play a crucial role in lowering the potential and high market price of farmed commodities. We observed that approximately half of the local population lives below the poverty line. Ethnic groups in the study area harvest a variety of WFPs from different ecological zones. However, for some ethnic groups, these WFPs are closely linked to their local traditions. The way they utilize and prepare these WFPs may differ from one ethnic group to another, depending on their preferred recipes and specific occasions. Therefore, the use of different WFPs among the investigated ethnic communities varies based on their unique cultural preferences. The results demonstrate that the majority of local communities sell veggies and WFPs in local markets to meet their basic necessities. Most people prefer WFPs over cultivated ones due to financial constraints [60]. A total of 113 WFPs were recorded from the study area. The inclusion of a diverse range of WFPs with varying habits, growth patterns, and useful parts in the nutritional repertoire emphasizes their acceptance and integration in food culture. The vast area and biocultural diversity in the region may explain why plant use is more diverse than in other regions [84]. The WFP diversity result showed that Polygonaceae and Rosaceae families were recorded as leading families, followed by Lamiaceae, Asteraceae, and Fabaceae. The members of these families showed broader ecological amplitude and adaptations and were mainly found in open habitat ecosystems [42]. The study area comprises four zones, including subtropical, temperate, subalpine, and alpine. So, members of the abovementioned plant families are most frequently utilized by local communities across the entire region due to their wide spread abundance. Our results are consistent with various studies in the region [42, 85, 86]. Growth form of WFPs results revealed that herbs were recorded as dominant, contributing 62.83%, followed by trees (18.58%), shrubs (12.39%), ferns (5.42%), and climbers (1.77%). The prevalence of herbs in the study area is mainly due to the extensive elevational gradient from 971 to 4229 m, whereas herbaceous vegetation increases along the elevational gradient [41, 87].

Presently, vegetables were observed as the most commonly used WFP category in the investigated area, with 47 species. The study found that the WFPs collected during the daily routine were substantially similar across all ethnic groups. All wild vegetables were mostly consumed in their early phases of growth, and the green leaves or aerial parts of the appropriate plant species were commonly used. The rapid social evolution of these settlements, including market access and economic reasons, may pose a significant challenge to environmental and natural resource sustainability[88]. Abbasi et al. [70] reported 45 wild vegetables from Lesser Himalayas. Generally, Kashmir region considered as biodiversity hotspot due to diverse array of agroclimatic zones and habitats with extensive elevational gradient from subtropic to alpine zone. These circumstances support the greater diversity of WFPs in the region. In comparison with the arid and semi-arid regions of Pakistan, Waheed et al. [80] reported 35 wild species from Punjab, whereas Aziz et al. [86] reported 21 species from Gilgit Baltistan. These areas exhibited severe environmental conditions and vegetation differences, which account for the low wild vegetable diversity as compared to the current study area. The most frequently consumed wild vegetables reported by ethnic groups are *Amaranthus retroflexus*, *Amaranthus spinosus*, *Amaranthus viridius*, *Chenopodium album*, *Chenopodium murale*, *Chenopodium botrys*, *Cucurbita maxima*, *Malva parviflora*, *Malva sylvestris*, *Nasturtium officinale*, and *Oxalis corniculata*. The average and total cultural importance of WFPs gathered diverse contexts

emphasizes of gathering environment over the number of species [89]. The variation in wild vegetables across the region might be due to limited access to conventional food. Furthermore, various factors, such as climatic conditions, the availability of wild vegetables, and ethnography, are the main factors that influence the usage pattern of wild vegetables among the diverse ethnic communities of the region. Humans have relied on wild plants for their food and health needs since ancient times. This is supported by scientific evidence that shows how ancient peoples utilized these plants to sustain themselves [90]. Traditional communities use wild vegetables to combat food security as well as medicine for the treatment of various diseases, indicating a relationship between medicinal and edible plants [91].

Fruits were recorded as second most dominant consumed WFPs category accounts for 35.40% among the ethnic communities of Kashmir region. We observed that ethnic groups harvested fruits from surrounding forests, alpine pastures, and gardens mostly during the spring season and consumed them as a raw snack. Ethnobotanical studies by Luczaj et al. [92] and Pieroni et al. [93] suggest that raw snacks may have originated during the evolution of mobile pastoralism, making them an interesting phenomenon of food anthropology. The most commonly utilized snacks plant mentioned by all ethnic groups were *Pyrus pashia*, *Pyrus communus*, *Prunus armeniaca*, *Punica granatum*, *Diospyros lotus*, *Ficus palmata*, *Berberis lyceum*, *Elaeagnus umbellata*, *Fragaria nubicola*, *Malus pumila*, *Punica granatum*, *Rubus fruticosus*, and *Viburnum grandiflorum*. Wild fruits are generally eaten raw as compared to cultivated ones since they are known to have a high fiber content, a high vitamin concentration, and a great variety of secondary metabolites [73]. The current study results showed greater number of fruits as compared to other studies. Likewise, Waheed et al. [80] reported 25 wild fruits from Punjab, and Abdullah et al. [60] reported 24 species from the Hindu Kush Mountains range in Pakistan. In comparison with the study area, these areas have harsh environmental conditions, like less annual rainfall and lower wild fruit diversity. On the other hand, Ahmad and Pieroni [36] reported 31 fruits from Takhte-Sulaiman Hills, Pakistan. Based on availability, climatic conditions, traditional knowledge, and nutritional value, we hypothesize that the variety, distribution, and consumption of wild fruits differ by region.

We reported 21 taxa have been used to prepare drinks such as herbal teas, coffees, decoctions, and cold drinks. Herbal teas are infusions produced from plant leaves, seeds, or roots with hot water. They are often used for their medicinal and energizing effects, including relaxation [94, 95]. Results revealed that bark (*Abies pindrow, Betula utilis, Taxus wallichiana*) and rhizome (*Bistorta amplexicaulis, Arnebia benthamii, Geranium wallichianum, Bergenia ciliata*) are often used by ethnic communities to make herbal drinks. Herbal teas frequently have immune-boosting and purging qualities, and they can aid with stomach-related problems [56, 96]. Different herbs may have particular therapeutic benefits, herbal teas, for example, are well recognized for their calming effects and ability to decrease blood pressure [81, 94]. We also reported that leaf or aerial parts (*Ajuga integrifolia, Mentha longifolia, Mentha arvensis, Mentha spicata, Plectranthus rugosus*) were used for the preparation of herbal drinks. Wild gathering is the primary source of therapeutic plants used in the herbal medication industry and by ethnic communities [78]. Herbal drinks are valued greatly, primarily for their medicinal applications [97].

Our study results demonstrate that various plant species are used as flavoring agents (condiments). In the study area, ethnic groups used this traditional method that some species used as condiments to enhance the taste of traditional food dishes. Additionally, informants tell us that the younger generation is not interested in the harvesting of plants as condiments due to the availability of some condiments in the local market. So, a declining trend was observed in retaining traditional ecological knowledge in younger generations compared to older generations. The most commonly utilized species as favoring agents (conditions) are *Mentha arvensis, Mentha spicata, Zanthoxylum armatum*, and *Juglans regia*. Various researchers also reported that these species are used as flavoring agents in traditional cuisine systems in different areas of Pakistan [60, 80, 86].

Cross-culture analysis

Cross-culture analysis of WFPs among the seven investigated ethnic community's revealed significant variation in plant consumption patterns. Ethnic communities consume plants based on the availability of WFPs in various regions of the study area. Gujjar ethic communities used majority of plants solely by them and not by other six ethnic groups. Gujjars, also referred to as a nomadic community, migrate to lower regions in the winter and move with their livestock to higher mountainous regions in the summer, allowing them to live in close proximity to nature. Furthermore, they are dedicated to shepherding in the high mountain meadows. As a result, the Gujjar and Bakarwal community consumes more WFPs, as they lack permanent settlements and spend much of their lives with cattle in the forest and pastures, harvesting and using WFPs on a daily basis [42]. They have a wealth of knowledge about WFPs, which they successfully transfer to the next generation. Compared to other communities, the Gujjars have a thorough awareness of WFPs and

traditional recipes, whereas most others rely primarily on market-based plants. The Gujjar community is strictly endogamic and therefore socio-culturally isolated from other communities, which might have deterred them from exchanging TEK of WFPs with their neighbors. A similar kind of result has been reported in various studies where endogamic communities preserved the TEK of WFPs [86, 98]. The second-most notable group in terms of using wild food plants (WFPs) was the Bakarwal community. The majority of their time was spent shepherding in the alpine pastures. This group has a great deal of experience with high-altitude wild food plants in the alpine zone, and they often include these plants in their daily diet [99]. The peculiar ways that Bakarwal employ plants suggest that they are more knowledgeable about plants that grow in higher alpine regions and meadows, and their unique culinary ethnobotany may also be connected to their identity. Four ethnic communities, including Syed, Khawaja, Mughal, and Kashmiri, having similarities in WFPs consumption patterns, might be due to the prevalence of local Kashmir culture in the region, which in turn significantly impacted daily cultural practices, including TEK, among most ethnic groups. In terms of plant utilization, these ethnic communities are relatively similar, suggesting that native plant knowledge has spread horizontally among the various communities. Participants in the study confirmed that ethnic communities, including Khawaja, Mughal, and Kashmiri, led us to hypothesize that the sociocultural agreements between these groups are responsible for the traditional ecological knowledge of WFPs. According to reports, intermarriages between various groups, except the Syed group, that coexist in the same socio-ecological region are also necessary for the intimate sociocultural exchanges between them [88, 100]. Notably, in comparison with other ethnic groups, the Awan ethnic group, which lives in the lower parts of Kashmir, uses fewer wild food plants (WFPs). This group is mainly engaged in farming and harvests plants from their agricultural fields. Furthermore, the Awan community is primarily urban and, as a result of their contemporary way of life, significantly depends on food items that are sold in markets, such as fruits and vegetables. Some ethnic groups, on the other hand, who reside in higher alpine regions interact and use WFPs more frequently.

Major threats

Changes in land use, including infrastructure development, shifts in agricultural practices, and the conversion of forests to agricultural land, pose significant threats to wildlife and plant species (WFPs) in the Kashmir region. These threats are exacerbated by habitat destruction from activities such as soil erosion, overgrazing, fuelwood collection, forest fires, and excessive timber harvesting. Other factors, such as diseases, overharvesting, climate change, and invasive species, also contribute to the decline of WFPs in the area. Local communities in the mountainous region heavily rely on natural resources for their livelihoods. However, their excessive use of these resources puts them at risk of survival, as it depletes the availability of WFPs. Based on our findings, we have identified climate change, agricultural expansion, and fuelwood collection as the top threats to WFPs in the region. The limited job opportunities in the area force many ethnic communities to depend on natural resources to sustain their lives. This further intensifies the pressure on WFPs in the mountainous region. Some similar threats were also reported in the previously done studies [42, 101–103]. WFPs in the Kashmir Himalayas are being overexploited, endangering their long-term survival as a result of the need to increase staple crop yields and satisfy a variety of human demands. This problem is a result of overharvesting as well as a lack of understanding of the value of traditional ecological knowledge and WFPs in terms of nutrition, economy, society, and ecology.

Mitigating threats to WFPs needs a diversified approach. Sustainable agricultural techniques and reforestation practices improve overall ecosystem resilience, which helps in mitigating the effects of climate change. Natural ecosystems in the Kashmir region can be preserved by encouraging agroforestry and limiting agricultural growth. Deforestation should be strictly banned, as should sustainably harvesting policies, community-based conservation initiatives, and educating the local communities about alternate energy sources. WFPs populations are safeguarded by controlled grazing, controlled debarking, and the prevention of overexploitation through the strict implementation of laws. These natural resources are protected by fire control measures and export policy monitoring. Soil erosion can be reduced by practicing conservation agriculture and growing cover crops. Finally, invasive species can be managed by implementing strict biosecurity controls and restoring native species. For these measures to be effective, governments, non-governmental organizations, and local communities must work together.

WFPs and future food security

Like in other developing regions, the utilization of common pastures, rangelands, and forests, livestock keeping, and subsistence gardening were the primary sources of income in Kashmir mountainous regions. In the research region, wild food plants continue to play a significant role in the local food basket. Approximately one million of an estimated eight million animal and plant species are currently threatened with extinction. Climate change is

causing severe repercussions in many countries, including prolonged droughts, harsher storms, heat waves, and wildfires. Climate change is causing rapid disruptions in biological systems, leading to biodiversity loss and degradation. Rapid land use changes impact the availability of wild foods, affecting smallholders' food and nutritional intake, notwithstanding their significant contribution to household food consumption globally. To prevent future food insecurity, it's critical to protect natural resources from exploitation. Stakeholders in the area should prioritize nutrition by reviewing local small-scale agriculture methods and biodiversity conservation strategies to improve wild food supply and food security. Wild food plants, which provide a significant portion of the local food system's food baskets in numerous human communities, are also under threat. Global changes have frequently affected local plant ecosystems, even in extremely remote locations across the world. The availability of plants has significantly declined in various geographical contexts as a result of human activities such as intensive farming techniques, population growth, overharvesting, and uncontrolled grazing. Monoculture agricultural practices negatively damage soil fertility and threaten the wild flora of the region [104]. The degradation of natural resources in Kashmir poses a significant threat to local food security, particularly for mountainous communities. Prioritizing sustainable growth requires valuing natural resources while incorporating traditional food traditions into local farming methods. Wild food resources cannot meet demand, but without them, the gap between supply and demand will be greater than expected. To enhance the importance of wild species, strategies for food security and biodiversity protection must be developed and a transition zone identified.

Revitalizing the traditional ecological knowledge

Traditional ecological knowledge is essential for human survival on the planet. In our study area, we observed that traditional food knowledge is being replaced by exotic knowledge across the Kashmir region. Traditional ecological practices are fading as a result of modern agriculture practices expanding across mountainous terrain. This could have a significant detrimental impact on future local food sovereignty and security. Furthermore, ethnic communities in Kashmir are gradually losing their local foraging methods due to socio-environmental change. Stallholders take some serious initiatives to preserve the traditional ecological knowledge of the Kashmir region and how this knowledge is transmitted to future generations. To strengthen the durability of TEK, it may be required to integrate it into the existing school curricula with traditional knowledge bearers. This could revitalize the TEK and raise awareness about the importance of preserving local natural resources and socio-ecological systems.

Local ecological Knowledge (LEK) about WFPs is disappearing or being replaced by non-native knowledge in the Kashmir region, posing a significant challenge. The conservation of cultural history and the sustainable use of the region's WFPs depend heavily on youth education. The sustainability of local practices is being threatened by the decline of traditional knowledge brought about by societal changes and reliance on standardized plant elements. The revitalization of LEK in educational programs is a collaborative effort including key stakeholders and local people to effectively convey cultural knowledge about WFPs. In our opinion, incorporating LEK into educational curricula will not only improve cultural and traditional cuisine preservation but also help the young generation understand science-based local ecological experiences. To strengthen the durability of LEK, it may be required to integrate it into the existing school curricula with traditional knowledge bearers. Globally, ethnobiologists advocate for dynamic frameworks that revive the LEK of WFPs and promote their application through holistic education [105, 106]. Revitalizing the LEK of WFPs is crucial for achieving socio-ecological sustainability. Ethnobiologists should be involved in the creation of culturally and ecologically relevant curricula in order to help curriculum designers and policymakers address the loss of local ecological knowledge (LEK). They should incentivize indigenous knowledge-bearers and work on reviving LEK through educational programs, maintaining it alongside contemporary science. LEK is essential for managing local habitats and resources, so promoting health-beneficial WFPs is an effective modern strategy. We advocate incorporating LEK into policy frameworks for future development, as traditional knowledge is critical to local ecosystems and economies. In order to accomplish sustainable development goals, policymakers should work with ethnobiologists to design policies that preserve and revitalize LEK and the local biocultural legacy through development and education initiatives [107].

Traditional ecological practices can mitigate future food security by addressing the issues within the communities instead from outside. Promoting sustainable rural development may benefit from reviving and elevating respect for the region's wild plant resources. Ecotourism in the region can help reduce social isolation and raise knowledge of indigenous food cultures, potentially preventing the future loss of TEK. It's possible that using TEK to design community-centered biocultural diversity conservation projects will produce better results than using conventional methods. To revitalize TEK among young community members, we suggest some strategies, which include study trips, traditional food day

celebrations, developing WFP herbaria, and incorporating "food scouting" (ethnobiology-centered documentation of threatened local foods) into the school curriculum [108].

Conclusions

This study sheds light on the vital role of wild food plants (WFPs) in sustaining the diets and cultures of rural communities and indigenous tribes in the Kashmir Himalayan Region. By examining seven different ethnic groups, the research provides valuable insights into the use, preferences, and traditional ecological knowledge of WFPs. The study included 321 participants, with 75.38% men and 24.61% women. It reported a total of 113 plant species from 74 genera and 41 families. The most commonly occurring families were Polygonaceae and Rosaceae, each with 17 species. Leaves were used most frequently at 41.04%, followed by fruits at 33.33%. The consumption methods varied, with 46.46% of the plants being cooked and 37.80% consumed raw. Out of the 113 species, 47 were used as wild vegetables and 40 as fruits. Furthermore, this study explores information regarding the market potential and ecological distribution of WFPs in the region. Cross-comparison showed that utilization of WFPs varies significantly across the region and communities, including their edible parts and mode of consumption. This diversity is quantified using the Jaccard index, which ranges from 5.81 to 25, indicating distinct patterns of WFPs use among the studied groups. Furthermore, the study reveals the existence of 29 traditional wild food plants (WFPs) and 10 traditional food dishes that have not been previously reported in Pakistan. This emphasizes the importance of preserving and promoting this unique culinary heritage. Climate change, invasive species, agricultural expansion, and plant diseases emerge as major threats to the sustainability of WFPs in the region. To address these challenges, conservation policies must be implemented to safeguard WFPs and their associated practices for future generations. Furthermore, efforts to revitalize traditional foraging methods among younger generations are critical to preserving indigenous flora, food knowledge, and cultural history. Consequently, the conservation of the complex ethno-ecological cobwebs made by local WFPs, their ecologies, and attached cultural practices not only protect biodiversity but may also help provide food security and enhance the cultural heritage in the study area.

Abbreviations

WFPs	Wild food plants
JI	Jaccard index
TEK	Traditional ecological knowledge
LEK	Local ecological knowledge
AJK	Azad Jammu and Kashmir

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Author contributions

S.W.G and M.M. carried out the fieldwork. S.W.G. and M.M. prepared the first draft of manuscript. M.W. contributed to data interpretation. L.Z. conducted the data analysis. R.U. and Z.I. contributed to the data curation and funding acquisition. A.P., N.S., and M.A. participated in the visualization and review. M.A. conceptualized and supervised the study. All authors read and finalized the manuscript.

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Availability of data and materials

No datasets were generated or analyzed during the current study.

Declarations

Ethics approval and consent of participants

This study is a part of the research work of Ph.D. scholar Mr. Syed Waseem Gillani (first author), which was approved by the Advanced Studies & Research Board (ASRB) at the Quaid-i-Azam University Islamabad, Pakistan. Present study is based on a field survey rather than human or animal trails, and we took verbal consent from participants regarding data collection and publication. All informants allowed us to share their opinions and photographs for publication. In addition, the ethical guidelines and rules of the International Society of Ethnobiology (ISE) (http://www.ethnobiology.net/) were strictly followed.

Consent of publication

All informants allowed us to share their opinions and photographs for publication. In addition, the ethical guidelines and rules of the International Society of Ethnobiology (ISE) (http://www.ethnobiology.net/) were strictly followed.

Competing interests

The authors declare no competing interests.

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