Decision support framework for the management and conservation of wild edible plants in Maharashtra, India

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Wild edible plants (WEPs) are important in ethnobiological research in India. Maharashtra has been chosen as a case study to understand the state of knowledge about WEPs and their use for sustainable development. A total of 436 edible plants have been listed so far, but documentation of management practices is less and needs systematic research in the future. We suggest future action research themes and a decision-support framework for using WEPs in Maharashtra.

Keywords: Conservation, indigenous knowledge, sustainable development, wild edible plants.

PLANTS are an essential component of the human diet. Around 2500 plant species have been domesticated worldwide[1]. In addition to the domesticated species, a number of wild plant species are also part of the human diet. Ethnobotanists documenting indigenous knowledge broadly refer to these as wild edible plants (WEPs).

Heywood[2] defined 'wild' plant species as those that grow spontaneously in self-maintaining populations in natural or semi-natural ecosystems and can exist independent of direct human action. 'Cultivated' or 'domesticated' plants are those that have arisen through human activity, such as selection or breeding that depends on management for their continued existence. Heywood[2] also mentions that in practice, there is a complete spectrum between 'completely wild' and 'completely domesticated' species depending on the degree of human intervention or management involved. Studies in many parts of the world have shown how communities directly or indirectly manipulate edible plant species in the wild, producing a semi-domestication or paradomestication process (i.e. caring for and promoting *in situ*)[3], even when it is not obvious to a researcher inventorying them. It has also been reported that WEPs may or may not be indigenous to the region where they are used[4], which raises interesting questions regarding the transfer of germplasm and indigenous knowledge on edible plants between cultures.

WEPs have been a recurrent research theme in India, documented by botanists, anthropologists and social workers. Ray *et al.*[5] documented 1403 species belonging to 184 families in their review of WEPs research in India. There is a growing interest in the importance of WEPs in rural nutrition, rural economy and potential commercial value as neutraceuticals[6]. However, there seems to be an underlying assumption that all species reported as WEPs from different parts of India are actually or truly 'wild' with no human intervention at any time. Based on this assumption, ethnobotany studies provide a floristic and nutritional analysis and a few broad suggestions regarding the need for more research and cultivation of WEPs. A few concrete action plans for the sustainable utilization of WEPs are given in studies by agricultural or horticultural scientists[6–8].

Taking a case study of WEPs reported from Maharashtra, India, we discuss heterogeneity in the group of plants assumed to be 'wild edibles' by ethnobotanical researchers working in the region. A large body of ethnobotanical literature pertaining to WEPs published from Maharashtra indicates that the exploratory phase of research on this topic is more or less complete, making it ideal for a case study[9–18]. Research themes on WEPs in Maharashtra are compared with the broad themes of research on WEPs in other parts of the world. Future research themes for conservation and sustainable use of WEPs in the state are also suggested.

The objectives of this study are:

(1) To review knowledge of domestication and management associated with the documented WEPs in Maharashtra.
(2) To suggest a decision support framework (DSF) for prioritizing WEP species for conservation action and sustainable use.

We continue to use the term 'wild edible plants' mainly to refer to the earlier research, but a more appropriate typology is discussed at the end of this note.

For this review, a working checklist of known WEPs from Maharashtra was prepared by reviewing ethnobotany

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papers from all eco-regions of the state; a selection of papers is given below[9–18]. These were reviewed chronologically backwards (the most recent first) and the search effort was stopped when the species list started plateauing, i.e. new species were not added with each paper. The final list had 434 species of angiosperms, two ferns (and three mushrooms excluded in this review) (see Supplementary Material). We did not aim to develop a database of WEPs in Maharashtra but to discuss future action research themes on WEPs that can support achieving Sustainable Development Goals at the state level. More edible species are likely to be added by increasing the survey and review efforts. However, considering our aim, we have preferred to use this list of 436 species for further discussion. Accepted plant names and distribution data for all the species were collected from POWO[19]. Secondary data on distribution, invasiveness, cultivation practices, management and other attributes of species were collected from global databases on useful plants, including the United States Department of Agriculture[20] and the Global Invasive Species Database[21] and the relevant Indian literature.

The list consisted of 338 indigenous species, 89 non-indigenous species and 9 species doubtfully indigenous to India. Fruits, vegetables and garden plants such as *Annona* spp., *Psidium guajava*, *Achras zapota*, *Coriandrum sativum*[9,12,17], *Cestrum nocturnum*[18], etc. were included in the list of WEPs along with their uses. Species such as *Trifolium* (*T. fucatum*, *T. pratense*) and *Sambucus nigra* which are cultivated in many countries and are likely only recently introduced in India, were reported as 'wild' edible weeds in Maharashtra[15]. They grow as ruderals or invasives in and around habitation, as escapes or naturalized taxa in the landscape. Compared to these, *Tamarindus indica* and *Azadirachta indica* are very old introductions[22,23] and have been part of indigenous knowledge for centuries. Non-indigenous, naturalized edible species fit Heywood's[2] definition of 'wild'. However, the presence of non-indigenous species in the region is due to human interventions, whether accidental or intentional. Hence they should not be grouped with indigenous wild species. None of the research papers traces the history of introduction of non-indigenous species into the indigenous food systems. Also, they do not delve into the process of incorporation of non-indigenous species into the ecological and cultural landscape of Maharashtra.

Out of 338 indigenous species, 183 are commonly reported from areas managed extensively by humans. None of the research papers (except a few[18,24]) describes any locale-specific ecological aspects such as the landscape element where these species were gathered or growing in their study areas, and readers may erroneously assume that all these are truly 'wild'. This list includes Cucurbitaceae, *Ziziphus* spp., *Corchorus* spp., *Dioscorea* spp., *Diospyros* spp., *Cissus* spp., *Amorphophallus* spp., *Tinospora cordifolia*, *Dillenia indica*, etc. These have been cultivated or managed (with active inputs, including tending, pruning, transplantation, weeding, watering, etc.) in and around home gardens or kitchen gardens in Asia[25–27]. They are also found in natural ecosystems such as forest edges, scrublands, etc. It is also possible that they have undergone some semi-domestication process, as described by Turner *et al*.[3].

Studies in South America, Africa, Asia and Australia have provided remarkable insights into the indigenous knowledge systems of food production. Recently, it has been shown how in the Neotropics, domestication had started even earlier than the food production systems such as agriculture[28]. Apart from agriculture and home gardens, plants in diverse landscape elements were managed by local communities, and entire landscapes can be considered domesticated[29]. Proper study and documentation of WEPs may help us understand indigenous knowledge associated with the management of species in human-use landscapes, which in turn will help in sustainable use. Listing species under human management as 'wild' is not only erroneous but also derogatory towards the indigenous ecological knowledge and management of plant resources practised by the local communities.

The present analysis shows that out of 436 WEPs in Maharashtra, 236 are already under cultivation in India or around the world. Of these, 120 are already farmed (on a subsistence or commercial scale), and 116 are managed in and around home or agroforestry areas, as documented in India and other countries in the world. *Amaranthus* spp.[9], *Carica papaya* (papaya) and *Moringa oleifera*[12] are listed as WEPs, though they have been domesticated for a long time. The list also includes farmed crops such as *Cicer arietinum* (chickpea), *Cyamopsis tetragonoloba* (gavar), various species of Cucurbitaceae, and even *Sorghum* spp., *Zea mays* (maize) and *Eleusine coracana* (finger millet), which have been in cultivation in India for many years. These are commercially farmed for several years and are not truly 'wild'. The only likely reason for their introduction in WEPs can be the distinction made between marketed plant parts and non-marketed plant parts by either the researchers or respondents. For example, the leaves of pumpkin and chickpea are used for subsistence, while their fruits or pods are sold in the market. Nevertheless, it is still wrong to name them 'wild' edibles, as they are harvested from a farm or home garden. Although some may be found as escapes near current or past habitations, they are unlikely to be found in areas where there has been absolutely no human activity.

There are 149 species that are not cultivated for food but have well-established cultivation practices, as they are known for their timber, ornamental or medicinal value. *Sterculia* spp. and *Phyllanthus* spp. are cultivated in local nurseries and planted as medicinal species. Though these are not grown for food production purposes, they could be easily brought into the agricultural system to encourage diversity in local food systems.

Finally, for about 51 species, there is no report of any known cultivation practice, even at the experimental scale.

<table>
<tr><td>Basic research</td><td colspan="4">Socio-ecological and ethnobiological research to understand processes of domestication, naturalization and indigenous knowledge development</td></tr>
<tr><td rowspan="3">Cultivated
(236 spp.)</td><td rowspan="2">Cultivated in farms
(120 spp.)</td><td>Cultivated in farms outside India (34 spp.)</td><td colspan="2">Farm practices can be introduced through agricultural extension work</td></tr>
<tr><td>Cultivated in India
(86 spp.)</td><td colspan="2">Farm practices can be introduced in Maharashtra through agricultural extension work</td></tr>
<tr><td>Managed around human landscape
(116 spp.)</td><td colspan="3">Farm or agroforestry practices can be promoted after considering the local ecology</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td rowspan="4">Not cultivated
(200 spp.)</td><td>Cultivation technique established
(149 spp.)</td><td colspan="3">Agricultural and horticultural research to scale up farming or orchards, where appropriate</td></tr>
<tr><td rowspan="2">Cultivation technique not established
(51 spp.)</td><td rowspan="2">Non-endemic broad distribution
(38 spp.)</td><td>Ruderal, weed or fast-spreading
(24 spp.)</td><td>Cultivation at least at the experimental level can be studied</td></tr>
<tr><td>Growth in wild unknown
(14 spp.)</td><td>Research on ecological attributes to study cultivation potential or need, strategic action plan for identification and mapping</td></tr>
<tr><td></td><td>Endemic, narrow distribution (13 spp.)</td><td colspan="2">Research and conservation action to protect the species in the wild</td></tr>
<tr><td>Applied research</td><td colspan="4">Product development, and rural and urban consumer research</td></tr>
</table>

Figure 1. Decision support framework for edible plants in Maharashtra, India.

This is a heterogeneous group of species with wide diversity in other ecological aspects. It includes 38 widespread species, 24 of them documented as ruderals, invasive and/or fast-growing (for example, *Xanthium strumarium*), which can be easily brought into cultivation if needed. There are no reports for the remaining species (14) and these can be studied further.

The true conservation concern is regarding a small group of 13 endemic species (*Pinda concanensis*, *Heracleum grande*, *Ceropegia attenuata*, *Ceropegia lawii*, *Ceropegia oculata*, *Amorphophallus konkanensis*, *Dipcadi minor*, *Impatiens inconspicua*, *Smithia hirsuta*, *Smithia purpurea*, *Sonerila scapigera*, *Dendrobium barbatulum* and *Zingiber cernuum*), which are edible and collected by local communities. Overcollection will negatively impact wild populations of narrowly endemic species for which cultivation techniques are unknown. More information regarding their extraction from the wild and sale is needed to take appropriate conservation measures. Cultivation techniques are known for other endemic species (e.g. *Boucerosia frerei*); hence efforts can be taken to establish their population to balance harvesting.

Edible plant species can play an important role in Sustainable Development Goals 2 and 3 (Zero Hunger, Good Health and Well-being respectively). They also hold potential for income generation through processing, value addition and market linkages. For this, the harvest of species should be managed sustainably without harming the actual resource. For more promising edible species, cultivation is the only possible option that will also ensure the quality and quantity required for the market.

As discussed above, many of the species are already under cultivation. Hence these can be easily cultivated in Maharashtra in farms or home gardens and further processed for the market. *Celosia argentea* (Kurdu) is a good example of a non-indigenous species incorporated into traditional knowledge in Maharashtra. It is a cultivated species elsewhere but a non-indigenous weed naturalized in Maharashtra. It is gathered as food from fallow fields, roadsides and scrub areas and is part of ritual food (food cooked as part of rituals) and traditional medicine. There have been no efforts of commercial production as a vegetable even when the cultivation practice is well known, and there is a cultural acceptance as well as a consumer group for this species. For the future management of WEPs, we suggest a DSF (Figure 1).

The role of ethnobotanists is crucial in decision-making regarding WEPs. However, the scope of their studies needs to expand from inventorying edible plants to identifying practices appropriate for sustainable management of the species[30,31]. Ethnobotanists interested in WEP research can use methods described by Martin[32] for the documentation of indigenous knowledge. A typology for WEPs based on management practices can be adopted from Casas *et al.*[33]. They suggest two main classes of management.

(1) *In situ* management involves interactions in the spaces occupied by populations of weeds or wild plants and includes gathering, tolerance or sparing, enhancement and protection.

(2) *Ex situ* management, on the other hand, includes interactions outside spaces occupied by natural wild populations or weedy plant populations in habitats created and controlled by man, including sowing and transplantation.

The present study is limited to understanding the broad themes emerging from research on WEPs. Preliminary analysis of the 436 species indicated that ethnobotanists use the

term ‘wild edibles’ without any ecological or ethnographic characterization or definition of the term ‘wild’. None of the publications discusses if ‘WEP’ is an etic or an emic category and the term ‘wild edible plants’ appears to be a shared construct developed through interactions of researchers and respondents in the study.

Majority of the papers scanned for this study showed much repetition of information on edible plant parts and their uses. It is suggested that a state-level database of edible species should be developed, and any new uses or practices in different parts of Maharashtra should be updated using a citizen-science model. This will help ethnobotanical research in the state to move beyond the exploratory or descriptive phase into experimental, correlational and explanatory research designs that can address pertinent questions about indigenous knowledge, environmental history of food systems, conservation and sustainable use.

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