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The need to include wild foods in climate change adaptation strategies

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Declining wild food use has been reported around the world for decades, with important implications for nutrition and well-being. Commonly listed threats include land-use change and overharvesting. Climate change acts to compound these. Herein, we examine the importance of wild foods around the world and the impact of climate change on wild food species. We highlight large variations between regions, both in terms of climate impacts on wild foods and their importance. The emerging evidence suggests that, in addition to the Arctic, arid regions (such as the Sahel region of West Africa) and mountain regions (such as the Himalayas) may be particularly vulnerable to the impact of climate change on wild foods. We conclude with a reflection on the role of wild foods in climate change adaptation strategies and the ways that climate change adaptation strategies could threaten or enhance availability and accessibility to wild foods.

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Introduction: importance of wild foods in food systems around the world

Wild foods can include both native and introduced species that are not cultivated or domesticated, but may be under varying degrees of management by humans (and may include escapee domesticated species) [1,2]. Commonly consumed wild foods include vegetables, fruit, mushrooms, meat, fish, and insects [1]. Wild foods are also often wild relatives of crops, and as such, they are an important reservoir of desirable traits for adaptation and resilience to climate stressors [3]. Wild foods contribute to income, food, and nutritional security and cultural identity to varying degrees around the world [1,4,5].

Information on the use and importance of wild foods for food security and nutrition is growing but remains limited [3]. Existing studies clearly show that, while they contribute little to energy intake, their contribution to nutrition and health can be significant because most wild foods (predominantly vegetables, fruits, mushrooms, insects, and meat) are rich in micronutrients (e.g. iron, calcium, and vitamin A) [1].

There is a large variation in the importance of wild foods between and within countries [1,6]. Of 91 countries surveyed for the State of Biodiversity for Food and Agriculture, 15 reported regular use of wild foods by the majority of the population and 26 reported regular use of wild foods by a subsection of the population [3]. In forest-adjacent communities around the tropics, wild foods contributed between 0% and 96% of fruits and vegetables (average of 14%) consumed [6]. These results are similar to the high variation described in a review of wild foods [1].

Wild foods are an important part of local and Indigenous food systems, knowledge systems, and cultural identity [4,7]. The sharing of wild foods supports and maintains social bonds and networks [8]. For Indigenous communities, harvesting wild foods, coupled with landscape stewardship to facilitate sustainable harvest, is central to attachment to place and essential to both human and environmental well-being [9–11]. Wild foods, their harvest, and culinary traditions are a way for Indigenous communities to (re)connect with their cultural heritage and identity [4,12,13]. For example, communities such as Biigtigong Nishnaabeg in Canada, are using canoe and bush-camp trips centered on hunting and collecting wild plant foods and medicines, to reconnect community members to each other, their history, and the land with demonstrated impacts on well-being [13]. In California, the Karuk Tribe is reviving tribal stewardship through wide-scale low-intensity fire throughout their territory to support the restoration of forest ecosystems and improve wild food access and availability [14].

This paper starts by summarizing the current state of knowledge on the importance of wild foods for diet and nutrition, as well as social–cultural well-being. We then examine the broad factors that shape changes in wild food use around the world, including climate change. To do this, we build on recent reviews [15], but have not done a systematic review because a fixed set of search terms proved ineffective in capturing key literature. We conclude with a critical examination of the possible impact some climate change adaptation efforts might have on wild food use and access and make recommendations for wild food-friendly climate change adaptation.

Change in use and importance of wild foods

Declining wild food use has been reported around the world for decades. Declining use is attributed to changes in social–political–economic–cultural factors (e.g. livelihood practices, market integration, access/use rights, and time use) and environmental factors (e.g. land-use change, harvesting pressure/overuse, and climate change).

Livelihood changes lead to interconnected changes in market dependence for food, demands on (especially women's) time, land use, knowledge of wild foods, and culture [16,17]. Colonialism has reconfigured time use in Indigenous communities in a way that constrains access to wild foods [18]. Social–cultural norms and declining preference for wild foods also drive declining use [19,20]. Notably, in some locations, a resurgence in land-based practices and wild food harvest is also reported [21].

Recent work has shed significant new light on the environmental drivers of wild food availability, with numerous global reviews finding deforestation, land-use change, and overexploitation as the dominant factors. A study by Hermans-Neumann et al. [22] looked at perceptions of forest product availability in 233 tropical forest-adjacent communities and found that 60% reported declining forest food availability. Increased collection of forest resources by local people and forest clearing were the factors that best explained the decline [22]. Another recent paper from Laos also reported deforestation and forest degradation as main drivers of declines in forest food use [23]. The State of the World's Biodiversity for Food and Agriculture conducted an assessment of 1039 wild plant and mushroom food species using the International Union for Conservation of Nature (IUCN) Redlist and found 63% of species are decreasing in abundance, 18% are stable, and 18% are increasing globally [3]. The primary direct drivers of decline listed were overexploitation, habitat alteration, pollution, and land-use change [3]. A recent systematic review of 78 studies on wild plant and mushroom food species change (as reported by communities) had similar results; most communities report a decline in the availability of the wild plants and mushrooms that they harvest (range shift, quality, phenology, and other changes were less frequently reported), identifying 14 drivers of change collectively. While the reported drivers varied according to continent and climate, land-use change and overexploitation were the most common (impacting 38% and 31% of taxa, respectively) [24].

These findings align with the growing literature on the relationship between forests, land-use, and diet. Forest cover has consistently been linked to dietary diversity, especially fruit and vegetable consumption in Africa [25–28]. The pathways that could explain these relationships include income generation from forests, ecosystem services from forests, agricultural practices that increase forest cover and support diets, or direct consumption of wild (forest) foods [29]. Pathway importance varies significantly from one context to another [30]. In Malawi, for example, forest cover was positively linked to wild fruit consumption [27].

Land-use change and intensity are also connected to changes in wild food availability. In many places, wild foods are harvested across land-use types in diverse landscapes [24,31]. Cooper et al. [32] looked at the geographic factors that shape wild food collection in four African countries and found both forest cover and grassland cover to be important (as well as population density). In Alaska, wild food consumption is higher in communities that lack road access [33]. In Laos, Broegaard et al. [34] showed that wild food use was twice as high in communities with less land-use pressure. Their findings suggest that land-use pressure from commercialization of agriculture and conservation is associated with lower wild food availability and livelihood changes that impact the amount of time allocated to gathering [34]. A number of other studies have also shown lower wild food use with agricultural intensification [17,35,36] or increased market access [16]. Others have reported no difference for those participating in agricultural intensification [37].

Climate change and wild foods

In Schunko et al.'s 2022 review [24], climate change was one of the least frequently reported drivers of declining availability of wild foods (cited only for 4% of taxa, most commonly reported in North America). Similarly, the State of the World's Biodiversity for Food and Agriculture's assessment found climate change as a threat to relatively few wild food species [3]. While not many communities are reporting impacts yet, climate change is indeed impacting wild foods in some places (e.g. Arctic and arid areas where it has been well documented by local and Indigenous Peoples) [38]. Climate change will further compound the impacts of other factors causing declining availability of wild foods [11].

The 2007 Intergovernmental Panel on Climate Change Fourth Assessment Report introduced the impact of climate change on wild foods only in the Arctic, highlighting interrelated impacts of climate change and loss of traditional knowledge on access to wild foods [39]. The 2022 Chapter 5 (Food Fibre and Other Ecosystem Products) of the Working Group II Sixth Assessment Report of the Intergovernmental Panel on Climate Change included a global review of climate impacts on wild foods. The growth of open-source and user-friendly species distribution modeling software, such as MaxEnt [40], has been associated with growing literature on species range shifts under future climate scenarios. Such studies are now more common than studies of impacts on abundance, yield, phenology, or quality (Figure 1) [15]. One notable recent study predicted range reduction for 66% of 1190 wild plant food species in southern Africa under a high-warming scenario [41]. Recent efforts are also trying to integrate Indigenous knowledge with modeling [42].

Although less numerous, many studies show climate change impacts the phenology of wild plant and animal food species. Phenological shifts are already occurring for *Melia azedarach*, *Bauhinia variegata*, *Grewia optiva*, *Morus alba*, and *Celtis australis* in the Himalayas [43], and a number of important berry species in North America (e.g. *Vaccinium membranaceum*) [44]. Changes in phenology will potentially create mismatches among human and animal seasonal activities and migrations [45,46], and pollinators and plants, impacting production and yield [15].

Finally, climate change is also impacting phytochemical composition and quality (Figure 1) [47]. In Saudi Arabia, drought decreased the content of phenols and flavonoids in *Mentha piperita* and *Catharanthus roseus* [48].

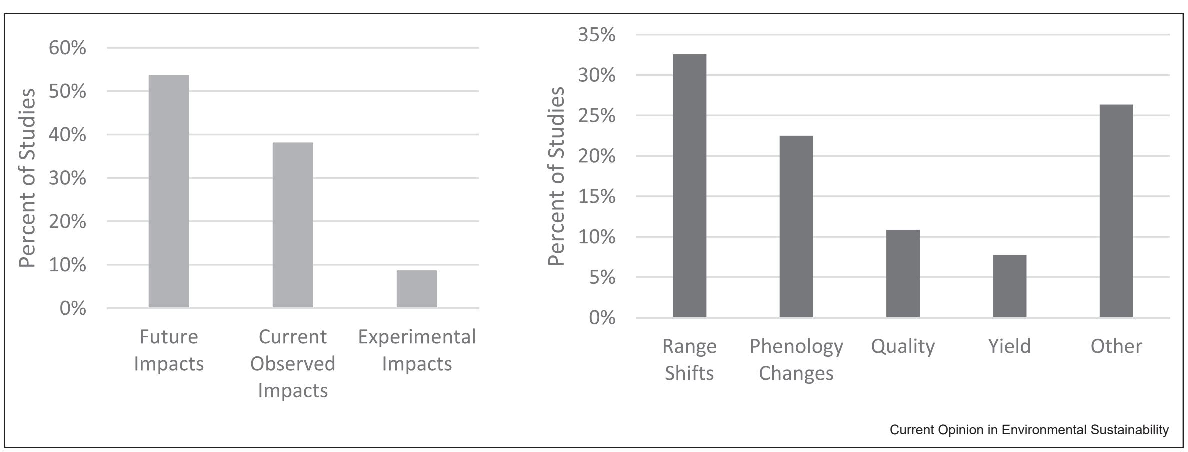
Regional variation in climate impacts on wild foods

The impacts of climate change on wild foods vary in time, space, and among species. Outside of Arctic regions, particularly in the tropics, wild foods have received less attention in assessments of climate change impacts on food systems [15]. Climate impacts in the humid tropics are more reported for agriculture than wild foods [15].

Regions, where wild foods are economically, nutritionally, and culturally important and likely to be highly impacted by climate change, include the Arctic, arid areas, and mountainous/ high-elevation areas (see Table 5.7 in Ref. [15]). These findings mirror observations made about regional variation in climate impacts on wild medicinal plants [49].

Climate impacts on wild food availability and access in the Arctic are now well documented [15]. Wild foods are

Figure 1



Focus of recent studies on impacts of climate change on wild foods (based on the 129 studies referenced in the Table in Chapter 5 (Food Fibre and Other Ecosystem Products) of the Working Group II Sixth Assessment Report of the Intergovernmental Panel on Climate Change) and an updated search that covers 2020–2022.

central to food systems of communities throughout the Arctic and sub-Arctic [50] and play an essential role in people's physical and emotional health [9,51]. Changes to the availability, abundance, access, and storage of wild foods associated with changing climate exacerbate or create food insecurity [52,53]. Climate change is causing ecological changes that impact Arctic wild food availability and abundance in many ways, including changes to breeding success, migration patterns, and food webs for marine mammals and fish. Reduced duration, thickness, and quality of sea ice are some of the most cited impacts of climate change on the consumption of wild foods in the Arctic. Traditional methods used to preserve wild foods, including ice/permafrost cellars, fermentation, and drying, are compromised by rising temperature and humidity levels [15]. Reduced mobility and increasing policy and institutional rigidity are limiting the ability of many communities to adapt to change [54].

Wild food use in arid regions is also significantly impacted by climate change [15]. Wild foods are important to Indigenous communities across arid regions of North America, South America (e.g. Argentina), Australia, and the Mediterranean basin [15]. In the Parklands of West Africa, wild trees that are left in agricultural landscapes during field clearing make a significant contribution to diets and nutrition: shea butter (*Vitellaria paradoxa*) provides the majority of fats and oils in rural diets; the leaves of trees such as baobab (*Adansonia digitate*) and others provide up to 50% of the green leafy vegetables in diets; and the leguminous néré tree (*Parkia biglobosa*) provides important micronutrients [55–57]. Climate change is already impacting the distribution of these trees and will continue to do so (see Section 9.8.2.3 in [58]). In western United States, documented impacts in the Klamath River Basin of Northern California include a steep decline in wild food health, harvest quality, and abundance in species such as tanoak acorns and multiple salmon species and huckleberries, foods that once made up 50% of a traditional diet [14,59,60]. Colonial suppression of low-intensity cultural burning practices, in combination with climate change, is driving increasingly frequent, larger, and more severe fires [61]. These new climate-driven fire regimes threaten many wild food resources and alter the ability of Indigenous Peoples to use traditional management practices, such as fire, to enhance the production of wild foods [14].

Mountain regions such as the Himalayas are another site where many wild foods are or will be impacted by climate change (see Table 5.7) [15]. For example, in Nepal, Thapa et al. [62] report decreased availability of a number of wild vegetables (e.g. *Asparagus racemosus*, *Urtica dioica*). Wild foods are important to the food and nutrition security of many communities in this region [63].

Wild food-friendly climate change adaptation

Wild foods exist under a broad range of management strategies and intensities. The impacts of colonialism in many places are now exacerbated by climate change, which some Indigenous communities are calling a new form of colonialism [64,65]. Although responding to unexpected events is not new, anthropogenic climate change is a more rapid and sustained reordering of food systems and harvesting cycles, and as such, new, innovative strategies to manage and restore food-producing ecosystems may be needed [46].

Even when climate change may not always be the primary driver, climate may interact with other stressors to exacerbate the loss of wild foods [59]. Communities are beginning to adapt to diminished access to wild foods, whether climate-induced or otherwise [66]. Transplanting and seed saving for wild plants are also used by Indigenous Peoples in North America to increase access by restoring wild foods to landscapes and to mitigate climate stressors and insure against total decimation of important species [67,68].

It is commonly suggested that wild foods act as a safety net during crises, including those induced by climate change, however, there is not strong consensus about what drives variation in wild food use over time. Seasonal variation in wild food use may be less related to seasonal food insecurity and more related to seasonal availability of wild foods or the time needed to harvest them [1]. Several studies have suggested that communities rarely turn to wild resources as a coping strategy after environmental shocks [69,70]. However, in contexts where wild foods are a regular part of local diets, they likely support resilience to shocks in the same way that crop and livelihood diversity do. A comparison of different cultures showed that hunter–gatherers have less famine than agricultural communities after controlling for habitat quality [71]. A study from southern Madagascar showed that livelihoods that combined foraging and agriculture carried significantly less risk of food insecurity than farming alone [72].

Climate change adaptation and mitigation interventions that lead to reduced access to forest and natural areas may reduce access to wild foods. For example, communities in Mexico have reported that participation in a payment-for-environmental service scheme to protect local forests has resulted in lower meat consumption because the financial benefits could not replace their lost access to wild meat [73]. Climate change adaptation and mitigation interventions that focus on 'agricultural and land-use intensification' (including 'sustainable intensification') are very likely to lead to land-use change and intensification. As discussed above, land-use change is currently one of the most consistently reported drivers of decreased wild food use and availability. Given that wild foods are consistently reported as obtained across land-use types in mixed landscapes (in most studies, more than half are obtained outside of forests [31]), climate change adaptation strategies that encourage agricultural intensification will likely decrease wild food availability. In rural communities around the world, very few policy measures are in place that attempt to conserve and support the sustainable use of wild foods [66]. Borelli et al. [66] review recent efforts to try to enhance sustainable wild food use.

We suggest the following recommendations for climate change adaptation strategies:

- Restoration of degraded lands through traditional and adapted management practices (including tree planting when needed) with a focus on enhancing and maintaining wild food yields and quality.
- Carbon storage projects need to not only pay attention to biodiversity and ecological integrity but also local use. Carbon storage/biodiversity conservation programs need to include community access to forests for wild food collection.
- Food policies and 'nutrition education' need to highlight the nutritional and cultural importance of wild foods.
- Agricultural policies need to support diet quality and nutrition, as well as sustainability [74,75]. Agricultural policies that intensify land-use and agricultural inputs will likely decrease wild food availability; at the bare minimum, replacements need to be identified as available and affordable.
- Wild foods should be considered as part of agrobiodiverse agricultural systems and valued for their role in resilience [76]. Wild foods are also important genetic resources for future adaptation and breeding [3].
- Efforts to understand the role of wild foods in agroecological frameworks should be promoted and supported [77].
- Climate change adaptation interventions and policies should work closely with local and Indigenous populations and be guided by their unparalleled knowledge of and relationship with wild foods and wild food-producing landscapes.

Conclusion

Wild foods have many values to communities around the world: their importance and the ways they are impacted by climate change vary from region to region. Food, agriculture, conservation, and land-use policies all act to shape the availability and use of and access to wild foods: how they do so shapes the ways climate change shifts and constrains people's ability to continue managing and using wild foods that are central to nutrition and cultural well-being. Climate change adaptation interventions and policies need to be sensitive to the cultural and nutritional importance of wild foods. Adaptation interventions and policies that change the composition and configuration of rural landscapes in ways that reduce the availability of or access to wild foods need to consider the trade-offs that the loss of wild foods has for cultural well-being, nutrition, and health.

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Author contributions

This work was conceptualized during work toward Chapter 5 (Food Fibre and Other Ecosystem Products) of the Working Group II Sixth Assessment Report of the Intergovernmental Panel on Climate Change by BP, IB, and RBK. BP prepared the initial draft. IB, SR, and SR provided the updated keyword search and bibliometric analysis. IB, MM, and RBK contributed significant editing. All authors reviewed and approved the final draft.

Data Availability

No data were used for the research described in the article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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