

2 Current Status and Main Factors Driving the Decline of Wild *Paris* spp. Resources

2.1 Distribution characteristics and population changes of wild resources

Paris spp. are distributed mainly in temperate and subtropical mountain systems of Eurasia, with clear diversity centers in Southwest China and the Himalayan region. The genus has been described as a small but taxonomically complex understory herb group concentrated in East Asia, with the Yunnan-Guizhou Plateau recognized as a major center of diversity, while *P. polyphylla* is reported across Bhutan, China, India, Laos, Myanmar, Nepal, Thailand, and Vietnam (Ding et al., 2021). Within this broad range, wild populations show strong geographic structuring and uneven local occurrence. In Nepal, field surveys recorded the species in 51 districts, while use and trade records were concentrated in fewer districts, indicating spatial heterogeneity in occurrence and exploitation intensity (Kunwar et al., 2020). Genetic and phylogeographic studies further show obvious geographic structure in wild populations of *P. polyphylla* var. *yunnanensis*, with Guizhou and western Yunnan identified as important conservation areas because they retain distinctive wild lineages and higher diversity (Huang et al., 2019; Zhao et al., 2021).

Despite this relatively wide distribution, most studies describe wild resources as sparse, fragmented, and declining. Field surveys in Arunachal Pradesh reported densities ranging from 0.42 to 1.48 individuals/m² in one study and 2.48 to 8.2 individuals/m² in another, showing that local populations can persist but are often thin and highly site-dependent (Kalita et al., 2026). In Sikkim, density ranged from 0.45 to 3.89 plants/m², and in Manipur from 1.3 to 2.4 individuals/m², again indicating low to moderate abundance with substantial variation among habitats (Lepcha et al., 2019; Singh et al., 2026). Nepalese ecological work reported an average density of only 1.78 individuals/m², while recent reviews note that many contemporary wild populations now occur as small isolated groups, with larger populations mostly restricted to remote areas or protected sites (Ye et al., 2025). Across regions, the consensus is that wild *Paris* resources are undergoing continuous decline under combined pressure from overexploitation, illegal collection, and habitat degradation, and several papers explicitly describe the taxa as vulnerable, endangered, or at risk of extinction (Thakur et al., 2023).

2.2 Effects of excessive harvesting on wild population regeneration

Excessive harvesting is the most consistently identified direct driver of wild *Paris* decline because medicinal use depends primarily on rhizomes, the same organs that support perennial survival and vegetative regeneration. Reviews and field studies agree that demand has risen rapidly in recent decades, stimulating both legal and illegal trade and intensifying extraction across China, Nepal, India, and neighboring range states (Cunningham et al., 2018; Kunwar et al., 2020). Price escalation has reinforced this pressure: one review documented a roughly 400-fold rise in rhizome prices in China since the 1980s, while more recent work notes that soaring prices since 2013 have encouraged large-scale farmer collection from wild stands. Because human activity is repeatedly identified as the primary factor affecting population size, commercially valuable populations near settlements or trade routes appear especially vulnerable to depletion (Singh et al., 2026).

The biological consequences of overharvesting are severe because *Paris* regenerates slowly and reproduces inefficiently under disturbance. Several studies state that the rhizome is the principal mode of regeneration in the field, while seed-based recruitment is constrained by low viability, poor germination, and long dormancy. Harvesting before seed maturation is singled out as especially damaging because it reduces seed formation and germination and removes plants before recruitment can occur (Thapa et al., 2022). Competitive and unscientific collection practices often remove the whole underground portion without leaving propagative fragments, directly interrupting vegetative recovery and accelerating population collapse. This harvesting pressure interacts with intrinsic life-history limits, including slow growth, delayed reproductive maturity, many non-flowering individuals, and lengthy breeding cycles, so wild populations recover far more slowly than they are being depleted (Ye et al., 2025).

2.3 Habitat alteration and ecological adaptation stress

Wild *Paris* populations are also highly sensitive to habitat alteration because the plants occupy relatively narrow understory niches. Ecological studies consistently place *P. polyphylla* in shady, moist, relatively undisturbed