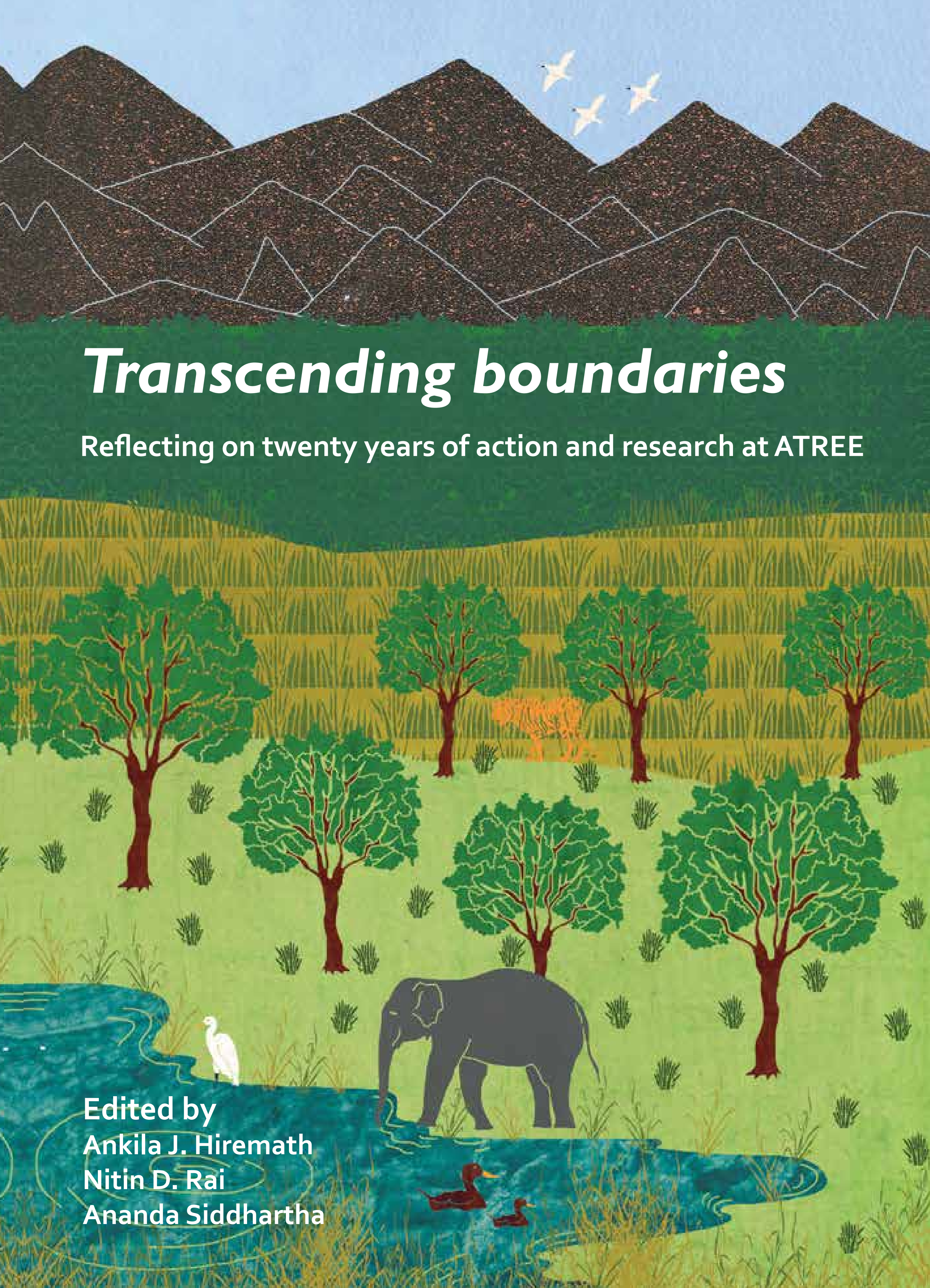

Transcending boundaries

Reflecting on twenty years of action and research at ATREE

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First published in 2017 by
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97 Residency Road,
Bangalore - 560 025.
Phone.: 91-80-2221 1168, 2224 0561

Recommended citation:

Hiremath, AJ., Rai, ND., Siddhartha, A. (Eds.) 2017. Transcending boundaries: Reflecting on twenty years of action and research at ATREE. Bangalore: Ashoka Trust for Research in Ecology and the Environment.

Design and Layout: Suneha Mohanty

ATREE Ashoka Trust for Research in Ecology and the Environment

Norwegian Embassy

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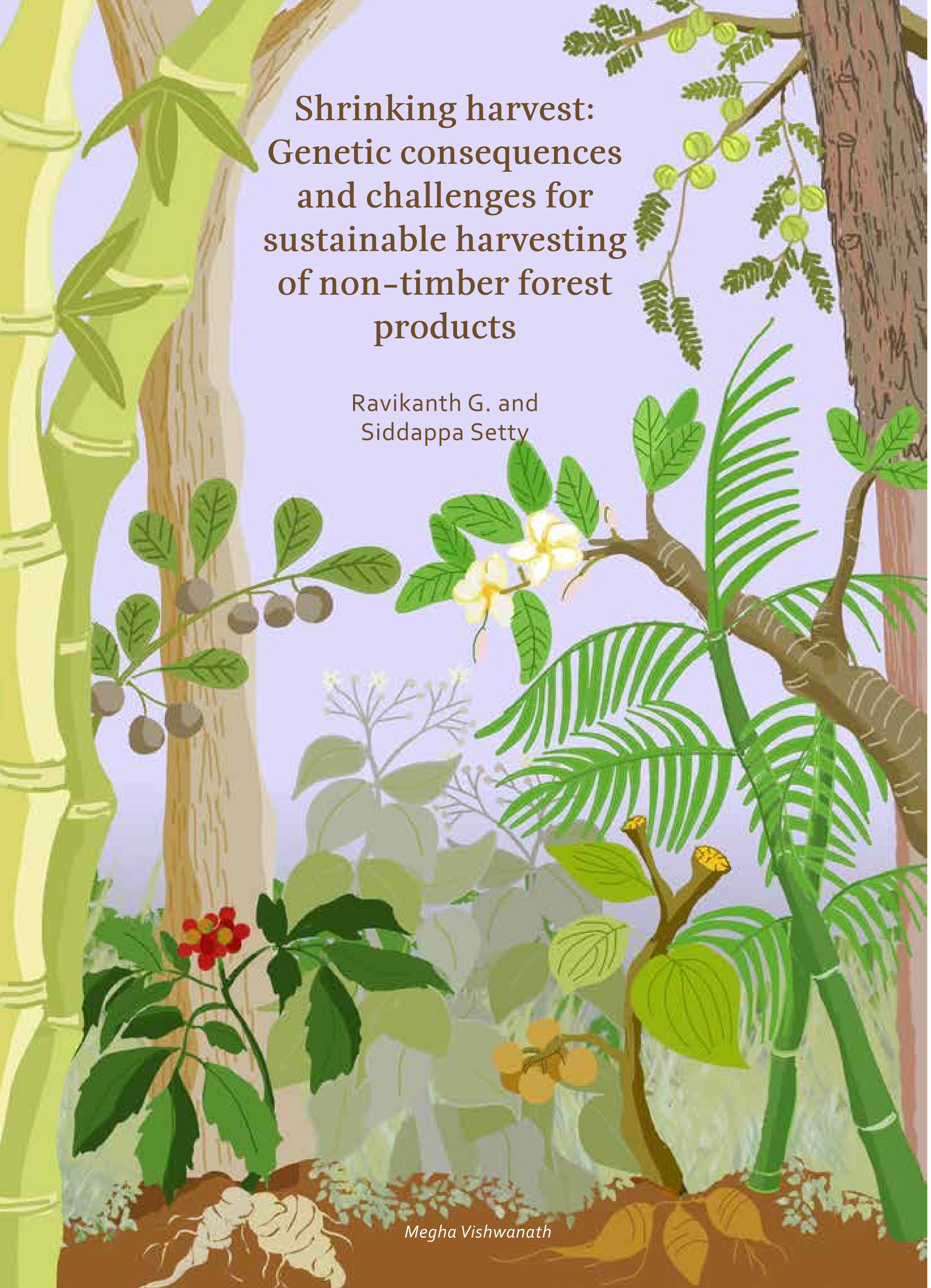
Shrinking harvest: Genetic consequences and challenges for sustainable harvesting of non-timber forest products

Ravikanth G. and
Siddappa Setty



Non-timber forest products (NTFP) have been an important source of subsistence as well as livelihoods for many forest-dwelling and forest-fringe communities across the developing world. NTFP collection has been promoted as a win-win strategy to not only conserve biodiversity but also provide livelihood options to scores of forest-dwelling communities. There has been evidence both for, and against, the impacts of harvesting and the ecological sustainability of harvested species. Harvesting can act as a selective force and reduce the population genetic diversity, especially for species in which the reproductive parts are harvested. A debate has been raging among scientists, resource managers, as well as policy makers for decades, over which methods, and what levels of harvest, can be considered ecologically sustainable.

In recent years, a resurgence of interest in herbal products, and liberalised markets, has led to over-exploitation of available NTFP resources, especially of some medicinal plant species. In the past, harvesting of plant-based NTFPs to meet subsistence demand rarely resulted in species-specific over-exploitation. Now, forest dwelling and rural communities in many parts of the world are increasingly transporting harvested products to distant markets. The shift from subsistence use to commercial-scale harvest has significant implications for resource management. It results in larger volumes being harvested, at a higher frequency and intensity, which affects resource status[1]. In recent years, scores of species have been over-exploited rendering many of them at the risk of becoming extinct. For example, *maramanjali* or tree turmeric (*Coscinum fenestratum*), an economically important medicinal plant, has been over-exploited to such an extent that the species is now red-listed[2]. Similarly, evidence of over-exploitation is reflected in the dwindling resource status of several economically important plants such as sandal, bamboo, and rattans.

Indiscriminate extraction could lead to reduction in population size, fragmentation, and alteration in the population structure. Reduced population size and fragmentation could lead to mating between closely related individuals, leading to inbreeding and other genetic consequences. An understanding of how NTFP harvesting modifies the genetic diversity and genetic composition can be used in conjunction with population structure to determine sustainable harvesting limits of these forest resources. Sustainable harvesting implies that the rate at which the harvesting takes place does not exceed the natural rate of regeneration in a given time period, or does not jeopardise the ability of the populations to maintain themselves. This definition does not take into account the fact that harvesting by humans deprives other fauna, which are dependent on these resources. Reduction in population size (as mentioned above) could reduce the number of pollinators and dispersal agents (higher densities attract more visitors), thereby reducing the gene flow, and thereby reducing the overall genetic diversity. Thus, harvesting of NTFP species does have subtle impacts, not only at the individual level but also at the community level, which can detract from long-term ecological sustainability. Although significant advances in assessing the ecological implications of harvest have been made, there is clearly a dearth of information available on the impacts of harvest of certain plant parts that hold great economic value, and on addressing the genetic consequences of harvesting. A decline in genetic diversity can have an adverse effect on the

[1] Shaanker, RU., KN. Ganeshaiah, MN. Rao, and NA. Aravind. 2004. Ecological consequences of forest use: from genes to ecosystem—a case study in the Biligiri Rangaswamy Temple Wildlife Sanctuary, South India. *Conservation & Society* 2(2): 347–363.

[2] Thriveni, HN., RC. Sumangala, SK. Nagaraju, G. Ravikanth, R. Vasudeva, and HNR. Babu. 2014. Genetic structure and diversity of Coscinium fenestratum: a critically endangered liana of Western Ghats, India. *Plant Systematics and Evolution* 300(3): 403–413.

ability of a species to survive, and this could have ramifications for other species that are components of the ecosystem.

In the last 2 decades, ATREE, along with researchers from University of Agricultural Sciences, Bengaluru, have been involved in understanding the impact of harvest on the genetic structure of NTFP species. We have been working with communities in developing sustainable methods of harvest, and examining the impacts of NTFP harvest on population structure, regeneration, genetic diversity, and evolutionary processes. This chapter highlights issues related to the potential genetic and evolutionary impacts of NTFP harvest. We discuss approaches for conservation of genetic resources of NTFP species that would not only ensure the survival of the focal species and maintain ecosystem integrity and stability, but also provide livelihoods to the dependent forest-dwelling and rural communities.

POTENTIAL GENETIC AND EVOLUTIONARY IMPACTS OF NTFP HARVEST

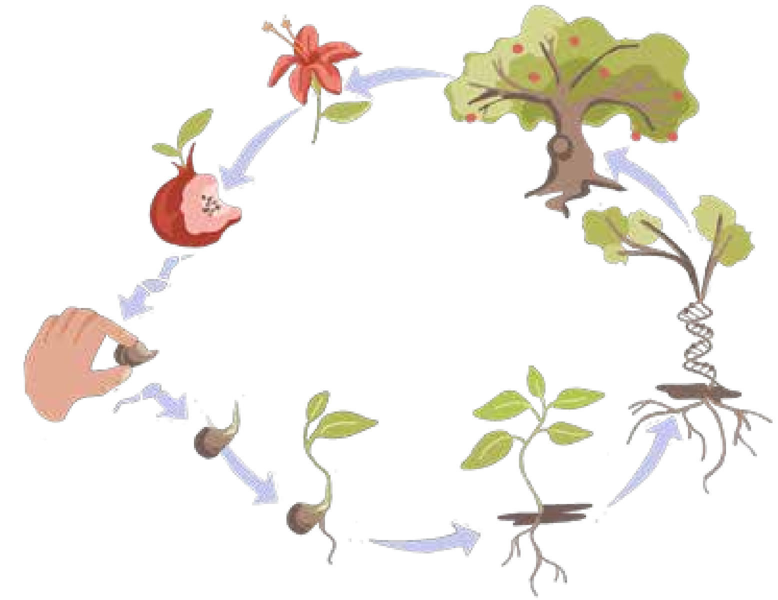
Indiscriminate harvest has been widely reported to reduce the effective population size (i.e., the number of reproductive individuals that contribute to the next generation), as well as genetic variability, in a number of NTFP species[3]. Genetic diversity is generally assumed to be the basis for adaptation of a species, and for providing the population the ability to respond to environmental stresses. Most often, NTFP harvesting involves removal of reproductive structures such as fruits or seeds, which can have a direct impact on the regeneration of the species. Even harvesting of non-reproductive parts such as leaves, resins, or stems, does affect the physiology, growth, reproduction, and survival of the individual, besides exposing the individual to pests and diseases. The impacts are severe if the entire plant, roots, bulbs, or the reproductive parts such as the immature fruits, seeds, or the flowers, are harvested. Threats to the NTFP species would increase further in the near future due to increased demand for these products, change in land-use patterns, and other factors such as the spread of invasive species. Thus, harvesting of NTFPs and the accompanying practices can affect genetic diversity, recruitment, and overall population structure of these species.

Tolerance to harvest varies according to life history (of the species) and the part of the plant that is harvested. The most direct ecological consequence of harvesting is alteration in the rates of survival, growth, and regeneration of harvested individuals. Changes in these vital rates can, in turn, affect the structure and dynamics of populations. For example, harvesting *amla* or Indian gooseberry (*Phyllanthus emblica*) fruits, may have a long-term effect on populations,

Fruits of Phyllanthus emblica, *also known as nelli (Kannada) or amla (Hindi), are extensively harvested from Southern India. (Photo: G. Ravikanth)*

[3] Ravikanth, G., MN. Rao, KN. Ganeshaiah, and RU. Shaanker. 2009. Genetic diversity of NTFP species: issues and implications. In: *Non-timber forest products conservation, management and policies* (eds. Shaanker, RU., AJ. Hiremath, GC. Joseph, and ND. Rai) Pp. 53-64. Bengaluru: Ashoka Trust for Research in Ecology and Environment, and Forestry Research Support Program for Asia and the Pacific, Food and Agriculture Organization, Bangkok.

either because of the effect on seedling recruitment, or because fruit collection involves branch pruning or sometimes tree felling. Heavy collection of fruits of this species, and that of *tare* or *bahera* (*Terminalia bellerica*), has resulted in lower recruitment and genetic differentiation (change in the genetic composition of individuals) of the populations, possibly due to selective harvesting of large-sized fruits. Selective harvesting from individuals bearing large-sized fruits over time has led to regeneration of the species largely from trees that were less harvested, and those that bore either small or irregular-shaped fruits.



The genetic impacts of NTFP harvesting were considered quite low and thus were not seriously considered in the management of NTFP species. However, in recent years there are numerous studies that have recognised that harvesting can have effects at several levels, including the genetic variability and genetic structure of the species. Genetic diversity could be lost through a host of processes consequent to harvesting the populations. Over time, the small incremental changes could have a cascading effect and might result in changing the original genetic configuration of populations. The genetic differentiation of the populations of species subjected to harvesting could be either due to 1) directional selection of populations due to harvesting pressures (selective harvesting or non-random harvesting, e.g., only large sized fruits as in case of *amla*); and/or 2) a reduced population size (due to harvesting) leading to less number of individuals available for mating leading to inbreeding (as mentioned above).

Harvesting whole individuals can lead to the loss of genetic diversity through genetic drift (due to chance disappearance of a particular gene or genes, resulting in changing the frequency of alleles in the population, usually due to a reduction in population size), while harvesting the reproductive parts, such as fruits or seeds, could do so by interrupting gene flow by disrupting pollination and dispersal. For example, harvesting whole trees, as in the case of a medicinally important tree *durvasane mara* or 'stinking plant' (*Nothapodytes nimmoniana*), has not only led to loss of private alleles, but has also reduced the overall genetic variability of the populations[4]. In the case of *Himatanthus drasticus*, a tree of the Brazilian savanna, which is highly exploited for its medicinal latex, the seedling allelic richness (a measure of genetic variability) was significantly lower in the high-harvested populations, indicating that allelic losses that may be associated with the exploitation of bark and latex. In case of American ginseng (*Panax quinquefolius*), where the roots have been harvested for more than 250

[4] Shivaprakash, KN, BT. Ramesha, RU Shaanker, S. Dayanandan, and G. Ravikanth. 2014. Genetic structure, diversity and long-term viability of a medicinal plant, *Nothapodytes nimmoniana* Graham. (Icacinaceae), in protected and non-protected areas in the Western Ghats biodiversity hotspot. *PLoS ONE* 9(12): e112769.

years, there was a significant reduction in the average expected heterozygosity (measure of genetic diversity of a population) in the harvested populations compared to the non-harvested populations. Further, the levels of genetic diversity in the juveniles were less compared to the adults, and the age-class structure also shifted towards smaller, non-reproductive plants.

These studies point to the necessity of maintaining harvesting intensities that least distort the original genetic variability and structure. While studies have documented that demography, genetic diversity, and several others parameters are affected by various NTFP harvesting practices, there has been a lack of clear signals on the extent of harvesting that can be considered as sustainable. Vital rate of growth and regeneration of NTFP may be significantly affected by differences in harvest techniques. These include timing of harvest, the part of the plant that is harvested, frequency of harvest, size of individuals harvested, and intensity of harvest.

APPROACHES FOR CONSERVATION OF NTFP TREE SPECIES

Clearly, while studies have shown a strong relationship between the extent of harvesting on the genetic structure of harvested populations, there have been no studies that have suggested genetically friendly harvesting methods. However, given the sheer number of NTFP species harvested, the plant parts harvested, and the variation in resource production levels, it is difficult to suggest one uniform method to sustainably harvest NTFP resources. Further, each species can have varying response to harvesting, and the recovery period is dependent on varying environmental factors. Thus, approaches to conserve NTFP species should take into account 1) the needs of the forest-dependent communities; 2) the NTFP species survival and ecosystem integrity; and finally 3) the need and ease of monitoring the populations (both demographic as well as genetic monitoring). Below we discuss genetically friendly management options that could be implemented for sustainable harvest of NTFP species: identification of genetic hotspots, gene banks, and NTFP harvesting plans.

Conservation and utilisation of NTFP species on a long-term basis requires understanding of the existing distribution of genetic diversity of the species, and then, assessment of threats to the genetic variability either due to harvesting, or due to other anthropogenic factors. For a number of NTFP species as well as medicinal plants, such as bamboos, rattans, wild nutmeg, *amla*, etc., the distributions of genetic diversity have been mapped using biochemical and molecular tools, and hotspots of genetic diversity have been identified for the first time. In fact, for many species, genetic diversity maps have been developed that provide spatial distributions of genetic diversity of the species. This provides a geographical perspective on the genetic resources of the species in question and is crucial for making informed decisions for the conservation and management of the genetic resources of these NTFP species. Similarly, the impacts of disturbance to the genetic resources of the NTFP species have also been assessed. For a number of species, we have addressed the loss of genetic variability and attempts have been made to genetically improve such populations. Efforts such as these will serve to identify the valuable genetic resources of these NTFP species and also pave the way for utilisation.

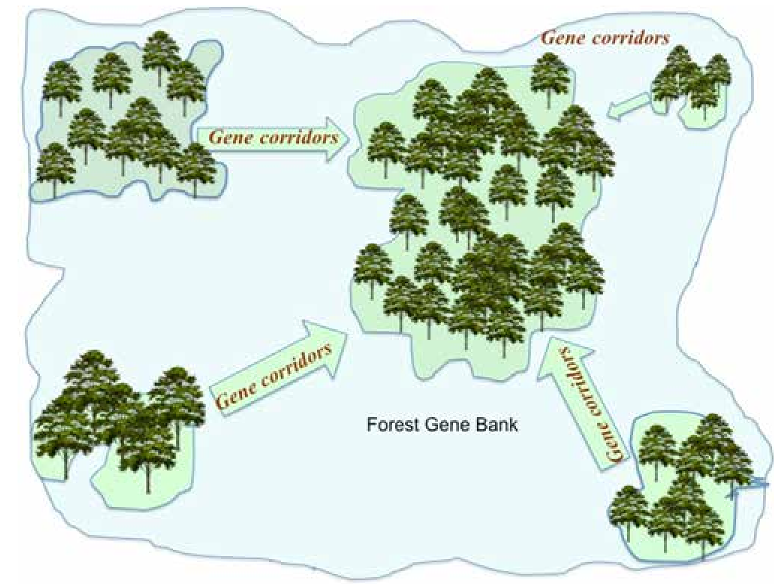


Figure 1. A schematic depicting the Forest Gene Bank Model. (Adapted from Uma Shaanker et al 2002) [5]

To ensure that NTFP species are not deprived of their genetic arsenal, one could adopt a 'genetically friendly' method by maintaining NTFP gene bank reserves. This approach is like the Forest Gene Bank[5] and serves as a repository of genes to ensure that adequate genetic variability is conserved (Figure 1). The forest gene bank approach would involve designating some areas with adequate populations as no-go areas. Ideally, over time these areas could be enriched with genetically unique individuals so as to maintain a repository of genes. By virtue of such enrichment, these forest gene banks could facilitate the maintenance of the full allelic set of the species. Besides that, the gene bank also facilitates continuous interaction between and among the different alleles maintained at these banks, enabling genetic diversity to evolve in response to local selection pressures.

Sustainable NTFP harvesting requires keeping track of the ecological health of the harvest-

[5] Shaanker, RU., KN. Ganeshaiah, MN Rao, and G. Ravikanth. 2002. Forest gene banks – a new integrated approach for the conservation of forest tree genetic resources. In: *Managing plant genetic resources* (eds. Engels, JMM., AHD. Brown, and MT. Jackson) Pp. 229–235. Oxon, UK: CABI Publishing.

ed populations at both the individual, as well as the population, level. A key challenge in maintaining the health of the populations is to ensure their adequate regeneration. One of the strategies of ensuring adequate regeneration (especially when reproductive parts are harvested) is to include systematic rotations, or ensuring that some percent of the harvest is reduced. This could be accomplished by a number of ways. One is by harvesting only low hanging fruits, and another is harvesting on a systematic rotation period or in alternate years. However, this is difficult to implement unless communities are provided information and the necessary knowledge about the usefulness of such rotations.

In the case of harvest of non-reproductive parts, collections should be restricted to only mature individuals, and individuals should be harvested once every few years. For example, in the case where bark is harvested, such as cinnamon or *asoka* (*Saraca asoca*), studies have shown that at least 3–4 years is required for the bark to heal, and repeated harvesting could endanger the survival of individuals.

GOING FORWARD

Genetic studies have clearly shown that harvesting of NTFP species (especially the reproductive parts of plants) has impacts on the genetic structure in the long run. Some of these impacts could be ameliorated through harvest rotations and by employing harvest friendly methods. Establishing gene banks could be another option to conserve the genetic resources of these NTFP species. These options should be incorporated into NTFP harvest plans even when studies to demonstrate genetic effects cannot be carried out. Simultaneously, efforts such as large-scale cultivation and domestication of over-exploited species should be encouraged to meet the demand for NTFPs.

Excessive harvesting of resin by damaging the bark can adversely affect the reproductive output of Boswellia serrata*, also known as dupada mara (Kannada) or salai (Hindi). (Photo: G. Ravikanth)*

Sustainable management of NTFP resources requires firm, mutually agreed upon, and enforceable regulations among indigenous communities, civil society institutions, and the Forest Department. The approaches suggested here for the conservation of genetic resources of NTFP species re-emphasises the need to re-evaluate existing management approaches. What may be most warranted in the present scenario is regulation of NTFP harvest, backed with appropriate policies for monitoring and management. These approaches would not only help in conserving the genetic diversity of the NTFP species but would also ensure a balance between local livelihoods and ecological sustainability.

Terminalia bellarica*, or tare (Kannada) or bahera (Hindi) is an important NTFP species whose fruits are used for various Ayurvedic preparations, including Triphala. (Photo: G. Ravikanth)*

Acknowledgements

The part of the work reported here has been carried out by the authors with a number of collaborators, especially with R. Uma Shaanker and K.N. Ganeshaiah from UAS, Bengaluru, and the Soliga communities in BRT and the Male Mahadeshwara hills (MM Hills). The work was supported by grants from USAID (No. AID-386 A- 14-00011) and from the Department of Biotechnology, New Delhi. The authors also acknowledge the support received from various agencies, including the Soliga Abhivrudhi Sanga, Karnataka Forest Department, VGKK and LAMPS society.

Further reading

Baldauf, C., M. Ciampi-Guillardi, FAM. Santos, AP. Souza, and AM. Sebbenn. 2013. Tapping latex and alleles? the impacts of latex and bark harvesting on the genetic diversity of *Himatanthus drasticus* (Apocynaceae). *Forest Ecology and Management* 310: 434–441.

Cruse-Sanders, JM., and JL. Hamrick. 2004. Genetic diversity in harvested and protected populations of wild American ginseng, *Panax quinquefolius* L. (Araliaceae). *American Journal of Botany* 91(4) 540–548.

Shahabuddin, G. and S. Prasad. 2004. Assessing ecological sustainability of non-timber forest produce extraction: the Indian scenario. *Conservation and Society* 2(2): 235–250.

Stanley, D., R. Voeks, and L. Short. 2012. Is non-timber forest product harvest sustainable in the less developed world? A systematic review of the recent economic and ecological literature. *Ethnobiology and Conservation* 1(9): 1–39.

Ticktin, T. 2004. The ecological implications of harvesting non-timber forest products. *Journal of Applied Ecology* 41(1): 11–21.