



Non-timber forest genetic resources of arid and semi-arid regions of India

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Summary

Forests have evolved in their natural ecosystems over millennia to become the world's most important and valuable renewable natural resources. Genetic variety in perspective trees has been defined as Forest Genetic Resources (FGRs). Forest genetic resources directly or indirectly sustain human livelihoods and provide raw materials for various forest-based enterprises. This chapter focuses on the FGRs of the arid and semiarid regions, which have a wide range of land formations, soils, fauna, plants, water balances, and human activities. Cultivating trees that have the potential to generate lucrative non-timber goods is the primary source of revenue in this problematic climatic situation. Arid and semi-arid regions have a diverse gene pool of tree species. The increased pressure and ongoing desertification threaten the gene pool of tree species in arid and semi-arid environments. These regions' FGRs are not sufficiently documented, and there is no way to access and use them effectively. This paper intends to establish a framework for writing, better understanding, protecting, and understanding the utility of non-timber forest genetic resources (NTFGR) in dry and semi-arid regions. It focuses on arid and semi-arid tree species that have the potential to yield non-timber value, to increase awareness and understanding of Forest Genetic Resources.

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Introduction

Forest genetic resources have the potential, enabling trees to be the most successful organism on the earth. A forest genetics resource includes the species gene pool from its development to evolution, the breeding unit, whether it is natural or artificial and the breeding system, *i.e.* reproductive behaviour or propagation. It may include woodlands and trees mainly to meet present and future societal and environmental challenges; its ability to meet this challenge depends on the availability of genetic diversity between and within tree species. Variation within species, genetic diversity is the variation among individuals and populations, and this is needed because it supports individual tree species to survive, adapt and evolve under changing environmental conditions and are resilient to biological and physical stresses. Due to deficient rainfall and increased resource overexploitation, arid and semi-arid regions are among the world's most vulnerable ecosystems. Arid and semi-arid terrain cover roughly one-third of the world's surface area and are home to approximately one billion people, most of whom are among the poorest (Malagnoux et al. 2007; Bana et al. 2022). The ecosystems of arid zone constituents, Forests, trees and grasses play an essential role in developing and maintaining suitable conditions for

farming and livelihood. Providing wood and non-wood products and environmental services to the dwellers and contributing to their household sources of income, forests and trees in arid zones reduce poverty and food insecurity.

The practice of genetic conservation is a long-term process; it is intended to conserve trees and wild animals. Priority is given to the dynamic conservation of forest genetic resources in situ and ex-situ. Many Western countries are adopting forest genetic resource conservation programmes, and efforts are underway to expand and strengthen these policies. Conservation aims to save species' evolutionary potential, maintaining genetic diversity. It also focuses on the qualitative traits (characteristics) for resistance to biotic and abiotic stresses. While planning and implementing policies and programmes dedicated to the environment, biodiversity and genetic resources, FGR's special emphasis on arid and semi-arid FGRs is often neglected. Thus, the under-evaluation of FGR resulted in its deterioration. Continuous monitoring is an essential element in a strategy to conserve. "National and international forestry programmes are necessary policy tools for integrating FGR conservation into actions at the practical forest management level. At the national level, The Indian Council of Forestry Research and Education (ICFRE) is an autonomous body under the Ministry of Environment and Forests, Government of India, with eight research institutes and three advanced centres in various parts of the country making efforts for the FGR, has been working to introduce, collect and conserve genetic resources of

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mainly forest tree species in India. "The statistics suggest that populations surrounding FGR rely on the reserve for domestic and commercial fuel use, medicinal herbs, fodder, and fruit nuts. According to a report released by ITTO (International tropical timber organization) and the Precious Forests Foundation, incorporating non-timber forest products such as nuts, fruits, latex, and rattan into the management of natural tropical timber production forests could be an essential step toward economic viable, sustainable forest management (2021). This study reviews non-timber FGR status in arid and semi-arid regions and knows the value of trees for the region's rural communities. It is based on non-timber products harvested from trees in natural forests and plantations.

Global reach of arid and semiarid regions

Drylands cover 41.3 per cent of the earth's land surface, including 15% of Latin America, 66% of Africa, 40% of Asia, and 24% of Europe. Regarding sustainable development, dry lands refer to arid, semi-arid, and dry sub-humid environments, excluding deserts in general. Arid and semiarid regions are water-scarce areas with low groundwater levels, limited rainfall, and considerable run-off. The annual precipitation ranges from 100 to 400 mm or 400 to 800 mm. These are the world's toughest ecoregions but may be the most important. In the year 2000, semi-arid regions covered 15% of the Earth's geographical surface and supported 14.4% of the world population (Safriel & Adeel 2005). Over semi-arid regions, the long-term global warming trend is particularly pronounced (Huang et al. 2012).

Arid regions of the world (Cresswell & Martin 1993)

North America	Western USA, Sonora deserts
Central America	The pacific coast
South America	The Atacama Desert, The Serrano of Brazil
Australia	The Central Desert
Africa	The Sahara Desert, The Sahel, The Kalahari Desert, East Africa
Asia	The Middle East, The Indian or Thar Desert, The Namub Desert, The Karakam Desert, The Gobi Desert

In India, northern arid regions in India comprise mainly the desert of Rajasthan, the Rann of Kutch and the semi-arid areas of Punjab and Gujarat. The arid southern regions are in the rain shadow of the Western Ghats covering the states of Maharashtra, Karnataka and Tamil Nadu. There is no systematic classification of arid and semi-arid regions. But According to the values of aridity based on precipitation and temperature (Koppen 1918), primary thorn forest is the expression of the arid environment's semi-arid climate, desert vegetation. Two zones of semi-arid climate are recognized in India. In the north, one is contiguous with the desert of Thar, extending into Rajasthan, Punjab, parts of Uttar Pradesh, Kutch, Saurashtra (the Mountainous region of Gir excluded) and North Gujarat. The other semi-arid zone is situated in the south. It includes the Deccan plateau, the Coimbatore plateau located in the shadow of the Nilgiri

and Palni hills and the extreme south-east corner of Madras State comprising Ramanatha-puram and Tirunelveli districts (Bharucha & MeherHomaji 1964).

Status of forest genetic resources in Indian arid and semi-arid regions

Arid and semi-arid imply prolonged dryness and are used concerning the climate and the land below it. In such regions, the ability to produce vegetation is restricted. The vegetation may be characterized according to the degree of aridity as dry forest, chaparral or brushland, grassland or savannah etc. Plants for arid regions are those that survive and produce despite aridity. Therefore, when speaking of tolerance of dry conditions, one mainly talks about the drought tolerance of the growing or mature plant. Stunted thorny or prickly trees, shrubs and perennial herbs inhabit the Indian Arid region. The vegetation in this land completes its life ring during the monsoon. In the Rajasthan state, which is land of both arid and semiarid tracks separated by Aravalli hills Some of the predominant species of arid are *Acacia nilotica*, *Prosopis cineraria*, *Salvadora indica*, *S. persica*, *Tecomella undulata* and *Ziziphus nummularia* in trees; *Capparis decidua*, *Calotropis procera*, *Grewia tuna* and *Lycium barbarum* in shrubs and *Crotolaria burhia*, *Leptadenia pyrotechnica* in perennial woody herb or under-shrubs, whereas, the common grasses of the desert are *Cenchrus prieurii* and *Cymbopogon* (Singh 2004). The semiarid track consists of tropical dry deciduous forest, and tropical thorn forest comprises several economically important tree species like *Annogeissus pendula*, *Buchnanania lanzan*, *Diospyros melanoxylon*, *Mitragyna parviflora*, *Cassia fistula*, *Schrebera swietenoides*, *Pterocarpus marsupium*, *Holoptelia integrifolia*, *Butea monosperma*, *Mallotus philipensis*, *Boswellia serrata*, *Terminalia arjuna*, *Sterculia urens*, *Annogeissus latifolia*, *Kydia calycina*, *Woodfordia fruticosa*, *Lannea coromandelica*, *Cochlospermum religiosum*, *Flacourtia indica*, *Tectona grandis*, *Bahunia spp.*, *Albizia spp.*, *Ziziphus spp.*, *Capparis spp.*, *Ficus spp.* (Kotia et al. 2008; Haldhar et al. 2016). Shah 1978 and Patel in 1971 enlisted the species in the semiarid region of Gujarat *Tectona grandis*, *Annogeissus pendula*, *Boswellia serrata*, *Acacia nilotica*, *Euphorbia caducifolia*, *Flacourtia indica*, *Helicteres isora*, *Holarrhena antidysentrica*, *Bridelia squamosa*, *Embllica officinallis*, *Butea monosperma*, *Diospyros melanoxylon*, *Anogeissus latifolia*, *Lannea coromandelica*, *Sterculia urens*, *Mitragyna parviflora*, *Wrightia*, *Carissa*, *Zizyphus* and *Capparis*, common grasses *Heteropogon contortus*, *Aristida spp.*, *Eragrostis spp.*, *Chloris spp.* and *Aeluropus spp.*

Non-timber FGRs

1 Fodder valuable species

Leaf fodder is one of the essential non-timber forest products, which is the essential life support of livestock in arid regions. In semi-arid climates, trees play a dominant role in livestock feeding and in providing fuel. The traditional Agroforestry system in arid and semi-arid regions that supplies leaf fodder to the tune of 33% of total livestock demand in a given area is sustainable in terms of fodder yield. A system of alternate husbandry has become established in some areas of Sind in

Pakistan. *Acacia* is mainly used for fuel, but its leaves and pods are used for fodder when other types of grass are in short supply. *Acacia* is cultivated in rows 10–12m apart, and the land in between is used for cropping until the trees mature (Akram et al. 1990). The top 5 tree leaves of the Mimosaceae family, i.e. *Acacia nilotica*, *Acacia tortilis*, *Prosopis cineraria*, *Prosopis chilensis* and *Albizia lebbeck* were identified and analyzed for proximate analysis, i.e., CP (Crude Protein), CF (Crude Fiber), Ash, EE (Ether Extract), NFE (Nitrogen Free Extract), OM (Organic Matter), TC (Total Carbohydrates). The foliages' CP, CF, ash, and EE contents varied from 12.5-19.2, 11.6-24.2, 6.4-9.5 and 3.4-6.9% per cent of DM, respectively (Chandra & Mali 2014). *Hardwickia binata* Roxb is a medium to large-sized deciduous tree of Indian origin, and it belongs to the family Leguminosae, subfamily Caesalpinioideae (Luna 2005). Anjan tree (*Hardwickia binata*) leaves were given as a sole feed to 4 adult Barbari goats, 10-14 months old and weighing 19.65 kg. The leaves could meet the maintenance requirements of the goats. Voluntary DM intake was 3.02±0.12 kg/100 kg body weight, and digestibility coefficients for DM, organic matter, CP, ether extract, crude fibre and nitrogen-free extract were 52.41, 56.46, 44.53, 48.96, 50.21 and 62.66%, respectively Singh et al. 1994. Chitra, in 2018 evaluated the nutritional value of indigenous leguminous tree leaves at Forest College and Research Institute Campus, Mettupalayam. The leaves of Indigenous leguminous fodder tree species, i.e. *Acacia nilotica*, *Albizia lebbeck*, *Dalbergia sissoo*, *Erythrina indica* and *Hardwickia binata* were selected and identified for analysing the proximate composition and structural constituents. The mean values for proximate composition, i.e. dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE) and total ash (TA) in leguminous tree leaves ranged were 27.94 - 42.21%, 9.86 - 23.46%, 17.81 - 28.16%, 3.34 - 6.17%, 6.86 - 9.92% of DM respectively. The mean values from the crude fibre fractions i.e. Neutral detergent fibre (NDF), Acid detergent fibre (ADF), Acid detergent lignin (ADL) and Hemicellulose and Cellulose content of the foliage varied from 36.30-56.13%, 25.97-38.86%, 10.05-13.20%, 10.32-17.94%, 15.92-28.78% of DM respectively. The ranking order of these tree species based on CP content was *Erythrina indica* > *Albizia lebbeck* > *Acacia nilotica* > *Dalbergia sissoo* > *Hardwickia binata*. It was concluded that moderate to high CP values of *Dalbergia sissoo*, *Acacia nilotica*, *Albizia lebbeck*, and *Erythrina indica* foliage are potential sources of protein for ruminant feed and *Hardwickia binata* tree leaves mainly used for supplement fodder for ruminants.

2 Fuel value species

Fuel wood is natural wood derived from the trunks, branches, and other sections of trees and plants and used for cooking, heating, power production, and other industrial applications through direct burning (FAO 1981). Plants now account for about 90% of the global use of fuel used for cooking and heating in poorer countries (FAO 2008). Biomass is one of the world's oldest sources of energy and the most widely utilised service material, having been used for over 5 lakh years

(Sharpe 1976). A case study in the semi-arid regions of Brazil. Residents in the area cited a total of 38 species for use as fuel. Both biological and ecological aspects influence the selection of fuelwood in the evaluated environment (Juliane et al. 2021). Cardoso studied traditional knowledge of fuel species in 2015, linking species preferences to the physical qualities of wood and its combustibility. In three rural settlements in Argentina's northwest, the physical features of 21 popular firewood species were studied. *Berberis microphylla*, *Prosopis denudans*, *Schinus johnstonii*, *Lycium spp.*, *Senecio subulatus*, and *Schinus marchandii* are some of the plants with the highest FVI values, according to the findings. The production of energy crops of favoured native species with high combustibility, to be used as bioenergy and multipurpose species is recommended in this study. A study conducted by Chavan et al. at CAFRI, India, revealed that *Acacia catechu*, *Acacia senegal*, *Anogeissus pendula* and *Prosopis juliflora* are listed as the best fuel wood tree species in the Bundelkhand region. They all have good physical properties like essential density, moisture content, and chemical properties including Ash content, fixed carbon, volatile matter, lignin content, calorific value, heating value, and fuel wood value index. Puri et al. (1994) compared the calorific value of indigenous and exotic species. Indigenous species, e.g. *Acacia nilotica*, *Casuarina equisetifolia*, and *Zizyphus mauritiana* are the most promising species, which contain high wood density, low ash content and low nitrogen percentage. The fuel wood value index was also increased in indigenous tree species. The highest standing biomass, 112 t/ha, was observed in *Leucaena leucocephala*, 96 t/ha in *Eucalyptus tereticornis* and 52 t/ha in *Acacia nilotica* at the four years age which was increased by 12 %, 6 % and 48 % in respectively in three species after eight years age (Singh & Toky 1995)

3. Natural resins and gums

The most important non-timber forest products are natural resins and gums (NGRs), which are widely sold on national and international markets. NTFP collection and processing employ around 400 million people living in and around India's forest (Prasad et al. 2019). Natural gums (plant gums) are hydrophilic carbohydrate polymers with high molecular weights and monosaccharide units linked by glucosidic linkages (Davison 1980).

Arid region's vegetation is the repository of natural resins and gums that are exudates from the bark of trees. Different species of *Acacia* has an abundance of source of gum, e.g. gum arabica is oozed out from the trunk of *Acacia Senegal*. Scientists in CAZRI are developing gum arabica production technology from different landforms of Rajasthan; they reported that if the *Acacia Senegal* growing on the sand dunes, it can yield higher gum as compared to the *Acacias* growing on iter dunes region and rocky and gravelly landforms (Pareek et al. 2017). *Acacia tortilis* and *Acacia nilotica* are also important arid species that yield gums. The gum delivered from these two species is also similar to gum arabica. *Acacia tortilis* can yield about 100 to 900 g gum

per tree. *Acacia nilotica* yields less (100 to 400 g gum per tree) than the *A. tortilis* but always comes under the significant gum-yielding species of Acacias. *Prosopis cineraria* and *Anogeissus spp.* are also gum-yielding species (Shiren et al. 2018). Some studies have been conducted to enhance gum production from *Acacia* species. Bhatt and Ram used 4 ml of ethephon solution containing 960 mg active substance through a hole in the sapwood of *Acacia senegal* to yield high-quality gum Arabica. According to Prasad et al. in 2015, if a farmer plant 100 trees of *Acacia senegal* on a hector land at a spacing of 10 x 10 meters, he can harvest 25 kg gum Arabica, 250 g/tree. If it would be sold in 400 /kg, then a farmer can earn 1000/ha/year. In India, mainly karaya gum (*Sterculia urens*), dhawara gum (*Anogeissus latifolia*), Prosopis gum (*Prosopis juliflora* (Sw.) DC.), khair gum (*Acacia catechu* (L.f.) Brandis), babool gum or gum Arabica (*Acacia nilotica*), jhingan gum (*Lannea coromandelica* (Houtt.) Merr.), Salai gum (*Boswellia serrata*) kamarkas, piyar gum and guggul gum (*Commiphora wightii*) are produced. In arid and semi-arid regions, species yielding minor amounts of gum are *A. catechu*, and *A. Senegal*. *Bauhinia retusa*, *Bombax ceiba*, *Butea monosperma* etc. The Central Arid Zone Research Institute (CAZRI) in Jodhpur, India, devised a viable technique for tree exudates gum tapping that has proven to be very effective for producing gum Arabic from *Acacia senegal*, which is widely distributed throughout western India, especially in Rajasthan. The approach proved quite profitable and gained widespread appeal in west Rajasthan, where gum tappers generated approximately 23.59 t gum Arabic and made about 235.9 thousand US\$ gross income from the sale of gum Arabic in local marketplaces over three years (2009-2011). Adopting this approach by all gum tappers in the world's gum-producing belts will increase global gum Arabic production and provide a better livelihood alternative for the community (Ram et al. 2013).

4. Tree-born oil seeds

TBOs (tree-borne oilseeds) are becoming more popular as a source of oil for food, fodder, fuel, and industrial purposes. *Jatropha* (*Jatropha curcas*), Karanja (*Pongamia pinnata*), Jojoba (*Simmondsia chinensis*), Neem (*Azadirachta indica*), Mahua (*Madhuca indica*), and other tree-borne oilseeds can grow and establish in a variety of agroclimatic conditions as well as in the country's wasteland. India is a major crude oil importer, spending over Rs. 1,200 billion in foreign exchange yearly to meet 75 per cent of its oil requirements. India holds significant promise as a producer of surplus raw material for biodiesel and bio-ethanol production due to its diverse climates, nutrient-rich soil, and capacity to cultivate various crops. Although all oils can be used to make biodiesel, edible oils must be avoided because they are utilised for cooking and food. The effort aimed to make biodiesel from *Jatropha curcas*, a tiny shrub that grows on damaged ground or wasteland and produces non-edible oilseeds. The National Policy on Bio-fuels, released in December 2009, set a 20 per cent blending target for bioethanol and biodiesel by 2017. Jojoba was first introduced in Rajasthan in the year 2000 at the Central Arid Zone Research Institute in Jodhpur. In a field

experiment at the Regional Agricultural Research Station in Bijapur, Karnataka, India, assessment of the potential oil-bearing tree species for dryland areas of Karnataka. Has been done. Six oil-producing tree species were tested in this study. *Pongamia pinnata*, *Simarouba glauca*, and *Azadirachta indica* were found to be the most promising to fast-growing nature which are suitable for the dryland areas of Karnataka for oilseed purposes (Devaranavadgi et al. 2010). Some of the important TBOs used in Indian arid and semi-arid regions are Neem (*Azadirachta indica*), Karanj (*Pongamia pinnata*), Mahua (*Madhuca indica*), *Jatropha* (*Jatropha curcas*), Kusum (*Schleichera oleosa*), *Simarouba* etc.

5. Organic matter and soil enrichment

The main characteristics of dry and semi-arid soils are nutrient inadequacy and water constraints. It resulted in deteriorated soil quality and unfavourable conditions for plant growth. Other underlying abiotic and biotic elements that affect the structure and function of these ecosystems also affect these settings (Ayansina & Olubukola 2021). A number of processes contribute to increased nutrient availability, one of which is the build-up of organic waste by trees. A sufficient amount of accumulation boosts rhizospheric microbial activity in the soil. Maximizing microbial activity in these dry and semi-arid zones restores soil production to its maximum level. Woody plants are vital for soil fertility restoration, especially in semi-arid zones like Niger, where low soil fertility is the principal barrier to crop production (Oumarou 2016). He looked at how common tree species in farmers' fields promote soil fertility in semi-arid climates. Except for P, the vertical distribution of all parameters was substantial and declined with depth. The findings also revealed that different tree species had distinct effects on the distribution of the soil parameters studied. *C. aculeatum*-associated soil was more acidic than those of the other species. Leguminous trees (*A. albida* and *P. reticulatum*) have higher organic carbon levels than non-leguminous trees (*A. senegalensis* and *C. aculeatum*). Ammonium-N, P, and K concentrations in *C. aculeatum* were generally lower than in other tree species. On the other hand, the contents of Na, Ca, and Mg in *A. senegalensis* were generally lower than in the other tree species. Litterfall and decomposition are the two fundamental processes in agroforestry that account for organic matter and soil enrichment. Tree type, management strategies, and litter quantity and quality determine the amount of soil enrichment. Litterfall production, decay rates, nutrient release, and subsequent changes in soil physicochemical qualities under the crowns of four multipurpose tree species (MPTs) in irrigated farm fields were investigated. *Prosopis cineraria* (L.), *Dalbergia sissoo* (Roxb.) ex DC, *Acacia nilotica* (L.) Del., and *Acacia leucophloea* (Roxb.) Willd. were the species involved. Annual litter accretion ranged from 36 to 54 kg tree⁻¹ year⁻¹, with *D. sissoo* accumulating the most and *A. nilotica* accumulating the least. The following was the sequence of litterfall production: *P. cineraria* > *A. leucophloea* > *A. nilotica* > *D. sissoo*. In the litter, *P. cineraria* had the highest content of NPK (Yadav et al. 2008). Deans et al. 1999 used regression approaches to quantify biomass, soil organic matter, soil

and tissue N, P, and K in widely spread *Acacia senegal* plantings. From age three to eighteen, tree biomass rose linearly with time and was linearly related to stem cross-sectional area at 30 cm height. For trees uniformly spaced at 6 m, above- and below-ground biomass accumulation averaged around 1770 kg ha⁻¹ year⁻¹ between the ages of 3 and 18. By 18, the average tree had acquired approximately 945, 38, and 420 grammes of nitrogen, phosphorus, and potassium, respectively. The soil organic matter concentrations, N, P, and K were usually highest in the surface layers closest to the stems.

6. Non-timber FGRs erosion

Some endemic species which has good economic importance in the Indian arid region (Bikaner, Jaisalmer and Jodhpur division) were surveyed based on the perception; according to researchers 25 per cent of the total 84 taxa were observed to be facing varying stages of risk (Singh 2004), they also reported that Eighteen species in Bikaner, 21 in Jaisalmer and 19 were reported to be at danger in the Jodhpur divisions. Researchers and conservationists assume that fuel wood and fodder extraction leads to deforestation, but according to a study on household fuelwood and fodder extraction pattern at some villages in Sariska Tiger Reserve, Rajasthan, India, Fuelwood and fodder extraction may not be the major reason for deforestation because communities adjacent to forests mostly use dry wood as fuelwood and grasses for fodder that Normally, this does not entail tree felling (Nagothu 2001). In Brazilian Amazon's southern and eastern regions, Forests that have been subjected to extractives have been reduced, primarily in municipalities. These declines are linked to forest biomass, fragmentation, edge impact, wildfire, and climatic change caused by deforestation, among other factors (Brandao et al. 2021). The majority of NTFP resources are managed in an unsustainable manner. This is due to the vast volumes collected and the products' domestication needs. Plant NTFPs are only cultivated in 5% of cases (Ingram 2012). Research by (Pauline et al. 2016) strongly supports a link between advancing along Mather's forest transition curve and a decrease in the role of NTFPs in village output and subsistence. The advancement of the forest transition curve is likewise associated with a decrease in the generation of hunting products, according to this study. As a result, the contribution of these items to household incomes and nutritional consumption is reduced, and agricultural and farmed products replace these products. Selective logging is also one of the major factors that are influencing the NTFPs of livelihood importance. Logging can degrade livelihood-related resources and essential ecosystem functions like carbon storage in biomass and soils, water balance and river flow regulation, regional climate pattern modification, and disease amelioration (Lucy Rist et al. 2011). According to a community estimate study of Menton in 2003, he observed changes in the abundance and accessibility of NTFPs after logging, overall negative impression was observed after commercial logging. Non-timber forest products, which annually contribute considerably to rural economies at the expense of timber trees, have been neglected by

Indian forest managers (Chambers et al. 1989). If these NTFP FGRs are properly managed, resources will only increase rural income without harming forest survival (Murali et al.1996).

Conclusion

The contribution of Non-Timber Forest Products (NTFPs) FGRS livelihood options to rural development and poverty alleviation in arid and semi-arid regions has piqued interest in recent decades. Trees and forest regions supply many items vital to the people who live in their vicinity. From these items, local stakeholders must have improved livelihoods and income generation opportunities to contribute and dedicate sufficient resources to restoration. As well as the long-term maintenance of arid land. According to the studies, any assumption about the capacity of NTFPs to favourably affect rural development, accumulative strategies of NTFP lift people out of poverty.

Declaration of Interests

The authors have no conflict of interest to declare.

Data Sharing

All relevant data are within the manuscript.

References

1. Akram M, Hanjra SA, Qazi MA & Bhatti JA. 1990. Availability and use of shrubs and tree fodders in Pakistan. In: Devendra, C. (ed.), Shrubs and tree fodders for farm animals. Proceedings of a workshop in Denpasar, Indonesia, 24–29 July 1989. IDRC-276e, Ottawa, Ontario, pp. 176–182.
2. Ayansina SA & Olubukola OB. 2021. Reclamation of arid and semi-arid soils: The role of plant growth-promoting archaea and bacteria, *Current Plant Biology*, 25:100173.
3. Bana RS, Dawar R, Haldhar SM, Godara S, Singh A, Bamboriya SD, Kumar V, Mishra AK & Choudhary M. 2022. Natural farming: Is it safe to march ahead? *Journal of Agriculture and Ecology*, 14 (14): 1–11. <https://doi.org/10.58628/JAE-2214-21>.
4. Bhatt JR & Ram Mohan HY. 1990. Ethephon-induced gum production in *Acacia senegal* and its potential value in the semi-arid regions of India, *Current Science*, 59 (23): 1247–250.
5. Brandao DO, Barata LES & Nobre, I. 2021. The effects of Amazon deforestation on non-timber forest products. *Reg Environ Change*, 21: 122. <https://doi.org/10.1007/s10113-021-01836-5>.
6. Chambers RC, Saxena NC & Shah T. 1989. To the hands of the poor: water and trees. Westview Press, Boulder, CO.
7. Chandra J & Mali MC. 2014. Nutritional evaluation of top five fodder tree leaves of Mimosaceae family of arid region of Rajasthan. *International Journal of Innovative Research and Review*, 2 (1): 4-16.
8. Chavan SB, Chauhan DS, Keerthika A, Uthappa AR, Jha A & Newaj R. 2015. Fuelwood characteristics of selected tree species from Bundelkhand region of Central India. *Eco. Env. & Cons.*, 22: S87-S95.
9. Chitra P. 2018. Nutritive value of Leguminous Tree leaves as a Protein Source for Ruminant Feed. *International Journal of Livestock Research*, 8 (07): 275 – 280.
10. Deans JD, Diagne O, Lindley DK, Dione M & Parkinson JA. 1999. Nutrient and organic-matter accumulation in *Acacia senegal* fallows over 18 years. *Forest Ecology and Management*, 124 (2–3): 153-167.
11. Devaranavadi SB, Patil SB, Mulla SR & Jambagi MB. 2010. Evaluation of tree borne oilseeds for dryland areas of Karnataka, *Advance Research Journal Of Crop Improvement*, 1 (2): 111-113.

12. FAO. 2008. Bosques y energía: cuestiones claves. Roma Italia: Organización de las Naciones Unidas para la Agricultura y la Alimentación, p. 69 FAO: Montes 154.
13. Food and Agriculture Organization of the United Nations. 1981. Map of the fuelled situation in the developing countries at a scale of 1:25,000,000. 45 p. FAO, Rome, Italy.
14. Haldhar SM, Deshwal HL, Jat GC, Berwal MK & Singh D. 2016. Pest scenario of ber (*Ziziphus mauritiana* Lam.) in arid regions of Rajasthan: a review. *Journal of Agriculture and Ecology*, 1: 10-21.
15. Huang J, Guan X & Ji F. 2012. Enhanced cold-season warming in semi-arid regions. *Atmos Chem Phys*, 12(12): 5391–5398.
16. Ingram V. 2012. Governance of non-timber forest products in the Congo Basin. Available online: <http://hdl.handle.net/11245/1.373174>
17. Juliane Souza Luiz Hora, Ivanilda Soares Feitosa, Ulysses Paulino Albuquerque, Marcelo Alves Ramos, Patrícia Muniz Medeiros. 2021. Drivers of species' use for fuelwood purposes: A case study in the Brazilian semiarid region, *Journal of Arid Environments*, 185:104324.
18. Kotia A, Tiwari UL & Rawat GS. 2008. Semiarid Region of India: *Vegetation Characteristics and Threatened plants*, 11 (1):109-116.
19. Lucy Rist, Patricia Shanley, Terry Sunderland, Douglas Sheil, Ousseynou Ndoye, Nining Liswanti, Julius Tieguhong. 2011. The impacts of selective logging on non-timber forest products of livelihood importance. *Forest Ecology and Management*, 268: 57-69.
20. Luna RK. 2005. Plantation Trees. International Book Distributors, Dehradun
21. Malagnoux M, Sene EH & Atzmon N. 2007. Forests, trees and water in arid lands: a delicate balance.
22. Menton MC. 2003. Effects of logging on non-timber forest product extraction in the Brazilian Amazon: community perceptions of change, *The International Forestry Review*, 5 (2): 97-105.
23. Murali KS, Uma Shankar R, Uma Shaanker, Ganeshiah KN & Bawa KS. 1996. Impact of NTFP Extraction on Regeneration, Population Structure, and Species Composition. *Economic Botany*, 50 (3): 252-269.
24. Nagothu US. 2001. Fuelwood and fodder extraction and deforestation: mainstream views in India discussed on the basis of data from the semi-arid region of Rajasthan, *Geoforum*, 32 (3):319-332.
25. Otsyina RM, Norton BW & Djimde M. 1999. Fodder trees and shrubs in arid and semi-arid livestock production systems. In: Buchanan-Smith, JG Bailey LD, McCaughey P (Eds.), Proceedings of the XVIII International Grassland Congress 2, pp. 429-438.
26. Oumarou MBD. 2016. Soil fertility under four tree species in the semi-arid climate of Niger. United Nations University Land Restoration Training Programme [final project] <http://www.unlrlt.is/static/fellows/document/Oumarou2016.pdf>
27. Pandey D. 2002. Fuel wood Studies in India: Myth and Reality. Centre for International Forestry Research pp. 108.
28. Pareek K, Tewari JC, Shiran K, Gaur MK, Bishnoi PR, Sharma A & Chaudhary V. 2017. Gum Production on Different Land Forms in Arid Western Rajasthan, *IOSR Journal of Agriculture and Veterinary Science*, 10 (9):14-17.
29. Patel RI. 1971. Forest Flora of Gujarat state. Gujarat Forest Dept., Baroda, Gujarat.
30. Pauline Gillet, Cédric Vermeulen, Jean-Louis Doucet, Elisabet Codina, Charlotte Lehnebach & Laurène Feintrenie. 2016. What Are the Impacts of Deforestation on the Harvest of Non-Timber Forest Products in Central Africa? *Forests*, 7: 106. doi:10.3390/f7050106.
31. Prasad R, Handa AK, Badre Alam, Singh R, Shukla A, Singh P, Tripathi VD & Prasad N. 2019. Integration of natural resins and gums yielding trees in agroforestry systems for enhancing livelihood security, *Indian J. of Agroforestry*, 21 (2): 1-12.
32. Prasad R, Tripathi VD, Dhyani SK, Handa AK, Alam Bandre, Ajit & Singh R. 2015. [Performance of *Acacia senegal* L.: Untapped Wealth of Gum Arabic in Rangelands and Grasslands in Arid and Semi-Arid Region of India](#). International grassland congress proceeding took place in New Delhi, India. <https://uknowledge.uky.edu/igc/23/2-9-1/7/>
33. Puri S, Singh S & Bhushan B. 1994. Fuelwood value index in components of ten tree species of arid region in India, *Industrial Crops and Products*, 3, (1-2): 69-74.
34. Ram M, Tewari JC, Harsh LN, Khan HA, Singh P, Ram P, Singh Y, Singh M & Singh N. 2013. Tree Gum Tapping Technique of CAZRI Proved to be a Boon of Livelihood for Gum Arabic Tappers of Western Rajasthan in India, *Popular Kheti*, 1 (1):16-20.
35. Safriel U & Adeel Z. 2005. Dryland systems. In: Hassan R, Scholes R, Ash N (eds) Ecosystems and human well-being, current state and trends, vol 1. Island Press, Washington, pp 625–658.
36. Shah GL. 1978. Flora of Gujarat state. Sardar Patel University, Vallabh Vidyanagar, Gujarat.
37. Shiren K, Varma A, Pareek K & Praveen Kumar. 2018. Gum Induction from Arid tree species: an alternative source of income. *Indian Farming*, 68 (09): 52–55.
38. Singh AK, Lodhi GN, Misra AK & Upadhyay VS. 1994. Nutritive value of anjan tree (*Hardwickia binata*) leaves for goats. *Indian Journal of Animal Nutrition* 11(3): 197-198.
39. Singh AK. 2004. Endangered economic species of Indian desert. *Genetic Resources and Crop Evolution* 51: 371–380.
40. Singh V & Toky OP. 1995. Biomass and net primary productivity and *Leucaena Acacia* and *Eucalyptus* short rotation, high density (energy) plantations in arid India. *Journal of Arid Environment*, 31:301-309.
41. Yadav RS, Yadav BL & Chhipa BR. 2008. Litter dynamics and soil properties under different tree species in a semi-arid region of Rajasthan, India. *Agroforest Syst*, 73: 1–12. <https://doi.org/10.1007/s10457-008-9106-9>.