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RESEARCH ARTICLE

Circa situm Conservation of Tree Genetic Resources: A Case Study from the Central Western Ghats of Karnataka, India

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Abstract

Tree species are an integral part of agrobiodiversity. Several tree species have multifarious uses. India's Western Ghats, with diverse climate, topography and soils, are home to a number of tree species. A study was conducted in the adjoining areas of Karnataka's Central Western Ghats, including coastal lowlands/plains (Dakshina Kannada) and high mountain ranges (Shivamogga and Uttara Kannada). A total of 93 species belonging to 75 genera and 41 families are being conserved *circa situm* by the farmers of this region. From our study, it was found that the conservation of tree species solely depends on the farmers' perception of the utilization of these species *i.e.,* "conservation through use" and the species recorded in the present study area are conserved due to their uses as timber, fruit/nut/spice/ornamental, border/windbreaker, fuel, cultural significance, shade and other uses (gum, resin, soil conservation, etc.). Conservation through *circa situm* recognizes the ownership of the farmers of a given region and also considers the socio-economic context of conservation by meeting the food, nutrition, livelihood and income security of the farmers.

Keywords: *Circa situm*, Conservation, Tree genetic resources, Conservation through use, Western Ghats.

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Introduction

India has rich diversity in terms of climate, weather, topography and culture, which has resulted in a vast diversity in flora and fauna, and is one of the 12 megacentres of the world (Gowthami *et al.*, 2021). Trees are an integral part of biodiversity and have been meeting multipurpose needs *viz.,* enhancing agrobiodiversity, mitigating the greenhouse effect, meeting the needs of humans (medicine, food, timber, fuel, fibres, ornamental, cultural and spiritual purposes) (Dhyani *et al.*, 2022). A recent assessment of the number of trees on earth has confirmed the existence of ~73,000 tree species, among which ~9,000 are yet to be discovered (Cazzolla Gatti *et al.*, 2022). Among these, 20.34% (14,853) species are threatened [critically endangered (CR)- 2,931; endangered (EN)- 5,890 and vulnerable (VU)- 6,032,54 are extinct (EX) and 28 species are already extinct in the wild (EW)] (IUCN, 2023). In India, about 2603 tree species are reported, of which 24.97% (650 species) are endemic and nearly 18% (469) tree species are threatened with extinction (Dhyani *et al.*, 2022). This may be due to overexploitation for timber and other products from the natural habitat, habitat loss naturally and human-induced, forest clearance, disease and climate change (Gowthami *et al.*, 2021; Dhyani *et al.*, 2022).

Karnataka state is endowed with a diverse climate, topography, soils and which has resulted in rich biodiversity and reported to have the highest number of tree species (325) followed by Tamil Nadu (252), Andhra Pradesh (242) and Kerala (238) as reported in the

current India State of Forest Report (FSI, 2019). In Karnataka, a total of 146 tree species are reported to be under different levels of threat; of which 75 tree species are threatened (CR-6; EN- 28; VU- 41), 54 are extinct (EX), 28 species are already extinct in wild (EW), 17 are near threatened, 48 are least concern and 6 are data deficient (IUCN, 2023). The Western Ghats of India are nearly 1,600 km long range of mountains from Tapti river in North to Kanyakumari in South, also recognized as one of the world's biodiversity hot spot rich in flora and fauna diversity. The southern Western Ghats covered in Karnataka, Kerala and Tamil Nadu has rich diversity *i.e.,* out of the 4000 species of flowering plants estimated, 3,900 occur in the region (Sasidharan, 2003). Western Ghats of Karnataka cover Belagavi, Chamarajanagara, Chikkamagaluru, Dakshina Kannada, Hassan, Kodagu, Mysuru, Shivamogga, Udupi and Uttara Kannada districts of the state. A great diversity of tree species having great economic importance exists in this region. Since the beginning, these tree resources are an essential component meeting the several demands of the communities *viz.,* five F's of food, fiber, forests, flowers, and fuel, also meeting the additional necessities such as shelter and medicine, ultimately meeting the food, nutrition and livelihood security, directly and indirectly balancing the biodiversity. The importance of conserving these tree genetic resources has been in place for many years and the government, research institutes, and non-government organizations have made efforts to safely conserve trees *in-situ* and *ex-situ* methods.

Generally, conservation in seed banks is the main approach for *ex-situ* conservation. However, seed conservation of many tree species is challenging due to the recalcitrant seed behavior, long juvenile phases, and highly heterozygous nature and therefore do not breed true, thus mainly propagated by cuttings/grafts. As a result, many of the species are maintained as living collects in orchards/ field genebanks/forest genebanks etc. and as *in-vitro* cultures in the *in vitro* genebanks. Among the different approaches, on-farm conservation of tree species *in-situ* in home gardens *i.e., circa situm* is one of the conservation strategies the farmers are using. *Circa situm* conservation is a form of farmer-based conservation in altered agricultural landscapes such as agroforestry, home gardens and orchards that are outside the natural habitats but within the native geographical range of a species (Agrawal *et al*., 2023; Boshier *et al*., 2004; Dawson *et al*., 2013; Vasudeva, 2022) mostly for the conservation through use. Hence, in the present study, efforts have been made to assess the level and quantum of the diversity of tree species conserved through *Circa situm* approach in the central Western Ghats of Karnataka.

Methodology

The present study was conducted in coastal lowlands/ plains (Dakshina Kannada district), high mountain ranges (Shivamogga, Uttara Kannada districts) of the central Western Ghats, Karnataka, India during November 2020 to 2021. Data was documented from the different custodian farmers using a questionnaire and semi-structured interviews. Initially, the socio-economic survey was conducted to document the data on different species of trees conserved. For the socio-economic surveys, semi-structured interviews were carried out with members of five farm holds in each category of small (< 2 ha), medium (2–10 ha) and large (>10 ha) farm holds in each district selected randomly. Each farm family was asked the use for growing of each species and was also asked to rank the species based on the usage.

Results and Discussion

Tree species are one of the important components of terrestrial ecosystems and agrobiodiversity. Great diversity by their direct and indirect value exists in tree species *i.e.,* they are deciduous, evergreen, ornamental, fragrant, edible fruit bearing, medicinal, timber yielding, fodder yielding, nitrogen-fixing, shade bearing, fuel yielding, dye yielding etc (Seth, 2003). Due to the multifarious uses of trees, globally, nearly 8,000 tree species are used by humans (FAO, 2014) and ~ 20.34% of tree species are threatened due to over-exploitation, deforestation, land use change, and climate change (Van Zonneveld *et al*., 2018). Conventionally, tree genetic resources are conserved *in-situ* in their natural habitat in the forests and mainly important species are conserved *ex-situ* in seed genebank, field genebank, *in-vitro* genebank and cryo-genebank. Many of the tree species are not highly domesticated and are maintained in the forests, nearby forest areas and untapped areas and, therefore, require human cultivation to persist (Brush, 1991). Some are planted or left as remnants in landscapes that are otherwise cleared for agriculture (Dawson *et al*., 2013). In such cases, farmer-based *circa situm* conservation approaches are particularly valuable for the conservation of such species. *Circa situm* conservation differs from *in-situ* (conservation of natural populations) and *ex-situ* (conservation in remote locations and gene banks) by being a conservation strategy to preserve near natural populations as artificial or human maintained populations.

In *circa situm* conservation, species are maintained within their natural ranges and climatic zones, but in habitats different from those in which they are assumed to have spent most of their evolutionary history. Otherwise, refers to the conservation of planted or remnant trees in farmlands or forest patches where natural forests or woodlands containing the same trees were once found; but the vegetation has been lost or modified significantly through anthropogenic intervention. The primary purpose of a farmer-based *circa situm* conservation may not be of conservation and species conserved are also may not be of immediate interest in the commercial market (Brush, 1991). Instead, they might be fulfilling many needs of the farmers such as food, fibers, medicine, live fences, and edibles among others (Dawson *et al*., 2013), more recently to provide

amenities and comfort in urban parks and streets (Han *et al*., 2020). It also acts as a "stepping stone" between forest patches and plays a significant role in gene flow (via pollen) as situated close enough to existing wild plants (Boshier *et al*., 2004; Dawson *et al*., 2013). *Circa situm* could be used to complement the role of *ex-situ* plantings as a second conservation population. Also plays an important role in maintaining insect, bird and mammal populations essential for pollination, biological pest control, and increasing crop productivity (Cristo'bal-Pe'rez *et al*., 2022).

In the study area, a total of 93 tree species belonging to 75 genera and 41 families were recorded, which are being actively conserved *circa situm* by the farmers (Table 1) (Figure 1). The number of stems/ trees conserved in each

Figure 1: *Circa situm* conservation model of tree species by the farmers of Central Western Ghats

Table 1: Tree species diversity in ***circa situm*** conservation of Central Western Ghats

Tree species	*Family*	*English name; Kannada name*
Acacia catechu (L.f.) Willd.	Fabaceae	Black catechu; Khadira
Acrocarpus fraxinifolius Wight and Arn	Fabaceae	Pink cedar; Balanji
Actinodaphne malabarica N.P.Balakr.	Lauraceae	Kambilivirinji
Adansonia digitata L.	Malvaceae	Baobab tree; Brahmamlika
Adenanthera pavonina L.	Fabaceae	Red lucky seed; Ane Golaganji
Aegle marmelos (L.) Correa	Rutaceae	Bael; Bilva
Aglaia elaeagnoidea Benth.	Meliaceae	Droopy leaf; Priyangu
Ailanthus integrifolia Lam.	Simaroubaceae	Tree of heaven; Hemmara
Alangium salviifolium (L.f.) Wangerin	Alangiaceae	Sage-leaved alangium; Ankola
Albizia amara (Roxb.) Boivin	Fabaceae	Bitter Albizia; Sujjalu mara
Albizia lebbeck (L.) Benth.	Fabaceae	Indian siris; Baage
Alstonia scholaris (L.) R.Br.	Apocynaceae	White cheesewood; Haale
Altingia excelsa Noronha	Altingiaceae	Oriental sweet gum; Rasamala
Anacardium occidentale L.	Anacardiaceae	Cashew nut; Godambi
Anogeissus latifolia (Roxb. Ex DC.) Wall. ex Guill. & Perr.	Combretaceae	Axlewood; Dindiga
Anthocephalus cadamba Miq.	Rubiaceae	Neolamarckia cadamba; Kadamba
Areca catechu L.	Arecaceae	Betel-nut Palm; Adike
Artocarpus altilis (Parkinson) Fosberg	Moraceae	Breadfruit; Divi halasu
Artocarpus lacucha Roxb. Ex Buch.-Ham.	Moraceae	Monkey fruit; Vatehuli
Artocarpus heterophyllus Lam.	Moraceae	Jackfruit; Halasu
Artocarpus hirsutus Lam.	Moraceae	Wild jackfruit; Hebbalsau
Atalantia monophylla (L.) DC.	Rutaceae	Indian atalantia; Kaadu nimbe
Azadirachta indica A. Juss.	Meliaceae	Neem; Bevu
Balanites aegyptiaca (L.) Delile	Zygophyllaceae	Desert dates; Karjura
Bauhinia malabarica Roxb.	Fabaceae	Malabar bauhinia; Basavanapada
Borassus flabellifer L.	Arecaceae	Palmyra palm; Taale mara
Boswellia carteri Birdw.	Burseraceae	Sali guggul; Guugulu mara
Buchanania lanzan Spreng.	Anacardiaceae	Chironji; Charoli
Butea monosperma (Lam.) Kuntze	Fabaceae	Flame of the forest; Palasha
Caesalpinia sappan L.	Fabaceae	Sappan wood; Sappanga
Callicarpa macrophylla Vahl	Lamiaceae	French mulberry; Ibbani

Calophyllum apetalum Blanco	Calophyllaceae	Konkan Beauty Leaf Tree; Bobbe mara
Canarium strictum Roxb.	Burseraceae	Black dammar; Raldhoop
Cassia fistula L.	Fabaceae	Golden Shower Tree; Konde mara
Ceiba pentandra (L.) Gaertn.	Malvaceae	Silk Cotton Tree ; Boorugada mara
Cinnamomum macrocarpum Hook.f.	Lauraceae	Dalchini; Tamaala
Cinnamomum malabathrum (Lam.) J.Presl	Lauraceae	Dalchini, Tejpatta
Cinnamomum sulphuratum Kurz	Lauraceae	Dalchini, Tejpatta
Cinnamomum wightii Meisn.	Lauraceae	Dalchini, Tejpatta
Citrus aurantifolia (Christm.) Swingle	Rutaceae	Key lime; Musambi
Citrus aurantium L.	Rutaceae	Sour Orange; Harale hannu
Citrus bergamia Risso	Rutaceae	Lemon; Kadu nimbu
Citrus limon (L.) Osbeck	Rutaceae	Lemon; Nimbe hannu
Citrus medica L.	Rutaceae	Citron; Kittale
Cocos nucifera L.	Arecaceae	Coconut; Tengu
Commiphora caudata Engl.	Burseraceae	Hill mango; Kondamavu
Cordia dichotoma (Ruiz & Pav.) Gurke	Boraginaceae	Indian cherry; Challe hannu
Cycas circinalis L.	Cycadaceae	Queen sago; Mandhichalu
Dalbergia sissoo Roxb. ex DC.	Fabaceae	Indian rosewood; Beete
Diospyros ebenum Koenig ex Retz.	Ebenaceae	Eboni; Abanasa
Diospyros sylvatica Roxb.	Ebenaceae	Forest ebony; Manjathuvara
Dysoxylum malabaricum Bedd. Ex C.DC.	Meliaceae	White cedar; Bili buddaliga
Elaeocarpus sphaericus (Gaertn.) K.Schum.	Elaeocarpaceae	Utrasum Bead tree; Rudraksha
Eucalyptus globulus Labill.	Myrtaceae	Eucalyptus; Nilgiri
Feronia limonia Swingle	Rutaceae	Wood apple; Belada hannu
Ficus benghalensis L.	Moraceae	Indian banyan tree; Ala mara
Ficus religiosa Forssk.	Moraceae	Peepal tree; Arali mara
Garcinia gummi-gutta (L.) N.Robson	Clusiaceae	Malabar tamarind; Uppage
Garcinia indica (Thouars) Choisy	Clusiaceae	Kokam; Purapuli
Garcinia morella (Gaertn.) Desr.	Clusiaceae	Indian Gamboge; Kadukaai puli
Grewia elastica Royle	Malvaceae	Phalsa; Chhaal
Juglans regia L.	Juglandaceae	Walnut; Akroot
Lagerstroemia microcarpa Wight	Lythraceae	Ben teak; Namdi mara
Leucaena leucocephala (Lam.) de Wit	Fabaceae	Horse tamarind; *Chiguru*
Madhuca indica J.F.Gmel.	Sapotaceae	Indian butter tree; Ippe
Mangifera indica L.	Anacardiaceae	Mango; Mavu
Mesua ferrea L.	Calophyllaceae	Indian rose-chestnut; Nagakesari,
Michelia champaca L.	Magnoliaceae	Champaka; Sampige
Mimusops elengi Bojer	Sapotaceae	Bullet Wood; Pagade mara
Moringa oleifera Lam.	Moringaceae	drumstick tree; Nuggegida
Murraya koenigii (L.) Spreng.	Rutaceae	Curry Leaf; Karibevu
Myristica dactyloides Wall.	Myristicaceae	Bitter Nutmeg; Kadu jaiphal
Myristica fragrans Houtt.	Myristicaceae	Nutmeg; Jatipatre
Myristica malabarica Lam.	Myristicaceae	Wild Nutmeg; Dodda jakai
Nyctanthes arbor-tristis L.	Oleaceae	Tree of Sadness; Harisringi
Phoenix dactylifera L.	Arecaceae	Datepalm; Kharjura
Phyllanthus emblica L.	Phyllanthaceae	Gooseberry; Bettanalli

Pongamia pinnata (L.) Merr.	Fabaceae	Indian Beech Tree; Honge mara
Prosopis cineraria (L.) Druce	Fabaceae	Khejri; Banni mara
Prunus dulcis (Mill.) Rchb.	Rosaceae	Almond; Badami
Psidium guajava L.	Myrtaceae	Guava; Seebe hannu
Pterocarpus santalinus L.f.	Fabaceae	Red sandalwood; Raktachandana
Quercus infectoria Oliv.	Fagaceae	Aleppo oak; Machikai
Rubia tinctorum L.	Rubiaceae	Common madder; Manjishta
Santalum album L.	Santalaceae	Sandalwood; Chandana
Saraca asoca (Roxb.) Willd.	Fabaceae	Ashoka; Ashoka
Shorea robusta C.F.Gaertn.	Dipterocarpaceae	Sal tree; Salada mara
Syzygium cumini (L.) Skeels	Myrtaceae	Jamun; Nerale
Tamarindus indica L.	Fabaceae	Tamarind; Hunase hannu
Tectona grandis L.f.	Lamiaceae	Teak; Tega
Terminalia arjuna (Roxb. ex DC.) Wight & Arn.	Combretaceae	Arjun tree; Nirmatti
Terminalia chebula Retz.	Combretaceae	Indian Almond tree; Kadu badami
Ziziphus jujuba Mill.	Rhamnaceae	Ber; Bogari

species was directly correlated with the number of use values of the species and its economic importance. A significant difference in the number of species conserved by the different farm categories *viz.,* small, medium and large, was observed in all three study areas. Irrespective of the district, a larger number of species was conserved *circa situm* farmers with larger land holdings (55.8–65.2) followed by those with medium holdings (38.2–52.2) and small holdings (12.6–14.4) (Figure 2). Higher diversity in the larger holdings may be due to the presence of larger landholdings with more 'corners' where trees can be grown and also the larger landholdings may focus less on optimizing total farm crop output by removing trees that compete with crops (Dhanya *et al*., 2013; Oli *et al*., 2015). Among the three survey areas, maximum number of tree species was conserved by farmers of Dakshina Kannada district (67) and Uttara Kannada (65.2) followed by Shivamogga (55.8). We also observed that species conserved by medium and small farmers were driven by their potential value of the species. Such high correlation

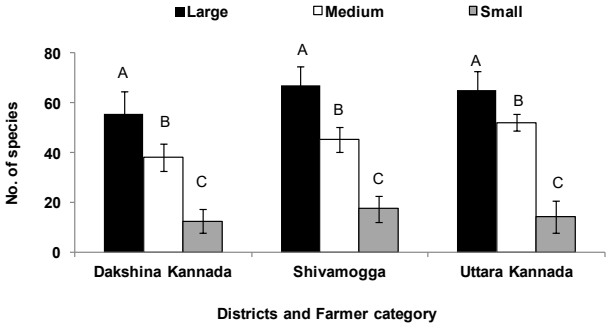

Figure 2: Mean number of tree species conserved *circa situm* by the farmers of different land holdings in central Western Ghats. Data represents mean ± SE of five farm holds in each category. Significant differences ($p \leq 0.05$) are presented by different alphabets analyzed by Duncan's Multiple Range Test.

of use values and community importance given to a species have also been documented earlier (Vasudeva *et al*., 2015).

The farmers conserve trees for their tangible and intangible benefits, termed "conservation through use". As those species enhance food, fuel and medical security, especially for low-income rural people and during hungry periods, diversify income, lower production risk and optimize the management of resources (Arnold and Dewees 1995). The farmer's preference for tree species was evaluated based on the respondents' rankings. Though most of the tree species possess multifarious uses, farmer's perception of conservation revealed that the major purpose for conservation in the study area was due to its use as timber, fruit/nut/leaves/bark, border/windbreaker, fuel, cultural significance, shade and other (gum, resin, soil conservation, etc.) (Figure 3). Among several species conserved *circa situm*, > 40% species are commercially important which are being conserved for their edible fruits or commercially important economic parts like nuts, bark, leaves etc. *Adansonia digitata*, *Aegle marmelos*, *Anacardium occidentale*, *Areca catechu*, *Artocarpus altilis*, *A. lacucha*, *A. heterophyllus*, *A. hirsutus*, *Atalantia monophylla*, *Balanites aegyptiaca*, *Borassus flabellifer*, *Buchanania lanzan, Callicarpa macrophylla, Cinnamomum macrocarpum*, *Cinnamomum malabathrum*, *C. sulphuratum*, *C. wightii*, *Citrus aurantifolia*, *C. aurantium*, *Citrus bergamia*, *C. limon*, *C. medica*, *Cocos nucifera*, *Commiphora caudate*, *Cordia dichotoma*, *Garcinia gummi-gutta*, *G. indica*, *G. morella*, *Grewia elastic*, *Juglans regia*, *Feronia limonia*, *Mangifera indica*, *Michelia champaca*, *Moringa oleifera*, *Murraya koenigii*, *Myristica dactyloides*, *M. fragrans*, *M. malabarica*, *Nyctanthes arbor-tristis*, *Phoenix dactylifera*, *Phyllanthus emblica*, *Prunus dulcis*, *Psidium guajava*, *Quercus infectoria*, *Syzygium cumini and Ziziphus jujube*. Next major group of timber purpose solely or in addition to other benefits. *Acacia catechu*,

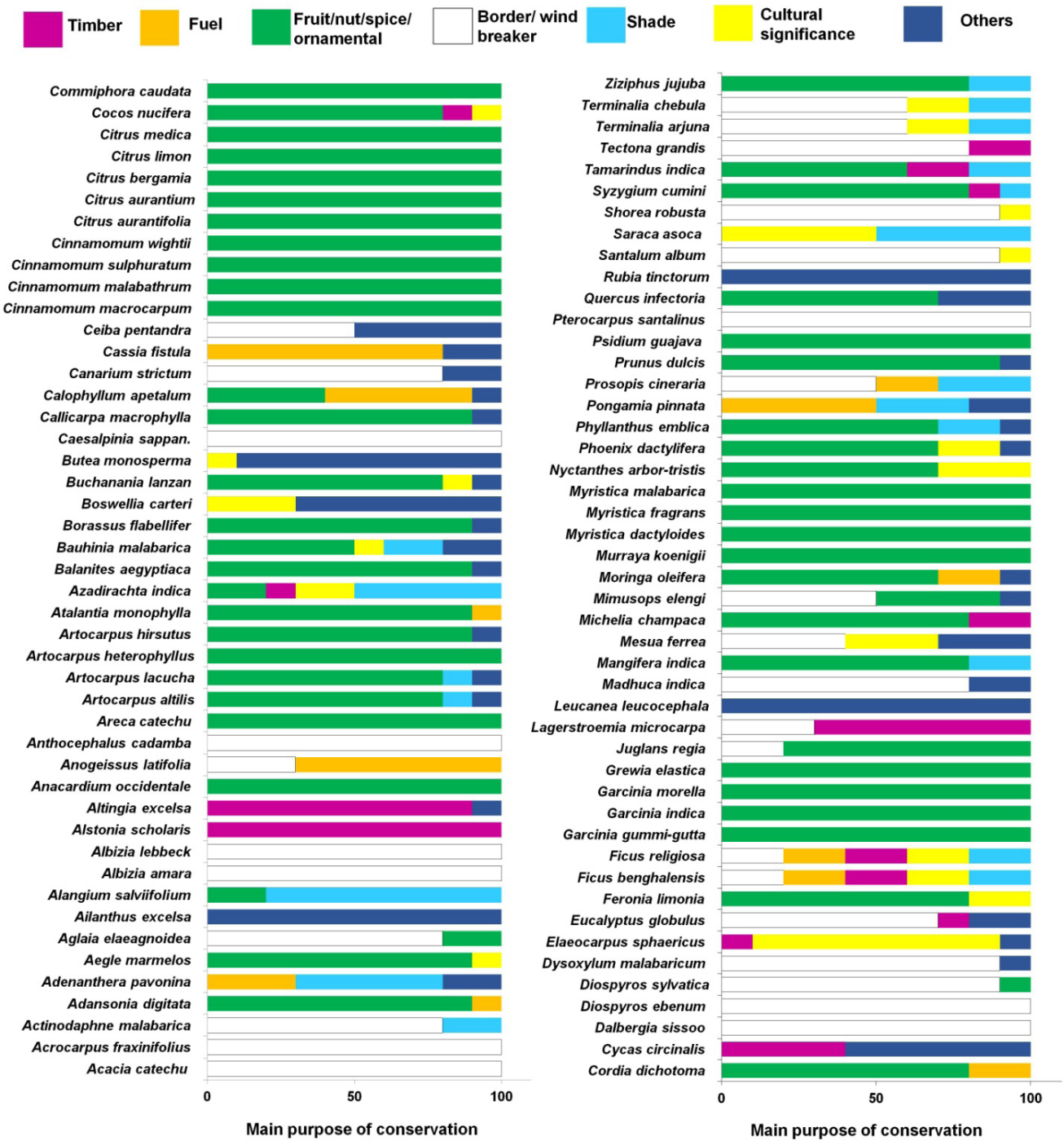

Figure 3: Use categories of tree species conserved *circa situm* by the farmers of Central Western Ghats

Acrocarpus fraxinifolius, *Actinodaphne malabarica*, *Aglaia elaeagnoidea*, *Albizia amara*, *A. lebbeck*, *Anthocephalus cadamba*, *Caesalpinia sappan*, *Dalbergia sissoo*, *Diospyros ebenum*, *D. sylvatica*, *Dysoxylum malabaricum*, *Madhuca indica*, *Pterocarpus santalinus*, *Santalum album*, *Shorea robusta* and *Tectona grandis* (80–100%). *Alstonia scholaris*, *Altingia excelsa*, *Lagerstroemia microcarpa* are majorly grown as a border crops for the demarcation of land holdings. *Elaeocarpus sphaericus* is being conserved for its biocultural significance of flowers (however exotic species such as *A. digitata*, *A. occidentale*, *My. fragrans*, *P. guajava*, *Q. infectoria* species were preferred for conservation suggesting a change in the species composition of the agro ecosystesms) The opinion of farmers is also consistent with the report of Aerts *et al.*, (2011) and Maheswarappa *et al.*, (2021). The first report on *circa situm* conservation of tree species in India specifically in the Karnataka coffee agroforestry system was reported by Maheswarappa *et al.*, (2021) and they observed

that many species are conserved for timber production, shade for coffee plantations, pollination, enhancement of quality of coffee beans, pest control were cited by farmers for retaining the native species.

Conclusion

Tree species are one of the important components of terrestrial ecosystems and agrobiodiversity. Karnataka state is endowed with a diverse climate, topography and soils and is reported to have the highest number of tree species. The present study has confirmed the conservation of vast diversity of tree genetic resources *circa situm*. The farmers conserved trees for their tangible and intangible benefits and termed "conservation through use", many species recorded in the present study area are being conserved due to their use as timber, fruit/nut/spice/ornamental, border/windbreaker, fuel, cultural significance, shade and other (gum, resin, soil conservation, etc.). This study emphasizes that there is a necessity from the government sector to encourage farmers practicing *circa situ* tree conservation through due recognition and remuneration for sustainability of the conservation practice.

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