land-use options can be changed to profitable ones for better economic returns and sustainable resource management of the given land, which could not have been possible through conventional land evaluation methods.

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Comparison of floristic diversity of evergreen forest inferred from different sampling approaches in the Eastern Ghats of Tamil Nadu, India

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Floristic inventory and diversity studies are conducted using various sampling methods. The present study compared floristic diversity of an evergreen forest of Kolli Hill based on three sampling methods, viz. (a) ad hoc (AH) vegetation survey, (b) stratified random plot (SRP) and (c) bigger plot (BP). The evergreen forest area (2889.5 ha) was classified with IRS 1D LISS III satellite data and the evergreen area belonging to different reserve forests were subset. Floristic inventory with SRP was carried out on 0.1% of total evergreen area using 20 × 20 m plot. An earlier study done on the same locality was considered as the BP. The AH, SRP and BP recorded, 121, 91 and 78 tree species respectively. The mean tree densities were 547 and 478 trees ha^{-1} and the mean basal areas were 46.74 and 43.6 m^2 ha^{-1} in SRP and BP respectively. All the diversity indices calculated based on SRP with 3 ha sampling area and BP with 8 ha sampling area varied considerably.

Keywords: Diversity indices, evergreen forest, floristic diversity, sampling techniques.

FLORISTIC inventory and diversity studies help us understand the species composition and diversity status of forests[1], which also offer vital information for forest conservation[2]. Quantitative inventories, moreover, help identify species that are in different stages of vulnerability[3] as well as the various factors that influence the existing vegetation in any region[4]. However, the efficacy of inventory studies depends critically on the selection of an appropriate sampling technique[5].

Floristic inventory and diversity studies are carried out following many sampling techniques such as random plots of various dimensions and sizes, viz. Whittakar and Niering[6], and Devi and Yadava[7] (10 × 10 m), Gillespie *et al.*[8] (2 × 50 m), Huang *et al.*[9] (50 × 20 m), random strip plots[3] of 2 × 50 m and 6 × 50 m, bigger plots[10] of 50 ha

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subdivided into contiguous plots of 20×20 m, bigger plots[4,11–13] of 1–3 ha subdivided into 10×10 m, bigger plots[14,15] of 1–2 ha, ad hoc vegetation survey[2] and variable area plot[2,16].

In India, majority of the tree inventory and diversity studies carried out hitherto can be broadly classified into two groups based on the sampling techniques, viz. (a) random/stratified random plot studies and (b) bigger plot studies. The random/stratified random studies[3,7,17–21] take into account the entire forest area or forest type in estimating the diversity status. Whereas the bigger plot studies[4,11–13,22–30] have usually taken into account only a disturbed site in comparison with adjacent undisturbed sites.

Although these studies contributed to the knowledge of floristic status of the respective regions, it is unclear whether the sampling technique adapted in these studies truly represents the floristic inventory and tree diversity, or not. Secondly, in the discussion part of many of the above studies, the results are compared with those of similar studies conducted elsewhere, to rank the diversity status into equal, higher or lower. We presume that these kinds of comparison may not be rational and may give a false impression about the floristic diversity status of a region because diversity measures are subjective to sampling methods. In order to test this hypothesis, the present study was taken up to compare floristic diversity of an evergreen forest based on three sampling techniques, viz. (a) stratified random plot (SRP), (b) ad hoc (AH) vegetation survey and (c) bigger plot (BP) (≥1 ha).

The present study was conducted on the evergreen forest of Kolli Hill (KH), geographically situated between 11°10′00″–11°30′00″N and 78°15′00″–78°30′00″E (Figure 1). KH is in the Namakkal District of Tamil Nadu (TN), above the river Cauvery, covering an area of about 503 km^2. The entire forest region comprises 14 reserve forests (RFs) covering 27,156.61 ha as well as a non-forest region covering 23,215.87 ha (Figure 1). Physiographically, KH is a mountainous region with altitudes ranging from 200 to 1415 m at the foothills and Bailnadu respectively. About 95% of the RFs is situated in the valley. The slope of this region varies from gentle to very steep. Geologically, the study area consists of acid charnokite with minor bands of pyroxene granulate and magnetite quartzite[31]. The plateau of KH is highly undulating, cut by a network of streams, most of which are semi-perennial or seasonal, flowing in all directions but mostly easterly and southeasterly, ultimately draining into the Ayyar River. The mean annual rainfall is 1318 mm, which is received largely between June and December. The annual mean maximum and minimum temperatures are 35°C and 18°C respectively.

Using the IRS 1D LISS III satellite digital data of April 2003 (Figure 2) and employing the on-screen visual interpretation method, the entire evergreen forest of KH was classified, based on standard visual interpretation elements[32], using Erdas Imagine 9.0 image processing software. The 14 RF boundaries were digitized from Survey of India (SOI) topographical maps and any evergreen forest area in an RF was subset. Of the 14 RFs, only 11 contained evergreen forest.

According to the satellite data analysis and mapping, the total evergreen forest distributed in the 11 RFs occu-

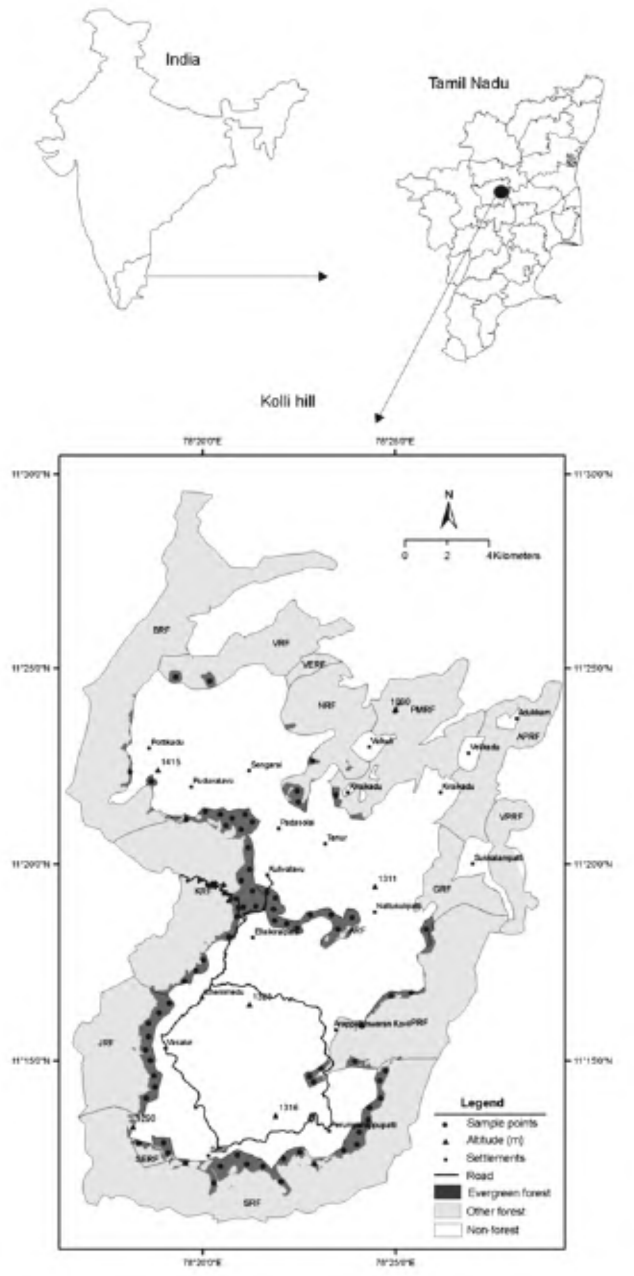

Figure 1. Location map of the study area and distribution of sample points for floristic inventory study in the evergreen forest of Kolli Hill with the acronyms of the various reserve forests (RFs). ARF, Ariyursholai RF; APRF, Adukkampudukombai RF; BRF, Bailnadu RF; GRF, Gundur RF; JRF, Jambuttu RF; KRF, Karavallikombai RF; NRF, Nayakkankombai RF; PMRF, Perumalmalai RF; PRF, Puliansholar RF; SRF, Selur RF; SERF, Selur extension RF; VERF, Varagur extension RF; VPRF, Vairichettipalayam RF and VRF, Varagur RF.

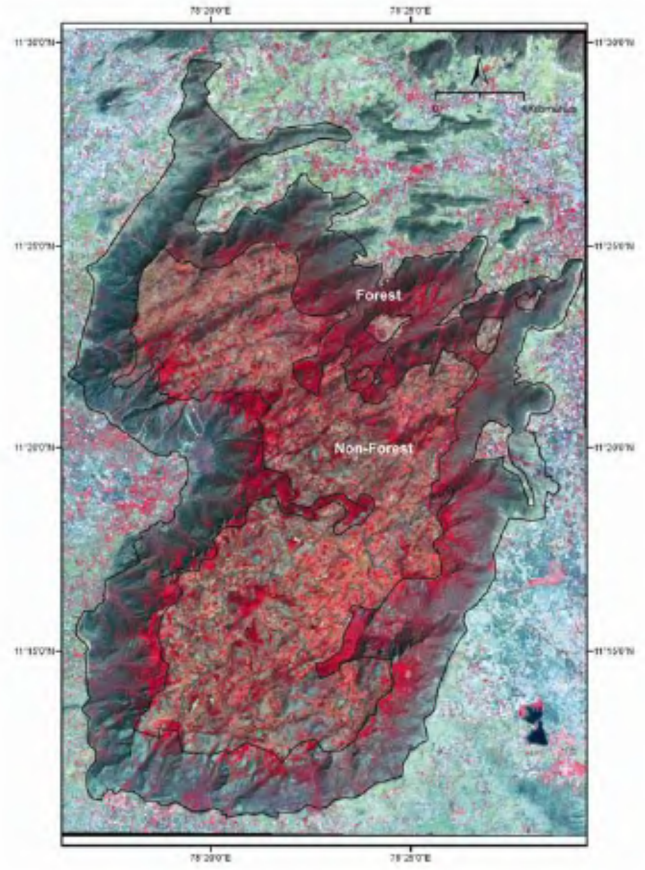

Figure 2. False colour composite of IRS 1D LISS III satellite data overlaid with the reserve forest boundary (band combination: band 3, 2 and 1 in red, green and blue colour guns respectively).

pied a total of 2889.50 ha (Table 1). We sampled 0.1% (3 ha) of the evergreen forest for floristic diversity study. The total area of evergreen forest in each RF was calculated, and the area to be sampled (0.1%) in each RF was also worked out (Table 1). A plot size of 20×20 m was set based on both the species–area curve method and Balaguru *et al.*[17]. The number of plots to be studied in each RF was proportionately determined (Table 1), after which sample points were randomly distributed in the RFs using the 'create random points' option in Erdas Imagine software (Figure 1). The geographical coordinates (in latitude and longitude) of each sample point were noted and located precisely in the field using a Leica GS20 Professional Data Mapper global positioning system of 1–4 m positional accuracy. In all, 75 plots were studied.

During the field survey, the girth of all trees ≥30 cm at 1.3 m height from the ground was measured in each quadrat. For multi-stemmed trees, the girth was measured separately for each bole, and the basal area was calculated separately and summed up. For buttressed trees, the girth was measured above the buttress. Voucher specimens for each species were also collected in triplicate for herbarium preparation, identification and confirmation. Field-identified specimens were reconfirmed and unidentified specimens were identified at the Botanical Survey of India, Coimbatore, India, and at Rapinat Herbarium Tiruchirappalli, India and also using regional flora[33].

The ad hoc method of floristic surveying is a mere checklisting of species available in an area of study[2]. An ad hoc floristic survey was conducted in the present study starting from the perimeter of the RF boundaries and circling inside and recording all tree species having ≥30 cm girth at 1.3 m height from the ground. Voucher specimens for all new tree species were collected.

The study made by Chittibabu and Parthasarathy[11] in four sites of the same evergreen forest of KH, to understand the diversity status and the level of anthropogenic disturbance gradients, using randomly selected 2 ha bigger plots, each subdivided into 10×10 contiguous plots was considered as the bigger plot survey. The four sites were graded into undisturbed, sporadically disturbed, frequently disturbed and highly disturbed based on the disturbance level.

The widely used Shannon (H') diversity index was calculated according to Magurran[34]. The relative frequency, relative density, relative basal area, and importance value index were calculated based on Cottam and Curtis[35]. From the data obtained in the ad hoc survey, only a checklist of species (species richness), genera and family was prepared.

$$H' = -\sum_{i=1}^{s} pi \ln pi, \tag{1}$$

where s is the total number of species, and pi the proportion of individuals of the ith species.

We compared only the simple diversity indices such as species richness (number of species), genus richness (number of genera) and family richness (number of families) among AH, SRP and BP, as the other diversity indices cannot be calculated from the AH survey. Comparison of all other diversity indices was made only between SRP and BP. In the BP study conducted in four distinct sites of 2 ha each, few diversity values such as girth class-wise species richness (number of species), abundance-based species richness and Shannon index had been expressed in minimum and maximum ranges based on the data recorded in the four sites. Therefore, the comparison of girth class-wise species richness, abundance-based species richness and Shannon index was made between the actual value of SRP (recorded from the 3 ha) and the minimum and maximum values of BP. The density (number of trees) and basal area between SRP and BP were compared based on the mean value per hectare. The comparison made between the sampling methods in the present study was intended only to infer how the diversity values vary and not to verify the best sampling method.

Table 1. Various reserve forests of Kolli Hill

Reserve forest	Total area (ha)	Area under evergreen forest (ha)	Percentage to total evergreen	Area to be sampled (0.1% of evergreen in m^2)	Total area sampled (m^2)	Number of plots studied (20 × 20 m)	Altitudinal range (m)
Adukkampudukombai	1436.14	0.00	0.0	0.00	0.00	–	–
Ariyursholai	406.96	389.00	13.5	3890.00	4000.00	10	1200–1350
Bailnadu	4425.76	70.66	2.4	706.60	800.00	2	1100–1380
Gundur	869.75	48.67	1.7	486.70	400.00	1	1050–1120
Jambuttu	2028.92	358.34	12.4	3583.40	3600.00	9	1100–1220
Karavallikombai	3434.31	757.07	26.2	7570.70	8000.00	20	1100–1350
Nayakkankombai	1668.55	125.73	4.4	1257.30	1200.00	3	1050–1150
Perumalmalai	2315.49	53.12	1.8	531.20	400.00	1	1050–1100
Puliyansholai	2799.24	222.25	7.7	2222.50	2400.00	6	1000–1050
Selur extension	197.32	95.61	3.3	956.10	1200.00	3	1100–1200
Selur	5066.83	700.33	24.2	7003.30	7200.00	18	1000–1320
Vairichettipalayam	846.12	0.00	0.0	0.00	0.00	–	–
Varagur extension	164.98	0.00	0.0	0.00	0.00	–	–
Varagur	1496.24	68.72	2.4	687.20	800.00	2	1050–1100
Total	27156.61	2889.50	100	28895.00	30000.00	75	–

Table 2. Comparison of floristic diversity values between the ad hoc survey, stratified random and bigger plot measurement techniques in the evergreen forest of Kolli Hill

Floristic diversity	Ad hoc survey	Stratified random plot	Bigger plot
Study area	Kolli Hill	Kolli Hill	Kolli Hill
Forest-cover mapping	Yes (using satellite data)	Yes (using satellite data)	No
Forest type in which floristic study was conducted	Evergreen	Evergreen	Evergreen
Number of RFs in which sampling was carried out	11	11	2
Total area of sampling	–	3 ha (0.1% of total area)	8 ha (0.277% of total area)
Number of plots studied	–	75 (20 × 20 m)	4 (100 × 200 m)
Species richness	121	91	78
Genus richness	89	71	61
Family richness	39	32	36
Shannon (H') index	–	3.140	3.340
Mean stand density (stems ha^{-1})	–	547	478
Mean basal area (m^2 ha^{-1})	–	46.74	43.6

The total species richness of the entire evergreen forest, distributed over 11 RFs with elevation ranges from 1000 to 1350 m, in the SRP study was 91 (Table 2). The BP study[11], conducted in four sites of 2 ha each in the evergreen forest in two RFs, namely the Karavallykombai and Ariyursholai RFs of KH, recoded a total of 78 species. Only 40% of the tree species was common between BP and SRP. The results of the AH method for the number of families (39), genera (89) and species (121) were higher than those for the other two methods (Table 2). However, only 74% of the tree species was common to both the AH and the BP studies.

Euphorbiaceae, with 13 species in the SRP and 16 species in the AH survey, dominates the evergreen forest of KH in terms of the number of species (Table 3). This result is in accordance with the results of other studies conducted in the Shervarayan Hills[12] of the Eastern Ghats, where Euphorbiaceae has been recorded as the dominant family with eight species, in the Western Ghats[4] with ten species, and in the Andaman Islands[3] with 27 species. However, in the BP[11], Moraceae (ten species) was found to be the dominant family. Moraceae might, in fact, be a locally dominant family, specific only to the four BP sites.

In terms of tree density (number of stems), according to the SRP, Melastomataceae is the dominant family, with a maximum density of 170 ha^{-1} followed by Lauraceae (90 ha^{-1}) and Myrtaceae (41 ha^{-1}). Whereas in the BP[11], Lauraceae is the dominant family with maximum density (119 ha^{-1}) followed by Melastomataceae (106 ha^{-1}) and Euphorbiaceae (30 ha^{-1}; Table 4).

The SRP yielded a mean tree density of 547 stems ha^{-1}. This value is higher than that of the BP (478 stems ha^{-1}; Table 2). The mean basal area of the SRP (46.74 m^2 ha^{-1})

Table 3. Top 15 families and their genera and species contribution recorded in the ad hoc survey, stratified random and bigger plot techniques in the evergreen forest of Kolli Hill

	Ad hoc survey		Stratified random plot		Bigger plot	
Family	Genus	Species	Genus	Species	Genus	Species
Euphorbiaceae	12	16	11	13	6	7
Lauraceae	7	10	7	9	7	9
Meliaceae	7	8	5	6	4	4
Anacardiaceae	5	6	5	6	2	2
Verbenaceae	5	5	4	4	2	2
Rubiaceae	4	5	3	3	2	3
Papilionoideae	3	3	3	3	–	–
Rutaceae	3	3	–	–	–	–
Sapindaceae	3	3	3	3	–	–
Sapotaceae	3	3	1	1	2	2
Moraceae	2	11	2	6	2	10
Combretaceae	2	5	2	5	–	–
Ulmaceae	2	4	2	2	1	2
Annonaceae	2	3	2	3	–	–
Myrtaceae	2	3	2	3	1	1

Table 4. Mean density (number of trees) of the top ten families recorded in the stratified random plot and bigger plot in the evergreen forest of Kolli Hill

Stratified random plot		Bigger plot	
Family	Density (ha^{-1})	Family	Density (ha^{-1})
Melastomataceae	170	Lauraceae	119
Lauraceae	90	Melastomataceae	106
Myrtaceae	41	Euphorbiacaea	30
Flacourtiacae	33	Moraceae	26
Combretaceae	32	Flacourtiaceae	23
Annonaceae	25	Myristicaceae	21
Anacardiaceae	24	Sabiaceae	19
Rosaceae	24	Myrtaceae	19
Euphorbiaceae	19	Anacardiaceae	19
Verbenaceae	17	Ebenaceae	18

is also higher than that of the BP (43.6 m^2 ha^{-1}). The dominant species *Memecylon edule* (135 stems ha^{-1}) and *Neolitsea scrobiculata* (54 stems ha^{-1}) occupied the top two positions in SRP, whereas the *Memecylon umbellatum* (101 stems ha^{-1}) and *Phoebe wightii* (29 stems ha^{-1}) occupied the top two positions in the BP (Table 5). The girth class-wise distribution of tree species and Shannon diversity index varied considerably between SRP and BP (Table 6). The rarity of tree species, based on their abundance, recorded in the SRP was classified in accordance with BP into five groups. The comparison of rarity between SRP and BP is given in Table 7.

Although the sample size of SRP was 0.1% (3 ha), it recorded more tree species than the BP of 0.277% sample size (8 ha). The more number of tree species recorded in the SRP might be due to the fair allocation of samples (75 plots) throughout the evergreen forest (2889.50 ha) situated in all aspects with varying slope conditions. This is because in the hilly terrain, the slope and aspect modify microclimate and are the key determinants of the ecosystem process, vegetation pattern and species distribution across forest landscapes[36,37]. Moreover, the BP survey was carried out only in four sites randomly in a forest region and the species composition of the unsampled area might be significantly different from the sampled area[2]. This sampling effect between SRP and BP could also be inferred in terms of family dominance based on the number of species and species dominance based on the number of stems. It may be argued that the disturbance factor might be responsible for less number of species recorded in the BP study[11]. But it is evident from the result of BP study that the disturbance has least affected the diversity values, e.g. similar species richness (35) has been recorded between highly disturbed site and sporadically disturbed site; the stand density recorded in the highly disturbed site (969 stems ha^{-2}) is higher than that of frequently disturbed site (651 ha^{-2}) and the basal area recorded from the frequently disturbed site (103.0 m^2 ha^{-2}) is higher than the sporadically disturbed site (93.2 m^2 ha^{-2}).

It is also worth noting that only 40% of tree species is common between BP and SRP. Therefore, even the well-distributed sampling of 0.1% is not a sufficient sample size to record the tree diversity in this region. The results of this study clearly show that diversity values are subject to sampling techniques as the entire diversity index values vary considerably between SRP and BP. Thus, comparing the results of such diversity studies with others may not be rational because it may lead to irrelevant notions about the diversity of an area.

In the present study, the comparison of floristic diversity in the evergreen forest of KH based on SRP, BP and AH sampling techniques produced different diversity values for the same region. SRP with 0.1% sample size

Table 5. Mean density (number of trees) of the top ten species recorded in the stratified random plot and bigger plot in the evergreen forest of Kolli Hill

Stratified random plot		Bigger plot	
Species	Density (ha^{-1})	Species	Density (ha^{-1})
Memecylon edule	135	*Memecylon umbellatum*	101
Neolitsea scrobiculata	54	*Phoebe wightii*	29
Syzygium cumini	39	*Beilschmiedia gemmiflora*	24
Memecylon umbellatum	35	*Neolitsea scrobiculata*	23
Scolopia crenata	33	*Myristica dactyloides*	21
Persea macrantha	25	*Mallotus philippensis*	20
Prunus ceylanica	24	*Syzygium cumini*	19
Polyalthia cerasoides	23	*Scolopia crenata*	18
Nothopegia colebrookiana	19	*Nothopegia heyneana*	17
Anogeissus latifolia	17	*Meliosma simplicifolia*	14

Table 6. Girth class-wise species richness (number of species) recorded in the stratified random plot (SRP) and bigger plot (BP) techniques in the evergreen forest of Kolli Hill

		Species richness	Shannon (H')	
Girth class (cm)	SRP	BP (minimum–maximum)	SRP	BP (minimum–maximum)
30–60	65	24–50	2.38	1.74–3.00
60–90	50	27–38	2.92	2.63–3.01
90–120	44	19–28	3.20	2.50–2.94
120–150	33	14–27	2.84	2.21–2.91
150–180	22	8–18	2.74	1.53–2.48
180–210	15	8–14	2.40	1.51–2.19
>210	15	6–21	2.35	1.24–2.74

Table 7. Abundance-based classification of trees ≥30 cm gbh and their species richness (number of species) between stratified random plot and bigger plot in the evergreen forest of Kolli Hill

		Species richness	
Group	Density	Stratified random plot	Bigger plot (minimum–maximum)
Pre-dominant	>100	4	1–3
Dominant	51–100	6	2–4
Common	21–50	2	8–22
Rare	3–20	41	8–17
Very rare	1–2	38	13–21

may not be sufficient for tree inventory in this region. It is obvious from the study that comparing and ranking the diversity values with other studies is irrational, since the sampling techniques do not bring out the true floristic diversity of a region. The present study stimulates certain issues worth considering in future studies: (a) the question of adequate sample size for floristic inventory, and (b) the best sampling technique for floristic inventory.

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Acacia nilotica-based traditional agroforestry system: effect on paddy crop and management

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A study was conducted in an age series of *Acacia nilotica* (L.) Willd. ex Del (6–28 years old)-based traditional agroforestry system in the sub-humid region of Chhattisgarh. The effects of this tree on different rice (*Oryza sativa*) crop parameters (plant density, plant height, effective tillers, total aboveground biomass and grain yield) under natural conditions (without any management practices in trees) and under tree management conditions (cutting of 10% of basal tree branches) were evaluated. The growth and productivity parameters were taken in three directions (a central line passing from the centre of the tree bole, and right

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