Several questions remain unanswered and detailed modelling studies would be required to completely understand the mode of deformation. The extremely high level of seismicity seen at the Chagos bank, remains an open question. The Euler pole models discussed, do explain the divergence at the Chagos bank, but fail to explain why normal faults are clustered here and not distributed west of the Euler pole. Further, the proximity of the Euler pole to this cluster of intense seismicity calls for an explanation. Verification of the model predictions can be directly made with the help of space geodetic techniques like Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR) and Global Positioning System (GPS). The possibility of incipient subduction in the north-eastern Indian ocean cannot be ruled out, although the evidence at present is insufficient.

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# Influence of disturbance on fine root biomass and productivity in two deciduous forests of Western Ghats, Tamil Nadu

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**The effect of anthropogenic disturbances on fine root biomass levels, net primary productivity (NPP) and distribution was studied in two deciduous forests of Western Ghats in Tamil Nadu, and it was found that the disturbances such as annual wild fire and cattle grazing enhanced the very fine root (≤ 1 mm) standing crop biomass and NPP. This could be due to the rapid re-occupation of land by a grass cover. Small scale disturbances such as canopy openings lowered the levels of very fine root biomass and NPP. This could be attributed to alteration in the edaphic environment. The marginal decline of fine root (> 1 to ≤ 3 cm) standing crop biomass and NPP may be because of mortality subsequent to the disturbance. Below-ground NPP showed seasonal variation during the study period. It has been concluded that the annual wild fire and cattle grazing enhances very fine root biomass and NPP, and also confirms the theory that the above-ground gap creates below-ground gap in deciduous forests.**

UNDERSTANDING of the fine root dynamics is necessary for addressing important issues at several levels of resolution in biology[1]. Greater proportion of the fine roots of many forests is located in the upper soil horizons and undergo rapid change due to disturbances. Anthropogenic disturbances create heterogeneity in edaphic environment. Very few studies have addressed the effects of disturbance on fine root dynamics in tropical forests. Raich[2] found similar amounts of fine root biomass in small, cleared plots after one year and adjacent intact forest in a lowland wet tropical forest in Costa Rica. Total fine root biomass was similar or somewhat lower in the disturbed area (treefall gap) when compared to intact forests during the first two years and the rate of root biomass accumulation tends to decrease as the size of area disturbed increases[3-5]. On the contrary, Yin *et al.*[6] reported that the disturbed (clearcut) forest had significantly greater fine root biomass and production as compared to undisturbed forests. Information on the fine root biomass following disturbance events in tropical deciduous forests is meagre. Our studies indicate that disturbances such as annual wild fire and cattle grazing enhance very fine root biomass and net primary productivity. But it declined under canopy openings. However, fine root biomass was lowered.

The study areas are located on Alagar hills (10°0′ N and 75°55′ E) in Madurai district and Kodayar hills (77°15′ E, 8°29′ N) in Kanyakumari district in Western Ghats of Tamil Nadu at 200–250 m and 300–365 m MSL elevations respectively. Annual rainfall in Alagar hills and Kodayar hills during the study period was 1087 mm and 3146 mm respectively. January to March represent relatively dry months. Average monthly maximum and minimum temperatures varied between 38°C and 26°C in summer and 28°C and 24°C in winter respectively. Two study sites (one each in disturbed and undisturbed sites) were selected in the deciduous forests at Alagar and Kodayar hills. At Kodayar hills, plant community is dominated by trees, such as species of *Terminalia*, *Buchanania* and *Pterocarpus*. In disturbed site (affected by annual wild fire), ground cover is dominated by *Themeda*, *Cymbopogon*, *Imperata*, etc. (Table 1), while undisturbed site is dominated by *Chromolaena*, *Helicteres*, etc. In Alagar hills, plant community is dominated by trees, such as species of *Ficus*, *Artocarpus* and *Tamarindus*. Ground cover under disturbed site (cattle grazing and trampling) is dominated by grasses, such as *Isachne* and *Panicum*, while undisturbed site is dominated by *Pseuderanthemun*, *Physalis*, etc. Open canopy areas were selected in each site to compare them with adjacent intact forests. While selecting canopy opening, care was taken to ensure equality in size and age (based on structure and composition of plant communities following Chandrashekara[7]).

Fine roots were sampled from the soil monoliths of 15 × 15 × 25 cm size, excavated with a sharpened stainless steel shovel. For each sampling during August 1993 to August 1994 [in two rainy (September–December and May–August) and a dry (January–April) season], twenty monoliths were collected at random from each site and under open canopies. Sample monoliths were cut into different depths (0–5, 5–15, 15–25 cm) and transported to the laboratory in polythene bags for further analyses. Fine root biomass of each sample was determined in the laboratory by wet sieve method[8-10]. Fine root net primary productivity (NPP) was estimated by

**Table 1.** Site characteristics of disturbed, undisturbed and open canopies of deciduous forests in Western Ghats, Tamil Nadu

| | Alagar hills | | | Kodayar hills | | |
|---|---|---|---|---|---|---|
| Characteristics | Disturbed | Open | Undisturbed (closed) | Disturbed | Open | Undisturbed (closed) |
| Tree density[a] (trees/ha) (> 10 cm GBH) | 960 | — | 910 | 610 | — | 700 |
| Tree basal area[a] ($m^2$/ha) | 6.30 | — | 14.31 | 29.4 | — | 34.18 |
| Herb density[b] (No./$m^2$) | 25 | 69 | 19 | 338 | 124 | 88 |
| Herb basal area[b] ($cm^2/m^2$) | 85.57 | 92.78 | 51.18 | 298.5 | 192.64 | 166 |
| Standing litter biomass[c] (g/$m^2$) | 228.64 (21.42) | — | 396.42 (41.62) | 384.84 (39.24) | — | 523.44 (53.29) |
| Soil[d] (pH) | 7.00 (0.28) | 7.04 (0.08) | 7.11 (0.15) | 6.5 (0.18) | 5.75 (0.12) | 5.88 (0.14) |
| Soil moisture[e] (%) | 12.58 (0.13) | 13.21 (1.06) | 14.08 (1.02) | 18.15 (0.54) | 22.13 (2.18) | 26.78 (4.46) |

Values in parentheses represent standard error.
[a] 10 × 10 $m^2$; $n = 50$ (Kershaw[28]).
[b] 1 × 1 $m^2$; $n = 20$ (Kershaw[28]).
[c] 0.5 × 0.5 $m^2$ litter traps; $n = 20$ (Mitchell *et al.*[29]).
[d] 1 : 2 soil water ratio; $n = 10$ (Allen *et al.*[30]).
[e] Gravimetric method; $n = 10$ (Allen *et al.*[30]).

sequential core (summation of positive increments) and ingrowth core methods[11].

Student–Newman–Keuls test was used to find out the significant difference between the sites, microhabitat and the seasons.

Disturbed deciduous forest at Alagar hills had significantly ($P < 0.01$) higher very fine root standing crop biomass and seasonal primary productivity (estimated by both sequential core and ingrowth methods) compared to that under undisturbed site (Table 2). A similar trend was observed in the Kodayar hills, except during the second rainy season (May–August). Whereas, the fine root biomass was comparatively higher under the undisturbed sites to that of disturbed sites in both the locations, however, annual NPP of very fine root was significantly ($P < 0.05$) higher under the disturbed sites than in the undisturbed sites in both forests. On the contrary, the reverse trend was observed for fine root NPP.

In closed canopies, very fine root standing crop biomass and seasonal primary productivity were significantly ($P < 0.01$ Alagar hills; $P < 0.05$ Kodayar hills) higher compared to those from under open canopies (Table 3). A similar trend was observed for fine root biomass and seasonal primary productivity ($P < 0.05$) at both the locations. Under closed canopies, NPP of very fine and fine roots were also significantly ($P < 0.01$ Alagar hills; $P < 0.05$ Kodayar hills) higher compared to those from under open canopies. Very fine and fine root standing crop biomass and NPP was maximum during the first rainy season (September–December) and minimum in the dry season (January–April).

Recurrence of annual wild fire alters the course of the succession by giving an advantage to certain species over others such as *Themeda* in the present case[12,13]. Staterson and Vitousek reported that the fine root biomass was higher in savannah than in the forests[14]. Higher fine root biomass and NPP at disturbed site in the present study could be attributed to positive effects of annual fire[15,16]. Similarly, Hadley and Kieckhefer[17] and Pandey[18] reported that the below-ground biomass and productivity in the first year after the annual fire exceeded that of unburned plots.

The biotic stress such as cattle grazing and trampling alter species composition of many plant communities and results into a change in fine root dynamics[19,20]. Similarly, Lorenz and Rogler[21] reported that below-ground biomass and turnover is affected in constantly cattle-grazed sites. The present study indicates that moderate grazing and trampling enhances the very fine root biomass and NPP. This is in confirmation with other reports available on Indian grasslands[22,23].

Fine root biomass and NPP were significantly ($P < 0.05$) greater under the undisturbed sites than in disturbed sites of both the forest locations, which could be attributed to high tree density and basal area along

**Table 2.** Seasonal variation in very fine and fine root standing crop biomass (g/m²) and net primary productivity (NPP) in disturbed and undisturbed deciduous forests in Western Ghats of Tamil Nadu

| Criteria | Season | Alagar hills Disturbed | Alagar hills Undisturbed | Kodayar hills Disturbed | Kodayar hills Undisturbed |
|---|---|---|---|---|---|
| Very fine root biomass (≤ 1 mm) | Rainy I (Sep.–Dec.) | 332 ± 72<br>2.72*<br>0.73** | 90 ± 18<br>0.72*<br>0.41** | 588 ± 46<br>4.82*<br>1.07** | 392 ± 52<br>3.69*<br>0.88** |
| | Dry (Jan.–Apr.) | 181 ± 21<br>1.84*<br>0.31** | 65 ± 7<br>0.53*<br>0.28** | 217 ± 34<br>2.39*<br>0.39** | 164 ± 23<br>3.2*<br>0.33** |
| | Rainy II (May–Aug.) | 224 ± 22<br>1.92*<br>0.51** | 82 ± 8<br>0.69*<br>0.38** | 257 ± 35<br>2.28*<br>0.69** | 300 ± 39<br>2.6*<br>0.52** |
| Fine root biomass (> 1 to ≤ 3 mm) | Rainy I | 104 ± 25<br>0.85* | 117 ± 11<br>0.96* | 124 ± 25<br>1.24* | 206 ± 18<br>1.69* |
| | Dry | 75 ± 8<br>0.51* | 83 ± 9<br>0.62* | 109 ± 13<br>0.98* | 163 ± 22<br>1.39* |
| | Rainy II | 93 ± 9<br>0.79* | 101 ± 10<br>0.89* | 184 ± 32<br>1.51* | 169 ± 13<br>1.7* |
| Annual NPP (g/m²/year) | | | | | |
| Very fine root NPP | | 393 | 164 | 666 | 604 |
| Fine root NPP | | 135 | 157 | 247 | 271 |
| Ingrowth NPP | | 177 | 136 | 262 | 210 |

*Seasonal productivity (g/m²/day) estimated by sequential core method.
**Seasonal productivity (g/m²/day) estimated by ingrowth core technique.

**Table 3.** Seasonal variation in very fine and fine root standing crop biomass (g/m$^2$) and net primary productivity (NPP) under open and closed canopies of deciduous forests in Western Ghats of Tamil Nadu

| Criteria | Season | Alagar hills Open | Alagar hills Closed | Kodayar hills Open | Kodayar hills Closed |
|---|---|---|---|---|---|
| Very fine root biomass (≤ 1 mm) | Rainy I (Sep.–Dec.) | 41 ± 6<br>0.42*<br>0.21** | 90 ± 16<br>0.72*<br>0.41** | 349 ± 46<br>3.44*<br>0.82** | 392 ± 54<br>3.69*<br>0.88** |
| | Dry (Jan.–Apr.) | 29 ± 4<br>0.34*<br>0.17** | 65 ± 7<br>0.53*<br>0.31** | 120 ± 15<br>2.56*<br>0.28** | 164 ± 23<br>3.2*<br>0.33** |
| | Rainy II (May–Aug.) | 36 ± 4<br>0.38*<br>0.2** | 82 ± 8<br>0.69*<br>0.38** | 258 ± 39<br>2.29*<br>0.42** | 300 ± 39<br>2.6*<br>0.52** |
| Fine root biomass (> 1 to ≤ 3 mm) | Rainy I | 57 ± 11<br>0.46* | 117 ± 11<br>0.96* | 140 ± 32<br>1.17* | 206 ± 18<br>1.69* |
| | Dry | 45 ± 5<br>0.39* | 83 ± 9<br>0.72* | 61 ± 11<br>0.69* | 163 ± 22<br>1.39* |
| | Rainy II | 51 ± 5<br>0.44* | 101 ± 10<br>0.89* | 109 ± 22<br>1.35* | 169 ± 13<br>1.70* |
| Annual NPP (g/m$^2$/year) | | | | | |
| Very fine root NPP | | 106 | 164 | 580 | 604 |
| Fine root NPP | | 65 | 158 | 263 | 271 |
| Ingrowth NPP | | 70 | 136 | 186 | 210 |

*Seasonal productivity (g/m$^2$/day) estimated by sequential core method.
**Seasonal productivity (g/m$^2$/day) estimated by ingrowth core technique.

**Table 4.** Fine root standing crop biomass (g/m$^2$) in different disturbed and undisturbed forest ecosystems

| Forest | Location | Diameter | Standing crop biomass (g/m$^2$) Undisturbed | Standing crop biomass (g/m$^2$) Disturbed | Source |
|---|---|---|---|---|---|
| Deciduous | Alagar hills India | ≤ 1 | 65–90 | 181–322$^a$<br>29–41$^b$ | Present study |
| | | > 1 to ≤ 3 | 83–117 | 75–104$^a$<br>45–57$^b$ | Present study |
| Deciduous | Kodayar hills India | ≤ 1 | 164–392 | 217–588$^c$<br>120–349$^b$ | Present study |
| | | > 1 to ≤ 3 | 163–206 | 109–184$^c$<br>61–140$^b$ | Present study |
| Dry deciduous | Varanasi India | ≤ 1 | 169 | 171$^d$ | Singh and Singh[27] |
| Tropical | Costa Rica | ≤ 2 | 139.9 | 89.7$^b$ | Sanford[3] |
| Shortgrass steppe | Colorado | All | 450 | 90$^b$ | Hook *et al.*[5] |
| Subtropical wet | Puerto Rico | < 2 | 294$^e$<br>204$^f$ | 344$^e$<br>168$^f$ | Silver and Vogt[24] |
| | | ≤ 1 | 406.9 | 226.7$^g$<br>288$^h$ | Kangas[31] |
| Hardwood | USA | All | 530 | 640$^i$<br>980$^j$ | Yin *et al.*[6] |

$^a$Cattle grazing; $^b$canopy openings; $^c$annual wild fire; $^d$unfenced; $^e$trenched plot after one month; $^f$trenched plot after one year; $^g$regrowth in pits after one year; $^h$regrowth in pits after four years; $^i$shelter woodcut; $^j$ clearcut.

with greater litter accumulation. Lower values detected in the disturbed sites may be due to high mortality and rapid turnover of fine roots[9].

The canopy openings alter edaphic environment such as soil moisture, soil temperature, light availability and nutrient cycling, which are ultimately reflected in fine root dynamics (Table 4)[3-5,9,24]. Ewel *et al.*[25] found no significant differences in fine root biomass 11 weeks following gap creation. A similar trend was reported in a low-land wet tropical forest of Costa Rica by Raich[2]. On the contrary, it has also been reported that fine root biomass and NPP in top 30 cm of the soil were much lower in openings in all sizes than under plants and declined steeply as opening size increased[3-5,24]. Lower levels of very fine and fine root biomass and NPP under canopy openings confirm and support the theory proposed by Wilczynski and Pickett[10] that the above-ground gap creates below-ground gap. This could be attributed to faster turnover rates[9]. Greater very fine and fine roots biomass and NPP under intact forests (closed canopies) could be attributed to greater litter accumulation along with higher tree density and basal area as suggested by Visalakshi[26].

Pattern of seasonal variations in root biomass and NPP (maximum during first rainy season and minimum in the dry season) observed in the present study is also in confirmation with others[26,27], and could be attributed to changes in edaphic environment such as soil moisture, soil temperature, litter accumulation and root turnover[5,9].

The present study thus reveals that disturbances such as annual wild fire and cattle grazing enhance very fine root biomass and NPP and also confirms the theory that the above-ground gap creates below-ground gap in deciduous forests.

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# Contrasting ultrastructures in the eggshells of olive ridley turtles, *Lepidochelys olivacea*, from Gahirmatha, Orissa

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**Normal and abnormal sized eggshells of olive ridley turtles, *Lepidochelys olivacea*, from Gahirmatha have been studied for ultrastructural characteristics. Fresh eggshells exhibit nodular shell units on the upper surface followed by a membranous network of fibres and a thin shell membrane. These structures are not seen in hatched eggshells as the calcium is resorbed during embryonic development. Abnormal shells do not show any such structure excepting disoriented fibres in its lower surface due to inadequate calcification.**

THE eggshell is a mediating boundary and together with other features it contributes to the isolation of the embryo from the nesting environment. Modifications of the shell structure have probably evolved for functional