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The characteristics, representativeness, function and conservation importance of tropical dry evergreen forest on India's Coromandel Coast

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Abstract: The central area of the Coromandel Coast, southeastern India, has been subject to a very long history of human habitation and land use change, substantially reducing the coverage of native forest. There are polarised views about definitive characteristics of native tropical dry evergreen forest (TDEF), albeit agreement that the habitat type is locally characteristic though now severely reduced, fragmented and degraded. A literature review was undertaken to determine the evolutionary origins of TDEF as well as its characteristics. A combination of both natural and human factors gives rise to TDEF, explaining the heterogeneity of existing stands even in close proximity to each other. Religious shrines are often associated with 'sacred groves', which are influential in the survival of stands of TDEF. These remaining stands are highly fragmented across the wider landscape and subject to species invasions from adjacent habitats as well as increasing human pressures. On the basis of existing evidence, it is not possible to describe TDEF through a definitive community of tree species, though typical constituent species are listed. TDEF may therefore be representative of a larger biome, as for example 'tropical rainforest', rather than a specific vegetation type. Nevertheless, there is general consensus about the importance of restoring TDEF, including its many associated plant and animal species, many of which have medicinal, spiritual and other uses and meanings. Regardless of biological definitions of TDEF, the functions it performs and the diversity of ecosystem services that it provides afford it substantial importance and reinforce the case for its protection and restoration. Successful local restoration activities highlight the feasibility of regeneration of TDEF, even from severely degraded and eroded land, and the associated regeneration of ecological and socio-economic values.

Keywords: Coromandel Coast, ecosystem services, restoration, Tamil Nadu, TDEF, tropical dry evergreen forest.

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Author Details: Dr. Mark Everard's research interests include ecosystem services, in particular human-ecosystem interdependences underpinning development challenges. He works extensively in India, with significant experience in other developing world settings including elsewhere in South Asia and both East and South Africa. Mark is a communicator in scientific and popular media about the multiple values that ecosystems provide for people.

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INTRODUCTION

The Coromandel Coast comprises the southeastern coastal region of peninsular India seaward of the Eastern Ghats and bordering the Bay of Bengal, between False Divi Point in the north and Kanyakumari (India's southern tip). There is a long history of human activity on the Coromandel Coast, ranging back to at least the second century AD based on artefacts from a Roman port near Pondicherry (Begley 1993; Begley et al. 1996) and possibly earlier with evidence of trade links with Egypt mediated by Romans (Chandra 2011). There is evidence of continuing occupation and settlement including archaeological records of villages dating back to the Chola period (around 1,000AD), settlements by European powers and a diversity of trading activities from the first half of the 16th century, and increasing Tamil populations in growing towns and villages. The population and, it can be assumed, associated environmental pressures of Tamil Nadu have boomed over the past six decades, rising from just over 30 million in 1951 to over 48 million in 1981 and continuing to ascend from nearly 79 million in 2014 (Indiaonline undated). It can be assumed that the native vegetation prior to its extensive exploitation, conversion or other forms of management was a climatic climax community, and in all probability a forest. Determining the precise natural forest type of the Coromandel Coast, however, has been contentious due as much to an extended history of landscape use and manipulation by dense populations long before formal surveys had been undertaken as to high natural climatic and topographical variability.

This paper draws on literature concerning the native forest of the central area of the Coromandel Coast, particularly the often polarised views around the tropical dry evergreen forest (TDEF), to describe its characteristics, representativeness, functions and conservation importance.

Coastal geography and development of the regional flora

The geological history of southern India includes migration of the Indian Plate, a major tectonic plate split off from Gondwanaland, that began moving northwards at about 15cm year^{-1} during the late Cretaceous Period (about 90 million years ago) (Zhu et al. 2005). Its collision with the Eurasian landmass, occurring from between 60 and 50 million years ago, is an ongoing process forming the Himalayan range and affecting physical and biological geography at subcontinental scale (Valdiya 2010). Data from fossil and contemporary fauna indicate that, throughout the late Cretaceous, India maintained exchanges with adjacent lands with no evidence, for example through a history of endemic species, of an extended period of isolation before its contact with Eurasia (Briggs 2003). The ecology of India therefore reflects substantial changes in physical geography, climatic zones and species invasions.

Southern India's biodiversity is diversified still further by wide variations in climate and geography across the contemporary Deccan Peninsula. Deciduous forests are most common on the better watered Malabar Coast and Western Ghats, the Western Ghats comprising a globally significant 'biodiversity hotspot' (Myers et al. 2000). Deccan thorn scrub forests are naturally more widespread in the drier, interior Deccan plateau. The Coromandel Coast falls in the rain shadow of the Western Ghats mountain range rendering the city of Chennai one of the driest cities in the country due in part also to the unpredictable, seasonal nature of the monsoon. Annual rainfall on the Coromandel Coast is approximately 1,250mm, but with a distinct gradation from north to south, and a highly seasonal pattern including light rains from June to September with intermittent heavy falls between October and December mainly resulting from depressions forming in the Bay of Bengal (the northeastern monsoon) (Balasubramanian & Bole 1993; Blanchflower 2003).

The Coromandel Coast is host to the 'East Deccan dry evergreen forests' ecoregion, constituting a narrow coastal strip and covering an area of 25,500km^2. Only two other ecoregions exhibit a similar pattern, the Sri Lanka dry-zone dry evergreen forests and the southeastern Indochina dry evergreen forests, reflecting related tectonic history and current climatic conditions (Dabholkar 1962). Similar forest assemblages are also found in northeastern Thailand (Bunyavejchewin 1999). The original vegetation of the ecoregion comprised forests with an understory of evergreen trees and an emergent canopy of taller deciduous trees, including Sal *Shorea robusta*, *Albizia amara* and *Chloroxylon* spp. (Dabholkar 1962).

Tropical dry evergreen forest (TDEF)

Champion & Seth (1968), with interests related primarily to forestry, identified six categories of Indian forests. One of these was 'tropical dry forests', in turn broken down into three distinct subtypes: tropical dry deciduous forests, tropical thorn forests, and tropical dry evergreen forests (TDEF). Under the Champion & Seth (1968) classification, 'typical' TDEF is dominated by the trees *Manilkara hexandra*, *Memecylon* spp.,

Diospyros sp., *Eugenia* spp., *Chloroxylon sweitenia*, and *Albizia amara*, though further sub-types were also noted. The definition of TDEF was therefore broad and described as 9–12 m high forest growing in lateritic and sand dune soils with a complete canopy and distributed along the coasts of Karnataka and Tamil Nadu states, and the Nellore District of Andhra Pradesh State.

Dabholkar (1962) characterised TDEF as a climax constituted by *Albizia amara* - *Acacia leucophloea* communities, recognising eight successional stages in its development from original ecoregional forests with an understory of evergreen trees and an emergent canopy of taller deciduous trees. Dabholkar (1962) attributed the elimination of the deciduous canopy species to intensive human forest use over a period of centuries. Meher-Homji (1974) corroborated the derivation of TDEF from dry deciduous forest by the disappearance of many typical deciduous species and invasion by some endemic species of the drier eastern half of southern India. Meher-Homji (1974) supported this analysis with an exhaustive list of TDEF species, with notes on biogeographical and fossil origins, of which the endemic southern Indian floristic element comprising >39% characteristic TDEF species but <10% of companion and dry deciduous species. Hunneyball (2003) found that 46-68% of tree species recorded across a range of TDEF sites surveyed in the literature are evergreen in habit. Paul Blanchflower (pers. comm. 30 March 2016) regards the evergreen nature of trees comprising TDEF as an adaptation to intermittent and often unpredictable rains, species with persistent, waxy leaves with low evapo-transpiration rates offering a selective advantage to exploit unpredictable rainfall events in preference to deciduous species that respond to more predictable annual weather patterns.

WWF (undated) recognises the vegetation in the eastern Deccan dry evergreen forests (type IM0204) as being "…distinctive from most of the other dry forests", occupying an area of 800 square miles (2,072km^2) extending as a narrow strip along the southern coastal areas of Andhra Pradesh and Tamil Nadu classified as a 'Critical/Endangered' habitat. The WWF vegetative definition of TDEF rests on the analysis by Champion & Seth (1968), including observations about the loss of original canopy-forming deciduous species, also noting a lack of endemic mammals or birds though supporting 66 known mammal species (two of them threatened) and 230 species of birds. Meher-Homji (1974) found that only six tree species were confined to dry evergreen forests: *Manilkara hexandra*, *Memecylon umbellatum*, *Drypetes sepiaria*, *Pterospermum suberifolium*, *Carmona microphylla* (now *Ehretia microphylla*) and *Garcinia spicata*. Whilst several of these species have a wider global distribution beyond the Coromandel Coast ecoregion, *M. hexandra* occurring as far north-east as China and *E. microphylla* with an Indo-Malaysian distribution, this is not inconsistent with the observation by Dabholkar (1962) that Coromandel Coast TDEF has similarities with Sri Lanka dry-zone dry evergreen forests and southeastern Indochina dry evergreen forests reflecting common tectonic history and current climatic conditions.

In a study of 37 stands of TDEF, Blanchflower (2003) found a total of 915 angiosperm species, both native and exotic, of which 343 were woody species. Blanchflower (2003) concluded that core tree species of remaining TDEF comprised: *Albizia amara* ssp. *amara*, *A. lebbeck*, *Atalantia monophylla*, *Azadirachta indica*, *Cassia fistula*, *Chionanthus mala-elenga*, *Crateva magna*, *Dalbergia lanceolaria*, *Diospyros ebenum*, *D. ferrea*, *Drypetes sepiaria*, *Lannea coromandelica*, *Lepisanthes tetraphylla*, *Manikara hexandra*, *Psydrax dicoccos*, *Pterospermum canescens*, *Sapindus emarginata* and *Syzygium cumini*. Blanchflower (2003) also concluded that broad common characteristics of this apparent climax vegetation, reflecting convergent evolution adapting to local climate, included evergreen, simple leaves often with waxy upper surfaces, seeds often contained in small fruits appearing between April and September, slow growth with wood generally dense and hard, and generally lacking thorns though with some exceptions. Blanchflower (2003) ascribed all of these features as resulting from convergent evolution adapting to infrequent, intermittent and unpredictable rains. Given the current fragmented and generally disturbed nature of TDEF patches, it is in practice difficult to assert that this is a genuine climax community, but it is certainly representative of an advanced stage in forest succession. Of the 310 woody species recorded at Pitchandikulam Forest (Pitchandikulam Forest Virtual Herbarium: www.pitchandikulam-herbarium.org, accessed 25 October 2017), 55 are in the family Fabaceae suggesting an additional nitrogen-fixing adaptation to low nutrient conditions.

Seeking a consensus across these different characterisations of TDEF reveals as much about the heterogeneity of extant forest stands as the commonalities. The commonly reported tree species across studies (including those listed on the Pitchandikulam Forest Virtual Herbarium) are *Albizia amara* (3 studies), *Manilkara hexandra* (4 studies), *Albizia lebbeck* (2 studies) *Diospyros ebenum* or *Diospyros* sp.

(3 studies: the Pitchandikulam Forest Virtual Herbarium lists six species of *Diospyros*) and *Drypetes sepiaria* (3 studies). Drawing from work by Meher-Homji (1974), Balachandran et al. (2015) suggest that a classification of '*Albizia amara* community' is a more useful definition based on the wide distribution of the species across the coastal plain, and Sprangers & Balasubramanian (1978) suggest '*Drypetes-Strychnos-Memecylon* association' due to the occurrence of species dominance in this forest type.

What is also clear from comparative analyses is the extent to which TDEF today is highly fragmented and substantially degraded, and that this has been the case for centuries. The original characterisation of Champion & Seth (1968) noted that the few remaining extant stands of TDEF were already substantially degraded through logging and grazing. Although problems with identifying original forest cover and type have been addressed previously, Ramanujam et al. (2003) estimate that 95% of the original forest cover has been cleared. Only about 4% to 5% of original TDEF patches remain today (Meher-Homji 1992; Wikramanayake 2002). Even in these isolated pockets, often afforded a degree of protection by their close association with sacred groves surrounding temples (Ramanujam & Kadamban 2001), species composition of the remaining forests has been altered by intensive human use including the removal of taller trees (Ramanujam et al. 2003). The size of sacred groves, whilst variable, is also generally small ranging in size from clumps of a few trees to a few hectares (Chandrakanth et al. 1990). The composition of surviving stands of TDEF may therefore reflect pressures imposed upon them due to, as an ecological generality, species often becoming hyper-disturbed in smaller habitat fragments (Laurance 1997).

The agency of human interference is not entirely damaging. The formation and characteristics of TDEF cannot be dissociated from changing geographical, climatic, biogeographic as well as human pressures, particularly the selective felling of taller deciduous trees. These pressures have changed over varying timescales, therefore constituting a habitat type in flux, and also a 'cultural landscape' the biodiversity and ecosystem services of which are shaped by human management over an extended history of settlement and land use (Antrop 1997, 2005; Jones-Walters 2008; Schaich et al. 2010). The ecoregion's remaining forests are now characterized by areas of leathery-leaved evergreen forest, populated by a range of birds, mammals, reptiles, fungi and other taxa, some of which play vital roles with associated close phenological linkages in seed dispersal, pollination and other supporting services within the forest ecosystem (Reddi & Reddi 1984; Balasubramanian & Bole 1993; Balasubramanian 1996; Blanchflower 2003).

Gadgil & Meher-Homji (1986), in a study identifying localities significant for conservation of Indian biodiversity, developed an alternative classification scheme that included a heterogeneous category of dry evergreen forest spread over a wide range with a gradation of annual rainfall, suggesting a categorisation of TDEF representative of a larger biome (as for example 'tropical rainforest') rather than a specific vegetation type. This conclusion is supported by the considerable variation between clumps of TDEF, even between forest patches in close proximity to each other, as well as over time and in response to human pressures as recorded by Hunneyball (2003) and Mani & Parthasarathy (2009). This heterogeneity between patches may be amplified by the fragmented nature of remnant TDEF, with greater vulnerability to species exploitation, invasion and other external pressures.

This story of TDEF development and characteristics is not without contest. In an opinion article, Daniels et al. (2007) sought to dispel "*…the myth of tropical dry evergreen forests of India*" as the original vegetation type that covered the coasts of peninsular India. Daniels et al. (2007) question whether the assemblages of plants identified by Champion & Seth (1968), Gadgil & Meher-Homji (1986) and Meher-Homji (1974) as characterising TDEF are remnants of a once widespread distinct forest type or are merely an opportunistic assemblage of species adapted to local microclimatic conditions, the most recent stage of succession rather than belonging to a climax vegetation type. There is certainly virtue in the argument erected by Daniels et al. (2007) as Meher-Homji (1974), to whom the definitive definition of TDEF is often attributed, believed that TDEF appears to derive from the dry deciduous forest through disappearance of many typical deciduous species and invasion of some endemic species of the drier eastern half of southern India. It is therefore likely that TDEF is as much a now fragmented 'cultural landscape' as a formerly pervasive, uniform habitat type shaped solely by fluctuating natural processes.

Current status of TDEF

On the southeastern seaboard of peninsular India, TDEF occurred only within a very limited range, extending inland only between 30km (Gamble 1967) and 60km (Champion 1936). This distribution is coincident with a high human population, the long-term pressures of which

Table 1. Areas and proportions of growth forms recorded in the literature, after Venugopal et al. (2008) with the additions of information from the Pitchandikulam Forest

Site	Area (ha)	No. of species (GBH = girth at breast height)
Point Calimere	2,400	200 dicots; 317 flowering plants (Blasco & Legris 1972; Balasubramanian & Bole 1993)
Kuzhanthaikuppam	1.2	54 (woody species ≥10cm GBH, sites combined) (Parthasarathy & Karthikayen 1997)
Thirumanikuzhi	1.6	54 (woody species ≥10cm GBH, sites combined) (Parthasarathy & Karthikayen 1997)
Puthupet	14	51 (woody species ≥10cm GBH) (Parthasarathy & Sethi 1997)
Arasadikuppam	1.5	31 (woody species ≥10cm GBH) (Venkateswaran & Parthasarathy 2003)
Oorani	1.8	30 (woody species ≥10cm GBH) (Venkateswaran & Parthasarathy 2003)
Pitchandikulam	26.3	310 woody species of trees, climbers and shrubs of which 55 are in the family Fabaceae (www.pitchandikulam-herbarium.org, accessed 5 April 2018)

have rendered TDEF one of the rarest types of forest ecosystem found in the subcontinent (Blanchflower 2005). Consequently, TDEF has not comprised a dense and extensive forest system in living memory, or perhaps even recorded history. Rather, it has existed as clumps of locally highly variable character in arid landscapes. For example, Venugopal et al. (2008) summarised from the literature the areas and proportions of different vegetative growth forms in TDEF stands, reproduced at Table 1. Data from Pitchandikulam Forest (not listed by Venugopal et al. 2008) are added to this Table 1.

Long-term human interventions are arguably one of the pressures that has characterised TDEF. The Coromandel Coast ecoregion has been substantially altered by human activity particularly throughout its long history, with an increasing intensity of agriculture, forestry and urban development. Human pressures certainly influence forest characteristics. Comparing the vegetation in two TDEF stands on the Coromandel Coast, Visalakshi (1995) concluded that soil properties and extent of human disturbance constitute major factors influencing the vegetation in both forests. Venkateswaran & Parthasarathy (2003) analysed human disturbance in two stands of TDEF hosting sacred groves or temple forests, classifying site disturbances into: site encroachment; temple visitor impacts; cattle and goat browsing; and resource removal. Comparison between the two sites found that greater disturbance reduced forest stature, though it increased tree density albeit with more multi-stemmed individual trees. The less disturbed site also had a greater proportion (77%) of evergreen species compared to 65% at the more disturbed site. Comparison with other stands of TDEF further supported evidence that human disturbances have impacts on forest stand characteristics such as stand height, number of strata, tree density and basal area. Mani & Parthasarathy (2009) investigated changes in tree species diversity, stand density and above ground biomass in two TDEF forests after a 10-year interval (1995–2005), recording 7.7% and 15% decreases in tree diversity, a 10.5% decrease and a 17.5% increase in tree density, and a 2.3% increase and a 6.8% decrease in basal area, with additions and losses of species and considerable variation in tree species, attributing most changes to the cumulative effects of site quality and human activities. Baithalu et al. (2012, 2013) undertook similar re-censuses of trees at two TDEF sites, recording species changes mainly attributed to human interference. Most of the Coromandel Coast ecoregion's former forests have been degraded into tropical dry evergreen scrublands, characterized by thorny species such as *Ziziphus glaberrima*, *Dichrostachys cinerea*, *Catunaregam spinosa*, and *Carissa spinarum* (Puri et al. 1989); however, even these 'agricultural fallows', or 'wastelands' (land not used for development), have societal value as Kinhal & Parthasarathy (2008) record that 64% of plant species found in them, mainly of widespread distribution, serve a range of uses by local people. These uses are mainly for traditional medicinal purposes (53 of 110 species), particularly by people lacking modern medicine, with other uses including raft-making, hair care, religious purposes, fuel wood, edible fruits, pesticide, fodder and carpentry.

Less than 1% of TDEF in the ecoregion lies in reserves or protected areas, generally existing as small and fragmented stands (Rajan 2001). Many extant TDEF stands are very small, such as the sacred grove near Marakkanam in Tamil Nadu preserving a section of evergreen closed canopy forest and several other temple groves in the surrounding area including Puthupet, Pillaichavadi, Mudaliarchavadi, and Kottakarai each preserving small enclaves of forest (Ramanujam & Kadamban 2001). The Point Calimere Wildlife and Bird Sanctuary protects a 17.26km^2 enclave of dry evergreen forest (Rajan 2001 records that it contains a 24km^2 patch of TDEF comprising one of the largest remnants of this

forest type), as well as tidal wetlands and mangroves (Blasco & Legris 1973). Scattered remnant TDEF stands are found in several other wildlife reserves in the region. Udayakumar & Parthasarathy (2010) identified 75 TDEF sites along the Coromandel Coast, many of them poorly known sites even within the Indian subcontinent.

Human interventions in TDEF also include active restoration. Restoration of indigenous TDEF at Pitchandikulam Forest, Tamil Nadu, has been in progress since 1973 as a pioneering activity of the Auroville green belt communities, transforming a 70-acre (28ha) bare eroded township site into a complete ecosystem now comprising more than 800 species of plants (Pitchandikulam Forest, undated a). The Pitchandikulam Bio Resource Centre (PBRC) continues to provide a focus for the teaching of restoration ecology, environmental science, identification and use of indigenous medicinal plants, and outreach with communities across the Kaliveli bioregion. PBRC is also working in close partnership with local people to promote restoration of TDEF with an integrated programme of educational, traditional medicinal and handicraft business and female empowerment initiatives on 35 acres (0.14km^2) of reforestation at Nadukuppam to the north of Auroville near the Kaliveli Estuary (Pitchandikulam Forest undated b). A floristic study of herbs and climbing plants in a 160ha forest stand between the eastern shore of the fresh water Ousteri Lake and about 10km west of Puducherry City, southern India, found that active human intervention over a 30-year period, including introduction of plant species and interventions to enhance soil fertility and groundwater levels, regenerated deteriorating TDEF vegetation allowing recovery of 172 naturally occurring herbaceous, climbing species with lowland herbaceous species also re-establishing as green cover at ground level (Ponnuchamy et al. 2013).

The functional significance of TDEF

Whatever the status of TDEF—definitive forest type or plastic biome distinctive to the Coromandel Coast and some other regions with a similar biogeography—the functions that it performs within the landscapes in which it is found are significant. The Millennium Ecosystem Assessment (2005) recorded a wealth of ecosystem services provided by global forests, of which their role in climate stabilisation through carbon storage and sequestration were particularly significant. Everard et al. (2017) explored the carbon sequestration services of restored TDEF, concluding that they were highly significant and represented a powerful business driver for forest restoration; however, it was also recognised that climate regulation, whilst an 'anchor service' (sensu Everard 2014) providing the driving business priority, is but one of a wide spectrum of interconnected ecosystem service benefits stemming from both renewable energy generation and TDEF restoration as summarised by Everard et al. (2017). A number of the (nonquantified) ecosystem service benefits likely to arise from restored TDEF are reproduced in Table 2.

All of these values are significant for multiple constituencies of society, despite historic tendencies to maximise one or a few generally utilitarian ecosystem services in ecosystem use or management, driven by the generally narrow disciplinary interests of specific government departments, regulatory bodies, businesses, land managers or other constituencies often blind to or dismissive of externalities. Recognition of systemic outcomes across all ecosystem services and their associated beneficiaries requires a more integrated basis for decision-making. Decisions about outcomes from management therefore need to be addressed on a systemic basis, taking account of the breadth of value systems and distributional outcomes central to the UN Millennium Ecosystem Assessment categorisation of ecosystem services (Millennium Ecosystem Assessment 2005), which took account of a broad range of often nonsubstitutable economic and noneconomic values flowing to humanity from nature. Externalities entailed in contemporary intensive farming systems and indeed the cumulative effects of agricultural activities are recognised as amongst the greatest threats to wetland and other terrestrial ecosystems and their broad range of services (Millennium Ecosystem Assessment 2005a,b). This consideration applies as much to novel markets and service-enhancing schemes, however, which are not immune from a blinkered approach to maximising a few favoured ecosystem services, to the net detriment of non-focal services. The hydrological roles of TDEF are particularly under-researched, though forests are known to play important roles in the capture, retention and cycling of water in landscapes (Shvidenko et al. 2005) amongst a wide range of other ecosystem services, suggesting that restoration of TDEF may have ecologically and socio-economically important roles to play in reversing saline intrusion and other forms of groundwater and water resource depletion on the Coromandel Coast (Bhattacharya et al. 2005).

Recognition of the broader, primarily nonmarketed services produced by ecosystems has been inconsistent. Some that are valued financially for recreation and tourism have been more widely recognised (Sen et al. 2014), whilst other habitats of widely-acknowledged

Table 2. Ecosystem service benefits likely to arise from TDEF restoration (after Everard 2017)

Provisioning Services: · **Fresh water** availability enhanced by quality, quantity and recycling processes. · **Enhanced aquifer recharge** resulting from water retention and percolation. · **Food security and food availability** by direct cropping or polyculture. · **Fuel and fibre resources** available for use or trade. · **Genetic resources** with potential value for stock or crops. · **Species with medicinal properties** particularly used in traditional medicine (Rajendran & Agarwal 2007; Parthasarathy et al. 2008).
Regulating Services: · **Enhancement of air quality** metabolism of pollutants, settlement of particulate matter and avoidance of aeolian erosion. · **Microclimate regulation** within and adjacent to the forest. · **Global climate regulation**, primarily by sequestering carbon. · **Catchment hydrology** buffered by tree cover. · **Buffering natural hazards** such as storms, protecting infrastructure and crops. · **Regulation of pests and diseases** through predation and purification. · **Erosion regulation** binding the surface of formerly eroded. · **Water purification** through slowing water flows and purification processes. · **Pollination**, by playing host to pollinating organisms. · **Regulation of soil salinisation** through restoration of landscape hydrology. · **Visual and noise buffering**.
Cultural Services: · **Cultural heritage** traditionally associated with forests, including trees of particular cultural significance such as the Banyan *Ficus benghalensis* which is the national tree of the Republic of India. · **Recreational and tourism** associated with forests. · **Aesthetic importance** contributing to physical and psychological health. · **Spiritual importance** including regenerating sacred groves and specimen trees (including for example Peepal *Ficus religiosa* and Banyan *Ficus benghalensis*). · Inspiration of **artistic, mythological, folklore** and other **cultural expressions**. · **Income, employment** and **training opportunities**, particularly women. · **Educational and research opportunities**, both formal and informal.
Supporting Services: · Enhancement of linked **soil formation**, **primary production**, **nutrient cycling**, **water recycling**, **photosynthetic oxygen production**, and **provision of habitat** rebuilding ecosystem integrity, functioning and capacity to produce other beneficial services, particularly where it replaces degraded habitats.

spiritual and/or heritage value also receive explicit protection including, for example, informal taboos surrounding Hindu temples and more formal designations such as qualifying features within world heritage sites and biosphere reserves. Diverse meanings attributed by different stakeholder groups, however, are often poorly represented in decision-making, with immediate utilitarian values often dominating perceptions and ensuing decisions. Where ecosystem services relating to traditional values are overlooked or undervalued, degradation of ecosystems through narrow utilitarian uses undermines the physical health and socio-economic wellbeing of communities, their cultural identity and their long-term viability. Recognition that human inhabitants shape the biodiversity and associated ecosystem services of the 'cultural landscapes' they inhabit is significant for informed and integrated management (Antrop 1997, 2005; Jones-Walters 2008). The diversity of ecosystem services that these landscapes provide create strong ties between humans and their natural surroundings, constituting amongst the strongest incentives for people to engage with environmental conservation even if they remain today too frequently marginalised relative to more quantitatively assessed services (Schaich et al. 2010).

DISCUSSION

Some classification schemes have definitive boundaries, for example discrete 'year classes' within populations of trees, fishes and other species with distinct annual breeding seasons. Other classification systems have more porous boundaries based on generic and often descriptive clustering across a continuum for management or other purposes, as for example chemical and biological river quality classes, human school years, and distinctions between subspecies across a broad biogeographical range.

The initial segregation of India's diverse forests into types and sub-types by Champion & Seth (1968) was of the latter kind, splitting the diversity of the whole of India's forest cover into six categories each with sub-categories, of which TDEF was one of three distinct subtypes within the 'tropical dry forests' category. Subsequent analyses and characterisations of TDEF have encountered high variability within and between often adjacent stands, as well as the significant degree to which this forest type is shaped by both natural (such as soil, topography, climate and genetic exchange with nearby habitats) and human agencies, significantly including the selective removal of taller tropical dry deciduous tree species to leave an evergreen canopy typically around 9m high.

The heterogeneity of TDEF is further compounded by its current fragmented state, the few remnant stands representing 4-5% of original TDEF patches (Meher-Homji 1992; Wikramanayake 2002) and probably a great deal less today due to increasing pressures from expanding human numbers as well as changing lifestyles in Tamil Nadu. Increasing fragmentation is likely to reduce the viability of some native species, accelerate invasions from adjacent habitats and land uses, and increase vulnerability to grazing, timber and fuelwood cropping and other human pressures.

TDEF then is far from a definitive forest type, but is rather one that is variable in characteristics. It is as much a product of natural forces as reflective of 'cultural landscapes' shaped by long-term human interventions that may be formative, destructive and also protective, as in the instances of temple and other sacred groves as well as nature reserves. From both biogeographic and cultural perspectives then, the wider evidence supports the conclusion arrived at by Gadgil & Meher-Homji (1986) that a categorisation of TDEF represents a generic biome rather than an unambiguously bounded vegetation type.

Recognition of TDEF as a necessarily plastic biome, however, in no way undermines the value of the categorisation. The vegetation of the Coromandel Coast has undergone substantial conversion, with loss of forests a significant feature over many centuries of intensifying human history. It may not therefore be possible to say with certainty which tree communities constitute a definitive 'natural' land cover, if indeed a meaningful baseline can be identified with confidence given continuing tectonic, climatic and human fluxes overextended time scales, as variations in exact forest composition can be expected across rainfall, topography, soil type and other gradients and exchanges with adjacent habitats. We understand some of the species diversity found in fragmented remnant of this forest type, which can form the basis for forest restoration efforts; however, local selection pressures will be likely to influence eventual species dominance on a site- and context-specific basis. Nevertheless, whatever the final species composition, restoration of this broad forest type/biome is a priority if the 'carrying capacity' of ecosystem services generated across the Coromandel Coast—for wildlife, hydrology, soil fertility and a range of associated human needs—is to be regenerated as a major contribution to sustainable development.

The 40+ year history of regeneration at Pitchandikulam Forest, reflective of significant and enduring dedicated efforts from a baseline of severely degraded and eroded land and now manifesting as a mature forest community with a wide assemblage of recovered species across multiple taxa, highlights that when an appropriate mix of species is planted and nurtured then a regionally representative forest can re-emerge from what was once a virtually useless and uninhabitable wasteland. As noted previously, whilst the Pitchandikulam Forest is largely protected, disturbed only by largely non-disruptive educational and research uses, it is contentious to assert that it represents a genuine climax community though it is certainly representative of an advanced stage in forest succession. There are also other localised patches of TDEF being restored in the Coromandel Coast strip, including at the Auroville Botanic Gardens and also at Nadukuppam in the Kaliveli catchment, where successes achieved at Pitchandikulum are being replicated with the involvement of people from local villages.

Beyond the biological relevance and demonstration of the potential for regeneration of a regionally representative biome, if not an exact replica of what may have preceded the previous history of forest and landscape destruction, there are also significant functional reasons for recognising, valuing and regenerating TDEF. Though derived on a largely illustrative basis, the analyses of ecosystem services likely to be enhanced by restoration of TDEF includes significant calculated benefits stemming from the 'anchor service' of climate regulation, but also a wider range of connected enhancements to additional ecosystem services likely (albeit not quantified) to stem from regenerated forest. The role of restoration of TDEF in recovery of the damaged freshwater systems of the Coromandel Coast may be particularly significant. Recognition of all of these diverse benefits, not merely those closest to markets, is important for connecting with the value systems of local people, as for example those instrumental in safeguarding remnant sacred groves, potentially representing strong incentives for their engagement in conservation efforts (Schaich et al. 2010). This emphasises the importance and indeed dependence of ecosystem regeneration on benefits connecting with the real-life experiences of local people, their roles as active managers, the importance to them of less tangible spiritual and cultural values, and collaboration across scales (Folke et al. 2005). Taking account of cultural context and associated, often highly localised cultural values is vital in decision-making that represents the needs and perspectives, and elicits the support, of local people who are at the root of community-based solutions. Local-scale decision-making and resource stewardship can make significant differences at landscape scale, rebuilding support,

management action and ensuing ecosystem resilience from village to sub-catchment and up to progressively higher scales.

In conclusion, TDEF is at best a coarse classification of a regionally representative forest type, plastic in local form due to a range of natural and human factors and significantly influenced by local variability in both as well as edge effects. It may well represent a biome rather than a definitive vegetative type, but the classification nevertheless remains valid if viewed from a functional perspective rather than a purist botanical definition. If understood in this context, the term TDEF remains useful, and indeed has already done so as evidenced by restoration efforts. The term 'Coromandel Coast forest', however, may be less contentious, and therefore more helpful, if it evades some of the criticism levelled at TDEF as a strict botanical rather than a more general descriptor.

What is of overriding importance, and a matter of generally unspoken consensus of supporters and critics of the term TDEF alike, is that more of it is needed to rebuild severely degraded regional ecology, ecosystem functioning and with it a diversity of ecosystem services helpful in addressing a range of local problems including, as pressing examples, combating coastal saline groundwater intrusion and the erosion of soil quality and quantity, hydrological buffering rebuilding resilience to droughts and flooding, and pollination of crops in a predominantly agricultural region underpinning food and livelihood security.

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