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‘Foresting’ the grassland: Historical management legacies in a forest-grassland mosaic in southern India and lessons for the conservation of tropical grassy biomes

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Abstract

Colonial encounters with tropical ecosystems were primarily driven by profit-oriented management practices; witness the extensive network of timber and forestry practices that were set up across colonial India. In contrast, the colonial engagement with the montane forest-grassland mosaics of the higher reaches of the Western Ghats in southern India was marked by intensive investment in vegetation management by colonial foresters that yielded no profits. In this archival study, we trace the history of extensive vegetation transformation in this landscape from the early nineteenth to the early twentieth century. We show how the misperception that the grasslands within this mosaic must have resulted from tree felling, fire-setting and buffalo grazing by indigenous communities led colonial foresters into a century-long effort at ‘foresting’ the grasslands, primarily through large-scale planting of exotic tree species. These efforts persisted despite economic losses and ecological evidence that native tree seedlings planted in the grasslands repeatedly failed to establish. These policies continued unabated into the late

twentieth century in newly independent India. Today, the once picturesque landscapes of these ancient forest-grassland mosaics are diminished by large-scale plantations of exotic species. Some of these species have become invasive and pose significant threats to the remnant natural grasslands. While this historical narrative is set in the forest-grassland mosaics of southern India, it finds striking parallels in the current day, with grasslands and savannas globally threatened by the misperception that they are 'degraded ecosystems' that can be 'forested' or converted to other 'productive' land uses. We suggest that this case history portends the potential fates of many of earth's threatened tropical grasslands and savannas.

Keywords: Colonial forestry; History; Invasion; Shola-grasslands; Tree plantations; Western Ghats

1. Introduction

Colonial encounters with tropical ecosystems were mostly driven by economic considerations, prominent amongst which was timber production (Gadgil and Guha, 1993). Colonial forestry was also marked by attempts to regulate nature in the name of 'scientific forestry' and 'conservation' (Kumar et al., 2011). In this regard, the transformation of the tropical forest (locally known as *shola*) - grassland mosaics of the upper reaches of the India's Western Ghats stands out as a unique example in the history of colonial forestry because, unlike other landscapes, there were initially no timber trees in these landscapes and thus no apparent economic benefits to be gained, but colonial foresters nevertheless strived to control the vegetation and indigenous people of these landscapes (Sutton, 2011). The huge ensuing effort to transform the native vegetation in this landscape, ostensibly to 'restore' it, appears to have been rooted in the misperception that the grasslands of these mosaics were the outcome of deliberate fires and extensive cattle grazing by indigenous communities, and it was thus necessary to reforest these in order to restore their integrity and productivity. These beliefs are evident from the following excerpts from the first manual of the Nilgiri landscape, a section in the southern Western Ghats that harbours one of the largest areas of shola-grassland mosaics in the Western Ghats : "*It is, however, to be remembered that the present park-like appearance of the higher plateau, with its downs and woodlands, is also, in a great measure, due to the annual recurrence of fires which sweep over the hills, burning the grass and outlying scrub and even the smaller sholas, and checking the larger woods in their persistent efforts to extend their domain further along the sides of the valleys…Periodical fires and the grazing of the buffaloes help to keep this line distinct, and if the trees are torn or cut for firewood, nature restores the injury done to her with a lavish hand, and throws a mantle of rich green drapery over the wound"* (Grigg, 1880).

Today, it is well-established that the shola-grassland mosaics of southern India are naturally bi-phasic Pleistocene relics that have been in existence for more than 20,000 years (Sukumar et al., 1993, 1995). Climatically sensitive, the relative extents of shola and grassland within these mosaics have naturally contracted and expanded with past climatic changes with grasslands expanding during periods of high aridity, low temperature and low CO_2 levels (Meher-Homji, 1967; Sukumar et al.,1993,1995). These unique ecosystems support a diverse array of plant and

animal species, many of which are endemic to these landscapes. These include such examples as the Nilgiri tahr (*Nilgiritragus hylocrius*; the only mountain goat in peninsular India), the Rhododendron tree (*Rhododendron nilagiricum*), and the white-bellied short-wing bird (*Brachypteryx major*), the closest relatives of which appear again only in the temperate Himalayas, more than 2000 km to the north (Schaller, 1971; Robin et al., 2002; Thomas and Palmer, 2007; Mohandass and Davidar, 2009). Importantly, of 306 recorded plant species occurring in grasslands at one of these mosaics, 51 are endemic (Karunakaran et al., 1998), attesting to the ancient assembly of the grassland communities.

In the following sections, we recreate from historical records and the literature, the ecological management of these forest-grassland mosaics in the Nilgiri landscape during the colonial period, focusing on the drivers of vegetation transformation in the region through large-scale introductions of multiple exotic plant species and subsequent invasions. We trace how these plantation experiments, based on cultural perceptions rather than ecological understanding, have had dramatic and long-term negative consequences for these highly diverse ecosystems. We conclude by comparing this case history with current day scenarios of grassland management, where tropical savannas and grasslands are heavily threatened by land-use conversion and large-scale afforestation, and have attracted prominent attention in recent scientific literature (Bond and Parr, 2010; Veldmann et al., 2015a,b; Bond, 2016; Lehmann and Parr, 2016; Ratnam et al., 2016; Griffiths et al., 2017).

2. Chronology of colonial management history of the Nilgiri mountain ranges, southern India

2.1. Early occupation and the fuel-wood crisis

"They [the hills] are as smooth as the lawns in an English park, and there is hardly one of them which has not a mass of dark wood terminating suddenly as if it had been planted…"
This is how Sir Thomas Munro, The Governor of Madras Presidency, described the newly discovered forest-grasslands mosaics in the Nilgiri mountain ranges of India's Western Ghats in 1826 (Fig. 1a; Price, 1908). These mosaics, which occur in the upper reaches (1200 m to 2650 m asl) of the Western Ghats (8° to 21°N, 73° to 78°E; Das et al. 2015), are characterized by stunted evergreen tree forest patches, locally known as *sholas*, interspersed within grasslands, with abrupt boundaries between the two vegetation types (Fig. 1b). These cool, scenic landscapes of the upper reaches of the Western Ghats were more reminiscent to the British of their homeland than the hot, dusty plains of southern India.

Mr. Sullivan, the Collector of the Coimbatore district in the Madras Presidency in the 1820's, was particularly taken with the montane landscapes of the Nilgiris and strongly recommended that the Madras Government develop these areas as a sanitarium for injured British soldiers. He began by building roads and few houses on the Nilgiri plateau with government grants, and other British officials soon followed suit and built a few more houses (Sutton, 2011; Baikie, 1857).

Prior to European settlement, the Nilgiri plateau was sparsely populated by indigenous communities. Prominent among these were the *Badagas*, then numbering 3778, who cultivated subsistence crops such as ragi and barley, whereas the *Todas*, with a population of merely 222, were buffalo herders. The *Kotas*, numbering about 317 were artisans who provided tools and implements to other indigenous groups. Finally, the *Irulas* and *Kurumbas*, with smaller populations of around 300 each practiced hunting-gathering and shifting cultivation for subsistence (Grigg, 1880). These communities, each with distinct ways of resource use, were living harmoniously with each other (Grigg, 1880; Prabhakar, 1994). Notably though, despite their low population densities, it was assumed that they had transformed the landscape through felling and fire.

As the European settlements in the region increased, the demand for fuelwood also increased, leading to large-scale felling of shola forests around the new colonial settlements: Udhagamandalam, abbreviated as Ooty (then known as Ootacamund) and Wellington. This in turn led to legislation by the Madras Government in 1836 to prevent such indiscriminate felling in the Nilgiri plateau, to protect the springs that provided water to the lower country (Grigg, 1880). Woodcutting without the permission of the Collector was prohibited, and brick manufacturing, which required high amounts of fuelwood, was completely banned (Grigg, 1880; Sutton, 2011). These were amongst the first attempts by the colonial government to exert control over the land and its indigenous people, most of who were completely dependent on these forests and grasslands for their living. Subsequently, in 1841, a contractual system was established for the commercial supply of fuelwood to Ooty and Wellington, where a contractor had to bid for the right to fell from a shola selected by local authorities and sell the fuelwood to the settlements (Sutton, 2011).

Despite these legislations, the steady felling of shola forests continued through the 1850's, and the Forest Department set guidelines to restrict forest destruction in 1857. The protection of springs, conservation of timber, as also the aesthetic appearance formed the basis for these guidelines for managing plant resources on the Nilgiri plateau (Sutton, 2011). However, recognizing the insufficiency of fuelwood supply to support the continued rise in demand, the government in 1861 nevertheless allotted a large number of sholas to wood contractors to meet fuelwood needs (Morgan, 1861; Sutton, 2011). At the same time, the rise in fuelwood demand also provided a lucrative opportunity for local communities who began cutting shola trees in their vicinity for sale as fuelwood to European settlers. The local forest authorities constantly complained about such illegal cutting and recommended that the rights of local communities to cut wood and graze cattle be restricted. The European settlers, on the other hand, appeared to have had no objection to the provision of fuelwood by local communities, despite it being "illegal". Rather, they opposed every attempt by the local government to stop local communities from cutting and selling fuelwood to enforce their monopoly over fuelwood supply (Sutton, 2011).

2.2. Introduction of exotics

The continued and ever-increasing demand for fuelwood eventually led to the introduction of fast growing exotic tree species in the Nilgiris. Through their rule and governance over forests from 1820's to 1937, British Forest officials introduced and widely planted more than forty exotic species on the Nilgiri plateau (Table 1). The first exotic tree plantations were established in grasslands in 1856 with the aid of government grants, and mainly consisted of the Australian species *Acacia melanoxylon* and *Eucalyptus globulus* (Grigg, 1880; Sutton, 2011). These were established near what is present-day Ooty and Wellington on 600 acres of grassland with 200,000 tree seedlings. Along with these two exotic species, attempts were also made to plant native shola species in grasslands. However, these were quickly abandoned due to the high mortality and extremely slow growth of native shola tree seedlings in grasslands (Sutton, 2011). In 1861, a further two species of Acacia, *Acacia stricta* and *Acacia mollissima* (most likely a synonym for *Acacia mearnsii* De Wild which was officially described only much later in 1925*;* Khan, 1962, The Plant List, 2013) were introduced. However, in archives, *Acacia mollisima* also seems to be used to refer to *Acacia dealbata* Link, a closely related species of *A. mearnsii*, which was planted on the cleared Governor's shola area located around eight km from Ooty (Morgan, 1861; Brandis, 1883). A nursery was established in 1862 to prepare seedlings for planting in cleared sholas and on grasslands, and within a year, the nursery had 300,000 to 400,000 tree seedlings, chiefly of different species of Acacia (Beddome, 1863).

The progress of these newly established plantations was, however, not satisfactory. The Forest Department came up with different explanations for this. The Conservator of Forests at the time, Mr. HR Morgan, in 1861 reported, "*These plantations have not hitherto made the progress expected of them, the causes are plain, the greater part of the plantations face the south, and from being exposed to the monsoon the surface soil has been completely washed away. Had the Northern face of the valley been first planted, I have no doubt from the excellence of the soil on that face, that the progress of the plants would have been everything we could have desired"* (Morgan, 1861). In his report from 1863, Mr. Beddome, who took over as Conservator of Forests following Morgan, stated , "*The department now has a very fine nursery in the Governor's Shola…it has supplied Ootacamund with firewood for the last two years and is now almost entirely felled; it has a north-west aspect, the soil is very fine, and it is admirably adapted for planting with Australian trees. Many thousand Australian trees were put down in this shola last year, but the Todas' buffaloes have committed very great havoc amongst them*" (Beddome, 1863). Eight years following the commencement of these plantations, a report from the Forest Department stated, "*These plantations were formed by the Public Works Department to ensure a supply of firewood for Barracks…Owing to the ground having been planted indiscriminately, without attention to soil and situation, they have cost far more than they ought to have done. It would not be a good policy to give up these plantations now, as in that case firewood for the Barracks would in future years have to be brought from a great distance at considerable cost for carriage*" (Beddome, 1863). It is clear that the Forest Department was convinced that plantations on grasslands failed due to poor soils whereas those on cleared sholas thrived due to good soils (Sutton, 2011). From 1856 to 1862, about 106 acres in the Nilgiri Plateau were planted with nearly 240,000 seedlings of *A. stricta* and *A. mollissima* (Morgan, 1862). Over this period, *A. mollissima* caught the attention of the British foresters, who began promoting it over

other *Acacia* species as is evident from this quote, "*I have recommended the trench system and a larger planting of the* Acacia Molissima *which grows quicker than the* Stricta*…With respect to the* A. mollissima *or yellow flowering Australian Acacia for firewood plantations, it is a curious fact that hares rarely touch it, whereas they will destroy the* A. stricta *by the hundreds.*" (Morgan, 1861).

By the early 1860's, the major responsibilities of the Forest Department were thus: i) the conservation of innumerable sholas to protect the source of springs and ensure water flow to the lower country, ii) the establishment of fuelwood plantations of fast-growing species in grasslands and cleared shola forest sites, iii) the provisioning of fuelwood and charcoal supplies to European settlements at Ooty and Wellington, and iv) the supervision of experimental Australian *Acacia* plantations (Morgan, 1861). In 1861, the Madras Government made it further clear that it intended to take up as much land as possible in the shola-grassland mosaics of the Nilgiris for fuelwood plantations. These fuelwood plantations were intended, not for the locals, but for the settlers (Sim, 1861). However, the Forest Department was finding it hard to perform their duties as local communities continued to cut wood from the remaining sholas, burn grasslands and graze their cattle, as they had been doing for generations. Given the superior knowledge of local communities of their surroundings, it was a hard task for the Forest Department to catch them in the act of cutting. In an attempt to solve this problem, it decided to make '*monigars'* (village officers) responsible for illegal woodcutting within their corresponding village boundaries (Morgan, 1861). The Forest Department believed that it was losing valuable timber to fire and grazing as trees at the edge of sholas got burnt and young saplings in plantations got trampled by cattle. In 1861, it urged the Government of Madras to provide aid to prevent these fires and for the provision to impose fines on illegal grazing to prevent this activity by local communities (Morgan, 1861).

2.3. Expansion of plantations and protection reserves

The period from 1861 to 1875 saw a major boost to plantations and protection reserves. On the one hand, the government tried to expand fuelwood plantations and private plantations of tea (*Camellia sinensis*), coffee (*Coffea* sp.) and cinchona (*Cinchona succirubra*), while on the other it made efforts to form reserves to preserve sholas to protect water sources and reduce soil erosion (Beddome, 1877). By 1882, there were 27 plantations on the Nilgiri plateau covering an area of 1230 acres and consisting chiefly of Australian *Eucalyptus* spp., *A. melanoxylon, A. dealbata* and/or *A. mearnsii* (Brandis, 1883). The government had also, by this time, leased out extensive areas of shola and grasslands for commercial plantations of tea, coffee, and cinchona. Planters felled shola trees on their land, which were then brought to the local markets for sale as fuel wood. In contrast to the earlier paucity, this led to a surplus supply of fuelwood in the market, resulting in a sharp drop in fuelwood prices. With the sale of fuelwood from their plantations starting to run at a loss, the Forest Department began pushing for a rail road to export surplus fuelwood from its plantations, and also felt the need to reconsider the policy of further expansion of plantations (Beddome, 1877).

In 1878, a commission consisting of a forest officer, a revenue officer, and a survey officer was appointed to select and delineate shola forests on the Nilgiri plateau as government reserves (Beddome, 1878). The commission recommended the reservation of around 12,000 acres of shola forests scattered across the Nilgiri plateau to protect the sources of springs and to preserve the aesthetic value of the landscape. It was decided that areas in cleared sholas would continue to be planted, presumably to counteract whatever effects may arise from the clearing of natural woodlands (Beddome, 1878). Existing fuelwood plantations were surveyed and it was decided to delineate the landscape into 'blocks', to facilitate management and effective protection. These blocks included plantations and shola forests. Further, portions of surrounding grasslands were also included into the blocks to make them into convenient shapes (Beddome, 1878; Sutton, 2011). The Inspector General of Forests, Dietrich Brandis, who visited the Nilgiris in 1882 endorsed the formation of these blocks that included sholas, plantations and grasslands, stating in his report (Brandis 1883), "*If these plantations are to be maintained, they must be included in a limited number of compact blocks, with convenient boundary lines, sufficiently large to make it worthwhile to place a forest guard in charge of each, who must reside in the same or in its immediate vicinity"*.

By 1887, 4650 acres of reserved forests in the Nilgiri district were declared closed against grazing, whereas 29,595 acres were open for grazing on payment of fees (Peet, 1887). By 1893, the total area under fuelwood and timber plantations increased to 1765 acres. By this time, the government had decided not to extend existing fuelwood and timber plantations as they were not in profit. It continued to do small-scale experiments with exotic tree introductions, but the overall area under exotic tree plantations remained largely unaltered until the beginning of World War II in 1935. During the war, when relations of the colonial government with South Africa were strained, the demand for wattle bark in India increased, again pushing the for large-scale *A. mearnsii* plantations. By the end of 1950, the area under plantations in the Nilgiris had increased to 4500 acres (Prabhakar, 1994). Unfortunately, the Forest Department in newly independent and developing India continued to push these policies further in the interests of food and firewood security: at the end of the twentieth century, the area under plantations had increased multifold to 32,500 acres (Sukumar et al., 1995).

2.4. Expansion of private plantations of exotic species

By the 1850's, tea, coffee and cinchona plantations had begun to be established on the Nilgiri plateau (Grigg, 1880). The Colonial government leased out large areas of forests and grasslands to private planters to promote these plantations (Morgan,1861). Planters however preferred shola areas over grasslands for planting even though all the land was given at the same rate (Morgan, 1861). The government, anticipating the expansion of these plantations, strongly favoured the selling of land to prospective plantations owners. The local communities, however, made this difficult, raising legal hurdles to the selling of such land. Local forest officials, in turn, had strong objections to the land tenure system for indigenous communities called '*grazing pattah*', under which the state government had allowed hill cultivators to occupy tracts of land near their settlements at one-quarter of the ordinary rate of assessment (Grigg, 1880; Brandis, 1883). In

1861, the Conservator of Forests complained about the local Badaga community (corrupted to 'Burgher' by the early European settlers; Francis, 1908). He reported, "*At present nearly the whole of the Hills at an elevation from 5 to 6,000 feet is practically held by the Burghers under the more than dubious title of what is called a grazing pattah. Let a settler make application for land in the neighbourhood of a Burgher village; and the land, though it has not been cultivated for years, is immediately claimed by the Burgher village, and a preposterous sum per acre demanded; if the demand be not acceded to, a complaint is lodged and the land pronounced to be Burgher land. I have had personal experience of this, and unless some remedy be devised, the obtaining of manipulators will be quite useless, as under the present rules, land suitable for Tea being unobtainable, colonisation is impossible*" (Morgan, 1861).

Tea and cinchona were both expected to establish in areas above 5000 feet in the Nilgiris, but of these, it was cinchona that caught the major attention of the Forest Department in the 1860's. By 1870, the area under cinchona cultivation had risen to 1200 acres (Veale, 2010). However, cinchona bark from Ceylon and Java overtook the market, leading to a decline in the demand for Nilgiri cinchona bark. As a result, planters started switching to tea which they found more lucrative (Veale, 2010). Likewise, attempts were made to cultivate coffee on the plateau in the mid-nineteenth century, but it was soon realised that coffee could be best grown on the slopes and not on the plateau. The economic non-viability of cinchona and coffee plantations led to their gradual abandonment or conversion into tea plantations (Beddome, 1879).

In contrast to coffee and cinchona plantations that failed after an initial success, tea plantations expanded steadily on the Nilgiri plateau. Officially, tea was introduced in the Nilgiris around 1835, but these initial efforts were failures. The first successful attempt to introduce the tea plant into southern India was made by Mr. Mann who imported plants from China in 1854 (Grigg, 1880). In 1861, tea plantations occupied a mere 30 acres, and proper methods of propagation and extractions were yet to be developed. Initial trials suggested that areas above 5000 feet were suitable for tea plantations (Morgan, 1861), and by the end of the 1860's, some 300 acres of land were brought under tea cultivation, increasing to 4200 acres by 1876. Over time, tea plantations came to occupy the largest area of all the introduced species in the Nilgiris. By the end of colonial rule in India, the area under private plantations of tea and coffee had expanded to 11,750 acres (Prabhakar, 1994). However, unlike other introduced exotic species, tea cultivation in the Nilgiris chiefly expanded as a private industry; the government was not directly involved in its promotion except for offering land to planters on lease at subsidised rates (Grigg, 1880). The relationship between planters and the government was however, not smooth, with boundary disputes between plantation lands and government-owned fuelwood plantations and protection reserves, as well as increased demands for lands by planters, emerging as contentious issues (Beddome, 1877). Post-independence (1947), a surge in development increased the area under tea and coffee to approximately 50,000 acres at the end of the twentieth century (Prabhakar, 1994).

2.5. Changing perceptions of exotic tree species and diversification of land-uses

Within twenty years of the introduction of exotic plantations since 1856, the Forest Department had concluded that acacias were inferior compared to eucalyptus in terms of their timber. Beddome (1869) strongly recommended the plantation of *Eucalyptus*, stating - "*The great value of the timber of Blue Gum or Eucalyptus globulus is not generally known, in Australia it is the best building timber known and is said to be fully equal to the best Indian Teak; its rapidity of growth on these hills exceeds that of any tree indigenous or introduced, and has been the admiration of all Forest Officers who have visited our plantations. Its cultivation should be largely extended on all our hill ranges; it grows well on grass land but its growth is not nearly so rapid as in shola land, the planting is more expensive and precarious, and it is much affected by wind. All sholas thinned out or deforested for firewood should be renewed with this tree, it exhibits the most favourable growth when planted inside sholas of the indigenous trees…*" (Beddome, 1869). He subsequently ordered the large-scale felling of *A. melanoxylon* plantations and the extension of eucalyptus plantations (Beddome, 1869; Beddome, 1878; Beddome, 1880; Walker, 1882).However, many seedlings faced heavy casualties due to wind and frost (Beddome, 1880; Walker, 1882).

In the 1880's, the Conservator of Forests, J S Gamble prepared new working plans for government-owned plantations. He introduced *Cryptomeria japonica,* and favored introducing temperate, especially coniferous species, which he thought were more suitable for this landscape than *Acacia* or *Eucalyptus* plantations (Gamble, 1883), as evidenced by his remarks, "*The Conservator has no faith in the endeavour to acclimatise the various species of Eucalyptus in the Indian plains. Doubtless, and as these trials show, a few plants can be reared if treated very carefully, garden fashion, and at some expense, but that is not what the Forest Department aims at. What we require are trees that can be grown easily and cheaply and on poor soil (for we have very little good soil indeed and what there is is mostly already covered with fine indigenous timbers of far greater value than those of the Eucalypti) in dry rocky places and it is a pity to waste money and time on such experiments when they might be applied so much more advantageously to works which we know are likely to succeed and pay, directly or indirectly*"(Gamble, 1889). For Gamble, the Nilgiri planting experience conclusively showed that the best species for cultivation on the hills were *Pinus longifolia* from the Himalayas, *Pinus maritima* from southern Europe, *Pinus insignis* from California, *Frenela rhomboidea* from Australia, *Cupressus macrocarpa* from California, *Cupressus torulosa* from the Himalaya, *Cryptomeria japonica* from Japan, and *Pinus laricio* from Europe. He also noted that *Bucklandia populnea* from Sikkim was a success in the Nilgiris, and recommended that more seeds be procured as it was useful timber as well as a beautiful tree (Gamble, 1889).

Within a decade of their introduction in 1880's, most introduced conifer species fell out of favour as a result of their extremely slow growth rates, and *Eucalyptus* once again became the major plantation species. In 1894, twenty-eight varieties of *Eucalyptus* from Australia were introduced in the Nilgiris; however, only a few of them established successfully. Gradually, the Forest Department replaced almost all old plantations of *Acacia*, *Frenela* and other exotics with *Eucalyptus,* chiefly *E. globulus* (McCarthy, 1915, 1916; Richmond, 1924; Madan, 1929). However, although they proved to be good timber trees in this landscape, government officials

began to realise that eucalyptus was water thirsty and could affect the streams on the plateau whose conservation was a priority for the security of water supply to the plains of south India. As a counter measure, the government in 1894 ordered that eucalyptus plantations not be established within human settlements and along streams (Gass, 1894).

Although the government tried its best to establish fuelwood and timber plantations on the Nilgiri plateau, unlike other regions of India, with few exceptions, the plantations in this landscape were consistently at a loss throughout the colonial period. Worried by these consistent losses, the government, by the end of the nineteenth century, decided not to expand plantations of exotic species (Cherry, 1893). In 1924, the Madras Government commented on the losses incurred by the Sixth Circle comprising the Nilgiri Division - "*…the fact that the Sixth Circle which contains the largest area of valuable timber was the only circle to show a deficit suggests that there must be some radical defect in the past system of working*"(Richmond, 1924). With the onset of the twentieth century, the Nilgiris, once the most favored landscape of the colonial government, started losing its importance. Tellingly, the annual report of Forest Department in 1914 stated, "*The Nilgiris - It is stated that there is nothing of interest to report*" (McCarthy, 1914). Subsequent annual reports barely mention the shola-grassland mosaics and the plantations on the Nilgiris.

By the end of the nineteenth century, large-scale plantations of exotic species were almost stopped, but the Forest Department continued to do small-scale experiments with exotic species. In 1925, planting of various species chiefly Alder (*Alnus nepalensis)* and Scotch broom (*Cytisus scoparius*) were carried out to afforest grassy areas and to protect sholas and streams (Richmond 1925). Scotch broom survived but most *Alnus* seedlings died. The Forest Department, frustrated with these failures, decided to stop its experiments with new exotics and continued to replace old acacia plantations with eucalyptus (Clear, 1926). Tea planters continued to apply pressure to the Forest Department to de-reserve their protected areas and assign them for commercial plantations of tea. Eventually, pressure from planters prevailed over the policy of shola protection for the maintenance of water sources, and between 1927 and 1929, 4125 acres of Reserve Forest land was re-assigned to private planters for plantations (Madan, 1929).

The colonial government, through its rule, remained undeterred in its intention to convert grasslands into tree clad forests. To this end, colonial officials often ignored the reality of hard evidence and undertook interventions based on perceptions. The effort to promote the use of acacia bark as a tanning material is a good example of this. The first effort towards this was in 1881. The Conservator of Forests stated–"*Wattle Tanning Bark - This is the produce of several Australian Acacias, viz.,* Acacia dealbata *(the Silver wattle),* Acacia decurrens *(the black wattle),* Acacia pycnantha *(the golden wattle),* Acacia saligna*, the* Acacia penninervis*; all but the last species have been introduced on to the Nilgiris, and it is not improbable that the growth of these trees for their bark will some day become a new industry for our hill stations, as the price of the bark has gone up very rapidly in the last few years*" (Beddome, 1879). Accordingly, in 1881, experiments were conducted on acacia bark as a tanning material, but the results were not positive (Beddome, 1881). Similarly, in 1916, *A. dealbata* bark was tested as a tanning material,

and once again the results were unsatisfactory (McCarthy, 1916).

Despite these failures, in 1928, the Forest Department once again considered the use of acacia bark as a tanning material. The Annual Report of the Forest Department in 1928 noted of acacia, - "*As it is cheaper and produces tanned hides of good quality it is being used in greater quantities year after year. So, Wattle bark has come to stay in this presidency. The black wattle (*Acacia decurrens *with its variety* Acacia mollissima*) are the most useful and profitable species because of their high percentage of tannin content and more ready adaptation to soil and climate conditions. Black Wattle and Silver Wattle have become acclimatised in the Nilgiris and the Palnis.*" (Madan, 1928). It further recommended, - "*It was suggested that the Madras Forest Department start Wattle cultivation in suitable localities in the Nilgiris and the Palnis to start with or at least start plantations for the purpose of demonstrating the cultivation of bark wattle on a commercial scale*" (Madan, 1928). However, later reports didn't mention acacia and its cultivation for tanning. Probably, the trials were again a failure.

2.6 Plant invasions

Several of the introduced exotic species quickly adapted to the Nilgiris, started propagating aggressively, and soon became invasive in this landscape. *A. mearnsii* and *A. dealbata* were the first introduced exotic species to become invasive in this landscape and to this day, their invasion, especially of *A. mearnsii*, remain a major issue of concern for conservation agencies. The following excerpts from the Annual Report of the Forest Department for 1869 give an idea of the invasiveness of these species on the Nilgiri plateau, a mere thirteen years following their introduction, "*The Acacia dealbata (Link) or Australian wattle (often but erroneously called Acacia mollissima on the Neilgherries) and the Acacia melanoxylon or Australian Blackwood are unrivalled on our hill ranges for firewood plantations or as screen from the wind, and the former grows wonderfully as Coppice, and the latter has very valuable timber, the former however is a perfect nuisance in small grounds or gardens and bids fair to overrun some parts of the station of Ootacamund as can be easily seen in the Bishopsdown grounds and many other places, its roots spread most rapidly in every direction and suckers come up by the thousands to the exclusion of all other vegetation, the roots of the latter tree also spread considerably and are a great nuisance near roads, nothing will grow near either tree without constant digging and removal of roots. If Ootacamund was deserted, the whole basin would probably at no lengthened period become a forest of these trees to the exclusion of almost all other vegetation*" (Beddome, 1869). In 1894, the Conservator of Forests stated - "*It is questionable policy to extend the growth of* Acacia dealbata *(yellow wattle) anywhere as it is an unmixed nuisance in many places from its habit of throwing up root suckers*" (Gass, 1894).

Another introduced exotic species *Ageratina adenophora* became invasive in the 1930's. The Forest Department initially welcomed its spread on the Nilgiri grasslands as it was considered preferable to grass (Minchin, 1930). As *A. adinophora* invasion became widespread however, the Forest Department introduced Kikuyu grass (*Pennisetum clandestinum*) to check its invasion (Wimbush, 1934). According to reports, Kikuyu grass could prevent *Ageratina* invasion to some

extent, however, its large-scale introduction could not be carried out as it was expensive (Wimbush, 1934).

3. **Untested assumptions, Lasting implications**

Colonial encounters with the shola-grasslands began with an appreciation of the aesthetic beauty of the landscapes, but in due course, colonial forestry mostly revolved around utility. Though protection reserves were created, they mainly served as resources for recreation and protection of water sources, with less importance given to the conservation of indigenous biodiversity (Sutton, 2011; Krishnan,2015, 2017). Although the perceptions of the colonial foresters on the suitability of different species changed over time, changing land-use patterns dramatically, one belief that remained constant was that the existence of grasslands in the region was the outcome of a long process of forest destruction by local communities through fire and grazing (Grigg, 1880; Sutton, 2011). Forest officials constructed a landscape history in which the Nilgiri plateau, once covered with thick vegetation, had been gradually eroded by ignorance and improvidence of the hill tribes who had destroyed forests over centuries. Empirical proof of this destruction was the apparent confinement of shola forests to inaccessible, damp valleys where they were protected from fire and cattle. Fires were condemned as a reckless and indiscriminate threat to forests. The Forest Department had no doubt that its interventions, in the form of planting exotic trees and restricting fire and grazing, had stopped the long destruction of *sholas* by local communities (Sutton, 2011).

Towards the end of colonial rule, however, these long-held assumptions began to be challenged. A Forest Officer Mr. Ranganathan, postulated that the grasslands existed because of winter frost that caused high mortality to shola tree seedlings in them (Ranganathan, 1938). This argument was countered by another prominent Forest Officer Mr. Bor who maintained as during the colonial period, that fire and grazing by local communities maintained the grasslands and restricted sholas to depressions (Bor, 1938). The debate continued in post colonial period with supporting arguments for frost (Meher-Homji, 1965; Meher-homji, 1967), fire (Gupta, 1960; Chandrasekharan, 1962; Noble, 1967), and soil properties (Jose et al., 1994, 1996).

Today, it is clear that the shola-grasslands of the Western Ghats are ancient ecosystems that are naturally bi-phasic and maintained by climate (Sukumar et al., 1993, 1995). Low temperatures and resultant frost in grasslands during winter kill native tree seedlings thereby restricting their establishment in grasslands (Joshi et al. in prep.). However, to the arriving colonial settlers, there was no doubt that the grasslands in the mosaic were the result of ecosystem degradation resulting from unsustainable grazing and fire. This incorrect assumption led to a century-long effort to "forest" the grasslands, the legacies of which have drastically transformed these ecosystems today(Fig. 2). Once picturesque forest-grassland mosaics have today been transformed into plantations of alien invasive tree species, prominent among them being the prolifically spreading *A*. *mearnsii*, and the grasslands greatly diminished in extent, with consequences for native biodiversity and ecosystem functioning of the entire landscape.

Recent analyses suggest that the shola-grassland mosaics on the Nilgiri plateau, constituting an area of around 1686 km^2, have lost 83% of grasslands and 50% of sholas (Sukumar et al., 1995). Likewise, for the shola-grasslands of the Palani hills, further south from the Nilgiris, it has been estimated that native grasslands and sholas have lost about 66% and 31% of their areas respectively to alien plantations over the last forty years (Arasumani et al., 2018). The endemic Nilgiri tahr is thought to have been severely impacted by this loss of its grassland habitat, with populations on the Nilgiri plateau reduced to less than 100 in 2007 (Alempath and Rice, 2008), while many endemic grassland orchids are now classified as endangered (Thomas and Palmer, 2007). Extensive alien tree plantations have adversely affected the ground water table (Sikka et al., 2003). Once an integral part of these ecosystems, indigenous communities have lost their traditional livelihoods, with many forced to become labourers in the plantations (Prabhakar, 1994).

In a recent win for conservation agencies, the judiciary in Southern India, responding to a public interest litigation in 2014, acknowledged the invasion of these grasslands by *A. mearnsii* as a serious conservation issue and directed the Forest Department to remove the invader to restore these ecosystems. The Forest Department has now begun the removal of *A. mearnsii* plantations; however, it remains unclear, and a matter of debate as to whether the removal of *A. mearnsii* will suffice to restore these grasslands (Ahrestani, 2016; Arasu, 2016; Lenin, 2017; Unkule, 2017).

4. Current day scenarios of management and conservation of tropical grassy biomes

While we detail the history of vegetation transformation in a southern Indian forest-grassland mosaic in this study, grasslands and savannas globally continue to be threatened by land-use conversions and aggressive afforestation schemes, most recently in the context of ecosystem management for carbon services (Lehmann and Parr, 2016; Zaloumis and Bond, 2016; Abreu et al., 2017). As with the Nilgiris in southern India, misperceptions of tropical grasslands and savannas as degraded ecosystems that were the result of human activities were widespread across the tropical colonies of the nineteenth and twentieth century. Fairhead and Leach (1996) describe an extreme case of such ecological misreading, where French colonials arriving in the savanna mosaics of West Africa in the nineteenth century, thought that patches of forests planted by local communities around their villages were the native vegetation, while the wide expanses of grassy savanna that stretched to the horizons were perceived to have been degraded from these forests (Fairhead and Leach, 1996). Likewise, Budowski (1956) considered the cerrado of South America, stretching across millions of square kilometers, as having been derived from tree felling and repeated burning.

In response, afforestation with exotic tree species, most commonly Pine, Eucalyptus and Acacia, has been the management intervention of choice, transforming thousands of acres of tropical and sub-tropical grassland (Table 2). Ominously, as was the case for the Nilgiris, many of these introduced species have either become invasive or have facilitated invasions by other species (Richardson et al., 1989; Loumeto, 1997; Clavijo et al., 2005; O' Connor, 2005), threatening the biodiversity and integrity of remaining grasslands. It appears that native grasslands across the

tropics are especially vulnerable to invasion by exotic non-native trees. However, despite this global evidence, at least two recent, influential global analyses of vegetation have identified vast areas of tropical and sub-tropical grasslands and savannas as areas suitable for afforestation and increased tree cover (WRI, 2014; Bastin et al., 2017).

It is striking that these current day scenarios strongly parallel this historical case study, and a sobering lesson emerges: two centuries on, the notion that grassy biomes are degraded ecosystems that can be improved by planting trees to make them into forests remains stubbornly entrenched in the mindsets of ecologists, foresters and policy makers today. Now, as it did then, it poses an insidious and covert threat to the recognition and conservation of grasslands, especially across the global south. As long as this widespread and outdated misperception persists, the conservation of tropical grassy biomes will remain a challenge, and many such regions will experience the same trajectories of invasion, biodiversity and habitat loss as the Nilgiris.

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List of Tables and figures

Table 1. A timeline of relentless introductions of exotic plant species

Species	Common name	Year of first plantation	Habitat	Outcome
Coffea sp.	Coffee	1838	Shola & Grassland	Initially established later declined in cultivated area
Camellia sinensis	Tea	1855	Shola & grassland	Established, extensively planted
Eucalyptus globulus	Bluegum	1856	Shola & Grassland	Established, extensively planted
Acacia melanoxylon	Australian blackwood	1856	Grassland	Established
Cinchona succirubra	Cinchona	1860	Shola	Established later declined in cultivated area
Acacia mearnsii	Black wattle	1861	Grassland	Established, later became invasive
Acacia stricta	Acacia	1861	Grassland	Poor growth
Acacia dealbata	Silver wattle	1862	Grassland	Established, later became invasive
Pinus longifolia	Pine	1861	Shola & Grassland	Established
Acacia pycnantha	Acacia	1869	Grassland	Established
Cryptomeria japonica	Cedar	1882	Grassland	Poor growth
Acer oblongum	Maple	1886	Shola	Poor growth
Toona ciliata	Toona	1886	Shola	Poor growth

Cedrus deodara	Deodar	1886	Shola	Poor growth
Acer campbellii	Maple	1887	Grassland	Poor growth
Exbucklandia populnea	Bucklandia	1887	Grassland	Established
Casuarina suberosa	Casuarina	1887	Grassland	Poor growth
Cupressus torulosa	Cypress	1887	Grassland	Poor growth
Eucalyptus botryoides	Eucalyptus	1887	Grassland	Poor growth
Podocarpus elongatus	Podocarp	1887	Grassland	Poor growth
Acacia decurrens	Acacia	1887	Grassland	Established
Frenela rhomboidea	Frenela	1887	Grassland	Established, later declined in cultivated area
Grevillea robusta	Silver oak	1887	Grassland	Established
Meliosma arnottiana	Meliosma	1887	Grassland	Poor growth
Pinus pinaster	Pine	1887	Grassland	Established
Eucalyptus rostrata	Eucalyptus	1893	Grassland	Established
Pinus insignis	Pine	1893	Grassland	Established
Eucalyptus acmenoides	Eucalyptus	1894	Grassland	Established
Eucalyptus corymbosa	Eucalyptus	1894	Grassland	Poor growth

Eucalyptus eugenoides	Eucalyptus	1894	Grassland	Poor growth
Eucalyptus paniculata	Eucalyptus	1894	Grassland	Established
Eucalyptus pilularis	Eucalyptus	1894	Grassland	Established
Eucalyptus propinqua	Eucalyptus	1894	Grassland	Established
Eucalyptus punctata	Eucalyptus	1894	Grassland	Established
Eucalyptus siderophloia	Eucalyptus	1894	Grassland	Poor growth
Abies douglasii	Fir	1897	Grassland	Poor growth
Widdringtonia whytei	African cypress	1908	Grassland	Established
Alnus nepalensis	Alder	1924	Grassland	Poor growth
Cytisus scoparius	Scotch broom	1924	Grassland	Established, later became invasive
Pinus khaysa	Pine	1926	Shola & Grassland	Established
Betula alnoides	Birch	1930	Grassland	Poor growth

Table 2. Examples of grassland afforestation across the globe and its impact on plant diversity (Entries NA mean that data were not available)

Publication	Country	Region	Plantation species	Plantation period	Area (Ha)	Impact on native plant richness
Nosetto et al. 2005; Clavijo et al. 2005	Argentina	Western coast of mid-Uruguay river	*Eucalyptus* spp.; *Pinus* spp.; *Populus deltoides*	1940-2005	101,600	Negative
Abreu and Durigan 2011; Valduga et al. 2016	Brazil	Brazil	*Pinus elliottii*; *Eucalyptus* spp.	1941-1950	5,962,002	Negative
Chen et al. 2016	China	Qilian Mountains	*Pinus crassifolia*	1970-2016	NA	Positive
Hu et al. 2008	China	Inner Mongolia	*Pinus sylvestris*; *Populus* spp.	1941 -1998	~2,000,000	NA
Loumeto and Huttel 1997	Congo	Pointe-Noire & Loudima	*Pinus caribaea*; *Acacia auriculiformis*; *Eucalyptus* spp.	1958 -1997	~40,000	Negative
Farley and Kelly 2004	Ecuador	Cotopaxy province	*Pinus radiata*	1920-1990	7700	Negative
Thomas and Palmer 2007; Karunakaran 1998	India	Shola-grassland landscapes, Western Ghats	*Acacia* spp., *Eucalyptus* spp., *Pinus* spp.	1856-2000	NA	Negative
Buscardo et al. 2008	Ireland	Ireland	*Pinus sitchensis*; *Larix kaempferi*	2002-2008	NA	Negative
Maccherini and Dominicis 2003	Italy	Monte Labro	*Cedrus* spp.	1974	13	Negative
Alrababah et al. 2007	Jordan	Jordan	*Pinus halepensis*	1941-onwards	NA	Negative

Publication	Country	Region	Plantation species	Plantation period	Area (Ha)	Impact on native plant richness
Igboanugo et al. 1990	Nigeria	Northern Guinea savanna zone	*Eucalyptus* spp.	Upto 1990	2000	Negative
Cremene et al 2005	Romania	Romania	*Pinus nigra*	1985-2005	NA	Negative
Zaloumis and Bond 2011	South Africa	Shores of Lake St. Lucia	*Pinus* spp.	1940-1960	3853	Negative
O'Connor 2005	South Africa	Southern Drakensberg	*Pinus patula*	1990-2005	NA	Negative
Richardson et al. 1989	South Africa	Fynbos biome, Cape province	*Pinus* spp.	1894-1960	NA	Negative
Six et al. 2014	Uruguay	Uruguay	*Eucalyptus* spp.; *Pinus* spp.	1991-2010	~1,000,000	Negative

Figure 1a. A shola-grassland landscape in the Nilgiris in 1830's before colonial settlements (Image source: Reproduced from Baikie 1857)

Figure 1b. A real view of a shola-grassland mosaic (Image credit: Chengappa SK)

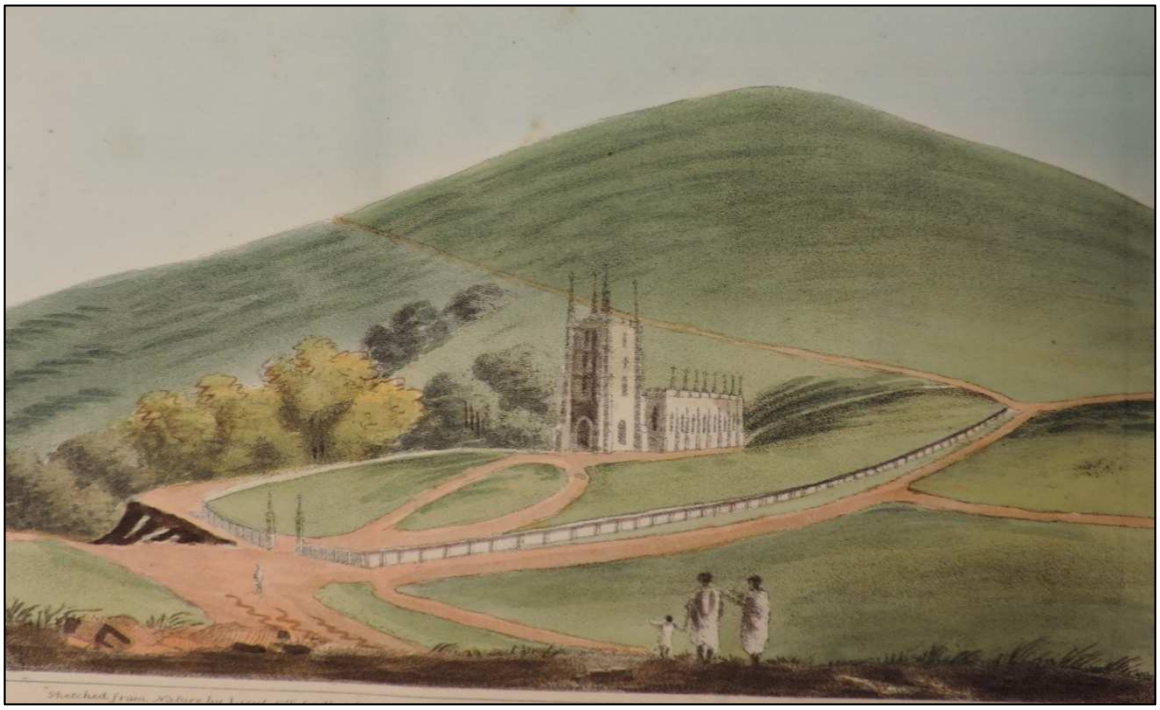

Figure 2 a. 1830's (Image source: a: Reproduced from Baikie 1857)

Figure 2 b. 1900’s (Image source: Reproduced from Price 1908)

Figure 2 c. 2015 (Image source: Wikimedia commons)

Figure 2. Landscape transformation in Nilgiris. St. Stephen church built in Ooty at the beginning of colonial settlement. Images show the area around the church at different time period