

Production Cycles and Decline in Traditional Iron Smelting in the *Maidan*, Southern India, c. 1750–1950: An Environmental History Perspective

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ABSTRACT

This paper explores how economics, technology, politics and ecology interacted in causing ups and downs in the production of traditional iron making, and its subsequent decline in the early twentieth century. In the course of this exercise we find many lacunae in the study of Indian environmental history. These include a neglect of the impact of traditional iron and steel smelting industry on forests in pre- and early-colonial times, the possible strategic motive in controlling iron and steel production through control of charcoal production, the institutional mechanism of forest use for industrial purposes and the role of ecology in the decline of traditional industry. Some of these are important questions for those who seek to reintroduce traditional technologies. A study of history throws up interesting clues on how we could correct mistakes made in the past so as to plan more effectively for the future.

KEYWORDS:

Iron smelting, charcoal, deforestation, forest policy, pre-colonial India, colonial India

INTRODUCTION

Through a careful scrutiny of historical observations and records, this paper attempts to construct a logical picture of how economic, political, technological and environmental variables interacted to cause cyclical fluctuations in traditional iron and steel smelting, and its subsequent decline. Of particular interest to us is the close circular relationship these production cycles may have had with the observed physical landscape of the region; iron and steel manufacture may not only have changed the landscape of the region but it was also affected by the changing landscape. Generally speaking, business cycles in traditional industries in pre- and early-colonial India have been largely ignored, and their subsequent decline attributed to policies under British Rule. The latter is based on naïve economic reasoning; local artisans and craftsmen were gradually pushed out of the market, as they were unable to compete with cheaper industrially manufactured goods imported from the West. Industrially manufactured goods were able to reap economies of scale from mass production, cut prices and wipe out traditional Indian industries, the latter being small-scale, high cost and primarily serving local markets. Such generalisations, though convincing and poignant, are simplistic and problematic. A study of one traditional industry, iron and steel smelting, in one particular region of India, tells us why this may be so. Foreign trade, political forces, new industrial technologies, deforestation and forest management were all important variables that interacted in bringing about a gradual end to this traditional industry.

Uncovering these interactions led us to many observations hitherto scarcely discussed in Indian history, in particular, Indian environmental history. But there is something more than mere academic questions and answers that this study revealed. Combined with visits to the specific areas under study and discussions with local people we were able to perceive a link between historical inquiry and the future through one of today's greatest preoccupations: global warming and climate change.

This study begins with an important ecological facet of traditional iron and steel smelting. I then proceed to demarcate the region chosen for this study. Key historical observations, records and events drawn from our rather limited sources of information are incorporated into a timeline. The significance of these observations is also closely linked to the political history of the region. Juxtaposing both onto the timeline reveals an interesting correlation between cyclical fluctuations in traditional iron and steel production, political history and the region's ecology. The cascading actions and reactions played out in the context of major technological changes ultimately took its toll on traditional iron and steel making. However, before drawing any conclusion as to the actual cause of its decline, a clear and precise definition of 'traditional' industry and how it differs from 'modern' or 'industrially manufactured' iron and steel is imperative. Questions arise as to whether there differences in the final product

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and/or in the process of manufacture between ‘traditional’ and ‘modern’ iron and steel? Was modern iron and steel a perfect substitute for the traditional product or not? Was it ‘superior’ to traditional iron and steel?

A study of history reveals what went wrong for the traditional smelter and whether there exists any possibility for his return. This may in fact be a relevant question as there are audible calls from the nationalist scientific establishment and appropriate technologists that traditional industries still have a place in today’s world. This analysis helps us take a more informed stand on such claims.

TECHNOLOGY AND ECOLOGY IN TRADITIONAL IRON AND STEEL SMELTING

Iron making is an ancient craft that began some 3000 years ago. The essence of iron making, however, has remained the same since that time. The ore, either mined or collected from sand, was melted and the oxygen in it burnt out. For millennia the fuel that performed this dual operation was charcoal. Charcoal, which is about 90 per cent carbon, is produced by heating wood in the absence of oxygen whereby water and other volatile compounds are removed. Charcoal burns at elevated temperatures of about 1100 degrees Celsius, high enough to reduce the oxides in the ore. Such temperatures cannot be achieved by burning dry wood, thereby making charcoal an essential raw material in the smelting process.

Producing a kilogram of refined iron needed about 16 kilograms of charcoal¹ and to produce a kilogram of charcoal requires four to seven kilograms of wet wood.² Therefore, to produce a kilogram of refined iron would need about 60 to 100 times its own weight in wet wood. More charcoal was needed as fuel to soften and transform refined semi-products into their final forms. If steel were to be produced from smelted iron, the further melting and forging operations required even greater quantities of charcoal. Put simply, traditional iron and steel smelting, or smelting of metals in general,³ required large amounts of wood for charcoal. Charcoal was produced within a forest and then transported to smelting sites. Moreover, poor transport from forest areas and brittleness of charcoal meant that smelting sites were located in reasonable proximity to forests.

In Europe, over centuries, iron and steel smelting had taken a toll on forest resources, sometimes denuding entire landscapes. The growing demand for iron and steel was severely constrained by limited forest resources. In the early eighteenth century, Abraham Darby, a British ironmaster, successfully substituted charcoal with coke produced from mined coal as fuel for iron smelting.⁴ Coal, mined from a surface of a few square metres, replaced the need for acres of forests. With the constraint on fuel lifted, production of iron grew rapidly to meet the increasing demand, and with it came technological change and economies of scale. The second Iron Age had begun and charcoal iron smelt-

ing gradually disappeared in the western world. These changes, however, were absent in countries like India, where iron and steel smelting continued to utilise wood charcoal as fuel well into the twentieth century.

But it is not charcoal *per se* that is the defining element of traditional iron and steel. Even today, large-scale manufacturers of iron and steel in Brazil continue to smelt iron and steel using charcoal rather than coke to reduce the oxides in the ore. The easy availability of wood is the determining factor in this choice.⁵ Utilisation of charcoal in iron smelting is, therefore, a necessary, but insufficient, condition in defining traditional iron and steel making. We will return to examine other defining elements of this traditional craft later in the paper; for now the strong linkage of traditional iron and steel-smelting technology to ecological landscape is evident.

THE REGION CHOSEN AND SOURCES OF INFORMATION FOR THE STUDY

Historically, iron and steel was manufactured extensively in southern India, including regions in the present states of Tamil Nadu, Andhra Pradesh and Karnataka. One such region is the Maidan, or the *bayaalu seeme* in Kannada,⁶ the latter meaning open boundary. It refers to the (Deccan) plateau portion of the former State of Mysore, encompassing the districts of Belgaum, Bellary, Bidar, Bijapur, Chikmagalur, Chitradurga, Dharwad, Gulbarga, Raichur, Shimoga, Bangalore, Chamarajanagar, Hassan, Kolar, Mandya, Mysore and Tumkur in the present State of Karnataka. The Maidan lies to the east of the Western Ghats, in its rain shadow. It is characterised by scanty rainfall and ranges of low rolling hills. The region was originally covered by extensive, open-canopied tropical dry deciduous forests with tree species like *Acacia*, *Albizia* and *Hardwickia binata*, but much of these have been replaced with scrub forests, the species *Prosopis juliflora* now dominating the landscape. The Maidan is abundant in iron and manganese ore and large-scale mining operations are presently carried out in parts of Bellary, Chikmagalur, Chitradurga and Tumkur districts.

The three major sources of information used in this study are Francis Buchanan's⁷ Journey,⁸ the *Mysore Gazetteers*⁹ and reports by Sambasiva Iyer.¹⁰ The first is a record of his survey of erstwhile Mysore and other regions of southern India in 1800–01. It is a detailed account of people's lives and landscapes. Amongst the several objectives of his journey was the specific and minute attention assigned to mines and minerals. Buchanan, therefore, meticulously traced and recorded his observations from several iron smelting sites that he visited in the Maidan. A careful and detailed investigation of his comments proved to be an invaluable source of information.

The *Mysore Gazetteer* also proved useful in tracing the state of iron smelting in the region towards the end of the nineteenth and first decades of the twentieth

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centuries. Finally, two reports by Iyer, published by the Mysore Geological Department in 1898–9 and 1900–01, provided important information on issues confronting iron smelters in Chitradurga district. Though our study deals with the entire Maidan, resources available on iron smelting are particularly meagre, compelling us to base some of our conclusions on a more intensive assessment of iron smelting in two particular (present) districts, Tumkur and Chitradurga.

THE PROCESS OF TRADITIONAL IRON SMELTING IN THE MAIDAN AND ITS DEPENDENCE ON FOREST, 1800

Buchanan visited several iron and steel smelting sites in the Maidan. His report from Magadi provides a clear picture of the need for charcoal at each successive step of iron and steel manufacture. Figure 1 is a schematic diagram of the process using black-sand along with some data pertaining to quantities and type of raw materials. The process using mined ore is very similar to the one using black-sand.¹¹

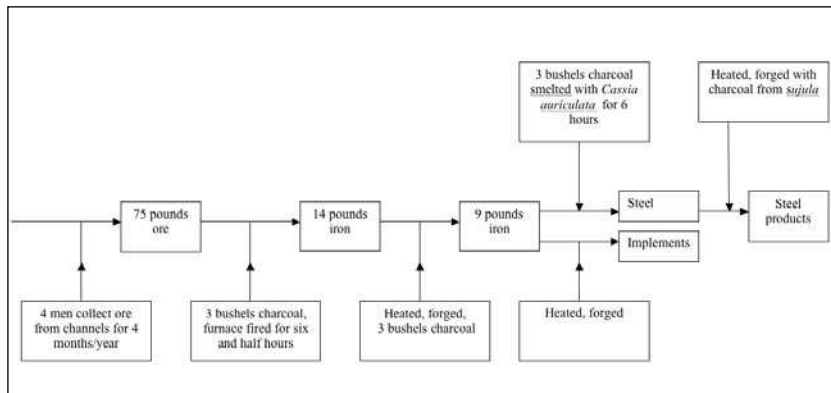


FIGURE 1. Buchanan's description of iron and steel smelting process at Magadi

Iron making went through two stages, smelting and forging, before it was pure enough to be converted into final products. The forged iron could be further processed into steel before it was converted into products like sword blades, chisels, outer lining of bullock-cart wheels, or strings for musical instruments. The missing details in Buchanan's report make it impossible to ascertain the precise amount of charcoal used by smelters. The importance of charcoal in iron-making can also be ascertained from the cost of charcoal as a proportion of its total cost. Buchanan reported that where iron was made from black-sand, charcoal-making costs were approximately 35 per cent of the total cost, and

for mined-ore, it was approximately 32 per cent of the total cost of making forged iron.¹²

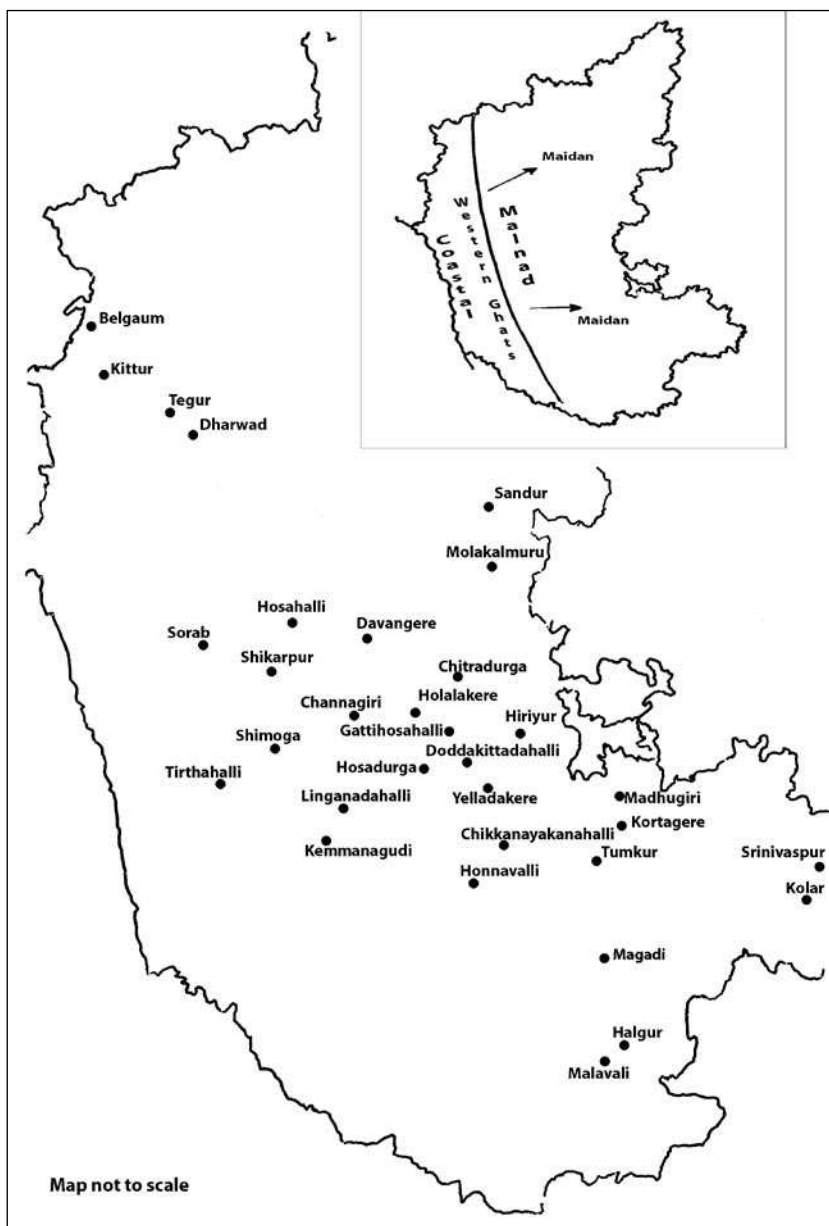
Charcoal for smelting had to be made only from certain select trees, not only because of calorific content but also strength of the charcoal required to carry the weight of ore without being crushed. In Magadi, Buchanan found smelters used bamboo, *sujalu* (*Mimosa tuggula*) and other tree species for charcoal, excluding *Ficus bengalensis* (*banyan*) and *Chloroxylon dupada*. In Tumkur district, he remarks that bamboos not being available, wood of trees had to be used. In Shimoga district, the *Inga xylocarpa* was largely used for charcoal-making. In many parts of the Maidan, one tree which iron smelters used extensively for charcoal was the tropical dry deciduous species, *Hardwickia binata*, not-so-coincidentally called *karachi* or '*kamara*', the latter meaning blacksmith in Kannada.¹³

It was charcoal making, more than ore, which inextricably linked traditional charcoal iron making to forest resources. By itself this cannot be taken as a sufficient condition that this method was actually 'wasteful' and caused significant forest degradation; the quantity of iron produced, distribution of smelting sites, the type of forests, vulnerability of the ecosystem, management of forest resources and even climatic factors could affect the outcome. The question, however, remains whether or not iron smelting had adversely impacted the forests of the Maidan.

THE SPATIAL DISTRIBUTION OF TRADITIONAL IRON MANUFACTURE AND FORESTS IN THE MAIDAN IN THE NINETEENTH CENTURY

The Maidan, as mentioned above, covers a large portion of central southern India. Map 1 indicates the distribution of iron and steel manufacture in the region during the nineteenth century.¹⁴ The map only shows the distribution of iron smelting across the region, it does not tell us how *intensively* it was practised at each location; this would depend on the number of furnaces operated at each place.

One can then imagine hundreds of iron smelters dotting the region using locally accessible forest resources for wood and charcoal. However, to appreciate the pressure that these smelters put on the forests, it is necessary to have some quantitative figures on the scale of operations. Information from Buchanan's *Journey* provided some 'order of magnitude' figures of iron production in one district, Tumkur.

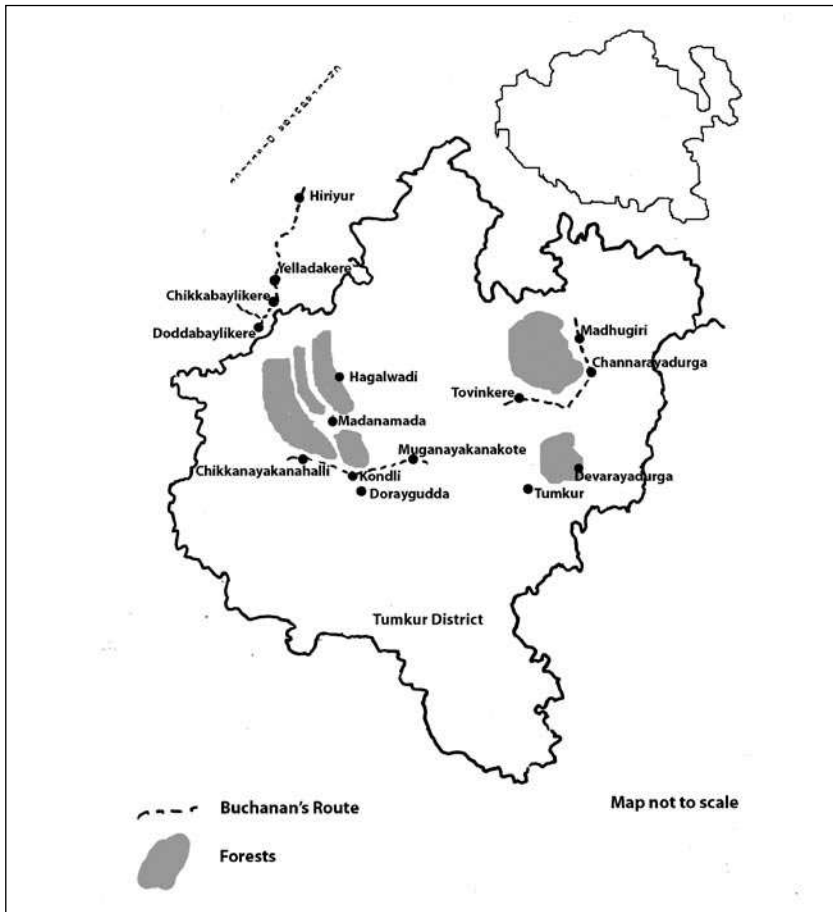


MAP 1. Karnataka State (inset with locations of iron production in the Maidan)

THE SCALE OF OPERATIONS IN TUMKUR DISTRICT

Map 2 summarises information about Tumkur district; both in terms of forest distribution and iron smelting. It illustrates:

- Buchanan's route through Tumkur district.
- The four (former) *taluks* where iron was smelted: Madhugiri, Channarayadurga, Hagalwadi and Devarayadurga.
- Some of the major forest areas in the district.



MAP 2. Iron smelting in Tumkur District

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In Madhugiri and Channarayadurga the ore was collected from torrents whereas in the other two *taluks*, mined-ore was used. More importantly, the number of sites where iron was smelted in each *taluk* can be found in Buchanan's records:

Madhugiri and Channarayadurga:	19 forges
Hagalwadi (including, Chikkanayakanahalli):	17 forges
Devarayadurga (near Tumkur town)	6 forges
Total	42 forges

However, Buchanan mentions that the number of furnaces in Hagalwadi and Devarayadurga stated above are the ones that used ore only from Doray Guda. There was another mine from where smelters could access ore. This according to Buchanan was a smaller mine. A reasonable estimate, therefore, of the total number of smelting sites in Tumkur district in 1800–01 is 50.

Buchanan also gives another vital bit of information: the total quantity smelted at each of the 19 works in Channarayadurga and Madhugiri taluks was approximately 100 tons per year, or an average annual production of iron *at each site* was 5 tons/year. Based on the description of operations including the number of people working at different sites, this figure could be used across *taluks* as well. The total quantity manufactured in Tumkur district as a whole would have been 250 tons/year. To reiterate, this is not a precise estimate but only an 'order of magnitude' figure.¹⁵

PRESSURE ON FORESTS FROM IRON SMELTING IN TUMKUR, 1800

What does this figure mean in terms of environmental impact? Based on the estimates stated above, wet wood required for smelting this quantity of iron would have been about 20,000-25,000 tons/year. A typical kamara 'plantation' (not forest) has approximately 250-500 trees/hectare. If each tree yielded 500 kg of wood, then as a very rough estimate, about one to two square kilometres of plantation would have had to be cleared annually to meet the total requirement of iron smelters in Tumkur district.¹⁶ To the extent that bamboo was used, the area could have been larger.

With the estimate on hand it is not possible to establish whether, and to what extent, this quantity of iron and steel production caused deforestation in the region. A look at what happened in other regions of the world provides some pointers as to the possible impact of iron and steel smelting on forest resources. Studies and reports from across the world acknowledge that iron manufacture using charcoal as fuel denuded and destroyed extensive tracts of forests locally, in and around areas of iron manufacture. For instance, large tracts of forests were virtually wiped out in both the United States of America and Britain.¹⁷ When we compare the figures we have for Tumkur with the U.S. where a single

furnace in the nineteenth century produced at levels of 10 tons/day,¹⁸ the drastic deforestation that occurred there is unlikely to have taken place in Tumkur or, more generally, the Maidan.

However, the experiences from Africa and Asia indicate that the estimated quantity of 250 tons/year may not be as trivial as it first seems. In an archaeometallurgical study of the Bassar region in Togo, de Barros found that iron was smelted there over hundreds of years and reached a maximum of about 200 tons/year in the nineteenth century. Even with such modest levels of production, he asserts most of the tree cover had been removed.¹⁹ Kilometre upon kilometre of forests were cut to satisfy the demands of the iron industry from the fourteenth to nineteenth centuries. One German forester, O.F. Metzger, gave an account that at the turn of the nineteenth century only 1.5 per cent of original forests remained, while the rest was turned to savanna. The report also mentions intense deforestation caused by traditional iron smelters in Malawi and Mali. Mountain ranges were denuded for wood, forcing local populations to migrate from the area.²⁰ In another archaeometallurgical study of West Africa, Goucher shows that a staggering number of trees were used as fuel at a single industrial site in Ghana (Dapaa, c. 1400–1700). The thousands of hardwood trees exploited by one iron smelter probably could not have been replaced during his lifetime.²¹

In Nepal, iron smelters may have altered the landscapes of the Himalayan ranges. Ives and Messerli argue that provision of iron was used as tax where local low-grade ores were extracted, smelted, and carried to Kathmandu. The smelting of iron ore required large amounts of charcoal and, since the annual demand was heavy and the iron smelting process very inefficient, depredations on the forests of Sindhu Palchok and Kabhre Palanchok were extensive. Evidence of iron smelting and charcoal making can be found throughout the two districts today.²²

It is believed that during the Northern Sung Dynasty which ruled between tenth and twelfth centuries AD, shortages of charcoal had induced iron makers to substitute charcoal with coal. An estimated production of 125,000–150,000 tons decimated the forests of the Shantung region in north-east China.²³

The problem of deforestation for iron smelting may have occurred even in ancient times; it may not be a purely medieval phenomenon. Miller found a strange coincidence between the fall in production of iron metal during the ninth century in Carchemish, one of the major centres of metal and ivory manufacture in north Syria and the last century that live elephants are recorded from this area. Although political factors certainly may have played an important role, it is also possible that increasing conversion of forests into charcoal and fuel led to localised desertification, which resulted in the eventual extinction of the elephants of northern Syria.²⁴

These reports from across the world and, in particular, those from parts of Africa and Asia, indicate that iron smelting took a heavy toll on forests in medieval, and even ancient, times. Over centuries the dry deciduous forests of

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the Maidan could also have been extensively depleted by iron and steel smelting industry.

IRON SMELTING IN THE PRE-1800 PERIOD

The quantum of iron smelting estimated from Buchanan's Journey may not be 'typical' of that historical period; it could have been higher in preceding years, the latter half of the eighteenth century. If so, the possibility that localised forest degradation took place around smelting sites is actually strengthened.

The three decades between 1767 and 1799 saw four major wars fought between the British East India Company and the State of Mysore then under the rule of Hyder Ali and later his son, Tipu Sultan. The wars, referred to as the Anglo-Mysore Wars, finally ended with the death of Tipu Sultan at Srirangapatnam in 1799. These were major battles employing tens of thousands of soldiers. Apart from conventional arms like swords, daggers, armours and helmets, guns, muskets, cannons and even rockets were used by Tipu Sultan's army. The Mysore Gazetteer reports that within the old fortifications at Ramnagaram iron was worked into 'Implements of War'.²⁵

Where did all the feedstock for weapons come from? Buchanan makes explicit reference to Tipu Sultan having purchased iron from smelters of the Maidan giving them 'great employment; as he made his shot of this iron, by hammering ...'. He reiterates, 'according to the iron-smelters' own account, the Sultan gave them a high price for their iron, and by his great demand afforded them constant employment. It is probable, however, that he compelled them to work much harder than they were inclined to do ...'.²⁶ The intermittent wars and battles in Mysore would have created enormous needs for iron and steel, a 'boom' for iron smelters of the Maidan.

However, there is another side to the use of iron and steel; agriculture. The Third War of Mysore between 1790–92 followed by the Fourth War in 1799 had left a trail of devastation through many parts of the region. Depopulation of the region during wars was common. It would, therefore, be safe to presume that the growth in demand for iron and steel from the agricultural sector stagnated or possibly declined over the second half of the eighteenth century. However, this low demand for iron from the agricultural sector is likely to have been more than compensated by the absolute level of and growth in demand for the military.

In 1800, a year after Tipu's defeat and the installation of the Wodeyars on the throne by the British East India Company, the region witnessed a drastic decline in conflict as compared to the past decades. The great demand for iron and steel during Tipu's reign would have crashed. At the same time, agriculture being at a low in the region, iron and steel production in 1800 may have been at its ebb. Casual remarks by Buchanan indicate that activities at some sites could even have been abandoned; at Ghettipura, near Magadi in present-day

Bangalore (Rural) district, he reported that ore found here was not smelted lately though 'much steel was formerly made here', and at Halagur he could not find iron forges, except a manufacturer of iron boilers for the sugar industry and common agricultural implements. Previous to his visit he was told that this place was famous for smelters who were the chief suppliers to Srirangapatnam, the capital of the Mysore kingdom. The information that Buchanan got was not wrong because, as confirmed by the Gazetteer, Halagur was indeed once the seat of a considerable iron industry²⁷.

A study of remarks on 'the general appearance of the countryside' made by Buchanan indicates possible deforestation from intensive iron smelting during the eighteenth century. Near the smelting sites at Channarayadurga he reported, 'nothing can be rougher than the neighbouring country, which at first sight appears as a mass of rocks and bare hills thrown confusedly together'. Then again between Tovinkere and Tumkur he remarked, 'at some distance on my left were hills; and the prospect would have been very beautiful, had the country been better wooded'. On the August 17, 1800, he travelled between Muganayakankote and Kondli via Doray Guda. *En route* he comments, 'owing probably to the vicinity of the iron mines', the hills 'are very bare of trees'. From Madanamada, a place from where the range of hills running between Chikkanayakanhalli and Hagalwadi are visible he repeats, 'the woods above the temple are rather taller than usual in these barren hills, and contain many trees of the *dupada*,²⁸ *Chloroxylon dupada*'.²⁹ These indirect remarks, however, only permit us to conjecture that iron smelting had denuded forests in the region. But one specific record transforms this conjecture into a real possibility; at Yelladakere, Chitradurga district, iron smelting had been abandoned from 'want of fuel' in the mid-1700s.³⁰

IRON SMELTING IN THE 'INTERIM' PERIOD

1800 to 1831 is another politically significant period in Mysore history. It marks the reinstatement of the Wodeyars as rulers of Mysore by the British East India Company. Till 1810, Dewan Purnaiah acted on behalf of the Maharaja after which Krishnaraja Wodeyar III assumed charge. The political situation that prevailed during this period was, however, far from conducive to economic growth and prosperity. During Dewan Purnaiah's reign the state's coffers grew only at the expense of ruthless exploitation of the peasantry.³¹ This state of affairs continued under the rule of Krishnaraja Wodeyar culminating in the peasant revolt of 1831.

No records on iron smelting are available for this period. We can only suppose that with negligible demand for the military, absolute levels in iron production would be lower than 1799. This in turn would have reduced pressure on forests for charcoal, and regeneration possibly exceeded the rate of harvesting trees, a factor that could have further eased the pressure on forests is based on some

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casual comments made by Buchanan. In and around the iron-smelting areas of Tumkur he saw many of the farmers' fields overgrown with trees after they were abandoned in the late eighteenth century.³² From what is presently happening in the same region,³³ it is likely that blacksmiths used these overgrown trees in the fields for making charcoal. In all probability the returning farmer would have asked the charcoal-maker to take the trees for 'free', but not pay for the labour of doing so. This would still have been cheaper for the blacksmith than paying a fee for the right to cut wood from forests. With pressure on forests easing, a regrowth of tree vegetation in some of the bare hills could well have taken place over the first few decades of the nineteenth century.

IRON SMELTING IN THE EARLY-COLONIAL PERIOD

The 1831 Peasant Revolt in Mysore had a major historical repercussion; the British East India Company dismissed the Maharaja and took direct control over the state. Colonialism brought with it sweeping changes in the landscape of Mysore: physical, economic and social. The administrators introduced extensive reforms which even percolated to specific industries like iron and steel. Between 1832 and 1840, the tax on blacksmith's forges was abolished. This last only formed part of an extended measure of relief granted to the manufacturers of iron throughout the country. In 1842-3, all transit duties were taken off iron and steel.³⁴ In agriculture, major qualitative changes were effected through administrative reforms, rationalisation of *khists*, the system of issuing *pattas* and transferring payments from kind to cash.³⁵

However, it is surprising to see that rather than agriculture growth, Chitradurga district witnessed a disproportionate surge in the number of non-cultivating households. Captain Chalmers in his report on Chitradurga Division of Mysore in 1842 provided the statistical data presented in Table 1.

TABLE 1. Cultivators and Non-Cultivators in Chitradurga District 1834-5 to 1840-1.

Year	Agricultural Ryots	Householders not Cultivating Lands	Ploughs
1834-5	55,457	22,792	61,973
1840-1	66,111	40,156	71,883
Per Cent Increase	19	76	16

Source: Swamy, *Agrarian Relations*, 67

Swamy interprets the substantial increase in the number of 'non-cultivators' as an increase in non-cultivating owners of land. However, it is likely that these numbers include persons employed as artisans and service providers, not only landlords. Political stability, establishment of public order and improvements of internal transport under British rule encouraged regional specialisation of production. The Maidan with its abundant supply of iron ore and regenerated forests could have become a centre for iron smelters. At the same time, the rise in average agricultural output per acre and per man during the nineteenth century along with a rather substantial expansion of land under cultivation and a shift from lower- to higher-value crops in many areas of the country would have provided a steady market for artisans.³⁶

The impact of the growth of local industries on the environment during the early colonial phase has been unequivocally captured in the Mysore Gazetteer. It is perhaps the most categorical statement which directly implicates traditional iron smelters of the region in environmental destruction, not merely damage, in the early-colonial period.

The third and by no means the least harmful was the practice of iron smelting, furnaces for which were allowed to spring up all over the country. The wasteful methods employed led to an enormous consumption of fuel and a corresponding denudation of jungles in the Maidan and regions bordering on the Malnad abounding in iron ore. The late General Dobbs, then Superintendent of the Tumkur District, thus graphically describes in 1854-1855 the damages wrought to tree vegetation by iron smelters:

'The district generally is very bare of trees. The jungles were however extensive when I first assumed charge in 1835, but these are disappearing fast under the axe of the iron and steel manufacturers. When I first visited the beautiful range of hills running between Chiknayakanahalli and Hagalwadi, they were clothed in trees from top to bottom; not a tree now remains except a few unfit for burning. In the immediate neighbourhood of Tumkur (Davaraidrug Hills) where three-fourths of the wooding has disappeared. I stopped the progress of destruction by prohibiting iron forges altogether. The decrease of rain amongst the hills referred to has been very marked; no one who has not witnessed the process can conceive the destruction made by these forges.'

Even greater ruin was caused in the Chitaldrug District from the same cause. Almost barren waste has taken the place of former wooded tracts, and that too in a district with but scanty rainfall. Luckily some forests were preserved by not being easy of access and they are now most carefully preserved.³⁷

Iron smelters 'were allowed to spring up all over the country', which obviously indicates new or renewed smelting activity in the region, supporting the statistical data provided by Chalmers (Table 1 above). The increased production of iron

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and steel in the Maidan to meet demands from across the region would have increased the demand for charcoal and a corresponding pressure for wood may once again have caused a rapid denudation of local forests. The initial phase of direct colonial rule could therefore have meant a return to the pre-1800 situation when demand for iron from the military may have denuded the hills.

If we put Buchanan's and Dobbs' observations together what emerges is an oscillating pattern in landscapes and iron smelting, summarised as follows:

- c. 1750: deforestation near Yelladakere reported by Buchanan
- c. 1800: bare hills seen by Buchanan around the places where he visited smelting sites
- c. 1835: forested hills noted by Dobbs
- c. 1855: severe deforestation and bare hills noted by Dobbs

Figure 2 summarises this conjectural analysis of how landscapes may have oscillated in iron smelting regions of the Maidan in the late eighteenth and early nineteenth centuries as a response to political changes, and thereby allowed for natural regeneration of landscapes.

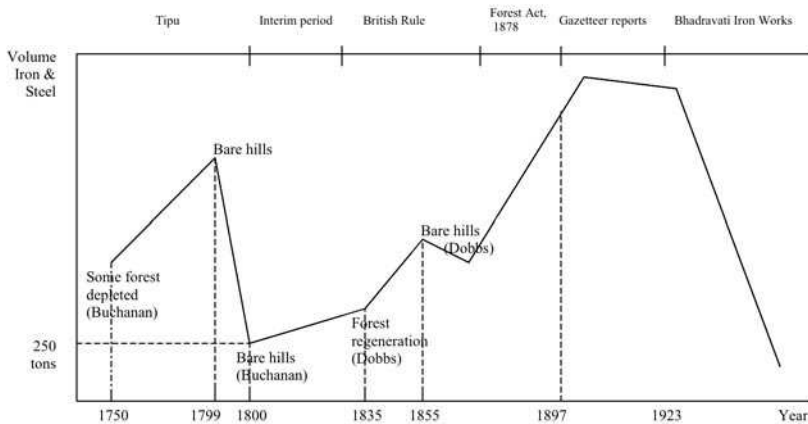


FIGURE 2. A conjectural analysis of changing landscapes and iron production in the eighteenth and nineteenth centuries.

Our findings show that traditional iron smelting had indeed adversely impacted the environment in pre-colonial and early-colonial periods. A shortage of fuel, just like that reported in other countries, was also a real threat to the sustainability of traditional charcoal iron smelting in the region under study. It may

well be pertinent to ask why iron smelting as a possible cause for widespread deforestation in pre- and early-colonial India has not been given sufficient attention in Indian metallurgical or environmental history?

MANAGEMENT OF FOREST RESOURCES IN THE PRE- AND EARLY-COLONIAL PERIODS

The cyclical change in demand for iron and steel may have caused an oscillation in landscapes and forest cover. However, institutions play an important role in regulating the use of forest resources. How was the use of wood for charcoal and mining of ore by smelters managed in pre- and early-colonial Mysore?

Under the Vijayanagar Empire, which ruled over southern India between the fourteenth and sixteenth centuries, permission for cutting down for charcoal and for digging the ore was regulated with a yearly fee called *hommal gutta* which was proportioned to the quantity of iron made in the district.³⁸ This system may have continued even into the nineteenth century. Figure 3 is based on Buchanan's reports of the organisation structure of iron-making operations involving the smelter, the village, the government and other officials in the system.

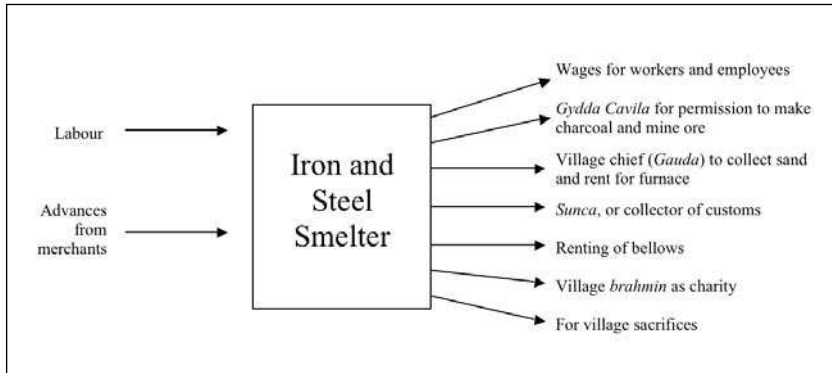


FIGURE 3. Organisation structure of iron-making operations as described by Buchanan

The system was neither a fully commercial one, nor 'communal'; it had elements of both. The ironsmith had a commercial dealing with the merchant (for sale of iron to towns outside his own village and directly to the State for the military) and at the same time was also linked to workers and the village through a system of reciprocity. He would exchange some produce with the farmer. In return he would be paid by allowances of grains from villagers and

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sometimes get land at low rents. The blacksmith would also sell for cash some of the output to village people for non-agricultural purposes like construction of houses.³⁹

We must emphasise the role of the *Gydda Cavila* in Figure 3 as an important institution in the regulation of use of forest resources. Access to trees for charcoal and mined-ore was controlled by the Gydda Cavila or what Buchanan refers to as ‘keeper of forests’ or ‘renter of forests’. The meaning of this term is not clear in present-day Kannada. The word which comes close in modern parlance is ‘*gidda kavalu*’ literally meaning, ‘watchman of plants’.

I reproduce below the role of the Gydda Cavila in Mysore State as explained by Buchanan:

In every taluc, or district, where there are forests, there is a Gydda Cavila, who annually pays to the government a certain sum, and has exclusive privilege of collecting honey, wax, and lac. On all such as cut timber for building their houses, he also levies a duty; and all the trees, except sandal-wood, are in fact his property. The government ought to pay him for all the trees which it requires ... the keeper of the forest exacts small duties on those who, without being privileged, feed their goats and cattle in the woods; on the women, who collect the leaves, which are used as platters ... and those who collect firewood, and grass for thatch.⁴⁰

In Madhugiri, the share ‘to the the keeper of the forest, for permission to make charcoal’ was 100 Fanams out of a total cost of 276 Fanams, i.e. more than 36 per cent of the cost (not including labour costs) and another 40 Fanams which had to be paid to the village chief (*Gauda*) for ‘leave to gather sand’. In Doray Guda, where ore was collected, the payment ‘to the renter of mines and woods’ was 130 Fanams, or 30 per cent of the total expenses (excluding labour costs). Though a steep fee was charged, strict control and monitoring of forest resources hardly seemed to be a concern of the Gydda Cavila. This is made clear in a remark by Buchanan, ‘the renter has no occasion to come near the mine. He knows the men that get a supply of ore, and each pays yearly a certain sum, and takes as much ore as he pleases’.⁴¹

The institution of renting forests continued in the early colonial period. It, however, was held responsible as the foremost reason for forest destruction in the nineteenth century, followed by shifting cultivation and iron smelting (the ‘third’ reason as mentioned in the above-referred passage from the Gazetteer). Leasing forests had the effect of offering a premium for the destruction of trees for present profit without any regard whatever for the future; no incentives existed to rationalise utilisation of forest resources over a long period of time. According to the Mysore Gazetteer in the earlier days of colonial rule as well as under former Indian Rulers, forests owed their preservation to a scanty population and poor road and railway communications which kept the demand for timber low. Therefore, in spite of the fact that no systematic effort or expenditure for

their maintenance or regeneration was allocated to the forests, the system of exploitation through 'renter of forests' continued to survive.⁴²

We must also understand that without a well-developed transport system, localised degradation of forests could have meant the suspension of iron smelting at a place. Degradation, therefore, need not have been extensive or widespread. Even if it occurred in small forest patches its consequences could have forced people to migrate, maybe just a few kilometres away, to seek fresh 'pastures' for charcoal. There are scattered references to this having happened wherein smelters adopted a nomadic form of life. In 1822 at Nersa, Belgaum district, 'iron was worked by a wandering tribe who came yearly in the fair season from Goa or the Savantvadi state ... the villagers were wholly unacquainted with the nature of the process by which the metal had been extracted'⁴³. Another report mentions that 'furnaces could be carted from place to place'⁴⁴. It cannot be inferred with any degree of certainty that such 'shifting smelting' was a response to an overuse of resources at any single location. However, it is a possible strategy that smelters might have used to regulate and conserve forest resources for charcoal.

The extensive deforestation that took place in the 1850s raises the concern, or rather the hypothesis, that in a more commercialised colonial economy, with an increased demand for iron and steel, the 'renter of forests' as an institution was unable to manage resources prudently and prevent rapid depletion of forest tracts. In the study of South Indian environmental history, the role, responsibilities and duties of the 'renter of forests' has received little attention. More importantly, it is necessary to explore how iron smelting in combination with this *laissez faire* institution of the early nineteenth century were legitimising factors in the development the 1878 Forest Act.⁴⁵

ATTRIBUTING A STRATEGIC MOTIVE TO DOBBS' BAN ON IRON SMELTING

It has been argued that the motive of the British in restricting shifting cultivation was essentially to preserve teak trees for the railways, to create 'free' labour in hilly regions for construction and plantations, and to widen the tax net. Could Dobbs' ban on smelters have served a more strategic interest of the incipient British regime: control over manufacture of weapons?

The British took direct control over Mysore in 1831 by squashing the Peasant Revolt. Though Mysore did not experience a similar situation in the immediate future, ferment was brewing in many neighbouring regions. Concerned by possible violent conflict, the British dismantled several forts and disarmed their political opponents. For instance, in 1857, the British Government collected several thousands of weapons from the Moplahs of the Malabar and systemati-

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cally destroyed them at the Beypore plant. Quoting Charles Wood, Krishnan elaborates:

... these knives were all made out of the native iron from the Indian blast-furnaces, and wonderful material they were. To break them was impossible ... the remarkable quality of the iron, and that it could so beautifully be tempered. These war knives were sent up to the works in native bullock-carts from Calicut, in charge of sepoys, in lots of about 1,000 to 1,500 at a time, until they were all destroyed ...⁴⁶

Control over forests, specifically to control local iron and steel production through the control over production of charcoal, could have been of strategic, not merely economic, importance in the process of colonialisation, a possibility hitherto unexplored in Indian history.

As we have pointed out, not only is iron smelting as a cause of deforestation under-explored, but also important is the role that this causative viewpoint played in legitimising the introduction of colonial forest policies. In comparison to the role of *swidden* or shifting cultivation⁴⁷, the inadequacies of the then existing institutional mechanisms and overexploitation of forest resources by smelters has not been delved into adequately. Moreover, parallels between the 'true' (non-ecological) objectives of controlling shifting cultivation could also be drawn in the case of iron smelting. Forests served a critical strategic function in medieval times; they provided the fuel to manufacture the metal for conventional weapons including swords and cannons. Control over forests could have been an important means to gain control over weapon manufacture.

THE BEGINNING OF THE END

It is not clear from archival records whether Dobbs' ban was successfully implemented. However, his comment was made in 1855, the pre-railways era. The initiatives for conservation at this time were 'limited in scope and effectiveness ... most officials still saw agrarian extension as the chief priority'⁴⁸. It is, therefore, not surprising that Dobbs highlighted the impact of deforestation on rainfall in the region. This causal link between deforestation and drought had been a major concern to some early proponents of forest conservation,⁴⁹ and the activities of iron smelters operating within an institutional regime that favoured short-term private gain, rather than prudent long-term use of resources, became the legitimising factors for state intervention in control of forests. Collection of fees as revenue was of relatively less importance.

Towards the end of the 1850s, forest conservation became more purposeful; timber was needed for the railways. With it came the need for a more independent institution with greater powers to 'protect' forests by excluding competing users. Even though railways came to Mysore decades later, in 1862, just seven

years after Dobbs' record, the Chief Commissioner of Mysore, Lewin Bentham Bowring, moved the Government of India to organise a Department of Forest Administration. The first conservator of forests, Major Hunter, was appointed in 1864. In 1865 some forests were declared as Government Reserved or 'Royal Forests'. Rules pertaining to use and fees for different classes of trees were enforced. However, these rules were not applicable to District Forests, which were only brought under the control of the forest department more than a decade later, in 1878.

A list of records of iron smelting in the Maidan between the late eighteenth and early nineteenth centuries is presented in the Appendix. In the final decade of the nineteenth century, smelting was still being carried out extensively in spite of a state controlled forest regime. In Tumkur district, 116 forges were still operating in 1897.⁵⁰ Interestingly this was more than three times the number operating in 1800 (as estimated from Buchanan's records). At the end of the nineteenth century, with an average output of a furnace being seven tons per year, total output would have been ~ 800 tons/year⁵¹. In fact, throughout India, at the beginning of the twentieth century, there were hundreds of furnaces each manufacturing two to three tons of iron every year.

What then was the impact of the 1878 Forest Rules on smelters? Or to put it differently, why had the enforcement of the Forest Rules not caused a complete dearth of wood for charcoal so that iron smelting continued at a fairly large-scale? One possibility might have been the attitude of the forest officials to less valuable woods, in particular, bamboo. D. Brandis, one of the key architects of India's forest policies, encouraged the use of 'inferior' species like bamboo as fuel for iron smelting. Bamboo, a grass, was seen as a competitor to growth of hardwood trees and its elimination could benefit the long-term prospects of more commercially valuable species.⁵² Buchanan's reports show that bamboo was used extensively in the Maidan for iron-smelting. Section 23 of the Forest Rules implemented in district forests of the Maidan confirms that bamboo was not a reserved species; availability of bamboo for charcoal-making may have continued unabated by state control over forests. It is, therefore, not surprising that at the end of the nineteenth century, we can find in Tumkur district an increase in iron smelting to 800 tons/year, and at the same time, the slopes of Devarayadurga hills and around Kortegere and Madhugiri were clothed with trees, including forests of *Hardwickia binata*.⁵³ The dependence and unobstructed use of bamboo by smelters might have also permitted the regeneration of hardwood trees in reserved or State forests, reversing the situation observed by Dobbs.

Perhaps it was only when a shortage of bamboo arose that iron smelters came in 'conflict' with the state. 'The great demand for fuel created by the railways and increasing consumption at Bangalore'⁵⁴ was also raising demand for hardwood species, bringing the smelter into direct collision with the state. This could have been the situation developing towards the end of the nineteenth century in the Maidan, leading to reports about a developing fuel shortage in the records.

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ANALYSING THE CAUSE/S FOR THE DECLINE OF IRON AND STEEL SMELTING IN THE MAIDAN

By the 1930s it is all but over for the traditional iron and steel smelters of the Maidan;⁵⁵ in fact, traditional iron smelting had vanished almost completely in many parts of India⁵⁶. Two specific causes for the decline of iron smelting in the Maidan are evident from a perusal of the records in the Appendix:

- i) Economic: cheap industrially manufactured iron, imported from England or domestically produced,
- ii) Ecological: shortage of and/or inaccessibility to wood for charcoal due to deforestation and/or forest policies.

For industrially manufactured products to replace traditional iron and steel, certain necessary conditions would have to be fulfilled by the former. Modern products would have to be:

- A 100 per cent substitute for traditional material,
- Cheaper,
- Readily available in required (especially small) quantities and suitable terms (leadtime and payment including credit).

Competition from modern industry did not wipe out traditional crafts in a day. In fact, in many instances they have been unable to completely eliminate traditional products even after decades. One reason is that 'modern' products are not perfect substitutes for 'traditional' ones. Consider, for instance, handlooms, which have survived stiff competition of textiles from Manchester and more recently from modern textiles mills. Another example is *jaggery*, Indian unrefined sugar. White mill-manufactured sugar has not replaced jaggery, which today sells at a higher price than sugar. This could be explained by the simple fact that sugar is not a 100 per cent substitute for jaggery; tastes and textures differ. Was modern iron and steel 'superior' to and a 100 per cent substitute for traditional iron and steel? It might seem so, but at the user-level, things were not so straightforward. According to Iyer, farmers actually preferred the metal of local smelters because it was easier to work on and also recycle.⁵⁷

This brings us to the second condition why traditional blacksmithing declined: price. The user of imported metals, the blacksmith, would obviously prefer a cheaper source of material. However, 'cheaper' may not mean just Rupees per kilogram. Apart from the preference for local material for the reasons given above, Iyer further states that the indigenous iron 'though costlier at first than imported ones, are stated to be cheaper in the long run, as they can be worked by the local smiths without requiring the services of men used to the imported iron and steel'.⁵⁸ Moreover, it was not licence fees imposed by the colonial government that could have caused smelting to become unprofitable. Under Section

23 of the Forest Rules of 1878 iron smelters who paid *mohartafa* (tax) were exempt from payment of fees for firewood or charcoal provided they were for bona fide private use, not to be sold, bartered or traded.⁵⁹ The tax itself was paltry: 12 Rupees and 12 annas (~R12.75) per furnace. Moreover, paying the tax meant that the smelter did not have to pay any royalty for ore collected or mined and further, no licence fee for collection of wood for charcoal-making! With a clear annual 'profit' of R300 per furnace, the tax worked out to just 4 per cent, and on revenue a mere 0.25 per cent.⁶⁰ As long as bamboo was abundant, the smelters operating under a state regulated regime seemed better off than that under the Gydda Cavila where, as seen above in Figure 3, a relatively 'hefty' fee had to be paid by the smelter.

A necessary condition for replacement of a traditional good is the ease of availability of the new product. This would include the form in which it is available (bars, flats, sheets) as well as quantities and terms of payment. Even before the last decade of the nineteenth century, iron and steel was imported by merchants from Bombay. On careful study of records, it is evident that iron smelters of Belgaum and Dharwad districts (then in Bombay Presidency) were facing competition from imported sources. However, further down south in Mysore, imported iron and steel had not achieved a significant presence. One reason for this could be the inadequate development of a distribution network in Mysore by Bombay merchants. This would have also contributed to the continuing presence of traditional iron smelting in the Maidan.

The above analysis shows that an economic argument by itself is not sufficient to explain the decline of traditional iron smelting. Ecology, as a 'shortage' of bamboo and inaccessibility of other wood as part of forest control by the state, may have played a role in tilting the balance in favour of imported iron and steel. Commenting on the possibility of reviving the dying traditional industry in Chitradurga district, Iyer makes this 'non-availability' evident: 'the fuel difficulty may be partly removed for some time at least if the dead and refuse green wood of the Malnad forests be converted into charcoal and distributed to the smelters close by ... if this industry be encouraged ... it will afford a profitable employment to a number of men who are now depending solely on agriculture – a comparatively non-remunerative profession'.⁶¹

Iyer's comment contains some important points: the shortage was localised; adequate wood for charcoal was not available in Chitradurga, a clear indication that over the years smelting had taken its toll on local resources. Wood would have to be converted to charcoal and brought from Shimoga and distributed to the smelters (perhaps with state assistance). The use of other trees like the karachi (which were abundant in Tumkur district as per the Gazetteer), it seems, was out of the question. Only 'dead and refuse green wood' could be made available to the smelters. If charcoal was made available, the smelters of Chitradurga could perhaps have survived the crisis. The shortage of charcoal was pushing artisans to

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take up a less profitable activity, namely agriculture. In other words, the physical 'shortage' of fuel meant a rise in the 'opportunity cost'⁶² of smelting.

In spite of this iron smelting continued in pockets, where perhaps the smelters made their own charcoal in compliance with Section 23 of the Forest Rules of 1878, or from other locally available trees. The final blow to the traditional iron smelters may well have been economics but not necessarily steel imported through Bombay. It was only with the setting up of the Bhadravati Iron and Steel Works in 1923 in Shimoga district by the Mysore Government that servicing the South Indian market became more feasible and it is quite possible that only then did traditional smelting actually cease, completely. Paradoxically, the Bhadravati plant used charcoal as fuel! However, the wood for charcoal came from carefully managed state owned tracts within a radius of 30 miles of the plant. Access to forest resources was based on a strong collaborative effort between the factory and the Forest Department.⁶³

Figure 2 illustrates the possible ups and downs and the period of decline in traditional iron and steel smelting in the Maidan. Our analysis so far captures the causative link between the economic, political and environmental variables and the conjectured production cycles.

IRON-SMELTING IN INDIAN ENVIRONMENTAL HISTORY

At a specific level, this paper brings in ecology, and not merely economics, as a significant variable in explaining the decline of traditional charcoal iron smelting in India. There are two ways in which ecology and iron smelting are interrelated:

- i. Where iron smelting caused deforestation, and
- ii. Where control over forests adversely affected iron smelters by cutting off their fuel source, charcoal.

In the first case, amongst other determinants, the degree of forest degradation from iron smelting depends on volume of production and management of resources. Using the *Maidan* in southern India as the region for analysis, we studied the spatial distribution of traditional iron smelting across the region and also estimated volume of production in one district, Tumkur. Comparisons with some important studies carried out in Africa and Asia indicate that the volumes being produced in this region could have impacted the environment severely. A few pieces of evidence from the late eighteenth and early nineteenth centuries also unequivocally point to such environmental destruction in the Maidan. This causal aspect of iron smelting on widespread deforestation in pre- and early-colonial India has not been given sufficient attention in Indian metallurgical or environmental history.

At a more general level, this study brings into focus some lacunae in the exploration of Indian environmental history. Foremost among these is the discounted role given to Indian industry in pre-colonial India. Numerous studies have been carried out relating to iron, its importance, archaeological studies pertaining to the Iron Age, and India's contribution to metallurgy⁶⁴. However, quite surprisingly, the possible impact of charcoal iron industry on forests has remained of little concern in the Indian environmental history literature⁶⁵; in particular, in pre- and early-colonial India. There is scant recognition, even at a basic technical level, that charcoal for iron consumed large quantities of wood from forests. Rangarajan, elaborating on the huge demand for sleepers by the railways, estimates that 'a mile of broad-gauge track required 1,800 to 2,000 sleepers. By 1878 over two million sleepers had been used for the construction of railway lines'.⁶⁶ If each sleeper weighed a ton, about 2,000,000 tons would have been needed over two decades. This leads environmental historians to conclude, 'the crucial watershed in the history of Indian forestry is undoubtedly the building of the railway network'.⁶⁷ No doubt the railways needed large amounts of wood in addition to sleepers. However, these figures pale in comparison with the amount of wood required by traditional smelters of iron and steel; with an estimated annual production of 200,000 tons,⁶⁸ about 15,000,000 tons of wood would have to be converted to charcoal, annually!

The substantial production of iron and steel for use in weapons is considered 'external' to a subsistence agricultural economy, arising from the demands of the State or 'a powerful segment of the population',⁶⁹ who are in a position to extract a surplus. However, extending the boundaries of cultivation may in fact be induced by the desire, or even necessity, to increase this surplus by the State to meet its own expansionary objectives. In a purely subsistence economy there seems to be no self-contained reason why the community may desire to bring new lands under cultivation. If we take the intentions and needs of the State as the dominant factor in propelling agricultural growth, the role of iron and steel in weapon manufacture in expanding the boundaries of political control deserves greater attention than merely subsuming it to agriculture. And weapons, which could change political outcomes and precincts, consumed a lot of iron and steel.⁷⁰ Imagine the large guns made in Bijapur: 'one of these was 24 feet long. A second, called *Landa Kasab* was 21 feet ... and weighed 47 tons';⁷¹ each of those weapons would have taken a few thousand trees to manufacture!

Apart from weapons, the demand for iron and steel were not purely for village or agricultural use. Quoting Bhanu Prakash, Joshi mentions that one Dutch consignment of this steel consisted of 20,000 ingots shipped from India.⁷² Alam in his study of iron manufacture in Golconda reveals that the Dutch East India Company had begun organising production of iron nails in its factory houses. In 1664, it had nail-making centres at Ponnepilly, Nagalwancha, Ramellepatam (Ramayapatnam), Narsapoer and Palicot where some 40,000 lbs. (Dutch) of nails were made annually. The number of artisans employed was about 300 at

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Narsapur alone and the Dutch used to purchase iron themselves presumably from indigenous sellers.⁷³ In the Maidan region, there is evidence of iron being produced for the 'external' sector. For instance, some of the best iron was manufactured in Malavalli taluk, Mysore district. Almost half the crude iron was exported. The remaining was converted into implements of almost every description. A major part of the finished manufactures were also exported in 'various directions'.⁷⁴ These 'external' markets also gave the smelter a degree of freedom from the village economy and institutions. Historical records are inadequate to understand how iron and steel smelting in pre-colonial India was affecting the environment. It is important that Indian environmental history extends its boundaries through archaeometallurgical studies like those conducted by Goucher and de Barros⁷⁵ in Africa. Only then can more truths about India's precolonial environmental history be unearthed.

Management of forest resources in the context of charcoal manufacture for industry also acquires greater importance. The notion of 'community management of common property resources'⁷⁶ which pervades popular Indian environmental history writing may be insufficient to realise the impact of iron smelting on forests. The conceptualisation of pre-colonial India as a peasant society has focused on the relationship between cultivation and forests.⁷⁷ Gadgil and Guha while attempting to provide a theoretical model of ecological history, reflect this predisposition. The discovery of iron facilitated colonisation of forests by agriculturists; iron tools being used to fell trees.⁷⁸ Apart from this deforestation that occurs on account of extending the boundaries of cultivation, such societies 'in approximate equilibrium with their environment, dominated by *local production for local use*, have only moderate levels of impact in transforming landscapes'.⁷⁹ The use of forest resources is seen as arising from this subsistence-level peasant economy: grazing, firewood, basket making and so on. The possibility of iron manufacture, as imposing demands on forests independent of a village community's needs, and its consequent management, is discounted.

Iron smelting was an important industry in pre-colonial India; its significance cannot merely be subsumed to agriculture. Over the course of hundreds of years, iron smelting adversely impacted the natural environment in which it operated. The British used this as a legitimising reason for state control and management of forests, which may also have served a more strategic purpose in controlling weapon manufacture. In the initial period after the imposition of forest rules, iron smelting flourished possibly with easy access to bamboo and low taxes. However, when shortages of bamboo became more acute, and difficulty in accessing other hardwood trees increased, the situation for traditional smelters deteriorated, ultimately causing the activity to cease.

One further point on South Indian environmental history: the focus has largely been on the Western Ghats. The transformation of the Maidan from tropical dry deciduous to thorn scrub forests as worthy of demanding specific attention has by and large been missing. Moreover, even in the case of the

Western Ghats, the influence of charcoal-making has been ignored. The name Mangalore is believed by some to be from the word, *mikala* or charcoal, which used to be made on the banks of the river Netravati⁸⁰, the wood obviously from the nearby forests. The Gazetteer also confirms that no ore was smelted by 1882 although there are signs that iron was formerly manufactured in different parts of the Sahyadris.⁸¹ This makes it pertinent to study how charcoal iron making may have altered the landscapes of the Western Ghats.

EPILOGUE

We⁸² decided to investigate what remains of traditional iron smelting along Buchanan's route in and around Channarayadurga (Tumkur district) and near Hiriyur (Chitradurga district). At each place Buchanan reported from, we were able to trace iron smelting sites⁸³ which ranged from half an acre to eight acres (see Photographs 1 and 2). We felt sure that some of these were the very sites Buchanan had visited 200 years ago. Most of the sites are presently under cultivation but even now covered with debris of iron slag, pottery pipes, and crucibles. The farmers told us that while ploughing the land, the debris keeps surfacing. To them, it will never end. Some of debris collected by the farmers lay in large heaps at the corner of the fields. We noticed the soil in these plots was black



PHOTOGRAPH 1. Heaps of slag and other debris at iron smelting site, Channarayadurga, Tumkur district

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PHOTOGRAPH 2. Iron smelting site (foreground) and barren hills (background), Channarayadurga, Tumkur district



PHOTOGRAPH 3. Charcoal-making with *Prosopis juliflora*, near Hiriyr, Chitradurga district

like ash. The black earth extends to a depth of five feet and in spite of rains over several years, it still remains that way. We checked the adjacent plots; they had a typical brown soil of the region. A lot of wood and charcoal had no doubt been burnt by iron-smelters. The size of the sites up to eight acres also seems to be much larger than what Buchanan had seen, making it possible that scale of operations had increased through the nineteenth century. At Channarayadurga, Maranna, now a blacksmith (but not smelter) and part-time farmer recollects his grandfather telling him how he melted iron and steel. He is confident he can smelt iron based on what he remembers, but he hasn't given it a try.

Paradoxically, even though charcoal was one of the reasons for traditional smelting to cease, it continues to be produced in the very same region that Dobbs had raised an alarm about more than 150 years ago. But Dobbs wasn't wrong, because today charcoal is made not from trees or bamboo, but from *Prosopis juliflora*, an exotic weed that grows abundantly in deserted landscapes (see Photograph 3). Charcoal makers are allowed to take the plant from the farmers' field for free; labour and other (earthmover) charges are to the charcoal makers account. Several hundred tons of charcoal are produced in the region providing employment to thousands of people and serving urban markets like Bangalore. Close to the charcoal works we found the traditional blacksmith using raw materials from modern industries like bars and flats to manufacture small agricultural implements. The methods used by them took us back to what Buchanan speaks off; the only change perhaps is that the bellows are now attached to a cycle wheel and turned by a hand-pedal.

We can only conclude that development over the last two hundred eliminated only one operation entirely in the Maidan: the smelting of iron. The charcoal-maker and blacksmith still continue to operate in the twenty-first century in almost the same way they did 200 years ago, or perhaps 2000. Could the smelter find a place back within the new order? Some scientists at the Indian Institute of Technology and National Metallurgical Laboratories⁸⁴ believe that traditional smelting can be and needs to be revived. The historical exploration carried out indicates that if physical shortages of charcoal can be overcome through better management of local forest resources, there are many applications where traditional smelting might still be able to withstand competition from modern industry. Apart from socio-economic benefits to smelters, charcoal iron smelting is also considered as ecologically sustainable using cleaner fuel from renewable resources. Trees absorb carbon as they grow and emit it when burnt; charcoal production from plantations, therefore, makes no net addition to greenhouse gases. Charcoal iron smelting might, therefore, allow developing countries to claim benefits under the Kyoto Protocol⁸⁵. If these ideas do fructify we would have come full circle from what was once considered as 'wasteful methods' in production of iron and steel.

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APPENDIX: IRON SMELTING SITES IN THE MAIDAN IN THE LATE EIGHTEENTH AND EARLY NINETEENTH CENTURIES

District	Year of Publication	Comments in the Gazetteer/Other Source
Dharwar	1884	<p>Large quantities of iron smelted at Tegur village.</p> <p>In former times when fuel was plentiful in the Kappatgudd hills and English iron was dear, much iron ore was smelted at Doni and other places in these hills. Iron is still (1883) smelted at Tegur ... and at Gulgi at Kalghatgi.</p> <p>Iron was formerly smelted at many places besides at Tegur. But chiefly from want of fuel the smelting did not pay and the works were closed.</p> <p>In Hubli ... iron-workers numbering about fifty houses ... make hooks, nails, buckets ... the competition of cheap English hardware has greatly reduced the demand for their work and presses heavily on them. Twenty persons trade but do not work in iron.</p> <p>The iron sheets are brought from Bombay though they arrive ports at Karwar and Kumta on the west coast. The imports are made by Bohras and other Musalmans who then sell the raw materials to blacksmiths, some of whom are men of capital and others are labourers. They convert the imported iron into axes, pickaxes, spades, and so on.</p> <p><i>(Land Survey of Dambal 1845-6):</i> Iron was also smelted in Doni and Chikvadvatti and prized by the people for field tools.</p> <p><i>(In Revision Survey of Dambal 1874-5):</i> River bed stones rich in iron, were smelted in Chikvadvatti, Doni and some smaller villages in the Kapat hills. Iron smelting had once been a large industry but cheap English iron and dear local fuel had ruined it between them.</p>
Belgaum	1894 ⁸⁷	<p>The <i>kulmarus</i> have given up their old craft of iron-smelting and work as husbandmen, some being under-holders and others field-labourers.</p> <p>Iron, nearly equal to Swedish iron, was formerly made near Kanur, Punare, and Patne in Belgaum, at Kaitnal and Tavaj in Gokak, at Kitur in Samgaon, and near the Ram Pass. The chief difficulty in the way of iron smelting was the large quantity of charcoal it consumed. Brown hematite ... is smelted at Tegihal ... the manufacture of iron has now ceased, partly on account of the increased price of fuel and partly because of the fall in price of iron.</p>
Chitradurga	1897 ⁸⁸	<p>In Molakalmuru ... a tract of nearly 9 square miles in the south is occupied by <i>kammar</i> (<i>Hardwickia bennata</i>) jungle, but the distribution is thin and the trees have been pollarded and much denuded. It seems a pity that steps are not taken to replant and conserve this valuable wood</p> <p>Iron is worked at the Gunderi <i>hobli</i> ...</p> <p>Though cultivation is wanting, manufacture is busy in the Mattod hobli and the neighbourhood of the hills. Iron is smelted at Arisingundi, Chikkabyaldakere and other villages.</p> <p>Iron and some steel is manufactured in Hiriyur, Hosadurga, Chitradurga taluks, in the neighbourhood of the central hill ranges.</p>

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Chitradurga	1900 ⁸⁹	Smelting furnaces operating at Siddayanakote, Vaderhalli, Maremanhalli (Molakalmaru taluk), Chikkabyalikere, Dodbbylakere and Dodkittadahalli (Hiriyur taluk).
	1930 ⁹⁰	Doddakittadahalli – Iron was smelted here formerly. Gattihosahalli – Steel was manufactured here formerly.
Tumkur	1897 ⁹¹	There are 116 forges for the manufacture of iron and steel. Iron ore is found in Chikkanayakanahalli, principally from quarries at Doray Guda. Metal is also smelted from black sand containing iron and is found in Korategere and Madhugiri taluks.
	1930 ⁹²	Some of these ores near Chikanayakanahalli and also the concentrates in the beds of streams in the Korategere and Madhugiri taluks appear to have been smelted previously. Pig iron is manufactured in small quantities at Davanada and Hosahalli.
Mysore	1897 ⁹³	By means of this channel, the former sugar and iron factories at Palhalli used to be worked. Ores are found near Malavalli. Halagur was once the seat of a considerable iron industry, but owing partly to lack of fuel and charcoal, and partly due to competition of foreign iron, smelting has almost been abandoned. Stones containing magnetic iron ore ... is smelted in the same manner as common iron ... at Devanur of the Nanjangud taluk.
	1930 ⁹⁴	There are indications of ancient smelting at ...Halagur in Malavalli taluk.
Shimoga	1897 ⁹⁵	Iron stone of a superior quality is obtained at Kabbaguda (iron hill), the iron made from which the Indians hold to be as good as steel. Smelting of iron from mines at Masrur, Shrigeri, and other places in Anantapur and Shimoga.
	1900 ⁹⁶	Smelting furnaces operating at Hoshalli near Joladahalli, Bulanyakanahalli near Basvapatna (Channagiri taluk), and Tandihalli, Chinnamane, Gangur (Shimoga taluk).
	1930 ⁹⁷	The ores in Shikarpur taluk appear to have been locally smelted about 30 years back.
Bangalore Rural	1897 ⁹⁸	In Magadi taluk much iron is made and some steel. Steel wire of a superior quality for strings of musical instruments is made at Channapatna. Iron ore is collected and smelted in the western parts of Anekal taluk.
Kolar	1897 ⁹⁹	Iron ore is found and manufactured in great quantities.
Hassan	1897 ¹⁰⁰	A little iron is smelted at Bagadi in the Arsikere taluk. It is used chiefly for agricultural implements, but is of inferior quality and no steel is manufactured.
Kadur	1897 ¹⁰¹	Fine iron ore is much worked in the Ubrani hills, and those at Lingadahalli at the foot of the Baba Budans.
Chikamagalur	1919 ¹⁰²	With reference to the prayer of certain raiyats of Chikbyalakere, Hosdurga Taluk, for exemption from payment of seigniorage on charcoal taken out of the forest for smelting iron, it is hereby informed that the question will be considered when a sufficient number of people come forward to take up the industry.

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NOTES

¹ Vibha Tripathi, 'Iron Technology in India: Survival of an Ancient Tradition', in *Tradition and Innovation in the History of Iron Making: An Indo-European Perspective*, ed. Girija Pande and Jan af Geijerstam (Nainital: Pahar Parikarma, 2002), 225–36.

² Wood: charcoal estimates can be found in FAO Forestry Paper 41, *Simple Technologies for Charcoal Making*, (Rome: The Food and Agricultural Organization, 1987). This study gives a ratio of 1:7 whereas others (including Tripathi above) report a ratio of 1:4. One reason for this wide range in ratios could be the difference in the quality of wood (its density, etc.) and also the quality of charcoal (moisture, calorific content, etc.) obtained. The FAO study also states that 1 m³ (= 1 x 1 x 1 m or 3' x 3' x 3' block) of wet wood weighs nearly 750 kg.

³ Helmut Foll, 'Defects in Crystals', University of Kiel, Faculty of Engineering, http://www.tf.uni-kiel.de/matwis/amat/def_en/index.html, mentions that the copper: charcoal ratio is about 1:20. Also on effects of copper smelting on forests, see J.R. McNeill, 'Woods and Warfare in Environmental History', *Environmental History*, 9, 3(2004): 388–410.

⁴ M.W. Flinn, 'Abraham Darby and the Coke-Smelting Process', *Economica*, New Series, 26, 101 (1959): 54–9.

⁵ M Kato, D.M. DeMarini, A.B. Carvalho, M.A.V. Rego, A.V. Andrade, A.S.V. Bonfim and D. Loomis, 'World at work: Charcoal producing industries in northeastern Brazil', *Occupational and Environmental Medicine* 62 (2005): 128–32.

⁶ Kannada is the language of Karnataka State, India.

⁷ Later known as Francis Hamilton but also referred to as Francis Buchanan-Hamilton.

⁸ Francis Buchanan, *A Journey from Madras through the Countries of Mysore, Canara, and Malabar, Volumes 1-3* (New Delhi: Asian Educational Services, 1999).

⁹ B.L. Rice, *The Mysore Gazetteer, Part 2*, (Mysore: Government Press, 1897) and C. Hayavadana Rao, *The Mysore Gazetteer, Vol.4*, (Mysore: Government Press, 1929).

¹⁰ V.S. Sambasiva Iyer, 'Report on Prospecting Work in Parts of the Chitaldroog and Tumkur District during the Field Season 1896-99', *Mysore Geological Department Records*, II (1898–9): 105-7; and V.S. Sambasiva Iyer, 'Notes on Economic Mineral Products of the Chitaldrug and Tumkur district, during the Field Season of 1896-99', *Mysore Geological Department Records* III (1900-01).

¹¹ Buchanan, *A Journey, Vol.1*, 170–76. The process employed for iron-smelting was quite the same everywhere Buchanan went.

¹² *Ibid.*, 175–7.

¹³ Information on species used is compiled from Buchanan, *A Journey, Vol. 2*, 36, and Rice, *The Mysore Gazetteer, Part 2*, 421.

¹⁴ Buchanan, *Journey, Vol. 1*, 2, 3; Rice, *Mysore Gazetteer*, 1897; Rao, 'Mysore Gazetteer', 1930; Iyer, 'Report on Prospecting Work', 1898–9; and Iyer, 'Notes on Economic Minerals', 1900–01.

¹⁵ All details in this section are from Buchanan, *A Journey, Vol.2*, 16, 19, 40.

¹⁶ Manjul Bajaj, 'An Examination of the Potential for Natural Regeneration with Community Participation', in *Selected Readings from Wastelands News on Forests*, (New Delhi: Society for Promotion of Wastelands Development, 2006); and H. Bharath Kumar, 'Smuggling of Timber goes Unchecked in Chitradurga', *The Hindu*, April 22, 2005.

¹⁷ On U.S. deforestation, see for instance, Alfred Philip Muntz, 'Forests and Iron: The Charcoal Iron Industry of the new Jersey Highlands', *Geografiska Annaler*, 42:4(1960): 315–323; Michael Bell, 'The Face of Connecticut, People, Geology, and the Land, State Geological and Natural History Survey of Connecticut', *State Geological And Natural History Survey Of Connecticut*, 110 (1985); Doug Ottke, 'An Environment History of the 19th Century Marquette Iron Range', M.S. Thesis (University of North Dakota: 1999); and in England, see, for instance: The Nature Conservancy, *The Colonial Iron Ore Industry*, <http://www.lastgreatplaces.org/berkshire/history/art6162.html>. On the effects of copper smelting on forests see J.R. McNeill, 'Woods and Warfare in Environmental History', *Environmental History*, 9, 3 (2004): 388–410.

¹⁸ Oswego Heritage Council, *Oswego Iron Smelting Research*, <http://home.europa.com/~heritage/ironintro.html>.

¹⁹ Phillip de Barros, 'Bassar: A Quantified, Chronologically Controlled, Regional Approach to a Traditional Iron production Centre in West Africa', *Africa: Journal of the International African Institute*, 56, 2 (1986): 148–74.

²⁰ Elizabeth Crittenden, *Environmental Impact of Iron Smelting in the Bassar Region of Togo: A Deforestation Problem in Precolonial West Africa*, <http://www.american.edu/TED/togo.htm#r1>, 1997.

²¹ Candice L. Goucher, 'Iron is Iron 'til it is Rust: Trade and Ecology in the Decline of West African Iron-Smelting', *The Journal of African History*, 22, 2 (1981): 179–89.

²² Jack D. Ives and Bruno Messerli, *The Himalayan Dilemma: Reconciling Development and Conservation*, (London: Routledge, 1989).

²³ Michael Williams, 'Dark Ages and Dark Areas: Global Deforestation in the Deep Past', *Journal of Historical Geography*, 26, 1 (2000): 28–46.

²⁴ Robert Miller, 'Elephants, Ivory and Charcoal: An Ecological Perspective', *Bulletin of the American Schools of Oriental Research*, 264 (1986): 29–43.

²⁵ Rao, Mysore Gazetteer, 1930, p. 213.

²⁶ Buchanan, *A Journey*, Vol. 1, 173, 180.

²⁷ Buchanan, *A Journey*, Vol.1, 177, 180 and Vol.3, 424. Also, Rice, *Mysore Gazetteer, Part 2*, 267.

²⁸ Recall this species is not used for charcoal-making.

²⁹ These comments are from Buchanan, *A Journey*, Vol. 2, 15, 24, 55, 44. Note that *dupada* is not used for charcoal-making. Also refer to Map 2 for locations.

³⁰ Buchanan, *A Journey*, Vol. 3, 560.

³¹ Siddalinga Swamy, *Agrarian Relations in Mysore: 1799–1881*, (Bangalore: Nation-builders Book-Sellers, 1997).

³² Buchanan, *A Journey*, Vol. 2, 4.

³³ Charcoal-makers use weeds overgrown on farmers' fields. This sustains the entire charcoal industry of the region today. I will discuss this point later in the paper.

³⁴ Rice, *Mysore Gazetteer, Part 1*, 555–56.

³⁵ *Khist* is an instalment of the annual assessment paid by holders at stated times, *patta* is a title deed granted by the Government. See Swamy, *Agrarian Relations*, 126, 127, 59–62, 64.

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- ³⁶ Morris D. Morris, 'Towards a Reinterpretation of Nineteenth-Century Indian Economic History', *Journal of Economic History*, 23, 4 (1963): 606–18.
- ³⁷ Rao, *The Mysore Gazetteer, Vol.4*, 191.
- ³⁸ Rice, *Mysore Gazetteer, Part 1*, 477.
- ³⁹ J.M. Campbell, *Gazetteer of the Bombay Presidency, Vol. XXI, Belgaum* (Bombay: Government Central Press, 1894), 233.
- ⁴⁰ Buchanan, *A Journey, Vol.1*, 391.
- ⁴¹ *Ibid.*, 37, Buchanan, *A Journey, Vol. 2*, 18, 40.
- ⁴² Rao, *Mysore Gazetteer, Vol. 4*, 188–89.
- ⁴³ J.M. Campbell, *Gazetteer ... Belgaum*, 53fn.
- ⁴⁴ P. Agarwal, 'Did you Know?', http://www.infinityfoundation.com/mandala/t_dy/t_dy_Q15_frameset.htm
- ⁴⁵ See Benjamin Weil, 'Conservation, Exploitation, and Cultural Change in The Indian Forest Service, 1875–1927', *Environmental History*, 11, 2 (2006): 319–43, for an account on the principles guiding the Forest Acts.
- ⁴⁶ M.S. Krishnan, 'Iron Ore, Iron and Steel', *Bulletin of the Geological Survey of India, Series A: Economic Geology*, 9 (1954): 71.
- ⁴⁷ M. Rangarajan, *Fencing the Forest: Conservation and Ecological Change in India's Provinces 1860–1914*, (New Delhi: Oxford University Press), 2002.
- ⁴⁸ Rangarajan, *Fencing the Forest*, 55.
- ⁴⁹ Pallavi Das, 'Hugh Cleghorn and Forest Conservancy in India', *Environment and History* 11 (2005): 55–82.
- ⁵⁰ Rice, *Mysore Gazetteer, Part 2*, 172.
- ⁵¹ Iyer, 'Report on Prospecting', 104, states that the average output of a smelter was 7 tons/year, total output would have been ~ 800 tons/year.
- ⁵² Rangarajan, *Fencing the Forest*, 65, 88.
- ⁵³ Rice, *Mysore Gazetteer, Part 2*, 160.
- ⁵⁴ *Ibid.*, 11.
- ⁵⁵ See Appendix for reports from across the Maidan.
- ⁵⁶ See Krishnan, 'Iron Ore', 68. Traditional iron smelting in 1916 in the Central Provinces was about 4500 tons/year. See P.P. Pillai, Iron and Steel Production in India, *Economica*, 7 (1923): 55–66. In 1931 iron smelting continued in the Eastern Ghat (Bastar) region. See L.A. Cammiade, 'Iron Smelting by Kois, a Jungle Tribe in the Eastern Ghats of India', *Man*, 31 (1931): 66–7. Iron smelting is even today carried out by the Agaria tribes in the Bastar region in the erstwhile Central Provinces. This is probably the last region remaining in India where traditional iron smelting can be found.
- ⁵⁷ Iyer, 'Report on Prospecting', 108.
- ⁵⁸ *Ibid.*, 108.
- ⁵⁹ Karnataka State Archives, The Mysore Gazette, S.No. 185, No. 6, February 9, 1889.
- ⁶⁰ Iyer, 'Report on Prospecting', 104 and 'Notes on Economic Minerals', 244.
- ⁶¹ Iyer, 'Report on Prospecting', 110.
- ⁶² In economics, 'opportunity cost' is defined in terms of cost of the next best alternative foregone.

⁶³ John E. Brush, 'The Iron and Steel Industry in India', *Geographical Review*, 42, 1 (1952): 39, and 'Working Plan for Supply of Fuel and Charcoal to Mysore Iron & Steel Works', Forest Files Mysore.

⁶⁴ For an interesting technical account on the metallurgy of Indian steel (wootz) see, T.R. Anantharamu, P.T. Craddock, K. Nagesh Rao, late S.R.N. Murthy and M.L. Wayman, 'Crucible Steel of Gattihosahalli, Chitradurga District, Karnataka, southern India', *Journal of the Historical Metallurgical Society*, 33, 1 (1999): 13–25.

⁶⁵ Artisans in colonial history have been a subject of attention in historical studies. See, for example, Tirthankar Roy, 'Home Market and the Artisans in Colonial India: A Study of Brass-ware', *Modern Asian Studies*, 30, 2 (1996) 357–85. However, the study does not raise any concern for the environmental consequences of copper smelting. Krishnan, 'Iron Ore' also fails to examine the possible impact of iron smelting on local forests, even though he extensively discusses the huge amounts of iron and steel produced for various applications. He does mention that iron-making in the nineteenth century faced a crisis because 'forests were disappearing'. However, he does not mention the contribution of iron smelting to the crisis of dwindling forests.

⁶⁶ Rangarajan, *Fencing the Forest*, 29.

⁶⁷ Ramachandra Guha, 'The Prehistory of Community Forestry in India', *Environmental History*, 6, 2 (2001): 231–8.

⁶⁸ D.P. Agarwal, 'Did you Know?'

⁶⁹ *Ibid.*, 31.

⁷⁰ See McNeill, 'Woods and Warfare', 388–410, for an excellent account of how forests have played an important role in warfare and politics.

⁷¹ Krishnan, 'Iron Ore', 66.

⁷² Maheswar P. Joshi, 'Some Aspects of Ironworking in Antiquity vis-à-vis Central Himalaya', in *Tradition and Innovation in the History of Iron Making: An Indo-European Perspective*, ed. Girija Pande and Jan af Geijerstam (Nainital: Pahar Parikarma, 2002), 47–59, p.53.

⁷³ Ishrat Alam, 'Iron Manufacturers in Golconda in the 17th Century', in *Tradition and Innovation in the History of Iron Making: An Indo-European Perspective*, ed. Girija Pande and Jan af Geijerstam (Nainital: Pahar Parikarma, 2002), 98–111.

⁷⁴ Rice, *Mysore Gazetteer, Part 2*, 209.

⁷⁵ See Notes 17 and 19 above.

⁷⁶ This notion may be more relevant to activities like cattle grazing, collection of non timber forest produce, and collection of firewood for domestic consumption. However, even for these activities, the Gydda Cavila, according to Buchanan, collected a fee.

⁷⁷ The use of forest resources is also limited to 'agriculture' and the 'village economy'. The commercial use of forest resources in pre-colonial India needs further investigations. For instance, the sandalwood trade was controlled directly by the monarch.

⁷⁸ Madhav Gadgil and Ramachandra Guha, *This Fissured Land: An Ecological History of India*, (New Delhi: Oxford University Press, 2000).

⁷⁹ *Ibid.*, 39.

⁸⁰ Apart from wood, water is also crucial in the manufacture of charcoal. Often, charcoal works are found on river banks, especially where timber could be transported along the river from the forest.

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⁸¹ R.E. Enthoven, *Kanara District Gazetteer*, (Bombay: Central Government Press, 1883), 262. Sahyadris refer to Western Ghats.

⁸² I was accompanied by Mahadev R. Nayak on my field visits. It was during our innumerable discussions that the idea for this paper developed. Mahadev provided many interesting insights into possible developments in the area, and also conducted many of our discussions at the places we visited. I am also grateful to the many people we met during our field visits for their comments and help in locating smelting sites.

⁸³ We traced three sites near Channarayadurga, one each at Yelladakere, Chikkabaylikere and Doddabaylikere. In the case of Doddabaylikere apart from one field, we were told the village itself was built on a smelting site. Here we could see debris embedded in the village streets. At Yelladakere, local people were unaware of any iron smelting sites. We were quite sure there must be some site in the village where debris could be found. The locals said they would check with an old man of the village and we should come back after a few days. When we did, they were more excited than us. There was indeed a site ... and it was exactly like what we had described. Buchanan was right after all.

⁸⁴ See Tripathi, 'Iron Technology in India', 233, and A.K. Vaish et al., 'Iron Making in Ancient India – A Critical Assessment', in *Tradition and Innovation in the History of Iron Making: An Indo-European Perspective*, ed. Girija Pande and Jan van Geijjerstam (Nainital: Pahar Parikarma, 2002), 237–49.

⁸⁵ For a general overview of the Kyoto Protocol and its implications, refer United Nations Framework Convention for Climate Change website, www.unfccc.int.

⁸⁶ J.M. Campbell, *Gazetteer of the Bombay Presidency, Vol. XXII, Dharwar* (Bombay: Government Central Press, 1884), 787, 25, 382, 740, 494, 541.

⁸⁷ J.M. Campbell, *Gazetteer ... Belgaum*, 108–9, 52–3.

⁸⁸ Rice, *Mysore Gazetteer, Part 2*, 533, 527, 524, 510.

⁸⁹ Iyer, 'Notes on Economic Mineral Products', Tabular Statement-I.

⁹⁰ C. Hayavadana Rao, *The Mysore Gazetteer, Vol.5*, (Mysore: Government Press, 1930), 1356.

⁹¹ Rice, *Mysore Gazetteer, Part 2*, 172, 158.

⁹² Rao, *Mysore Gazetteer, Vol.5*, 383, 422.

⁹³ Rice, *Mysore Gazetteer, Part 2*, 258, 267, 209.

⁹⁴ Rao, *Mysore Gazetteer, Vol.5*, 565.

⁹⁵ Rice, *Mysore Gazetteer, Part 2*, 483, 421.

⁹⁶ Iyer, 'Notes on Economic Mineral Products', Tabular Statement-1.

⁹⁷ Rao, *Mysore Gazetteer, Vol. 5*, 1207.

⁹⁸ Rice, *Mysore Gazetteer, Part 2*, 33, 37.

⁹⁹ *Ibid.*, 118.

¹⁰⁰ *Ibid.*, 338.

¹⁰¹ *Ibid.*, 410.

¹⁰² Karnataka State Archives, Proceedings of the Government of Mysore, R.5113-Ft.8-18-6 dated 3 Nov 1919.

