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Impact of traditional Iron manufacturing on Forest in the Khasi hills of Meghalaya

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***Abstract*:** Iron manufacturing in the Khasi and Jaintia hills Meghalaya which dates back to about two thousand years old remain undisturbed till it was finally replaced by the factory-made British iron. The traditional iron industry of preliterate Khasi-Jaintia Hills has however generated keen interest among scholars right from the colonial times. Although no systematic investigation has been conducted from the science of Archeology to excavate any iron smelting sites in these hills, yet there are some documented literatures of the colonial period which provide figures to help quantify the magnitude of this traditional iron smelting and manufacturing industry on the forest vegetation in these hills. The current paper is a preliminary attempt to assess the destruction of the primary forest cover of on these hills due to the traditional iron industry leading to new adjustment in the social behavior with their surrounding environment.

Key Words: **Khasi-Jaintia Hills, Traditional Iron manufacturing, Forest cover, Sacred Groove**

I. Introduction

The inhabitants of the Khasi-Jaintia hills of Meghalaya of the North Eastern region of India, could boast for being one of the earliest manufacturers of iron tools in the region. The tradition of iron manufacturing in these hills continued undisturbed throughout the preliterate period and survived well into the time of British annexation of these hills in the later part of the 19^{th} century. Scholars are of the opinion that the Khasis (collectively; including the Pnars) are the authors of the iron industry in the hills and could probably be the first iron using culture among the innumerable tribes entering the North Eastern India region[1]. Documentation of the Iron Industry in its dying stage was recorded by officials and ethnographers of the British Government. They provide us with authentic reports to measure the scale of the industry during the early and Middle part of the 19^{th}century[2].

Iron slag which is staple to archaeo-metallurgical research are the most abundant and best-preserved product of which offers clue in understanding iron manufacturing right from its incipient stage. Radiocarbon or $C\text{-}_{14}$ date from of a charcoal that was extracted from one of such iron slag from the site at Nongkrem of Khasi hills, produce a date of 2040 ± 80 years BP[3]. Iron manufacturing in the Khasi Hills was thus initiated at least 2000 years ago[4] and continued right to the middle of the 19th century. The large-scale metallurgic

[1] Namita Sadap Sen.1984, *Origin and Early History of the Khasi-Synteng People*, Firma Publication, Calcutta.

[2] Sir.William Hunter.1879, *Statistical Account of Assam*, Tubener, London, pp.203-255 [2] Thomas Oldham. 1854, *On The Geological structure of a portion of Khasi Hills with observations on the meteorology and ethnology of that district*, Calcutta, pp.70-77. Sir Henry Yule.1943, *JASB* Vol XI part ii p853, P.R.T. Gurdon. 1914, *The Khasis*, Macmillan and Co.Limited London etc..

[3] Pawel Prokop and Ireneusz Suliga, 2013 "Two thousand years of iron smelting in the Khasi Hills, Meghalaya, North East India" *Current Science* VOL. 104, NO. 6, pp 761-768.

[4] World's earliest date for Iron manufacturing is fixed at 1350 B.C, on the basis evidence from the site of Gerar Palestine dated by Sir.Flinder Petrie way back in 1927.

production from these hills was a response to the demand for iron from the adjacent lowlands, which did not have ore-resources.

Iron Smelting and Charcoal Fuel Consumption

Charcoal which can burn to about 1100 degree Celsius is high enough to reduce the oxides in the ore and therefore became the basic ingredient of fuel used for smelting iron in the early stages of human cultures. Using a primitive iron manufacturing bloomery furnace as one that are found in Khasi hills, experiment were conducted by a team of scientist from the National Metallurgical Laboratory, Jamshedpur to understand the quantity of Iron: slag ratio production per unit. The results from such an experiment produce the following figures[5]:

Experiment Study Results

25 Kg Iron Ore + 30 Kg Charcoal **Produce** 5.51.Kg Wrought Iron + 21 kg Slag

It has been known that a considerable quantity of iron was exported from the Khasi Hills into the plains of Bangladesh through Sylhet. The earliest record by colonel Lister in 1853 shows that approximately 20,000 maunds of finished iron products and pig iron was exported to the Assam and Surma valley[6]. A more precise report came in 1864 which accounted that the annual export of pig iron was estimated to be 45,000 *maunds* valued to about Rs.67,500/- during those days[7]. The figures certainly helped to evaluate the role of iron as a base of the people's economy besides agriculture. Thomas Oldham also provided a detailed report on the process of manufacturing iron. He stated that, there is a complete division of labour after the stage when pig iron was finished into working implements in the hills itself to the extent that different villages have specialised in the manufacturing of selected implements. In the Khasi hills, charcoal was the only fuel used for the entire process of iron smelting and manufacturing. The best charcoal from these hills was produced from local oak species, but in cases where there was a lack of a hardwood other kinds of trees was used for carbonization[8].

While estimating the amount of iron production from the above-mentioned report of Khasi hills, it is imperative to consider that the estimates are based only for the exported material which was recorded in 1864, a stage when the industry had considerably decline.

Based on the calculations arrived from the said experiment on traditional iron smelting (in bloomery furnace as those used by the Khasi smelters), the following figures can be generated in the context in the Khasi hills:

[5] A.K. Vaish et.,al, 1997, Iron Making In Ancient India: Critical Assessment", *Tradition and Innovation in the History of Iron Making.* National Metallurgical Laboratory, Jamshedpur, pp. 237-249.
[6] Gurdon, P.R.T.1914, *Op.,cit*. pp.57.
[7] Thomas Oldham**,** *Op.,cit.*and W.W. Hunter, William.1879, *Op., cit*.
[8] Hooker, J. D. 1854, *The Himalayan Journals*, *Vol 2,* pp.1-345. John Murray, London.

Annual Exports from the Khasi hills

45000 Maunds = 1800000 Kgs

Based on Experiment Study
5.54 Kgs of Charcoal **Produce** 1 Kg of Wrought Iron
Result for Khasi Hills=9972000 Kgs of Charcoal **Produce** 1800000 Kgs of Pig Iron

There are studies which also try to investigate the amount of charcoal usages and its impact on deforestation due traditional iron smelting. The following figures are the model results[9]:

Figures Derived From Study Report
1tree **Produce** 500 Kg wood
4-7 Kgs of wet wood **Produce** 1 Kg charcoal
16 Kgs of charcoal (80-110 Kg Wet Wood) **Produce** 1Kg of refine Iron

Applying the Experimental Study and the Study Report, the following are the results on the range of deforestation in Khasi hills caused by traditional iron smelting as per the colonial reports:

1 single Tree **Produce** 70-120 Kg Charcoal
16 Kgs charcoal **Produce** 1 Kg Refined Iron
1 Single Tree **Produce** 4-7 Kgs of Refined Iron
Annually 260000 – 450000 Trees **Produce** 1800000 Kgs Pig Iron

Charcoal Production and Forest degradation

Way back in 1910, PRT Gurdon observed that in the higher ranges, the hills are denuded of forest and covered with short grass. The landscape was thus laid barren of trees as the wood was being used for fuel for iron smelting in the days gone by[10]. The denudation of the forest was also caused by the method extraction of metals from rock boulders which led to large scale erosion of the soil.

The impact of charcoal on ecosystems occur at every stage in the production-consumption chain, but here the work is focused only on the impacts of production in the subtropical forest ecosystems, a condition prevailing in the Khasi-Jaintia hills. Charcoal is produced from aboveground tree biomass, implying that the whole or parts of trees must be felled, followed by wood carbonization process in traditional kilns. In most cases there have been reports highlighting concern about deforestation and forest degradation accompanying the iron production process. Forest degradation refers to less obvious changes in woody canopy cover while deforestation is the more or less complete loss of forest cover that is often associated with forest clearance

[9] Sivaramakrishnan Sashi, 2009, "Production Cycles and Decline in Traditional Iron Smelting in Maidan, Southern India 1750-1950,: An Environmental Historical Perspective", *Environment and History Vol. 15 No. 2* pp.163-197.

[10] Gurdon, P.R.T.1914, *The Khasis*, Macmillan and Co.Limited London, pp.4

[11]Degradation therefore represents the temporary or permanent reduction in the density, structure, species composition or productivity of vegetation cover[12].

The impact of producing a specified amount of charcoal depends primarily on tree size and density which vary among the forest types. In the present study, traditionally managed private and community forests in the state of Meghalaya, called the "sacred groves"[13] are used as the reference of the forest types that once thrived in the area of the investigations. Till date 79 such groves have been documented [14]in Meghalaya, of which 32 are located in East Khasi Hills, 13 in West Khasi Hills, 3 in Ri Bhoi, 15 in Jaintia Hills and 16 in Garo Hills.

Today these forests have a sharp contrast to their immediate surrounding grassland. Out of the total area of 10,511.7 ha under sacred forests, 138.1 ha area which constitutes a little over 1% of the total, is still undisturbed which includes the Mawphlang sacred grove in east Khasi Hills district, Raliang and Ialong sacred groves in Jaintia Hills. These groves represent the climax subtropical broad-leaved forests. The most common tree species belonging to different families are shown in the appendix.

Regeneration of Vegetation

Biomass for charcoal production is obtained from natural forests in which natural regeneration is the main source for forest recovery. Regeneration of tree species takes place through either sexual or vegetative means. Sexual regeneration is achieved through seed germination and establishment of seedlings and their recruitment into tree phase. Vegetative regeneration occurs through the recruitment of sprouts or re-sprouts into the tree phase from pre-existing trees that are cut or damaged, often termed as coppice. Sprouting is the production of secondary trunks as an induced response to injury or to profound changes in growing conditions. The significance of these regeneration mechanisms depends on the floristic composition of the forest and nature of disturbance. Seedlings are a significant source of regeneration in tropical moist forests after disturbance, such as cutting, than in tropical dry forests where regeneration from saplings is more important. Re-sprouting is a common source of regeneration in both moist and dry forests because many tree species are capable of re-sprouting. However, re-sprouting may be more important in tropical dry forests than in moist forests because of the longevity of trunk bases and the adaptation of plants to seasonal drought.

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[11]Grainger A. 1999, “Constraints on modelling the deforestation and degradation of tropical open woodlands”. *Global Ecological Biogeographer*.(8):pp.179-190.

[12] Chidumayo EN, Gumbo, D.J. 2013, ” The environmental impacts of charcoal production in tropical ecosystems of the world: A synthesis”. *Energy for Sustainable Development*, (17): pp. 85-94.

[13] In the Khasi traditional belief, there is so much of taboo attached with the Sacred Grooves that whoever cut down a tree from these forest would faced the wrath of the forest’s presiding deity and would suffer physical deformity.

[14] Tiwari BK, Barik SK, Tripathi RS. 1999. *Sacred Forests of Meghalaya*, Regional Centre, National Afforestation and Eco-development Board, North-Eastern Hill University, Shillong.

In the study, the mean density (1200 ha^{-1}) of trees found in the sacred groves today is used for estimating the degree of clearance of forest for charcoal production. The trees within the range of 5-15 cm dbh class are found about 60%, while above 60 cm dbh class are found about 5% only.

Taking into consideration that a number of 2,60,000–4,50,000 trees were required to annual production of 18,00,000 kgs of pig iron in Khasi hills, and the mean tree density of 1200ha^{-1} found in the sacred groves, it is estimated that 217–375 ha of forest cover would be cleared within a time period of one year alone. While the mean density of individual trees was considered (11 ha^{-1}), it would have required to cover an area of about 23636–40909 ha (236.36 – 409.09 sqkm) within the same period of time (see variation in table below).

Year (s)	**Clear Cutting**		**Selective Cutting**	
	1200 ha^{-1}		**11 ha^{-1}**	
1	216.67 (2.17)	375.00 (3.75)	23636.36 (236.36)	40909.09 (409.09)
10	2166.67 (21.67)	3750.00 (37.50)	236363.60 (2363.63)	409090.90 (4090.90)
15	3250.00 (32.50)	5625.00 (56.25)	354545.50 (3545.45)	613636.40 (6136.36)
20	4333.33 (43.33)	7500.00 (75.00)	472727.30 (4727.27)	818181.80 (8181.81)
25	5416.67 (54.17)	9375.00 (93.75)	590909.10 (5909.09)	1022727 (10227.27)

Note: all figures in **ha**; figures in parenthesis **sqkm**

Many tropical forests have the potential to regenerate after clearing for charcoal. The forest regeneration rates are a function of forest type, cutting system, rainfall, fire management and grazing intensity. Considering poor natural seedling regenerations of tree species such as *Quercus*, *Lithocarpus*, *Schima*, *Symplocus*, *Ligustrum* etc. which are most commonly used, and the high demand for charcoal requirement, coupled with very large forested area to be covered to collect selective tree species, it is most likely that there had been very little species and size selection in tree felling for charcoal, such that there was virtual clear-felling of the woodland around a kiln site. It would imply that 2166.67 – 3750.00 ha (21.67 – 37.50 sqkm) to 3250.00 – 5625.00 ha (32.50 – 56.25 sqkm) respectively were required to be cleared within 10 – 15 years time.

The presence of marked vast grasslands adjacent to each of these sacred groves in both Khasi and Jaintia hills today is an indication of large scale non-selective forest clearance. Over the years, perhaps removal of large forest areas for charcoal productions had altered the structure, species composition and productivity of the harvested areas and gradually transformed them into such grassland. Owing to the same factor, spaces were created for other faster growing and resilient species to populate the forest covers.

It is also important to consider the role of microorganisms and the nutrients level of these forest areas with regard to successful establishments of seedlings. The areas are known to receive very high precipitation (2500 mm) and this factor coupled with steep slopes of such areas might have accelerated the removal of nutrients in the top soil along with the microorganisms (such as ecto and endo mycorrhizae), which play crucial role in establishment of seedlings at their early stages. Another important factor that exacerbated poor regenerations of trees might have come from unregulated forest fire, which is practiced by the people of the area. Under severe wood resource depletion, even stumps left over from previous charcoal production may be dug up and used to make charcoal, resulting in acute reduction in the potential for natural forest regeneration.

Analysis

In the assessment of the impact of charcoal production in subtropical forests of the study area, it is assumed that clear-cutting rather than selective cutting for charcoal production is the primary reason for alteration of vegetation[15]. Forest re-growth having high tree species diversity indicates clear cutting removal of the entire canopy[16]. The sacred groves of these areas were reported [17]to have very high species diversity. It is assumed that the very idea of traditional managements of such sacred groves attached to religious beliefs were an attempt to prevent such large-scale clearance of the forests. It is interesting to note that 40%[18] of the total sacred groves documented till date are concentrated in a relatively small area of East Khasi Hills on the southern slopes of the central highland, areas that are relatively closer to the iron smelting sites of the past.

The massive demand for charcoal in the pre-colonial iron smelting of Khasi hills had certainly created keen awareness in forest management among the inhabitants of Khasi-Jaintia hills leading to the mushrooming of preserved Sacred grooves, that are attached with strong religious sentiments. Although deforestation for charcoal production appears to be small at a national level today, yet at the local level, the inhabitants of these hills have not been so *noble* in their relationship with the wild forest around them even during the preliterate times. It is not surprising to read from the colonial who wrote in amazement that the whole of Khasi hills is remarkable for the absence of forest[19]. Their experiences learnt through the 'famed' and yet destructive iron smelting and manufacturing [traditional] industry, have gradually dotted the Khasi-Jaintia landscape with sacred grooves, an effort though, quite contrary to *savagery*[20]. The destruction was so massive that the entire landscape had to pay with an alternative forest-cover, a topic which continues to generate keen interest among students of botany and environmental science.

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[15] From the broad leaf species to confer vegetation which forms the major forest cover of Khasi-Jaintia hills today.
[16] Hosier RH. 1993. "Charcoal production and environmental degradation". *Energy Policy*, (21):pp.491-509.
[17]Tiwari BK, Barik SK, Tripathi RS. 1999. *Op. cit*
[18] Upadhaya K, Pandey HN, Law PS, Tripathi RS. 2003, "Tree diversity in sacred groves of the Jaintia hills in Meghalaya, Northeast India". *Biodiversity and Conservation*,(12): pp.583-597.
[19] W.W. Hunter, William.1879, *Op., cit*. p212
[20] H.Godwin-Austen 1872, "On the stone Monuments of Khasi tribe and some of the peculiar rites and custom of the people" *Journal of Anthropological Institute of Great Britain and Ireland* Vol.1 p122

Appendix:

Common tree species found in the sacred groves

	Tree species	Family		Tree species	Family
1	*Baliospermum micranthum*		39	*Medinilla erochrophylla*	Melastomataceae
2	*Beilschimieda assamica*	Lauraceae	40	*Marus indica*	
3	*Breynia retusa*		41	*Myrica esculenta*	Myricaceae
4	*Brucea mallis*		42	*Olea dental*	
5	*Callicarpa psilocalyx*	Verbenaceae	43	*Pentapanax subcordatus*	
6	*Camellia kissi*	Theaceae	44	*Phorbe lanceolata*	
7	*Carpinus viminea*		45	*Photinia arguta*	Rosaceae
8	*Casearia kurzii*	Flacourtiaceae	46	*Photinia fulgens*	Rosaceae
9	*Castanopsis kurzii*	Fagaceae	47	*Photinia polycarpa*	Rosaceae
10	*Cinnamomum impressinervium*	Lauraceae	48	*Pinus kesiya*	Pinaceae
11	*Clerodendron wallichi*	Verbenaceae	49	*Prunus phaeostica*	Rosaceae
12	*Daphne bhalua*	Thymelaeaceae	50	*Prunus undulate*	Rosaceae
13	*Daphne shilling*	Thymelaeaceae	51	*Psychotria adnephylla*	
14	*Docynia indica*	Rosaceae	52	*Psychotria symplocifolia*	
15	*Elaeocarpus lancifolius*	Elaeocarpaceae	53	*Pyrularia edulis*	
16	*Engelhardtia roxburghiana*	Juglandaceae	54	*Pyrus bacata*	
17	*Engelhardtia spicata*	Juglandaceae	55	*Pyrus khasiana*	
18	*Eurya acuminate*	Theaceae	56	*Pyrus pashia*	
19	*Exbucklandia populnea*	Hamamelidaceae	57	*Quercus griffithii*	Fagaceae
20	*Ficus nerifolia*	Moraceae	58	*Quercus kamroopii*	Fagaceae
21	*Flocourtia jangamas*	Flacourtiaceae	59	*Rhododendron arboretum*	Ericaceae
22	*Helicia nilagirica*		60	*Rhus chinesis*	
23	*Ilex excels*	Aquieoliaceae	61	*Saurauia punduana*	Saurauiaceae
24	*Ilex griffithii*	Aquieoliaceae	62	*Schima wallichii*	Theaceae
25	*Ilex odorata*	Aquieoliaceae	63	*Schoepfia fragrans*	
26	*Ilex venulosa*	Aquieoliaceae	64	*Skimmia melanocarpa*	
27	*Ligustrum lucidum*	Oleaceae	65	*Symplocos theifolia*	Symplocaceae
28	*Ligustrum nepalense*	Oleaceae	66	*Symplocos glomerata*	Symplocaceae
29	*Ligustrum robusta*	Oleaceae	67	*Symplocos spicata*	Symplocaceae
30	*Lindera pulcherima*	Lauraceae	68	*Taxus baccata*	
31	*Lindera thomsoni*	Lauraceae	69	*Vaccinium sprengelii*	
32	*Lithocarpus dealbatus*		70	*Zanthoxylum armatum*	Rutaceae
33	*Lithocarpus fenestratus*		71	*Zanthoxylum ovalifolium*	Rutaceae
34	*Litsaea elongate*	Lauraceae			
35	*Luculia pinceana*	Rubiaceae			
36	*Mallotus nepalensis*	Euphorbiaceae			
37	*Manglieta caveana*	Magnoliaceae			
38	*Manglieta insignis*	Magnoliaceae			

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(Above) Entrance to the Sacred Groove at Mawphlang Village, arrow pointing to the sacred monuments showing the sanctification of the forest

Traditional Iron Manufacturing that survives today in Khasi Hills

Finished Iron tools from traditional manufacturing units in Mylliem, Khasi hills

Remains of Tuyers from an ancient Iron smelting furnace at Nongkrem, Mylliem, Khasi Hills

Traditional charcoal making pit in Khasi Hills, Meghalaya