Use of charcoal species for ironworking in Tanzania

Edwinus Chrisantus Lyaya

ABSTRACT: The study of the chemistry and physics of African metal production has received more attention than the biology of African metal production (tree, plant and animal species that were part and parcel of ironworking processes), because archaeometallurgists rarely attempt to explain the properties of such species; for example, accounting for their selection for metal production and processing. One possible reason for such omissions is the rarity or lack of evidence as compared to slags, furnace walls and tuyères, which are common and durable materials on ironworking sites. In order to redress this discrepancy, this paper presents an investigation of ethnographic tree species, alongside the criteria used to select such species for charcoal production, as well as their socio-cultural uses. It becomes apparent that in this part of the continent ironworkers did not practice omnivorous consumption of wood for ironworking, but instead they were species selective. Selection criteria for preferred species were dependent on both technical aspects and socio-culturally relevant parameters. It is argued here that due to species selection, it is improbable that ironworking technology led directly to total deforestation.

Keywords: Ethnographic species, traditional ironworking, bio-archaeometallurgy, omnivorous, species-selective, charcoal, deforestation, Tanzania, ironworking processes

Introduction

This paper presents an ethnographic and botanical study of tree species that were used to produce charcoal for ironworking processes in some ironworking societies in Tanzania, which include the Pare (Mwanga in Kilimanjaro), Luguru (Morogoro), Rangi (Kondoa in Dodoma), Nyamwezi (Tabora), Rongo (Geita in Mwanza), Haya (Kagera), Fipa (Sumbawanga in Rukwa), Nyakyusa (Chunya in Mbeya), and Ngoni (Ruvuma) regions (Fig. 1). The need to conduct this study is motivated by two main reasons. First, while the physical and chemical operating parameters of an iron smelting furnace are well known (Brelsford, 1949; Childs and Schmidt, 1985; Childs, 1996; Schmidt, 1997a; Buchwald and Wivel, 1998; Mucke, 2003), the properties and role of certain organic materials selected for ironworking (Todd and Charles, 1978; van der Merwe and Avery, 1987; Rehder, 1999) have received little attention. Second, the living memories concerning charcoal species are quickly disappearing from societies that were involved in ironworking in the past (e.g., Barndon, 2004), and so it is imperative to prioritise collecting such ethnographic information. Consequently, this investigation was formulated with the purpose of enriching our understanding of African bio-archaeometallurgy.

This paper has the following objectives: (1) identifying the tree species selected to make the charcoal used for ironworking; (2) an examination of the criteria for the selection of such tree species; and (3) an exploration of the socio-cultural uses of such species in particular societies.

Background information

Few published works on the biological component of African ironworking are available. The nature of the organic remains associated with ironworking may have contributed to this problem because they are rarely found at archaeometallurgical sites. However, there have been sporadic reports of the use of organic materials, such as charcoal, herbs and plants (Greig, 1937; van Noten and Raymaekers, 1988; Barndon, 1996; Childs, 1996; Schmidt, 1997a; Mapunda, 2010), as well as considerations about historic environmental conditions (Muntz, 1960; Haaland, 1985; Schmidt, 1997b; Stromquist, et al., 1999; Mapunda, 2003; Lyaya, 2008b). The following subsections discuss the ways in which organic materials have been used in metallurgy: as source of energy, for techno-medicinal purposes, and their association with environmental issues. The discussion eventually establishes significant gaps in current understandings of this bio-archaeometallurgical factor.

Tree species as source of energy

Iron smelters in Tanzania, as elsewhere in the world, used certain trees and plants for fuel purposes during iron and steel production. Charcoal was employed for the following technological functions: (1) providing energy in the form of high temperatures (van der Merwe and Avery, 1987; David et al., 1989; Rehder, 1999; Mapunda, 2002); (2) as a reducing agent (Cottrell, 1975; Avery, et al., 1988; Schmidt, 1997a; Rehder, 1999; Henderson, 2000), and (3) as a means to facilitate the

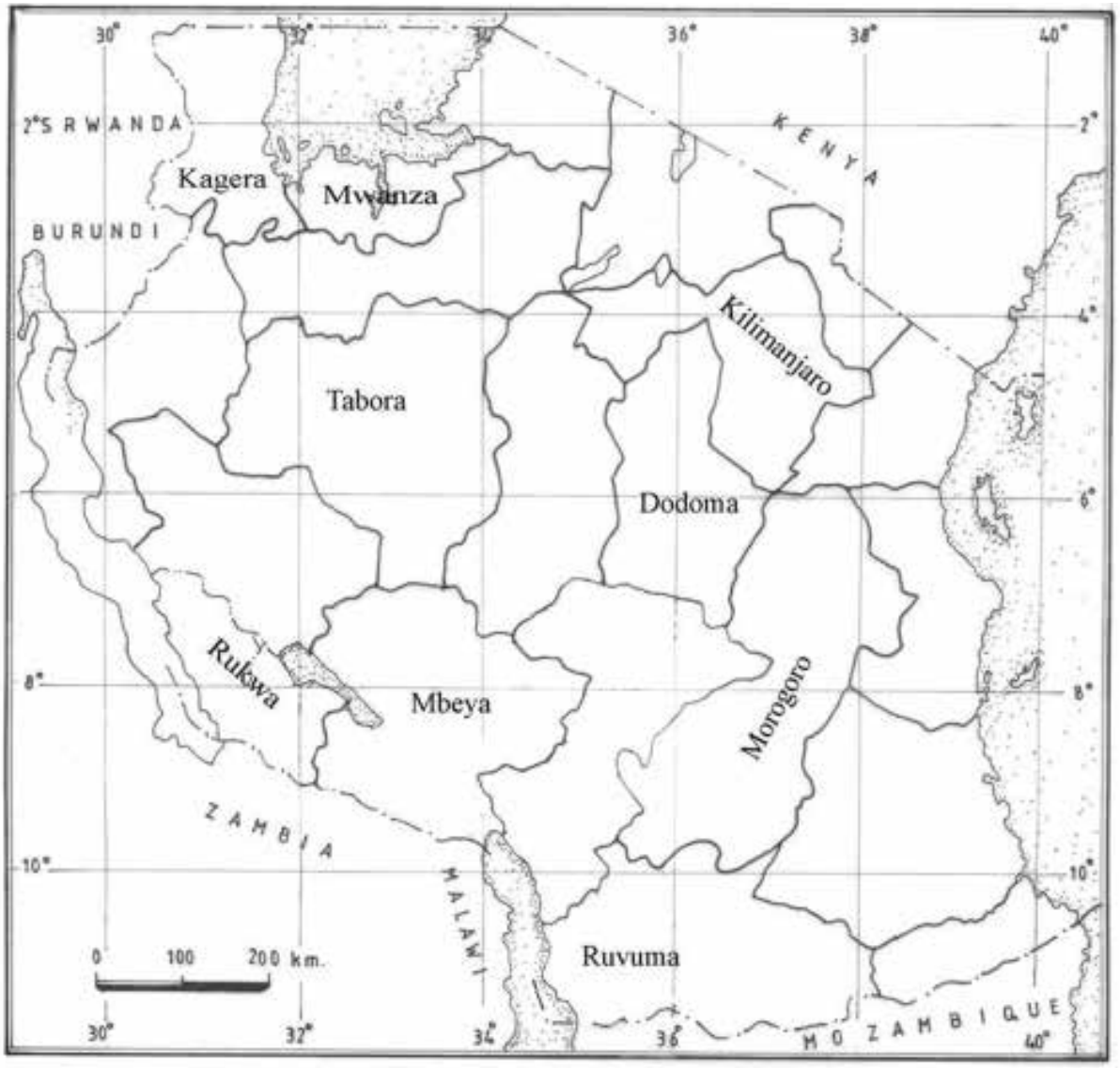


Figure 1: Map of Tanzania showing the studied ironworking regions.

formation of slag (Wertime, 1980; Schmidt, 1997a; Henderson, 2000). Other suggestions for the use of charcoal include its value as a strong, slow-burning platform within which smelting can occur, as well as ritual and ecological factors (David et al., 1989; Schmidt, 1997a, 2006; Mapunda, 2003, 2010). In addition to the employment of charcoal for iron smelting, researchers have identified species that were preferred for iron refining and forging processes respectively. As such, the tree and plant species selected for smelting charcoal were not necessarily selected for the forging process (Barndon, 2004). For example, while in Upangwa in Tanzania local tree species such as mahato, mtelea, and mdolbole were used to produce charcoal for iron smelting, the mfukwa species was specifically used for the forging process (Barndon, 2004).

Plant species for techno-magical functions

Archaeologists and archaeometallurgists suggest that the use of medicines – most of which were herbal or faunal – in ironworking activities served to ensure high quality products in many African ironworking societies (e.g., Phillipson, 1968; Wembah-Rashid, 1969, p.66; Killick, 1987; Mapunda, 1995a, p.46, 2010; Schmidt, 1997a, 2006; Barndon, 2004). For example, Barndon found that the use of umboocha medicines by Pangwa iron smelters of Rudewa Tanzania were intended for guarding the smelting furnace against evil intents (Barndon, 2004). It was also found that both the Ndamba of Ifakara and Bena of Njombe (both areas in Tanzania) respectively used the Luwopola and Mkufwa species as medicine to protect against mishaps at the ironworking sites (Lyaya, 2008a, 2008b). Mapunda (1995b, 2010) identified elaborate ritual practices among the Fipa of south-western Tanzania, who buried herbal materials (techno-magical) at the base of almost every furnace excavated. These materials were covered by a clay pot to protect them from burning to ash during the smelt and so losing their otherwise interminable power. Ethnographic sources claim that these materials were used for the protection of the multiple smelts going on in the furnace against evil spirits and witchcraft.

Charcoal and environmental studies

There are a growing number of studies that consider the environmental impact of iron smelting, examining charcoal consumption as a direct cause of total deforestation (e.g., Greig, 1937; Schmidt and Avery, 1983; Schmidt and Childs, 1985; Haaland, 1985; Schmidt, 1997a, 1997b; Stromquist et al., 1999). These scholars claim that iron smelters practiced omnivorous wood consumption where no selection of wood for charcoal was observed, hence upholding the belief that charcoal for iron smelting eventually led to total deforestation (e.g. Haaland, 1985; Schmidt, 1997b; Stromquist et al., 1999; Msemwa, 2001, p.49). Schmidt (1997b, p.407) writes that "the presence of charcoal from light and soft woods, as well as from wetlands trees, supports this picture of 'omnivorous' use of wood, especially surplus wood from other activities". However, it has been difficult to substantiate this claim because there are examples of ironworking societies who were selecting specific tree species for charcoal production; for example, the Rangi and Bena in Tanzania (Mapunda, 2003; Lyaya, 2008b), the Yoruba in Nigeria (Ige and Rehren, 2003, p.16), and the Lungu and Kaonde iron smelters in Zambia (Chaplin, 1961, p.53). In support of the species selection view, Mapunda (2003) argues that upon exhaustion of the preferred species, smelters may have relocated to a new area where the favoured species were available or just changed the source of the preferred charcoal species, depending on how far away the potential new source was located. For the purposes of this paper, it suffices to propose that there are two viewpoints on the relationship between ironworking technology and the environment, and both views are evaluated in the discussion section.

As mentioned above, previous researchers have acknowledged the use of flora (and fauna) in metallurgy, whether for fuel or for ritual purposes, and some have mentioned the species used (e.g., Mapunda, 1995b, 2002, 2003; Schmidt, 1997b; Ige and Rehren, 2003; Barndon, 2004). However, few authors have attempted an explanation of the properties of the species used, and from this gone on to explain their selection for use in metallurgical processes. The data below illustrates the potential of such a high-resolution study.

Methods

Following interviews with sons and daughters, grandsons and granddaughters of the people who used to be involved in iron and steel production, a survey of the tree species used for charcoal was conducted in collaboration with village governments across ironworking societies in Tanzania (see Tables 1, 2, and 3). During this survey, the majority of the species mentioned during the interviews were identified and photographed. Samples were collected for botanical classification at the Botany Department of the University of Dar es Salaam, with the assistance of Khasimu Imamu. It is acknowledged that some species may well have been forgotten during the intervening years, or simply may no longer be found.

Results

For the sake of clarity, the major findings of this study are divided into three categories: the selection of trees for the ironworking processes; the selection criteria for those species; and other socio-cultural uses of the tree species used in ironworking societies.

Selection of tree species for ironworking in Tanzania

This study has revealed that ironworking societies in Tanzania selected certain tree species for charcoal production during various ironworking processes. As outlined below, certain species were selected for iron smelting (Table 1), refining (Table 2), and smithing (Table 3).

Table 1: Charcoal species for the smelting process.

No.	Local Name	Scientific Name	Family	Zone
1	Muwanga	Cassia siamea	Caesalbinaceae	Morogoro
2	Msisimizi	?	?	Morogoro
3	Mpingo, Gembe	Dalbergia melanoxylon	Papilionaceae	Morogoro, Tabora, Kondoa
4	Mlama	Bridelia cathartica	Euphorbiaceae	Morogoro
5	Mbaazi	Cajanus cajan	Papilionaceae	Morogoro
6	Mlungulungu	Cassia abbreriata	Casalpinaceae	Morogoro
7	Mkambala	Albizia anthelmintica	Mimosaceae	Morogoro
8	Mkwaju	Tamarindua indica	Casalpinaceae	Morogoro
9	Mkalati, Ikaranyika	Agauria salicifolia	Ericaceae	Geita, Mwanga
10	Mgando	Burkea africana	Caesalpinaceae	Geita, Tabora
11	Mbanga	Pericopsis angolensis		Geita, Tabora
12	Kamwamba	Monotis africanus	Dipterocarpuceae	Rukwa
13	Umula	Parinari curatellifolia	Planchonex Benth	Rukwa
14	Mtomola, Mkame	Combretum molle	Combretaceae	Rukwa, Mwanga
15	Nansaku	Albizia sp.	Mimosaceae	Rukwa
16	Unzombo/Umputu	Brachystergia manga	Cabalpinaceae	Rukwa
17	Yunga	Maytenus senegalensis	Celastraceae	Rukwa
18	Nachipa	Faurea saligna	Proteaceae	Rukwa

cont'd...

Table 1: Cont'd...

No.	Local Name	Scientific Name	Family	Zone
19	Namtiti	?	?	Rukwa
20	Chimba	?	?	Rukwa
21	Chinga	?	?	Rukwa
22	Mzima	Terminalia sericea	?	Tabora
23	Kasanda	Swartizia madagascansis	?	Tabora
24	Idubilo	Acacia albida	?	Tabora
25	Muhanga	Burkea africana	Caesalpinaceae	Chunya
26	Myombo Dume	Brachystegia boehmii	Caesalpinaceae	Chunya
27	Myombo Jike	Julbernarchia globiflora	Caesaepinaceae	Chunya, Kondoa
28	Mwembe Pori	Ozoroa insignis	?	Chunya
29	Mpururu	?	?	Chunya
30	Mjululuzi	?	?	Kagera
31	Mshakwanyonyi	?	?	Kagera
32	Mshasha	Sapium ellipticum	?	Kagera
33	Mziru	Turraea robusta	Meliaceae	Kagera
34	Mshamako	?	?	Kagera
35	Mtoma	Ficus sar	Moraceae	Kagera
36	Mgege	?	?	Kagera
37	Mkaraito	Eucalyptus sp.	Myrtaceae	Kagera
38	Mnazi	?	?	Kagera
39	Mmo	?	?	Kagera
40	Muembe	Mangifera indica	Anacartiaceae	Kagera
41	Nkindo	?	?	Kagera
42	Mlulu	Albizia gummifera	Mimosaceae	Mwanga
43	Ng'andi	?	?	Mwanga
44	Mgunga Maji	?	?	Mwanga
45	Mgunga Chuma	?	?	Mwanga
46	Kikwata	?	?	Mwanga
47	Migunga	Acacia tortitilis	Mimosaceae	Kondoa
48	Michakai	Dombeya shupangae	Sterculiaceae	Kondoa
49	Dabili/Mitunduru	?	?	Kondoa
50	Kijame	Acacia nilotica	Mimosaceae	Kondoa
51	Mwanya	?	?	Kondoa
52	Milola	Ficus sycomorus	Moraceae	Ruvuma
53	Mikuyu	Ficus sp.	Moraceae	Ruvuma
54	Mikagati	Monotes africanus	Dipterocarpaceae	Ruvuma
55	Miyombo	Brachystegia longifolia	Caesalpinaceae	Ruvuma
56	Muwanga	Pterocarpus angoleysis	Papilionoceae	Ruvuma
57	Mivenge	Syzygium guineense	Myrtaceae	Ruvuma
58	Mtombati	Dalbergia nitudila	papilionaceae	Ruvuma
59	Misuku	Uapaca kirkiana	Euphorbiaceae	Ruvuma
60	Mihekela	Terminalia mollis	Caumbrutaceae	Ruvuma
61	Migheleghele	Brachystegia spiciformis	Caesalpinaceae	Ruvuma

Table 2: Charcoal species for the refining process.

No.	Local Name	Scientific Name	Family	Zones
1	Kamwamba	Monotis africanus	Dipterocarpuceae	Sumbawanga
2	Nansaku	Albizia sp.	Mimosaceae	Sumbawanga
3	Umputu	Brachystergia manga	Cabalpinaceae	Sumbawanga
4	Yunga	Maytenus senegalensis	Celastraceae	Sumbawanga

Table 3: Charcoal species for the smithing process.

No.	Local Name	Scientific Name	Family	Zone
1	Muwanga	Cassia siamea	Caesalbinaceae	Morogoro
2	Msisimizi	?	?	Morogoro
3	Mpingo	Dalbergia melanoxylon	Papilionaceae	Morogoro, Kondoa
4	Mfulu	?	?	Morogoro
5	Mlama	Bridelia cathartica	Euphorbiaceae	Morogoro
6	Mkwaju	Tamarindua indica	Casalpinaceae	Morogoro
7	Mkalati, Mkaranyika	Agauria salicifolia	Ericaceae	Geita, Mwanga, Ruvuma
8	Mgando	Burkea africana	Caesalpinaceae	Geita, Tabora
9	Mbanga	Pericopsis angolensis		Geita, Tabora
10	Kamwamba	Monotis africanus	Dipterocarpuceae	Rukwa
11	Umula	Parinari curatellifolia	Planchonex Benth	Rukwa
12	Mtomola, Mkame	Combretum molle	Combretaceae	Rukwa, Mwanga
13	Nansaku	Albizia sp.	Mimosaceae	Rukwa
14	Unzombo/Umputu	Brachystergia manga	Cabalpinaceae	Rukwa
15	Yunga	Maytenus senegalensis	Celastraceae	Rukwa
16	Namtiti	?	?	Rukwa
17	Chimba	?	?	Rukwa
18	Chinga	?	?	Rukwa
19	Mzima	Terminalia sericea	?	Tabora
20	Kasanda	Swartizia madagascansis	?	Tabora
21	Idubilo	Acacia albida	?	Tabora
22	Muhanga	Burkea africana	Caesalpinaceae	Chunya
23	Myombo Dume	Brachystegia boehmii	Caesalpinaceae	Chunya
24	Myombo Jike	Julbernarchia globiflora	Caesaepinaceae	Chunya, Kondoa
25	Mwembe Pori	Ozoroa insignis	?	Chunya
26	Mpururu	?	?	Chunya
27	Mlingoti	?	?	Chunya
28	Mshasha	Sapium ellipticum	Pax	Kagera
29	Mziru	Turraea robusta	Meliaceae	Kagera
30	Mkaraito	Eucalyptus sp.	Myrtaceae	Kagera
31	Muembe	Mangifera indica	Anacartiaceae	Kagera
32	Mlulu	Albizia gummifera	Mimosaceae	Mwanga
33	Mkithingo	?	?	Mwanga
34	Mfilifili	Croton macrostachyus	Euphorbiaceae	Mwanga
35	Mgunga	Acacia tortitilis	Mimosaceae	Mwanga, Kondoa
36	Michakai	Dombeya shupangae	Sterculiaceae	Kondoa
37	Dabili/Mitunduru	?	?	Kondoa
38	Kijame	Acacia nilotica	Mimosaceae	Kondoa
39	Mwanya	?	?	Kondoa
40	Milola	Ficus sycomorus	Moraceae	Ruvuma
41	Mikuyu	Ficus sp.	Moraceae	Ruvuma
42	Mikagati	Monotes africanus	Dipterocarpaceae	Ruvuma
43	Miyombo	Brachystegia longifolia	Caesalpinaceae	Ruvuma
44	Miwanga	Pterocarpus angoleysis	Papilionoceae	Ruvuma
45	Mivenge	Syzygium guineense	Myrtaceae	Ruvuma
46	Misuku	Uapaca kirkiana	Euphorbiaceae	Ruvuma
47	Mihekela	Terminalia mollis	Caumbrutaceae	Ruvuma
48	Migheleghele	Brachystegia spiciformis	Caesalpinaceae	Ruvuma
49	Mwai	Trichilie emetica	?	Lindi
50	Mtachi	Cassia abbreviata	?	Lindi
51	Mkangazi	?	?	Lindi
52	Mkunguwi	?	?	Lindi
53	Mpimbi	?	?	Lindi

The tables above illustrate that iron production cannot be associated with deforestation in the traditional ironworking regions of Tanzania. It is known, for example, that there are more than 51 tree and shrub species in Ufipa of Tanzania (Mbuya et al., 1994, pp.13-14), but only ten tree species were selected for charcoal production. Furthermore, out of 73 species documented in Uluguru, in Morogoro Tanzania (Mbuya et al., 1994, pp.22-23), ironworkers selected only eight tree species for charcoal production. It can therefore be argued that unless numerous other tree species were also being felled for different uses, this specific selection would not have caused total deforestation. Therefore, the association between indigenous iron smelting and deforestation is a simplistic one (Lyaya, 2008b).

The results also highlight that iron producers became accustomed to selecting the best species for specific processes. For example, the use of Burkea africana in Tabora, Cassia abbreriata and Albizia anthelmintica in Morogoro, Dalbergia nitudila in Ruvuma, and Kikwata in Mwanga was restricted to the smelting process and not employed in the smithing stage. In addition, among Fipa ironworkers, the use of the Albizia sp., Brachystargia manga and Monolis sp. species was restricted to the refining process. Finally, Agauria salicifolia was used for the smithing process in many ironworking societies in Tanzania, such as the Rongo of Kahama (De Rosemond, 1943) and the Ndamba of Ifakara. It appears that this species is economical in terms of the rate of charcoal consumption, because it does not burn continuously, i.e. it stops or slows down the burning when one stops bellowing and vice versa. This quality was essential for the smiths, especially during lifting of the red-hot metal out of the hearth and beating it on the anvil with hammers to shape it, in these moments ironworkers saved charcoal as the fire slowed down. This information can be used to suggest that ironworking processes (smelting, refining, and smithing) were technologically, functionally (Lyaya, 2007, 2009), and bio-archaeometallurgically different. As such, there is a need for archaeometallurgists to devise a method for identifying and differentiating between these processes both in the field and in the laboratory.

It should be noted that ethnographic sources suggest that iron workers mixed compatible charcoal species to perfect performance, but that not all species could be combined successfully. For example, during interviews the author was told of the failed smelt carried out by Randi Barndon among the Fipa in the early 1990s (e.g., Barndon, 1992, 2004). It was suggested that the initial failure of the smelt was due to incorrect combination of charcoal, because when the charcoal mix was corrected, the smelt succeeded.

Criteria for the selection of charcoal species for ironworking

Regarding the selection of species, the present research has found that the selection of charcoal species for ironworking was based on several criteria. Tables 4, 5, and 6 present the list of the selection criteria.

Table 4: Criteria for the selection of charcoal species for the smelting process.

S/No.	Criteria for selection	Example tree(s)
1	Had very strong fire	Albizia gummifera
2	Had quite fire with less or no sparks	Mjululuzi
3	Had heavy charcoal	Monotis africanus, Brachystegia boehmii
4	Had less ash	Burkea africana, Swartizia madagascansis
5	Availability in nearby environment	Cassia siamea
6	Needed constant bellowing	Agauria salicifolia
7	Quality to lit and burn quickly	Mfulwe, Cajanus cajan
8	Ability to soften iron by something like oil?	Tamarindua indica, Albizia sp., Dalbergia melanoxylon
9	Ability to clean and not to dirt iron?	Agauria salicifolia, Combretum molle
10	Provided very long lasting fire	Cassia siamea
11	Able to collect all iron together?	Albizia sp.
12	Provided very hard charcoal	Acacia tortitilis
13	Ability to separate iron from ores?	Eucalyptus sp., Nkindo

Table 5: Criteria for the selection of charcoal species for the refining process.

S/No.	Criterion for selection	Example Tree(s)
1	Able to clean bloom to purity	Monotis africanus
2	Gave heavy and strong fire	Albizia sp., Monotis africanus
3	Quality to collect all iron together	Albizia sp.

Table 6: Criteria for the selection of charcoal species for the smithing process.

S/No.	Reason for its selection	Example Tree(s)
1	Gave very strong fire	Dalbergia melanoxylon,
2	Gave quite fire with less or no sparks	Agauria salicifolia
3	Gave heavy charcoal	Pericopsis angolensis, Brachystegia boehmii
4	Had less ash	Burkea africana, Swartizia madagascansis
5	Needed constant bellowing	Agauria salicifolia
6	Quality to lit and burn quickly	Mfulwe, Cajanus cajan
7	Ability to soften iron by something like oil	Albizia sp., Dalbergia melanoxylon
8	Did not dirt iron	Agauria salicifolia, Combretum molle
9	Provided very long lasting fire	Ozoroa insignis, Sapium ellipticum
	Acted as substitutes to missing species	Croton macrostachyus and Agauria salicifolia
10	Gave very normal fire for smithing	Parinari curatellifolia

The tables above demonstrate that the selection of tree species for ironworking processes was based on specific qualities such as hardness or high calorific values necessary to raise temperatures for iron smelting. Apparently, ironworkers knew of the qualities of specific tree species through learnt experience passed down through generations (e.g., Schmidt, 1997a; Mapunda, 2002). As a result of their experience they knew and controlled the physical aspects of iron production, and ensured the successful manufacture of high quality iron objects. Through their understanding of the trees (and of all the other facets and materials involved in iron production), they were able to make choices that guaranteed the best outcomes. The following ethnographic examples could be considered. Fipa oral traditions maintain that the Dalbergia melanoxylon species were selected because they 'softened' iron, Agauria salicifolia species because they 'cleaned' iron, Nansaku species because they 'collected' iron together, and Nkindo species because they 'separated' iron from ores. I became a hesitant believer, because it was difficult to fully comprehend what the informants exactly meant concerning the abilities of these species. However, we can hypothesise that these tree species provided strong and perfect fire for ironworking, so that whenever they were used they led to success in the smelt, as well as resulting in good products with less or no impurities (clean iron); or it could be that these tree species naturally contained fluxing oxides (e.g., David et al., 1989; Schmidt, 1997a). It should not be surprising, therefore, that in order to take advantage of the qualities of the trees, which were possibly understood after repeated experiences, ironworkers carefully devised a working or technical belief for them and posterity. However, these oral testimonies and the validity of such properties have yet to be confirmed from a western 'scientific' perspective, and remain a focus for research.

It is noteworthy that the tendency of writers to concentrate on the technical reasons for the selection of tree species for ironworking (e.g., Cottrell, 1975; Avery et al., 1988; David et al., 1989; Rehder, 1999) is problematic, because it gives no weight to cultural beliefs in the selection of trees as presented above. There are trees with good qualities which were left out due to beliefs or for cultural reasons. For example, the author was told by informants from Upare that among the Shana and Finanga clans of the Gweno tribe in the Mwanga zone, trees which produced lots of sparks were left out regardless of their high calorific values. These tribes in particular believe that gods, the insurers of good products, are always unhappy with sparking fires. Instead, they require charcoal species that produce fires with no sparks. Another aspect supporting this argument is that when taking into consideration the importance of beliefs, the size of trees did not matter among the Fipa of Tanzania (e.g., Lyaya, 2009), for example. Because of strong belief systems, Fipa ironworkers sometimes selected small trees and left out big ones, and vice versa (e.g., Mapunda, 1995b). Based on these ethnographic examples, it seems appropriate to suggest that cultural as well as technical reasons for the selection of charcoal species are important and require due weight for the holistic understanding of this area of ironworking technology.

Socio-cultural uses of selected species

Ethnographic sources (e.g., Schmidt, 1997a, 2006; Mapunda, 2003, 2010) claim that there is a relationship between the use of charcoal tree species and society at large, because some of the species used for ironworking in Tanzania also had other socio-cultural uses (for similar observations in Malawi, see also van der Merwe and Avery, 1987).

Table 7: Socio-cultural functions of charcoal species.

No.	Species Name	Socio-cultural function
1	Cassia siamea	Cure for women frequent vomiting
2	Swartizia madagascansis	Stomach ache cure
3	Acacia albida	Medicines for abdominal pains
4	Pericopsis angolensis	Ritual medicine
5	Mlingoti	Cure of coughing, fever, and influenza
6	Sapium ellipticum	malaria and dizzying medicine, food
7	Albizia gummifera	Tooth brush and dental medicine
8	Cassia abbreriata	Cure of sexually transmitted diseases
9	Agauria salicifolia	Spices for traditional milk
10	Ozoroa insignis	Cure of diarrhoea
11	Swartizia madagascansis	Protection against witchcraft, insecticides in farms
12	Dalbergia melanoxylon	Increase of male sexual power
13	Maytenus senegalensis	Snake medicine
14	Albizia sp.	Cure for diseases such as nausea, hernia, sharp pain, bilharzias, convulsion, nose breeding and fresh wounds

Based on the list presented above (Table 7), it is clear that the majority of tree species selected for ironworking in Tanzania were also used to cure problems and diseases related to pregnancy. This information is unsurprising because African iron production processes have been associated with conception, pregnancy, and childbirth across the continent (Sutton, 1985; Nyagava, 1988; Collett, 1993; Herbert, 1993; Mapunda, 1995b, 2010; Schmidt, 1996, 1997a, 2006; Barndon, 2004). For example, Rhynchosia resinosa has been associated with fertility magic among the Fipa of Tanzania for a long time (Mapunda, 1995b, 2010, pp.158-160, 2011, p.172). Among the Luguru of Morogoro and Nyakikyusa of Mbeya, the Cassia siamea species is used to cure maternity-related problems at large. Likewise in Kagera, dizziness and nausea, as well as frequent fever and malaria problems, which are often associated with pregnant women, are essentially cured with the Sapium ellipticum species. Furthermore, the Dalbergia melanoxylon species was used to increase male sexual prowess (interview with Ernest Albert Mwanisawa, 2 September 2011). Based on such ethnographic sources, we can argue that ironworkers held the belief that because such trees cured fertility, maternity and child delivery-related problems, they could also ensure the successful delivery of an iron bloom (e.g., van der Merwe and Avery, 1987; Schmidt, 1997a; Mapunda, 2010). This illustrates the significant integration of socio-cultural beliefs with ironworking and enriches our

understanding of ancient ironworking technology (e.g., van der Merwe and Avery, 1987; Collett, 1993; Herbert, 1993; Barndon, 1996, 2004; Schmidt, 1996, 1997a, 2006; Mapunda, 2003, 2010).

Discussion and conclusion

In the introduction section, we noted that this paper aimed at (1) identifying the tree species selected to make charcoal for ironworking, (2) examining the criteria for the selection of such species, and (3) exploring the socio-cultural uses of such species in respective societies. I would like to return to these objectives based on the data presented above. First and foremost, Tables 1, 2, and 3 presented the tree species preferred by ironworkers for charcoal production in some regions of Tanzania. It appears that the ironworkers did not harvest each and every tree species for charcoal, because out of the known species in their regions (see Mbuya, et al., 1994) only a few were selected.

With regard to the second objective, it appears that African ironworkers had a sound understanding of the various properties of specific charcoal wood types and mixtures of these, from both a technological and ritual perspective. Their selection criteria for charcoal for the specific stages of iron production were therefore based on both physical (such as burning time) and socio-cultural factors (such as use in fertility magic). Without denying the technical function of the species, it is noteworthy that the socio-cultural factors were critical to the smelters, as to them they represented a reality and never a myth (van der Merwe and Avery, 1987; Mapunda, 2011, p.171). To strengthen and elucidate this point, van der Merwe and Avery (1987, p.144) correctly observed that, "[iron] smelting could not be conducted without [considering socio-cultural aspects], because [these were] very important for the smelters. [In fact], it is a technology in its own right". Therefore, if we are to fully comprehend the African metal production technology, we eventually need to critically consider both technical and social aspects of the ironworking process.

Ironworkers were selective with charcoal species, therefore the association of indigenous ironworking with deforestation appears doubtful. This is because they did not practice the so-called 'omnivorous' consumption of wood (for an opposite view, see Schmidt, 1997b). Ironically, the European colonial administrators associated ironworking alone with total deforestation, in an attempt to excuse and justify the importation of metalware to Africa, which eventually, as expected, led to the demise of the indigenous African metal production technology (for details, see Kapinga, 1990; Mapunda, 2002). Although we know that iron smelting consumed large quantities of charcoal (e.g., Killick, 1991, p.64), it is difficult to believe that the cutting down of eight trees, for example, in Morogoro for ironworking charcoal would directly cause total deforestation if the other hundreds of tree species were not felled (e.g., Mbuya et al., 1994, p.22). However, there are two points to consider: (1) That the selection and removal of ironworking charcoal species could have altered the ecological system; yet, there is no environmental evidence whatsoever to prove the extinction of the species used for ironworking charcoal. For example, the bio-archaeometallurgical samples used in this study from southern Ufipa were collected from within the smelting sites' premises; this attests that the charcoal species did not undergo extinction and more likely ironworking did not utterly damage the ecological system, as some scholars would tend to believe. (2) If ironworkers are to be held responsible for deforestation, then their contribution was an indirect one, through the supply of farm implements which could have been used to clear forests much faster than stone, wooden, or bone implements (e.g. Kimambo, 1969; Mapunda, 2003) for agricultural lands (e.g., slash-and-burn type), settlements, and domestic fuel energy.

With respect to the third and final objective, we have noted that most of the selected charcoal species had additional socio-cultural uses (Table 7), and, more strikingly, that most of the species were used to heal reproduction-related problems. The symbolic association of ironworking with aspects of reproduction is a common phenomenon the world over, and Tanzania is no exception. However, what needs critical evaluation is the question regarding the originality of this association of technology and society. The question to ask is that of the two concepts, which one was the primary or original source of the association? There is no right or wrong answer in attempting to address this question, but it is critical to examine and evaluate the answers we suggest. There is an understanding that ironworkers, especially master smelters, automatically became healers of people. This is because both smelting assistants and non-smelting people trusted the techno-medicines of the smelters simply because the techno-medicines transformed stones into iron (hoes, knives, etc.). For such clients and strong believers in techno-medicines, it was not the reduction process that led to the production of metals, but the magic and strong techno-medicines of the chief smelters (Mapunda, 2010, 2011). These people strongly believed that because the techno-medicines worked for metals (turning stones into metal), they would have 'certainly' worked effectively to heal reproduction-related problems, as well as other issues. Thus, the original source of the association appears to be from ironworking to society at large. However, a second interpretation contrary to this is that society was the original source. It is difficult and impractical to believe that before ironworking there was no witchcraft, no diseases such as those related to fertility, and thus that there were no traditional healers! It could be suggested that non-ironworking healers existed and people knew and used their 'socio-medicines' to cure reproduction-related diseases and others. There is also a possibility that, by virtue of inheritance, some of these early healers could have become chief smelters, and, having turned to ironworking, they possibly re-used their 'socio-medicines' as techno-medicines, this time for a different function: assisting in the production of metal instead of a child, or protecting ironworking sites instead of households or cattle yards against mishaps and witchcraft ailments. Furthermore, those who were not lucky in turning to ironworking must have been consulted by ironworkers (who did not know the medicines before) for medicinal assistance, a transmission procedure that was always performed privately and verbally. To elucidate this point, among the Fipa of southwest Tanzania, the medicines for treating infertility and providing 'advanced bodily immunity' (zindiko in Swahili) were the very same

techno-medicines used for ironworking, to protect against malevolent intentions (for similar observation, see Mapunda, 2010, p.160). As noted above, the problems of infertility and witchcraft existed long before ironworking began, and it is reasonable to assume that societies must have looked into such problems. One solution was to make use of trustworthy traditional healers to heal the diseases and to protect the society. Thus, the original source of the association between charcoal species and aspects related to fertility should be considered from this direction: it was knowledge originating in society at large that was transmitted to the ironworking technology. We need to learn the socio-cultural aspects associated with the ironworkers in order to fully comprehend some of the bio-archaeometallurgical and technological aspects of ironworking.

However, there is a need in the near future to test the applicability of these findings in a wider area, and across a greater time span, perhaps using multidisciplinary approaches that would include ecological and environmental concerns.

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References

Avery, D.H., van der Merwe, N.J. and Saitowitz, S., 1988. The metallurgy of the iron bloomery in Africa. In: R. Maddin ed. The Beginning of the Use of Metals and Alloys. Cambridge, Mass.: M.I.T. Press, pp.245-60.

Barndon, R., 1992. Traditional Iron Working among the Fipa, An Ethnoarchaeological Study from Southwestern Tanzania. MA Dissertation, University of Bergen.

Barndon, R., 1996. Fipa ironworking and its technological style. In: P.R. Schmidt ed. The Culture and Technology of African Iron Production. Florida: University Press of Florida, pp.58-73.

Barndon, R., 2004. An Ethnoarchaeological Study of Iron Smelting Practices among the Pangwa and Fipa in Tanzania. Oxford: Archaeopress.

Brelsford, W.V., 1949. Rituals and medicines of Chishinga ironworkers. Man, 49, pp.27-9.

Buchwald, V.F. and Wivel, H., 1998. Slag analysis as a method for the characterization and provenancing of ancient iron objects. Material Characterization, 40, pp.73-96.

Chaplin, J.H., 1961. Notes on traditional smelting in northern Rhodesia. South African Archaeological Bulletin, 16, pp.53-60.

Childs, S.T., 1996. Technological history and culture in western Tanzania. In: P.R. Schmidt ed. The Culture and Technology of African Iron Production. Florida: University Press of Florida, pp.277-320.

Childs, S.T. and Schmidt, P.R., 1985. Experimental iron smelting: the genesis of a hypothesis with implications for African prehistory and history. In: R. Haaland and P. Shinnie eds. African Iron Working: Ancient and Traditional. New York: Norwegian University Press, pp.121-41.

Collett, D.P., 1993. Metaphors and representations associated with precolonial iron-smelting in eastern and southern Africa. In: T. Shaw, P. Sinclair, B. Andah and A. Okpoko eds. The Archaeology of Africa: Food, Metals, and Town. London: Routledge, pp.499-511.

Cottrell, A., 1975. An Introduction to Metallurgy, 2nd edition. London: Edward Ashold Publishers Ltd.

David, N., Heimann, R., Killick, D.J. and Wayman, M., 1989. Between bloomery and blast furnace: Mafa iron-smelting technology in North Cameroon. The African Archaeological Review, 7, pp.183-208.

De Rosemond, C.C., 1943. Iron smelting in the Kahama district. Tanganyika Notes and Records, 16, pp.79-84.

Greig, R.C.H., 1937. Iron smelting in Fipa. Tanganyika Note and Records, 4, pp.77-80.

Haaland, R., 1985. Iron production, its socio-cultural context and ecological implications. In: R. Haaland and P. Shinnie eds. African Iron Working: Ancient and Traditional. Oslo: Norwegian University Press, pp.50-72.

Henderson, J., 2000. The Science and Archaeology of Materials: An Investigation of Inorganic Materials. London: Routledge.

Herbert, E.W., 1993. Iron, Gender and Power: Rituals of Transformation in African Societies. Bloomington: Indiana University Press.

Ige, A. and Rehren, Th., 2003. Black sand and iron stone: iron smelting in Modakeke, Ife, south Nigeria. Institute of Archaeometallurgical Studies, 23, pp.15-20.

Kapinga, V., 1990. Kuathiriwa kwa Maendeleo ya Mwafrika: Mfano Halisi Tanzania [How an African Development was Affected: Real Example from Tanzania]. Peramiho: Peramiho Printing Press.

Killick, D.J., 1987. Recent iron-smelting in central Malawi. Nyame Akuma, 28, pp.27-9.

Killick, D.J., 1991. A little-known extractive process: iron smelting in natural-draft furnaces. Journal of the Minerals, Metals and Materials Society, 43, pp.62-4.

Kimambo, I.N., 1969. The interior before 1800. In: I.N. Kimambo and A.J. Temu eds. A History of Tanzania. Nairobi: East African Publishing House, pp.14-33.

Lyaya, E.C., 2007. The Physical Properties of Metalliferous Slag: The Case of Smelting and Smithing Processes. MA Dissertation, University of Dar es Salaam.

Lyaya, E.C., 2008a. Archaeological field research at Ifakara, Tanzania. Nyame Akuma, 70, pp.11-20.

Lyaya, E.C., 2008b. Archaeological field research in Njombe, Tanzania. Nyame Akuma, 70, pp.21-9.

Lyaya, E.C., 2009. Revisiting African bloom refining technology in Tanzania. Nyame Akuma, 72, pp.30-40.

Mapunda, B.B., 1995a. Iron Age archaeology in the south-eastern Lake Tanganyika region, southwestern Tanzania. Nyame Akuma, 43, pp.46-57.

Mapunda, B.B., 1995b. An Archaeological View of the History and Variation of Ironworking in Southwestern Tanzania. PhD Thesis, University of Florida.

Mapunda, B.B., 2002. Ufundichuma Asilia Africa Mashariki: Chimbuko Kukua na Kukoma Kwake [Iron Technology in East Africa: Origins, Development, and Its Fall]. Peramiho: Peramiho Printing Press.

Mapunda, B.B., 2003. Iron Technology and Deforestation: Myths and Realities. Sussex: AFRAS, University of Sussex.

Mapunda, B.B., 2010. Contemplating the Fipa Ironworking. Kampala: Fontain Publishers.

Mapunda, B.B., 2011. The jack of two trades, master of both: smelting and healing in Ufipa, southern Tanzania. African Archaeological Review, 28, pp.161-75.

Mbuya, L.P., Msanga, H.P., Ruffo, C.K., Birnie, A. and Tengnas, B., 1994. Useful Trees and Shrubs for Tanzania: Identification, Propagation, and Management for Agricultural and Pastoral Communities. Nairobi: Regional Soil Conservation Unit, SIDA.

Msemwa, P., 2001. Archaeology of Upper Rufiji catchment. In: F. Chami, G. Pwiti and C. Radimilahy eds. People, Contacts, and the Environment in the African Past. Studies in the African Past 1. Dar es Salaam: DUP(1996) Ltd., pp.40-52.

Mucke, A. 2003. Magnetite, ilmenite and ulvite in rocks and ore deposits: petrography, microprobe analyses and genetic implications. Mineralogy and Petrology, 77, pp.215-34.

Muntz, A.P., 1960. Forests and iron: the charcoal iron industry of the New Jersey highlands. Geografiska Annaler, 42, pp.315-23.

Nyagava, S.I., 1988. A History of the Bena to 1980. PhD Thesis, University of Dar es Salaam.

Phillipson, D.W., 1968. Cewa, Leya, and Lala iron smelting furnaces. South African Archaeological Bulletin, 23, pp.102-13.

Rehder, J.E., 1999. High temperature technology in antiquity: a sourcebook on the design and operation of ancient furnaces. In: A. Hauptmann, E. Pernicka, Th. Rehren and Ü. Yalçin eds. The Beginnings of Metallurgy. Der Anschnitt, Beiheft 8. Bochum: Deutsches Bergbau-Museum.

Schmidt, P. R., 1996. Reconfiguring the Barongo: reproductive symbolism and reproduction among a work association of iron smelters. In: Schmidt, P. R. (ed.) The Culture and Technology of African Iron Production. Florida: University Press Florida

Schmidt, P.R., 1997a. Iron Technology in East Africa: Symbolism, Science, and Archaeology. Oxford: James Curry.

Schmidt, P.R., 1997b. Archaeological views of a history of landscape change in East Africa. Journal of African History, 38, pp.393-421.

Schmidt, P.R., 2006. Historical Archaeology in Africa: Representations, Social Memory, and Oral Traditions. Lanham: Altamira Press.

Schmidt, P.R. and Avery, D.H., 1983. More evidence for an advanced prehistoric iron technology in Africa. Journal of Field Archaeology, 18, pp.421-34.

Schmidt, P.R. and Childs, S.T., 1985. Innovation and industry during the Early Iron Age in East Africa: The KM2 and KM3 sites of Northwestern Tanzania. The African Archaeological Review, 3, pp.53-94.

Stromquist, L., Yanda, P., Msemwa, P., Lindberg, C. and Simonson-Forsberg, L., 1999. Utilizing landscape information to analyse and predict environmental change: the extended baseline perspective. Ambio, 28, pp.436-43.

Sutton, J.E.G., 1985. Temporal and spatial variability in African iron furnaces. In: R. Haaland and P. Shinnie eds. African Iron Working: Ancient and Traditional. Oslo: Norwegian University Press, pp.164-96.

Todd, J.A. and Charles, J.A., 1978. Ethiopian bloomery iron and the significance of inclusions analysis in iron studies. Journal of the Historical Metallurgy Society, 12, pp.63-87.

van der Merwe, N.J. and Avery, D.H., 1987. Science and magic in African technology: traditional iron smelting in Malawi. Africa, 57, pp.143-72.

van Noten, F. and Raymaekers, J., 1988. Iron smelting in central Africa. Scientific American, 258, pp.104-11.

Wembah-Rashid, J.A.R., 1969. Iron workers of Ufipa. Bulletin of the International Community of Urgent Anthropological Research, 11, pp.65-72.

Wertime, T.A., 1980. The Pyrotechnologic Background. In: T.A. Wertime and J.D. Muhly eds. The Coming of the Age of Iron. New Haven: Yale University Press, pp.1-24.

Author's address

• UDSM, Archaeology Unit, P.O Box 35050, Dar es Salaam, Tanzania.
UCL Institute of Archaeology, 31-34 Gordon Square, London WC1H 0PY
Email: edwinusl@yahoo.com