Commonw. For. Rev. 64(3), 1985

WOOD AS A SOURCE OF FUEL IN UPPER SHABA (ZAÏRE)*

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SUMMARY

At the beginning of the 20th century the creation of mining towns in Upper Shaba brought about the development of large urban centres and a resulting increase in their wood needs. The surrounding vegetation, mainly open forest, was exploited. Today the forest, for 70 km around Lubumbashi, is menaced with destruction, whilst an area of 30 km radius has already been completely clear-cut. Only unproductive derived savannas and a few rare vegetable plots in the valleys have replaced it.

The present stage of destruction of the original forest has reduced forest product capital by 19%, and future developments indicate complete deforestation of the square degree of Lubumbashi in 2050 Plantation and afforestation solutions are known, but the probability of their being applied in the coming years is slight, even though just 20% of the area being given over to forestry would be enough to satisfy the woodfuel needs of the population.

RÉSUMÉ

Au début de ce siècle le développement des mines dans le Chaba supérieur a créé de nouveaux centres urbains ayant des besoins importants en bois. La végétation des alentours, en grande partie de la forêt était mise en exploitation. Aujourd'hui sur un rayon de 30 km autour de Lubumbashi rien ne reste, et le menace de destruction pèse sur un rayon de 70 km. Seules les savannes secondaires et pauvres subsistent, mis à part quelques champs de légumes dans les vallées.

L'état actuel de la forêt représente la perte de 19% du capital forestier, et l'on prévoit le déboisement total du degrécarré autour de Lubumbashi d'ici l'an 2050. Les solutions par le réboisement existent mais ne seront probablement pas appliquées à temps, bien que 20% de la superficie soit suffisant pour subvenir aux besoins en bois de chauffage de toute la population.

RESUMEN

En los inicios del siglo 20 la creación de pueblos mineros en Upper Shaba resultó en el desarrollo de grandes centros urbanos. Esto trajó como consecuencia un aumento en sus necessidades por productos forestales y la explotación de los bosques aledaños. Actualmente 70 km de bosques alrededor de Lubumbashi se encuentran en peligro de destrucción, mientras que el area en un radio de 30 km ya ha sido completamente devastada, solamente reemplazada por savanas improductivas y escasas parcelas agricolas en los valles.

La destrucción de bosques hasta el momento ha reducido la capital de productos forestales por un 19% y se crea que la explotación futura dejará completamente deforestada un area de 100 km por 100 km alrededor de Lubumbashi en el año 2050! La solución mediante reforestación es bien conocida pero la posibilidad de su aplicación en los años venideros es remota, aún cuando el 20% del area, si fuera plantaciónes, seria suficiente para satisfacer las necessidades para leña de la población.

Introduction

According to energy experts (Pimentel 1974, Makhijani and Poole 1975, Revelle 1976, Beyna 1978, Brown 1978, Eich 1978, Gohmann 1980, Hrabovszky 1980, Chatterjee and Biswas 1981, Lerat 1981 . . .), about two centuries ago the quasi-totality of energy

* Contribution No. 55 to the study of the Miombo open forest ecosystem.

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consumed in the world came from traditional sources, of which wood was by far the most important. Today, developed countries, with a total of 1.2 billion inhabitants consume 5/6ths of conventional energy, whereas the less developed countries (LDCs), with a population evaluated at more than 3 billion, consume less than one sixth (Revelle 1980). This state of affairs is linked to the fact that the LDCs use large amounts of non-commercial energy derived mainly from wood transformed to a greater or lesser extent. Thus in the LDCs 80% of the population depends on woodfuel as their primary energy source (Openshaw 1974). In 1971 woodfuel was estimated to provide 75% of energy in sub-Saharan countries, and to exceed 90% in some countries (Earl 1975).

Estimation of the woodfuel reserves is a frequent preoccupation in black Africa, as various local studies show: Dakar (Pagni 1975, Berlureau and Berlureau 1981), Ouagadougou (Ouedraogo and Vennetier 1977), Ndjamena (Bertrand 1977), Upper-Volta (Bertrand 1977), Niamey (Delwaule and Roederer 1973), Abidjan (Monnier 1972), Gabon (Villien 1981), Rwanda (Bart 1981), Shaba (Schmitz and Misson 1960, Schmitz 1974, Malaisse *et al.* 1980, Binzangi 1983, Malaisse *et al.* 1983), Lusaka (Brown 1978), South Africa (Gandar 1984).

Table 1

Relative importance of fuelwood (in %) in the global energy needs of certain African states (after Lerat 1981, Ki-Zerbo 1981, Binzangi 1983).

State	% of woodfuel in energy needs
Mali	97
Upper Volta	94
Tanzania	94
Ethiopia	93
Chad	89
Gambia	87
Niger	87
Zaïre	76
Kenya	74
Ghana	74
Cape Verde	70
Mauritania	69
Senegal	63

This preoccupation is justified by the fact that organic combustible materials are the major energy source for most African countries (Table 1) and concern the vast majority of their populations.

The creation of large urban agglomerations has caused a concentrated demand for wood and a dispersed supply, bringing about commercialisation and this has had far-reaching consequences when wood merchants compete for a resource without being responsible for protecting or replacing it (Gandar 1984).

The deforested zones surrounding large African towns are reaching alarming proportions (Table 2). Thus more than 60,000 m^3 of indigenous wood was trucked into Harare in 1980 from as far as 120 km away (Whitlow in Gandar 1984). In the Ivory Coast, over 18 years (from 1956 to 1974), more than six million hectares of rain forest were cleared and became fields, fallow lands or secondary bushlands (Monnier 1981). This ever-increasing deforestation augurs a growing scarcity of firewood.

In Zaïre, wood represents around 76% of the global energy consumption (Binzangi 1983). However the wood production in the different regions of Zaïre is very variable. Forested areas alternate with grasslands. In fact, botanists distinguish 11 phytogeographical districts, each with its own individual characteristics. The following discussion only concerns one of these, Upper Shaba (Figure 1). This phytogeographical entity is integrated into a larger, relatively homogeneous area, namely the Zambezian region (White 1976), where woodland dominates (CSA 1956, 1960, Malaisse 1978). In order to evaluate deforestation dynamics in this area, we followed the evolution of the vegetal cover on a basis of cartographic documents and aerial photographs. The square degree of Lubumbashi (27–26° longitude East, 11–12° latitude South) was chosen as a reference. This choice is justified by our close knowledge of the land at ground level in this area, as well as by the recent publication of a map of the vegetation (Malaisse

Table 2

Size of the deforested area, of the firewood volume and number of charcoal sacks consumed by some large African cities.
(1): values obtained on the premise that one charcoal sack weighs 48 kg;
(2): this amount of wood equals 864 hectares of evergreen forest exploitation;
(3): estimation of the population's wood needs (after Malaisse *et al.* 1980, modified).

Town (Country)	Number of inhabitants (reference year)	Approximate radius of the deforested area (km)	Firewood volume (Mm^3/yr)	Number of charcoal sacks Thous./yr	References
Abidjan (Ivory Coast)	600,000 (1971)	—	0.06	288[(2)]	Monnier (1972)
Bamako (Mali)	200,000 (1970)	over 100	—	—	Le Houérou (1977)
Dakar (Senegal)	799,000 (1976)	—	0.066	1502	Berlureau and Berlureau (1984); Pagni (1975)
Kano (Nigeria)	342,610 (1971)	over 100	—	—	Le Houérou (1977)
Karthoum (Sudan)	262,000 (1971)	90	—	—	Eckholm (1978)
Kinshasa (Zaïre)	2,000,000 (1979)	50	1.2[(3)]	—	Bride in Pain (1979)
Kisangani (Zaïre)	425,000 (1980)	15	—	—	Harroy (1979)
		50	—	—	Lisowski (pers. com.)
Kolwezi (Zaïre)	218,000 (1982)	over 20	0.034	411	Binzangi (1983)
Likasi (Zaïre)	200,000 (1982)	20	0.031	376	Binzangi (1983)
Lubumbashi (Zaïre)	534,000 (1980)	30	—	—	Schmitz (1974)
		18	0.06	418	Leblanc and Malaisse (1978)
		30	0.084	1011	Binzangi (1983)
Lusaka (Zambia)	448,000 (1972)	70	—	54	Brown (1978)
N'Djamena (Tchad)	150,000 (1971)	over 100	0.1	—	Le Houérou (1977)
Niamey (Niger)	100,000 (1970)	over 100	0.1	—	Le Houérou (1977)
Ouagadougou (Upper Volta)	260,000 (1980)	75 to 100	0.146	—	Ouédraogo and Vennetier (1977)
		70 to 100	0.114	31	Chauvin (1981)
Pointe-Noire (Congo)	100,000 (1970)	20	0.120	—	Vennetier (1968)
Sokoto (Nigeria)		over 100	0.1	—	Le Houérou (1977)
Zinder (Niger)	45,000 (1970)	over 100	0.1	—	Le Houérou (1977)

et al. 1983). This latter distinguishes 8 different vegetation types. Our estimations of firewood reserves have been established for these 8 sections.

Open forest is the most widespread vegetation type. Although reputed poor (Delevoy 1928), it provides products that may be grouped as follows: charcoal, firewood, fuelwood, construction wood and wood for industrial purposes (Malaisse *et al.* 1980). Open forests and woodlands are important producers of lightweight poles and fuel for the local population. Only a few species in the Miombo woodlands have the dimensions necessary for heavy construction (de Vos 1975, Liengwe 1981). The most important products are charcoal and firewood which represent respectively 73 and 18% of the need for woody combustible material in Lubumbashi.

The present study follows the evolution of wood reserves in Upper-Shaba from the beginning of the century, and sketches out the main characteristics of future evolution.

Photo 1. View of Miombo type open forest near Lubumbashi.

Charcoal yield of the different types of open forests and wooded savannas

Studies on charcoal production in Upper Shaba generally distinguish small-scale production from that performed by steel ovens. Today this latter technique only continues at Kikeka.

Traditional production involves well known successive stages, which are felling, chopping, collecting and piling of the logs, these being covered by clods of earth, their charring, uncovering and packing in sacks (Delevoy 1948, Misson 1952, Schmitz and Misson 1960, Binzangi 1983).

In order to estimate the wood reserves in the area studied, several methods of quantification were tested and compared. Production may in fact be expressed in terms of the area deforested, the basal area values, the gross volume of the logs, the net volume of wood to be charred, the volume of the charcoal stack, or lastly the weight or volume (number of sacks) of charcoal produced.

Photo 2. Charcoal production ('Makala'): one of the main causes of open forest destruction and its replacement by derived savanna.

To fix a precise relationship between these methods of expression is not easy. One source of miscalculation for the weight may be found in the variable hydration of charcoal: 18.5% in April (end of rainy season), 1.5% in October (dry season). As for production measured in sacks, the volume of these may vary, and in addition there may, or may not be an overload in mushroom form.

The deforested area does not give a concise evaluation as in this region is found a mosaic of woodland types with very variable density. Early studies (Delevoy 1928) furthermore distinguish 5 classes of productivity for the 'wooded savannas' of Upper Shaba. Today, phytogeographers (CSA 1956) and ecologists define 4 types of 'wooded savannas': open forest, wooded savanna in the strict sense of the term, tree savanna and shrub savanna.

Basal area has been found to be a precise, useful method of distinguishing the 4 vegetation types noted below (Table 3); unfortunately there are large differences between the basal area of a tree, and its above-ground wood volume.

The volume of the charcoal pile is a very consistent method of evaluation, especially when small stacks, where the earth covering forms a large part of the whole, are not included. In the end, the net volume of chopped wood was found to be the most precise factor, its only weakness being in the variation of specific density of tree species which causes a slight variation in yield. However, evaluation by this method is long and laborious.

Table 3
Charcoal production per hectare for different vegetation types in Upper Shaba.

	a	b	c	d	e	f	g
Vegetation type	Number of stems per hectare	Basal area (m^2/ha)	Wood (net volume) (m^3/ha)	Volume of steres (m^3/ha) c × 2.566	Volume of charcoal stack (m^3/ha) d × 1.1173	Number of sacks/ha e × 1.30	Charcoal (T/ha) f × 0.0483
Riparian forest	—	27	130	333.6	272.7	484.5	23.4
Dry evergreen forest	1463	33	150	384.9	430.0	559.0	27.0
Open forest	570	19	80	205.3	229.4	298.2	14.4
Wooded savanna	210	11	30	76.9	85.9	111.7	5.4
Tree and shrub savanna	45	2	4	10.3	11.5	14.9	0.7

To establish the relationships between these forms of evaluation we conducted about thirty experiments, made in 3 different localities (Luiswishi, Mususwa and Tumbwe; These experiments include a forest inventory over 5 hectares and wood felling on more than 3.5 hectares (more than 1,000 felled trees were measured). From this enormous mass of data we obtained the following average relationships.

— 1 ha of open forest equals 570 trees whose diameter $\geqslant$ 5.0 cm (Malaisse 1982);
— 1 ha of open forest equals 363 trees whose diameter $\geqslant$ 10.0 cm (Malaisse 1982);
— 1 ha of open forest equals (15) – 19 – (25) m^2 of basal area (Malaisse 1982);
— 1 ha of open forest equals $\pm$ 80 m^3 of wood (net volume) (Binzangi 1983);
— 1 m^3 wood (net volume) equals 2.566 steres (Malaisse *et al.* 1980);
— 1 m^3 steres equals 1.1 m^3 charcoal stack (Binzangi 1983);
— 1 m^3 of charcoal stack produces (1.0) – 1.3 $\pm$ 0.2 – (1.8) sacks of charcoal (Binzangi 1983);
— 1 sack of charcoal weighs 48.3 $\pm$ 5.6 kg (Malaisse *et al.* 1980).

The square degree of Lubumbashi

There has been, and still exists, a long controversy as to the nature of the climatic vegetation in Upper Shaba. Some (Schmitz 1962, 1971) consider that the dry evergreen forest is the most luxurious vegetation in balance with the soil and the climate in Upper Shaba, and that without the intervention of man it would be omnipresent. Other authors (Duvigneaud 1958, Streel 1963) defend the theory of a mosaic of open forests and dense climatic forests whose relative importance would vary with changes in the regional climate.

The earliest information available today on the Lubumbashi area dates from the beginning of the 20th century and is composed of various accounts, completed with ancient photographic documents, made by travellers (1910–1915) as well as a vegetation map of the Lubumbashi area (Sys and Schmitz 1959). The analysis of this information, together with an examination of the existing vegetation cover generally reveals the vegetation of the years 1900–1920.

We used this technique, which enabled us to define the main tendencies of the evolution of the vegetation in the studied region (Table 4). At the beginning of the 20th century, 85 per cent of the square degree of Lubumbashi was covered by open forest. However this and other forest types covered more than 92%. The first deforested areas appeared around 1910, with:

— copper exploitation;
— the creation of Lubumbashi and Kipushi towns;
— construction of the railroad (clearing for construction and sleepers);

— woodfuelling of steam engines;
— the creation of farms and rural centres around the towns;
— the appearance on the market of woodfuels, such as charcoal.

Table 4
Area and relative importance of the types mapped in the square degree of Lubumbashi (Zaïrian sector)*

	Original vegetation cover (beginning of century)		Present vegetation cover	
Type	Area	%	Area	%
Open forest	884,675	83.76	729,113	69.03
Wooded savanna	40,347	3.82	15,925	1.51
Tree and shrub savanna	40,348	3.82	15,925	1.51
Dambo	39,429	3.73	26,559	2.51
Grassy alluvial or Acacia-dominated savanna	34,920	3.31	30,200	2.86
Dense riparian forest	7,877	0.75	162	0.02
Marshy vegetation	7,747	0.73	4,027	0.38
Cupriferous steppe-type savanna	565	0.05	565	0.05
Dry evergreen forest	260	0.02	220	0.02
Derived savanna	—	—	214,821	20.34
Urban zone	—	—	8,000	0.76
Cultivation	—	—	5,777	0.55
Open water	—	—	3,720	0.35
Afforestation	—	—	1,154	0.11
Total	1,056,168	99.99	1,056,168	100.00

*The evaluation of the cleared areas was made by adding together the surface areas of open forest and other vegetation types found in the deforested zone. In order to compensate for the cleared areas, the patches of open forest found inside this area have not been taken into account.

— The urban area has been estimated at 8,000 hectares: 7,000 hectares for Lubumbashi (Bruneau and Mbuyu 1983) and 1,000 hectares for Kipushi (Okito 1984).
— The area covered by cultivated fields was established on the basis of a systematic enquiry carried out in 1982–1983 in villages in the Zaïrian sector of the square degree of Lubumbashi (Malaisse and Ipanga 1985).
— Open water corresponds to the Lufira and Lubumbashi reservoirs. The Mwadingusha dam was built in 1930, then raised twice, bringing about a considerable increase in the open water surface area when compared with the original Lake Tshangalele. It covers at present 44,600 hectares (Goorts *et al.* 1961). Lubumbashi lake was created in 1962 and covers 40 hectares (Freson 1972).
— The Kimbembe plantation was created in 1959–1960 and covers around 1014 hectares. To this we added that of the Inera-Kipopo, which covers 140 hectares. These values were obtained from evaluations on the basis of 2 Landsat photos which appeared in 1973.

All these human activities caused ever-increasing deforestation. Although the use of electricity, coal and diesel oil by trains has relatively diminished the consumption of firewood, electricity has not brought about the same phenomenon in medium and small industries or in the home. The expansion of human activity has caused the demand for woodfuel to grow. In consequence, the different forest and woodland types have suffered a variable but considerable recession since the beginning of the century, *viz*:
— 97.9% for dense riparian forest
— 60.5% for woodland
— 60.5% for tree and shrub savannas

— 17.6% for open forest
— 15.4% for dense dry evergreen forest.

Taken as a whole, the total retreat of woodland and forest involves, 212,162 ha (1984), or 21.6%. Deforestation is still progressing, mainly along roads.

The comparison of present wood reserves with those of the beginning of the 20th century is revealing (Table 5): some 50.6 million sacks of charcoal have been consumed, thus diminishing the woodfuel capital by 18.8%.

Table 5

Comparison of the firewood reserves in the Lubumbashi square degree (expressed in number of charcoal sacks) at the beginning of the 20th century and today (1984).

Beginning of the 20th century

Type	Area (ha)	Production (charcoal) kg/ha	Production (charcoal) Tons	10^3 sacks
Dense riparian forest	7,877	23,402	184,338	3,817
Dense evergreen forest	260	27,000	7,020	143
Open forest	884,675	14,403	12,650,852	261,922
Wooded savanna	40,347	5,395	217,672	4,507
Tree and shrub savanna	40,348	720	29,050	601
Total	973,507		13,088,932	270,992

The present day (1984)

Type	Area (ha)	Production (charcoal) kg/ha	Production (charcoal) Tons	10^3 sacks
Dense riparian forest	162	23,402	3,791	78
Dense evergreen forest	220	27,000	5,940	123
Open forest	729,113	14,403	10,499,227	217,375
Wooded savanna	15,925	5,395	85,915	1,778
Tree and shrub savanna	15,925	720	11,466	237
Afforestation	1,154	33,540	38,705	801
Total	762,499		10,645,044	220,392

Prospects for future evolution

Forest farming has been an established practice in the Zambezian woodland area for centuries, almost entirely in the form of shifting cultivation. As long as there was only one or less cultivator per square kilometer (Malaisse 1979) and provided the patch of farmed forestland could be left fallow for at least fifty years in order to renew itself, the system worked well enough. But with the increase in population densities and their more sedentary lifestyle as well as the establishment of villages along the road network, people abandoned ecologically balanced subsistence strategies based on a wide range of available energy sources in favour of ecologically destructive concentrated exploitation, with the result that reforestation no longer occurred. Furthermore, along the timber tracks some 'subsistence' cultivators created new settlement areas, and by clearing away more trees in order to plant their crops, they soon caused serious damage to, if not the destruction of, the open forest, as already underlined for the tropical moist forests by Myers (1981).

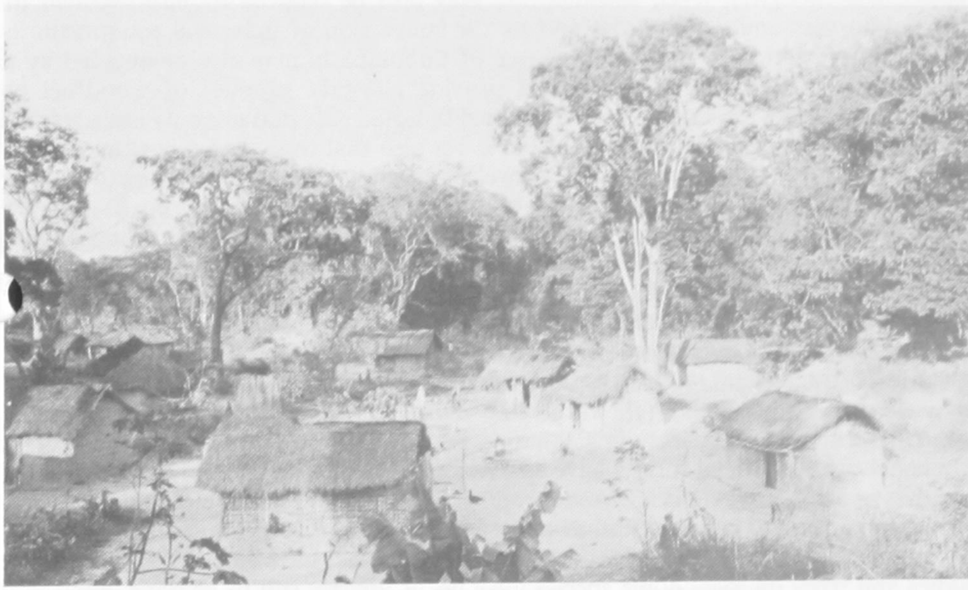

Photo 3. A village in the Zambezian open forest.

Lubumbashi town's development, and the corresponding growth in its woodfuel needs poses the problem of how long the Lubumbashi square degree will be able to supply firewood. Although it is not possible to give a definite answer to this question at present, due to the large number of variables that must be taken into consideration, it is nonetheless possible to estimate the future.

The present and future urban and rural population numbers of the square degree of Lubumbashi are the first vital data. Two towns, very different in size, are built on the territory studied: Lubumbashi, the copper capital, and Kipushi, a company town, completely orientated around the mine. Although the population of the latter is known precisely (42,322 inhabitants in 1983), such is not the case for Lubumbashi. Different values have been proposed: 680,000 inhabitants in 1980 (Lootens-De Muynck *et al.* 1980), 586,000 inhabitants in 1980 (de Saint-Moulin 1977) and 580,000 in 1984 (Bruneau and Lootens 1984). Recent studies show that in the last 5 years immigration has considerably decreased. Thus the urban population can now only grow through its own dynamism (Bruneau, pers. comm.). Let us remember that even in 1977, de Saint-Moulin considered that the rate of growth in large Zaïrian towns was slowing down, and tending to stabilise.

Using the 1984 figures, we have drawn up a plan of the developing woodfuel needs of the town, with two growth rates. Presupposing a growth rate of zero, both from a demographic point of view and from the annual average consumption per inhabitant (124.7 kgs), the square degree of Lubumbashi could supply wood up to the year 2120. On the other hand, taking into consideration an average annual demographic growth of 2% (Bruneau, pers. comm.), the last energy provided by woodfuel in the square degree of Lubumbashi would be consumed in 2050!

However, in the meantime there may be a change in lifestyles with an eventual increase in financial means of the working masses, which would clearly encourage the use of petrol, natural gas and electricity, especially if reasonably priced cooking rings were to be developed. As far as charcoal production is concerned, taking into account a necessary increase in productivity and thus a change in charring methods, we may also hope for an improvement of production techniques, which would slow down deforestation. On a home and industrial level, consumption may also be reduced by improvement of charcoal burners and wood grates and by the conversion of industrial equipment.

Total deforestation of the square degree of Lubumbashi may also be avoided by a reforestation programme, which would provide constant supplies of woodfuel to Lubumbashi after a reasonable period. It must be noted here that not only has a reform in forest law been proposed (Schmitz 1969), but also that trials and a healthy start in Upper Shaba forestry have been made. As well as general observations relating to Shaban forests (Schmitz and Herincks 1969), we also possess studies relating to *Eucalyptus* planting on burnt ground (Schmitz and Delvaux 1958), to Pine plantations (Misson 1952, Schmitz 1966) and to enrichment and tree selection in open forest (Schmitz 1959). Trials of other species (Schmitz *et al.* 1959, Schmitz 1966) have also given encouraging results. Woodyields may be found in the literature on the subject. Schmitz and Herincks (1969) note that *Eucalyptus saligna* and *E. camaldulensis*, when 15 years old and on rich soil, may give 75 to 150 steres of wood (or 3.5 to 9 tons of charcoal). Schmitz (1969) calculates the yield of various *Pinus* (*P. kesiya*, *P. patula*, *P. pseudostrobus*), as being at 300–650 m^3 of wood/ha, including thinning products, at 20 years of age.

In conclusion, artificial forests have an average yield per hectare 4 to 6 times greater than that of good natural open forest over 60 years old that has been clear-felled. Thus, in the framework of a reforestation programme destined to produce firewood, the problems relating to species choice and thinning techniques have already been resolved. Studies and trials on local noble species have unfortunately still to be done, and their slower growth does not encourage their substitution for exotic fast growing species.

The present needs of Lubumbashi could be met by a reforestation programme with a rotation period of 20–25 years, covering about 220 thousand hectares, or a little more than 20% of the territory. In this context, if a reforestation programme were perfected and applied, our predictions for the future would obviously have to be revised. However, pending these considerable changes, none of which are very likely, we should try to manage what remains rationally by changes in production and woodfuel consumption techniques. For, after copper, — we are in the Zaïrian Copperbow — , the open forest should be considered as the second treasure of Upper Shaba for a long time to come.

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