Electromagnetic Radiation and Health Hazards

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Introduction

Prior to the middle of this century, very little concern has been given to the biological effects from electromagnetic radiation. However, with the rapid development in the instrumentation engineering leading to the proliferation in the number of equipment emitting radiofrequency (RF), various and systematic research programs began to emerge to determine the bioeffects of this ubiquitous form of radiation. At present, there are numerous applications of RF devices both at commercial establishment or at home. For instance, in the electronic manufacturing industries, RF devices can be found at various locations, such as, at the product molding and at the assembly test lines. At home, the main electrical appliances which operates on RF bandwidths are those that generally produce heat such as the microwave oven or those that enable wireless communications such as the cellular telephone. In addition and due to the rapid increase in the usage of high power electrical energy in both domestic industrial societies, the level of exposure of biological systems to electromagnetic fields has grown by orders of magnitude over a frequency range extending from zero to hundreds of GHz.

In many instances members of the public, are not aware that exposure takes place, and may be willing to take any risks associated with exposure. Generally, the exposure can takes place 8 hours per day (occupational), 24 hours per day, and over the whole period of lifetime (public). Electromagnetic radiation at sufficient levels of intensity and duration of exposure can produce variety of adverse health effects. Such effects include cataracts of eye, overloading of the thermoregulatory response, convulsions, decreased in endurance, stimulation of nerve and muscle cells, an electric shock and RF burns. The evidence to the definite risk to health from electromagnetic exposure was initially given by Wertheimer and Leeper (1982). They have provided some experimental evidence showing a strong correlation between the electromagnetic fields exposure and cancer. Recently, the works published by Savitz *et al* (1988) have also indicated the increased in risk as high as 40 % of leukaemia in children exposed to electromagnetic radiation. Their findings have attracted wide publicity from the media who has also equated such reports with cellular telephones and video display terminals. With new findings and discoveries been made, there has been a growing public concern about the possible health hazards from the exposure to the electromagnetic fields. This presentations examined the possibility that deleterious biological effects could be caused by electromagnetic exposure ,and, the evolution of standards and guidelines as a means of protection against electromagnetic radiation.

Electromagnetic Sources

Equipment emitting radiofrequency radiation can be divided in different frequency bands assigned to telecommunication industry, medicine and science. A common used frequencies are 27.12 MHz (short-wave), 433 MHz (decimetre wave) and 2.45 GHz (microwave). To-date, the main source of high-frequency and microwave radiation is those that originated from information technology. In addition to the well established and powerful transmitter stations, smaller transmitter mainly the potable sets (mobile telephones, pager, walkie-talkie, CB radio, etc) have resulted in the steady growth of radiation exposure to the publics. Also the wide spread used of microwave heating devices in both industry and households has also contributed to the increased of exposure levels. Electromagnetic sources can be both intentionally and unintentionally. The former one are those that are designed to release electromagnetic energy into space such as the radar, radio and television stations. In contrary, the sources that produce radiation within an enclosed unit such as the microwave oven can accidentally emit the electromagnetic energy due to poor design of the unit or malfunctions. Table 1 summarized the typical power rating of some major electromagnetic sources.

Source	Frequency	Power
Microwave oven	2.45 GHz	800 - 1000 W
Traffic radar	9 - 35 GHz	0.5 - 100 mW
Airport radar	1 -10 GHz	0.2 -20 kW
Walkie-talkies	27 MHz	1 - 5 W
FM stations	87.5 - 108 MHz	up tp 100 kW
VHF-TV	47 - 230 MHz	100 - 300 kW
UHF-TV	470 - 890 MHz	up tp 5 MW
Short wave	3.95 - 26.1 MHz	up to 750 kW
Long wave	120 - 1606.5 kHz	1.8 MW
Cellular communications	450 - 900 MHz	up to 5 W

Table 1

Biological Effects

The biological effects can generally be divided into direct and indirect effects. Direct effects are those that are caused by the absorption and penetration of the electromagnetic energy by the body exposed to RF radiation.. This is frequency dependent effects and on the microscopic level leads to the heat effects, the generation of electrical potential difference and the field-induced force effects. Under given physiological conditions, the heat effect is predominant in most cases. Hence, the same biological effects as those from other thermal sources, including burns, temporary or permanent changes in reproduction in cataracts are some lethal effects that can be caused by electromagnetic radiation. Saunders *et al* (1991) observed in an average increase in temperature from 0.5 to 2 ^{o}C in human when irradiated with electromagnetic fields having power flux density of 100 W/m^2. In a poorly circulated organs, such as the eye lens, the temperature increase is greater. Cleary (1980) reported that power flux densities of more than 1 kW/m^2 may lead to the formation of cataract. Apart from these effects, there is hardly any data from investigations on man revealing a connection between cancer and electromagnetic exposure. A few attempts have been made to find such a connection but only producing a series of conflicting results and were repeatedly criticized for a number of important sources of error.

In comparison to the direct effects, the hazard from the build-up of dangerous body currents as a result of the indirect effect due to the electromagnetic exposure can be very dangereous. Many studies have shown that a high density of radiofrequency currents will be induced in humans when exposed to electromagnetic fields specially from those that are vertically polarized. The total short-circuit current I_{SC} flowing from the feet to the ground of the irradiated body is given by (Gandhi *et al* 1985)

$$I_{SC} = \alpha h^2 f E$$

where,

$\alpha = 0.108$ nA
h = height (m)
f = frequency (Hz) and
E = electric field strength (V/m).

For example for the body of height 1.67 m such as the author, when exposed to the electromagnetic radiation having power electric field intensity of 1 v/m at frequency of 10 MHz, produces a short-circuit current of 3.0 mA. At high frequency the induction of I_{SC} is much higher reaching a few tens of ampere in GHz range. When induced, the body is practically acts as capacitor on which an electric discharge will occur when it come close to any conducting object in a fraction of centimetre. In human, the discharge currents may release various reactions but the prominent among them are the RF shocks and burns.

Exposure Standards

The first standards for controlling electromagnetic exposure were introduced in 1959's, in the USA and the USSR. Subsequently many countries have developed their own national standards based on the US or USSR standards or intermediate between them. Unfortunately, there are many uncertainties and difference of opinions, so that the safe exposure limits proposed in various countries differ from each other greatly. Ideally, the standard should be based firmly on human data. Since, no such data is readily available, it is extremely difficult to draw guideline that clearly defined relationship between electromagnetic exposure and physiological effect.. As a results, many standards are based on the extrapolation from well-designed and adequately performed animals experiments. Some of them are shown in Table 2 below.

Country	Frequency	Exposure limit (mW/cm^2)	Safety Code
USA (ANSI standard)	10.0 MHz - 100 GHz	10.0	Less than 6 minutes
Canada	10.0 MHz - 300 GHz	1.0	Less than 1 minutes
USSR	30.0 MHz - 300 GHz	0.01	Entire day
Sweden	10.0 MHz - 300 MHz 300.0 MHz - 300 GHz	5.0 1.0	Occupational Occupational
Poland	10.0 MHz - 100 GHz	0.01 to 0.1	Entire day

Table 2

In general, the promulgation of the standards is not an easy task. Most of the scientific data obtained on small animals and extrapolated these results to man is not a clearly defined process. In addition, there is large amount of uncorroborated and controversial evidence of various biological effects. At the international level, the bodies such as the IRPA (International Non-Ionizing Radiation Committee of the International Radiation Protection), in cooperation with Environmental Health Division of the World Health Organization, has undertaken responsibility for the development of health criteria documents on electromagnetic radiation.

Conclusions

The health hazards due to the electromagnetic exposure are know to exist. As such, standards and guidelines have been introduced to protect human health from the potentially harmful effects. However, the safety exposure limits adopted by various countries differ significantly reflecting the level of uncertainties in the subject. However, research is continuing and the published standards will be subjected to periodic revision and amendment.

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e use of demographic studies in mangrove silviculture

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words: mangrove, demography, silviculture, management

tract

Matang Mangrove Forest Reserve in Malaysia has been managed for timber production since the beginning ıe century and is reputedly the best managed mangrove forest in the world. The present management plan is -year rotation period with two thinnings, at 15 and 20 years. However, there has been a decline in yield from t ha^{-1} of green-wood from virgin stands to the second generation yields of 158 t ha^{-1} in 1967–69 to an even ır 136 t ha^{-1} in 1970–77.

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he high density of 15 030 *Rhizophora apiculata* trees per hectare in the 5 year-old stand and the sharp decrease 810 in the 8 year-old stand indicate that the initial stocking was too high. We suggest that artificial regeneration ıld be carried out at 1.2 m intervals only if the natural regeneration is less than 50% (rather than 90% as is the ıent practice). Extremely high mortality occurred in the 13 year-old and the 18 year-old stands where 43% and ı respectively of the *Rhizophora* trees were dead. We therefore suggest that the thinnings be carried out earlier – 2/13 and 17/18 years (instead of 15 and 20 years) to reduce this wastage due to natural thinning. An additional cultural thinning could be carried out at 8–9 years to remove non-*Rhizophora* trees and to reduce stand density ound 8000 ha^{-1} to allow better growth. The standing biomass of the trees did not increase from 23 years (155 t ı to 28 years (153 t ha^{-1}). Based on biomass, we suggest that a rotation of 25 years be used instead of the ıt 30. This is also supported by size distribution of the stems which showed slow increase in the girth after 18

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tang mangrove Forest Reserve, reputedly the ıaged mangrove forest in the world, has been primarily for timber production (mainly *Rhi- ıpiculata* Bl.) since the beginning of this cen- agement is carried out by the State Forestry ıt, Perak, Malaysia, through the implemen- ınstantly updated management plans ranging ıf 40-year rotation period with three thin- ıd out at approximately 15, 25 and 30 years nt plan of a 30-year rotation period with ıs at 15 and 20 years (Ong, 1982). After sites which are considered inadequately stocked are replanted. Despite the intensive management, there has been a decline in yield from 299 t ha^{-1} of green-wood from virgin stands to the second generation yields of 158 t ha^{-1} in the period 1967–69 and 136 t ha^{-1} in the period 1970–77 (Tang *et al.*, 1984).

The decline in yield from virgin stands to second generation stands is understandable as the trees in the virgin stands were much older (perhaps 50–70 years) and therefore bigger than the second generation harvest at 30 years. However, there appears to be a decline between yields in the seventies (136 t ha^{-1}) compared to yields in the sixties (158 t ha^{-1}). If the decline is real, what are the reasons for this decline? Is it caused

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The use of demographic studies in mangrove silviculture

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Key words: mangrove, demography, silviculture, management

Abstract

The Matang Mangrove Forest Reserve in Malaysia has been managed for timber production since the beginning of the century and is reputedly the best managed mangrove forest in the world. The present management plan is a 30-year rotation period with two thinnings, at 15 and 20 years. However, there has been a decline in yield from 299 t ha^{-1} of green-wood from virgin stands to the second generation yields of 158 t ha^{-1} in 1967–69 to an even lower 136 t ha^{-1} in 1970–77.

This study on the demography of the forest was conducted to try to determine ways to improve the silviculture and management system. The species of the tree, whether it was living or dead, and the girth at breast height were recorded for all trees in selected representative plots covering a range of ages (5, 8, 13, 18, 23 and 28 years). The standing biomass of these plots was calculated using previously obtained allometric regressions.

The high density of 15 030 *Rhizophora apiculata* trees per hectare in the 5 year-old stand and the sharp decrease to 9810 in the 8 year-old stand indicate that the initial stocking was too high. We suggest that artificial regeneration should be carried out at 1.2 m intervals only if the natural regeneration is less than 50% (rather than 90% as is the present practice). Extremely high mortality occurred in the 13 year-old and the 18 year-old stands where 43% and 29% respectively of the *Rhizophora* trees were dead. We therefore suggest that the thinnings be carried out earlier – at 12/13 and 17/18 years (instead of 15 and 20 years) to reduce this wastage due to natural thinning. An additional silvicultural thinning could be carried out at 8–9 years to remove non-*Rhizophora* trees and to reduce stand density to around 8000 ha^{-1} to allow better growth. The standing biomass of the trees did not increase from 23 years (155 t ha^{-1}) to 28 years (153 t ha^{-1}). Based on biomass, we suggest that a rotation of 25 years be used instead of the present 30. This is also supported by size distribution of the stems which showed slow increase in the girth after 18 years.

Introduction

The Matang mangrove Forest Reserve, reputedly the best managed mangrove forest in the world, has been managed primarily for timber production (mainly *Rhizophora apiculata* Bl.) since the beginning of this century. Management is carried out by the State Forestry Department, Perak, Malaysia, through the implementation of constantly updated management plans ranging from one of 40-year rotation period with three thinnings carried out at approximately 15, 25 and 30 years to the present plan of a 30-year rotation period with two thinnings at 15 and 20 years (Ong, 1982). After final felling, sites which are considered inadequately stocked are replanted. Despite the intensive management, there has been a decline in yield from 299 t ha^{-1} of green-wood from virgin stands to the second generation yields of 158 t ha^{-1} in the period 1967–69 and 136 t ha^{-1} in the period 1970–77 (Tang *et al.*, 1984).

The decline in yield from virgin stands to second generation stands is understandable as the trees in the virgin stands were much older (perhaps 50–70 years) and therefore bigger than the second generation harvest at 30 years. However, there appears to be a decline between yields in the seventies (136 t ha^{-1}) compared to yields in the sixties (158 t ha^{-1}). If the decline is real, what are the reasons for this decline? Is it caused ı decrease in soil fertility with number of crops? the result of competition due to successful inva-ı by other species, like the fern *Acrostichum*? Is it result of the length of the rotation or the thinning me? All these need to be considered to fully under-d the reasons for the decline; but a quick synoptic : at the demography at different stages of the rota- should provide indications as to how the various icultural practices and management systems may e contributed to this decline.

This study on various aspects of the demography *. apiculata* at Matang was therefore carried out to ιin more information on what actually takes place in erent aged stands of a 30-year rotation, which will establish what is really happening through the tion and suggest possible reasons for the decline ield. These information can then be used in the iculture so that the forest can be managed better to ıre sustained yield.

: study site

study site is located near Kuala Sepetang (Port d), in the Matang Mangrove Forest Reserve (4 ° N, 100 ° 36′E) which covers an area of 40 000 ha. s forest has been managed by the Perak State estry Department since the early part of this cen-, for timber production (mainly for charcoal and wood), and the preferred species is *R. apiculata*.

At present, the forest is logged on a 30-year cycle ron, 1981), and about 1000 ha are clear-felled every : in patches of a few hectares. The slash is left ecompose and after about two years, the area is cked for the stocking of seedlings. In some 50% hese clear-felled areas, manual planting (at 1.2 m rvals) is carried out. The seedlings are left to grow around 15 years when the first thinning is carried using a 1.2 m stick so that any tree within a 1.2 m us of a selected central tree is removed (and the ger trees sold as poles). Thus theoretically, with a m interval planting and a 1.2 m stick thinning, there be no poles to harvest. In practice, seedling densi-are increased considerably by natural recruitment ı after manual planting which results in a harvest bout half of the trees during the first thinning. A ond thinning takes place at about 20 years when a m stick is used. This thinning also removes about of the trees.

As the Forestry Department keeps quite good records, it is possible to estimate the age of any particular stand to within three years of the actual age.

Methods of study

In November 1980, 5, 8,13, 18, 23 and 28 year-old stands were selected for study so that a whole range of different aged stands within the 30-year rotation period was covered. The stands selected were close together and of the same soil-type and tidal inundation class (Watson 1928's Inundation Class 3) so as to minimise differences due to physical characteristics and history. Varying number and size of plots were set up in the different aged stands depending on the density of trees. Four 10 m × 10 m plots were established in the 5 year-old stand; six 10 m × 10 m plots in the 8, and 13 year-old stands; three 20 m × 20 m plots in the 18 year-old stands; and four 20 m × 20 m plots in the 23 and 28 year-old stands. The species of every tree (defined as plants above 2 m in height) in every plot and whether the tree was dead or alive were noted, and the GBH (girth at breast height *i.e.* 1.3 m) of every tree measured.

The total above-ground weight and trunk weight of every tree was calculated using the regressions obtained by Ong *et al.* (1985) for *Rhizophora apiculata* in the Matang Mangrove Forest Reserve. These are:

$$W_{\text{ag(total above-ground weight)}} = 0.0135\text{GBH}^{2.4243}$$

(kg) (cm)

and

$$W_{\text{trunk (total trunk weight)}} = 0.0067\text{GBH}^{2.5414}$$

(kg) (cm)

where GBH = girth at breast height (1.3m)

Results and discussion

Table 1 summarises the density of *R. apiculata* and *Bruguiera parviflora* Wight and Arnold ex Griffith trees, both living and dead, in the six different aged stands. Using these data, we can look at the initial stocking, as well as the changes in stand density, size distribution, mortality rates, and increment in biomass with age of stand.

Table 1. Density (no. ha^{-1}) of living and dead *Rhizophora apiculata* (Ra) and *Bruguiera parviflora* (Bp) trees in different aged stands of the Matang Mangrove Forest. Values are means ± s.e.

Stand (Age in yrs)	5	8	13	18	23	28
Trees						
Living Ra	15030	9810	9250	2740	2190	2550
	±2910	±2730	±1170	±770	±480	±290
Dead Ra	2380	700	6970	1120	380	110
	± 660	±200	±990	±180	±60	±30
Living Bp	1800	17	517	592	19	0
	±945	±17	±119	±211	±12	
Dead Bp	125	0	50	150	6	0
	±95		±34	±95	±6	

Initial stocking

In the 5 year-old stand (Table 1), the density of live *R. apiculata* trees was 15 030 trees ha^{-1}. There were 2380 dead trees (14% of the total standing stems). We estimate that at this age, dead trees do not remain standing for more that about a year so most of the standing dead trees would have died within the last year. It is reasonable to assume the presence of some mortality in the first few years as well, perhaps in the region of 3000 to 5000 trees. At the same time, there will also be natural recruitment over the first three years or so. From these, we estimate an initial stocking of some 20 000 seedlings ha^{-1}.

We would like to point out here that variability is high. With the four adjacent 10 m × 10 m plots we obtained a *R. apiculata* density of 15 030±s.e. 2910. With non-adjacent plots the standard error would no doubt be higher. A more intensive sampling regime would be needed for a more definitive study but the present data gives a reasonable indication of trends.

The estimated initial stocking of 20 000 is much higher than the initial stocking of 12 500 estimated by Srivastava & Daud (1978) in their study in Matang, as sufficient for 'a fully stocked stand at the end of a rotation if there is no large scale mortality'. According to Haron (1981), the mortality rate of *Rhizophora* seedlings may be more than 50% in Watson's (1928) Inundation Class 1, 4 and 5 (Haron, 1981). These areas are not optimum for *R. apiculata* (too wet in Class 1 which is inundated by all high tides, and too dry in Class 4 and 5 which are inundated by spring tides and exceptionally high tides respectively). In Inundation Class 3 (inundated by all high tides) where our stands were located, the mortality rate would be much lower. Thus, in these stands, it would appear that the problem of initial stocking did not occur. That the initial stocking and recruitment in the early years might in fact be too high is also shown by the fact that the high density of *R. apiculata* at 5 years dropped to 9810 ha^{-1} (about 35% mortality) at 8 years.

Under the present management scheme in Matang, artificial regeneration is carried out if stocking of natural regeneration two years after final felling is less than 90% (Haron, 1981). The recommended spacing for artificial regeneration is 1.2 m × 1.2 m, which allows a planting density of 6726 seedlings in a hectare (Haron, 1981). From the high density in the 5 year-old stand (Table 1), it would appear that there is quite a lot of natural recruitment. To minimise wastage of propagules, we suggest that artificial regeneration at 1.2 m intervals should only be carried out if natural regeneration is less than 50% (*i.e.* less than 3400 seedlings ha^{-1}) at two years after final felling. When the natural regeneration is between 50 to 90%, we suggest that enrichment planting to bring the density to 6726 seedlings ha^{-1} be carried out. This reduction in the number of propagules needed for artificial regeneration is important especially now that insufficient seed is a problem in certain areas (Haron & Cheah, 1979).

Stand density

From Table 1, it can be seen that the density of *B. parviflora* is extremely variable being 11, 2, 5, 18, 1 and 0% of the total living trees in the 5, 8, 13, 18, 23 and 28

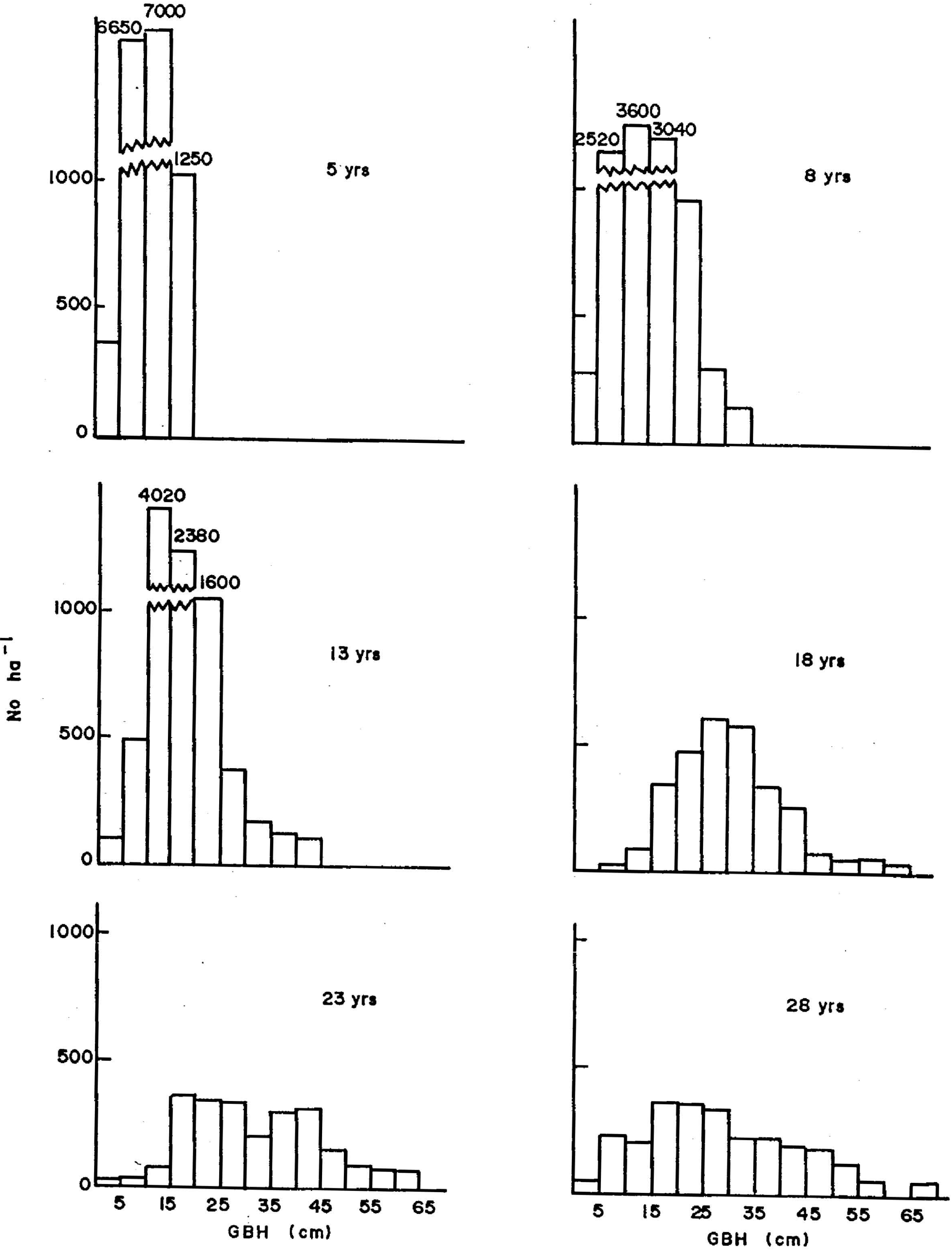

Fig. 1. Size distribution of *Rhizophora apiculata* trees in different aged stands of the Matang Mangrove Forest.

ear-old stands respectively. Since *B. parviflora* con-
ituted a significant proportion of the stand density (at
ast in the 5 and 18 year-old plots), we have included
is species in our discussion on stand density.

The high density of *R. apiculata* of 15 030 trees
a^{-1} in the 5 year-old stand dropped to 9810 ha^{-1}, or
5%, in the 8 year-old stand (Table 1), but dropped
nly slightly to 9250 ha^{-1} in the 13 year-old stand.
owever, care must be taken in interpreting these data
om different stands as they may have started off with
fferent densities. That this was indeed the case here
borne out by the fact that the total density (of live
nd dead *R. apiculata* trees) in the 8 and 13 year-old
ands were 10 510 and 16 220 trees ha^{-1} respectively,
dicating a much higher initial (before death) density
the 13 year-old stand. The number of dead *R. apicu-
ta* stems as a percentage of the total living and dead
ems in the 5, 8 and 13 year-old stands was 14, 7 and
3% respectively. Taking *Bruguiera* trees into consid-
ation as well, the density of living trees was 16 830;
827 and 9767 ha^{-1} in the 5, 8, and 13 year-old stands
spectively and the corresponding percentage of dead
ems were 13, 7 and 42%.

The high percentage of dead stems (over 40%) in
e 13 year-old stand is wasteful. We therefore suggest
at the first thinning should be carried out earlier than
5 years (the present practice) to decrease wastage due
natural thinning. Admittedly, the size of poles at this
age would be less than what is presently considered
desirable, but it is likely that trees of 12/13 years
at had been planted at a lower density would attain
bigger girth than trees under the present silvicultur-
practice. In addition, we suggest that the Forestry
epartment look into the possibility of a purely sil-
cultural thinning at between 8 and 9 years, during
hich the density of the stand should be reduced to
ound 8000 ha^{-1} to enable remaining stems to grow
tter so that trees of 12/13 years would attain com-
ercially acceptable pole size. In this silvicultural thin-
ng, trees of other species (other than *R. apiculata* and
izophora mucronata* Lamk.) should be removed; in
e case of a pure stand of *Rhizophora*, the smaller
es should be removed. Although the data in Table 1
ggest that a higher mortality of *R. apiculata* occurred
ere living *B. parviflora* density is high, the high vari-
ility encountered reduces the confidence of such an
erpretation. The question of whether *B. parviflora* is
ignificant competitor merits study.

The density of *R. apiculata* trees in the 18 year-old
nd dropped to 2740 ha^{-1} or 30% of that in the 13
ar-old stand (Table 1). A large part of this decrease

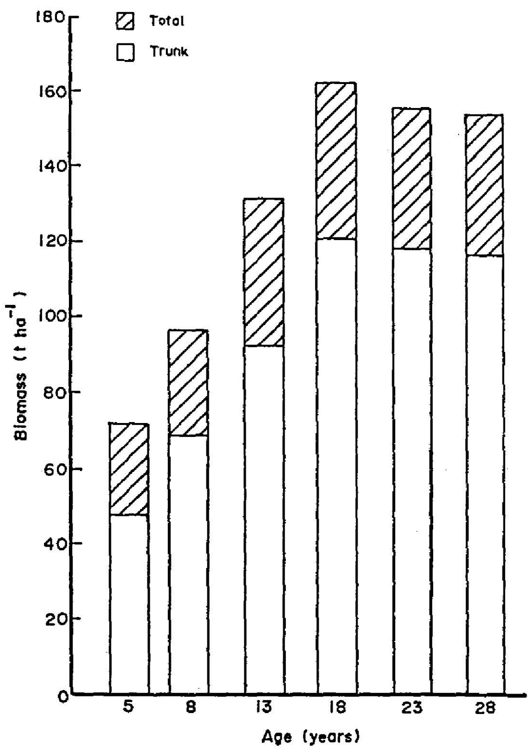

Fig. 2. The total above-ground and trunk biomass of *Rhizophora apiculata* trees in different aged stands of the Matang Mangrove Forest.

is the result of first thinning at 15 years, when a 1.2 m stick is used and usually, about half of the stems is removed. There were 1120 dead trees, or 29% of the total *R. apiculata* trees. This high percentage of dead trees is wasteful and we suggest that the second thinning should be carried out at 17/18 years (by which time the trees would definitely have reached desirable pole size even under the present management plan) rather than the present practice of second thinning at 20 years. We should also point out here that there were 592 live and 150 dead *B. parviflora* in this 18 year-old stand. Thus, this species constituted a fair proportion of the standing density (18%) and would result in lower density for the preferred species, *R. apiculata*. Haron (1981) had in fact suggested that areas heavily infested with *B. parviflora* after final felling should be treated to convert them to *R. apiculata* areas. As further recruitment of *B. parviflora* and other species is possible after the initial treatment, we have earlier suggested that a further silvicultural thinning which includes removal of non-*Rhizophora* species be carried out at 8–9 years.

The density of *R. apiculata* in the 23 year-old stand 2190 trees ha^{-1} or 80% of that in the 18 year-old. ing *B. parviflora* into consideration as well, the sity of the 23 year-old stand was 66% that of the 18 r-old stand. Under the present management plan, cond thinning would have been carried out at 20 rs, with a 1.8 m stick which would have removed ut half of the stems.

In the 28 year-old stand, the density of *R. apiculata* s increased to 2550 ha^{-1}. The size distribution (see t section) of the trees suggest that the increase in sity was due to new recruitment.

distribution

ure 1 shows the size distribution (5 cm GBH inter-) of *R. apiculata* trees in the different aged stands. ne 5 year-old stand, trees were found only in the first r size classes (*i.e.* GBH up to 20 cm), with most of trees in the 5–15 cm range. In the 8 year-old stand, trees had become bigger with some trees in the 30-cm girth class, but with most in the 5–20 cm range. biggest trees had reached the 40–45 cm girth class ne 13 year-old stand, with the majority in the 10-cm range. In the 18 year-old stand, the biggest trees attained girths between 60–65 cm, but most of the s were in the 20–35 cm range. At this stage, there e no trees in the smallest size class and indeed very trees less than 15 cm girth because thinning at 15 rs had removed most of the small trees. A notewor- point about the 23 year-old stand was that there eared to be no increase in girth; the biggest trees e still between 60–65 cm in girth and most of the s were in the 15–30 cm range (rather than in the ected larger size classes of, say, 25–40 cm). One sible explanation for this is that at the second thin- at 20 years, many of the bigger trees might in have been removed (instead of being left behind final harvest). This is not a problem with the silvi-ural practice but with the management. We agree Haron (1981) that there should be stricter control nsure that the stands are not degraded because of type of thinning ('for purely commercial purposes') ctised. In the 28 year-old stand, the biggest trees had ched the 65–70 cm size class but the mode was still ween 15–30 cm. There were also quite a number of s less than 15 cm, suggesting that some recruitment occurred after 18 years, and especially between 23 28 years. However, a lot of this recruitment is ted for as Haron (1981) pointed out, during final ing, a lot of the small trees are destroyed despite the fact that manual (with a chain-saw) felling is carried out.

Biomass increment

Figure 2 shows the total above-ground and trunk biomass in the different aged stands. The biomass increased rapidly from 72 t ha^{-1} at 5 years to 131 t ha^{-1} at 13 years. The biomass increase between the 13 and the 18 year-old stands was masked as thinning was carried out at 15 years. The standing biomass decreased from 161 t ha^{-1} to 155 t ha^{-1} at 23 years. Again, this could be attributed largely to the thinning carried out at 20 years. The biomass did not increase at 28 years (153 t ha^{-1}). From these biomass figures, it appears that a 30-year rotation may be too long as the same standing biomass may be obtained at 23 years. This is supported by Ong *et al.* (1984) who showed that the mean annual increment of *R. apiculata* trees at Matang peaked at 10 years at 18 t ha^{-1} and decreased at 15 years to 13 t ha^{-1} and to 12 t ha^{-1} at 25 years.

The trunk biomass (which is essentially the biomass of importance to the fuel wood industry) followed the same trend as the total above-ground biomass, increasing from 50 t ha^{-1} in the 5 year-old stand to 70 t ha^{-1} in the 8 year-old stand and 95 t ha^{-1} in the 13 year-old stand before levelling off at 120 t ha^{-1} in the 18 year old stand. The slight drop in biomass at 23 years may be the result of thinning at 20 years, but, once again, there was no increase in biomass between 23 and 28 years. So, once again, based on the trunk biomass data, it would appear that the rotation cycle should be shortened, perhaps to 25 years. There is however the point that there is a demand for larger-sized charcoal. However, as we had earlier discussed, there was no marked increase in GBH after 18 years (Fig. 1). The Forestry Department has to weigh the advantages of the larger-sized charcoal against the total volume produced and the shorter rotation period.

Conclusion

This study has illustrated how a quick demographic study, using plots of different ages at one instant of time rather than following the fate of permanent plots, does give a good idea of possible improvements in the silviculture, especially with respect to the density of initial stocking, the spacing for artificial regeneration, the age of thinning and the rotation cycle. Further study to look into details (e.g. causes of mortality, ıctors affecting the rate of growth at different ages) needed to further improve the silviculture. In the ıore detailed study, it is necessary to have more plots ecause of the high variability and it is also necessary) have plots under different conditions (e.g. inunda-on classes) to cover the range existing in Matang. It ıould be noted that not all of these problems are eco-ɔgical, some involve management decisions that may e commercially-based. The Forestry Department has) look into all these now to ensure the sustained yield ıanagement of this important resource.

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