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FIRE PROTECTION OF INDUSTRIAL PLANTATIONS,

ZAMBIA

Report

by

N.P. CHENEY

F.A.O. FORESTRY CONSULTANT

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SUMMARY OF MAJOR RECOMMENDATIONS

FIRE HAZARD

1. The fuel build up in the Industrial Plantations and the fire weather in the Copperbelt Region provide the potential for a disastrous fire. A single fire starting on the south-east side of a plantation could burn uncontrollably through the plantation regardless of any firebreak system. Because of the small size of the plantation blocks, a single fire would probably burn out around 4,000 acres in one day. If more than one fire occurred on a bad day the area could be much larger.

HAZARD REDUCTION

2. Piling of slash within the compartments and back from the compartment edges should cease.

3. All trees should be pruned to 7 feet at the first pruning.

4. Uncommercial thinnings should be killed and left standing. Experiments on poisoning techniques should be initiated.

5. Control burning should be carried out in *P. kesiya* after the first pruning when the average height of the compartment is 35 feet, and before the first thinning.

6. Control burning in older stands should be carried out periodically to keep the fuel quantity below 5 tons per acre.

7. Control burning of *E. grandis* should not be attempted until considerable finesse in control burning techniques has been obtained. *E. cloeziana* can be control burnt at an early age (3½-4½ years).

8. Control burning techniques should be developed by carrying out a series of experimental fires. Carry out control burning late in the wet season or early dry season.

FIREBREAKS

9. Do not plough firebreaks in sandy soil.

10. Create a trafficable road along all existing firebreaks. New firebreaks should consist of a graded road 20 feet wide, with trees planted up to the edge of the road formation.

11. Plant up existing wide firebreaks with *E. cloeziana* or *E. paniculata* where this is feasible and burn periodically.

DETECTION

12. Equip one firetower in each district with a direct reading pressure tube anemometer and obtain regular reports of wind direction and strength.

13. Investigate the possibility of using light aircraft for detection patrols during days of high fire danger when the plantation areas become larger.

EQUIPMENT

14. Purchase adequate stocks of hand tools, in particular the McLeod tool and plastic knapsack spray.

15. Equip initial attack tankers with a 200 gallon tank, a single stage centrifugal pump directly coupled to a 4-stroke motor, a live-reel containing 200 feet of hard rubber hose, and a suitable shut off nozzle designed for fire fighting purposes. Ensure that pumps and live-reels are firmly mounted on the tanker.

16. Add a wetting agent to all water used for firefighting purposes.

17. Investigate the designs of tankers used in various parts of Australia before purchasing any large tankers, designed solely for firefighting.

18. Equip several rubber tyred tractors with a hydraulic operated, front-mounted blade.

FIRE DANGER ASSESSMENT

19. Maintain a chart showing the cumulative drought index throughout the fire season.

20. Arrange to obtain daily fire weather forecasts from the Department of Meteorology.

21. Assess daily fire danger using the McArthur Forest Fire Danger Meter.

22. Install a small weather station at each district headquarters and maintain daily records of temperature and relative humidity during the dry season.

ORGANISATION

23. Create a fire control section to be employed full time on fire suppression, hazard reduction and in charge of radio communications.

24. Draw up a fire plan, stating the responsibilities of all personnel engaged in firefighting and detailing the functions of the fire control section, and the procedures to be taken in the event of a fire.

25. Create a permanent fire crew of 12 men in each district who will carry out initial attack. These men should be fit and highly trained in firefighting techniques and be able to assist in the training of general forest workers in fire fighting techniques.

COMMUNICATIONS

26. Install radios in vehicles to be used by people engaged in fire control activities.

27. Draw up a standard radio procedure.

FIRE FIGHTING TECHNIQUES AND TRAINING

28. Instruct all personnel on the effect of the daily wind change and night wind squalls, on fire behaviour and fire fighting principles.

29. Train the fire crews on the "jump up" technique of hand line construction and in the efficient use of water.

30. Carry out regular monthly training periods for all people engaged in fire control.

CONCLUSION

The recommendations listed above are mostly fundamental to any efficient fire control organisation. As a fire control organisation is virtually non-existant, it is imperative that a fire control section is created and staffed with people working full time on fire control activities.

The officer in charge of this section should be a professional forester, preferably with experience of large fire suppression and experience in control burning techniques.

As control burning should be carried out in a scientific manner, a fire research officer with experience in area control burning should be employed for a period of two months at the end of the 1971 wet season (say April-May) to study fire behaviour in *P. kesiya* fuels, draw up a control burning guide and train the officer in charge of the fire control section in any special control burning techniques.

SECTION 1. GENERAL FIRE HAZARD TO INDUSTRIAL PLANTATIONS

1.1. General Climate

The Copperbelt region has a well defined summer rainfall with a long dry season generally from May to early October.

The average rainfall is 45.96 inches and the monthly distribution of rain is given in figure 1.

The average monthly maximum and minimum temperature curves are given in figure 2. The hottest month is October and the coldest month is generally June, although the coldest minimum temperature of 28°F for Ndola Airport was recorded in July.

During the dry season the wind direction is predominantly from the east or south-east (figure 3), and has a regular diurnal pattern. The wind is generally from the east during the morning and the maximum average wind speed occurs about 11.00 hours. Maximum gusts can occur at any time but generally occur during the morning when they may be up to 30 knots on occasions. During the afternoon the wind strength gradually decreases and becomes more gusty. The wind also veers towards the south during the afternoon and night and generally dies to calm at night.

Night calms are often broken by a 20-30 knot squall during the dry season which take about 2 hours to die right out. These squalls can be repeated more than once during the night. The first squall usually occurs between 1900 and 2000 hours.

The night wind squalls are associated with an increase in temperature of 5-10°F and a corresponding drop in relative humidity, and are very important from a fire control point of view.

An analysis of maximum gusts and frequencies has not been carried out by the Meteorological Department and this would be useful to the fire control organisation.

During the night shallow katabatic winds less than 5 mph drain into the dambos (or swampy areas). These winds are generally towards the north assisted by a light southerly drift.

1.2. Fuel build-up

1. P. kesiya plantations

These plantations are clean weeded for the first three years but then fuel is accumulated rapidly, from needle fall, pruning and uncommercial thinnings.

The plantations normally receive 3 uncommercial thinnings between the age of 5 and 11 years which reduce the number of stems per acre from around 400 to 120. These heavy thinnings produce a very heavy fuel at age 11 which will probably exceed 12 tons per acre of fine fuels and 10 tons per acre of log fuels.

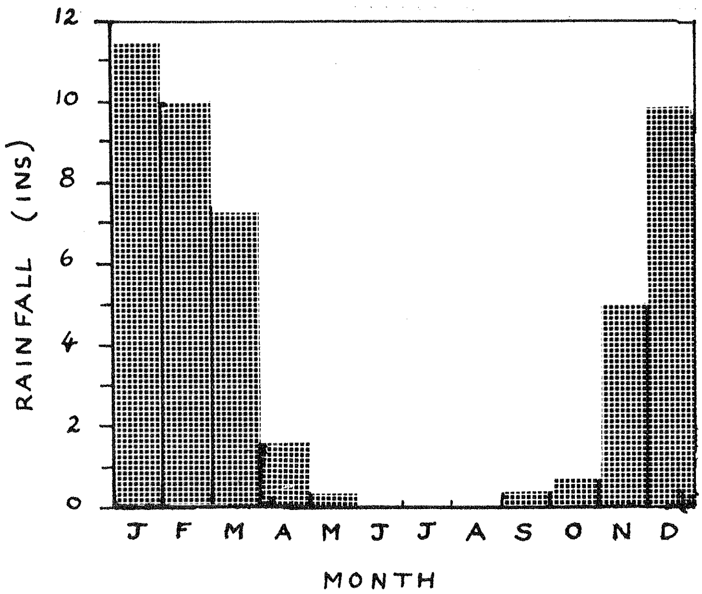


FIGURE 1. Monthly Distributions of Rainfall, Ndola Airport. Based on a 30 year period 1931-1960.

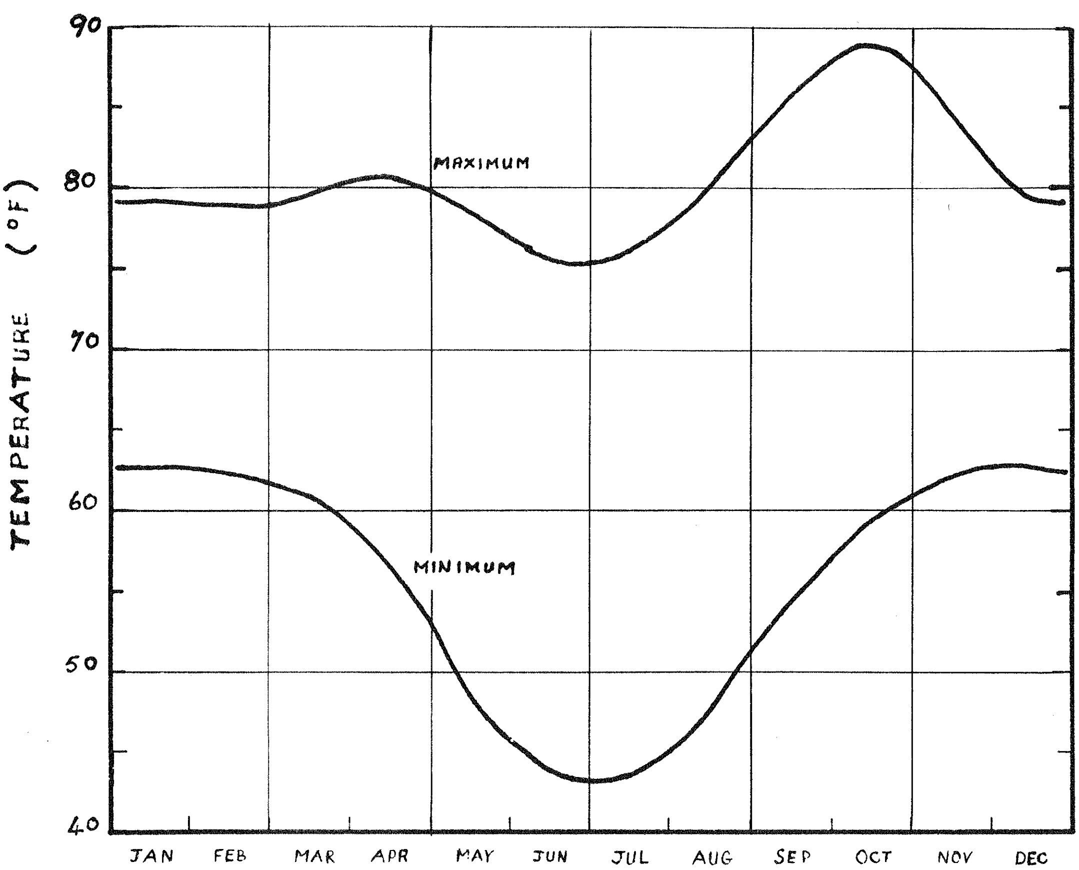


FIGURE 2. Mean Monthly Maximum and Minimum Temperature, Ndola Airport, for period 1931-1960.

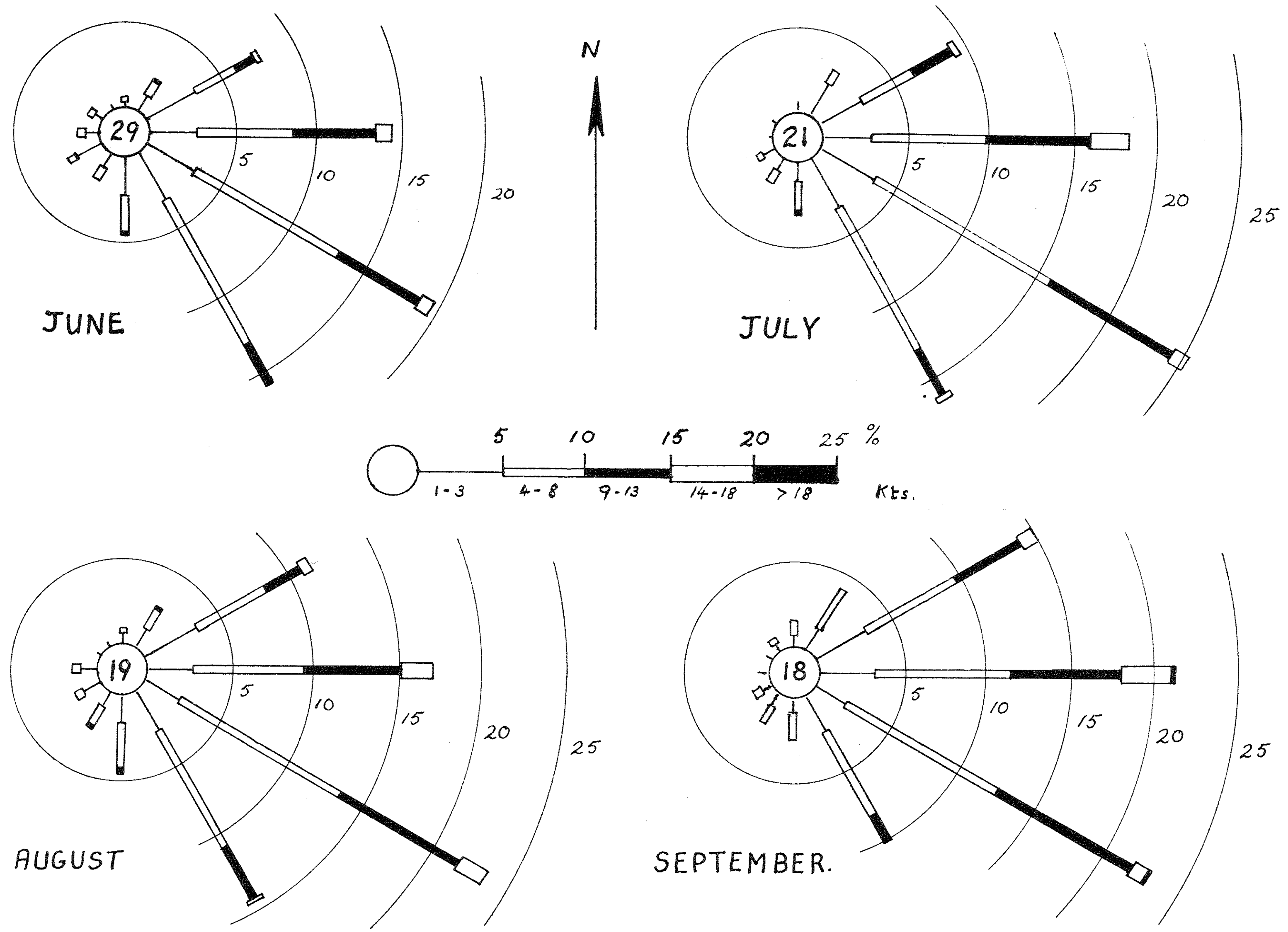


FIGURE 3. Wind Roses, Ndola Airport, for the dry Season June to September (showing the percentage time of various wind velocities. The figures in the centre circles showing the percentage of calms.)

This presents an impossible problem to any fire control organisation. The weight of fine fuel will cause a rapidly spreading high intensity fire even under mild conditions while the heavy log fuels will make fire fighting and fire line construction extremely difficult. The breakdown of pine litter appears to be slow in undisturbed plantations and a higher fuel accumulation could be expected as the plantations get older.

Pine plantations at Ndola are troubled with the invasion of Lantana species which not only limits visibility and access within the plantation but also burns very severely during high fire danger periods.

2. Eucalypt plantations

The fuel build up in Eucalypt plantations is less severe than the pine, as there is a market for 2nd and 3rd thinnings. However, the build up of fine fuels is quite rapid, going from less than 1 ton per acre (T.P.A.) at two years to 8 ton per acre at 5 years and probably reaching 10-11 tons per acre at 8 years. While this fuel accumulation can result in severe fire behaviour, the absence of large log material makes the fire fighting job easier than in the pine areas.

Since the rotation age of the eucalypt plantations is anticipated at about 8 years it is unlikely that there will be large areas of continuous, heavy fuel.

1.3. Fire Weather

Although maximum temperatures are recorded in October, the humidity is generally high during this month just prior to the commencement of the rainy season, and the most dangerous fire weather occurs in September when low humidities and high winds can be commonly expected. Dangerous fire days can occur from June onwards, particularly if the wet season finishes early.

It was not possible to make a complete analysis of the fire weather conditions for the Copperbelt region but the records did show that dangerous fire weather conditions did occur regularly.

For example, during the month of September 1969 the average fire weather conditions for 1400 hours were:-

Temperature $86^{\circ}F$
Relative Humidity 21%
Average wind speed 9.6 miles per hour.

This gives an average monthly fire danger rating of 23 or just below Very High at 1400 hours. (See Section 6 for an explanation of fire danger rating).

During September 1969 there were at least 5 days when the fire danger rating rose above an index of 30 and typical daily trends of the fire weather factors and Fire Danger Index (F.D.I.) are shown in figure 4.

It can be seen that although the maximum average wind speed was recorded at 1000 hours the maximum fire danger index occurred at about 1500 hours with fire danger index remaining above 40 for 4 hours between 1230 hours and 1630 hours.

On the 9th September 1969 between 1230 and 1700 hours the expected fire behaviour in a mature forest, carrying a full load of 10 tons per acre, would be a crown fire spreading at around 60 chains per hour and throwing spot fires at least 40 chains and probably further. Clearly fire control would be impossible until conditions ameliorated.

A fire danger index of 43 is rated at Very High and almost Extreme on the Australian Fire Danger Rating System.

The burning conditions above are about half the worst possible conditions in Australia and it is quite likely that Extreme Fire Danger could be experienced in the Copperbelt region.

Now that the plantation area is increasing rapidly it would be possible to lose 4,000 acres in a single fire if the fuel build up is allowed to continue. (All of one block with a fire starting on the windward edge of the area).

If multiple outbreaks of fire occur even on an average September day the fire control organisation could probably only cope with one or two fires and the total area burnt could be much greater.

1.4. Human Agencies

One most important factor of the fire hazards to Industrial Plantations is the sociological attitude to fire held by the general public. Fire has been used by the indigenous population for thousands of years to clear the forest or flush out game. Now burning off has become a part of life that is carried out, either purposely or accidently, every year. Children are quickly versed in the need for burning off and it is not unusual to see children setting fire to clumps of grass and joyfully watching it burn.

Extensive forest fires are not common in the indigenous forest because most of the fuel has been removed (or reduced) early in the dry season either by deliberate burning off (early burning) or by accidental burning. In areas where early burning is not practised deliberately, accidental burning off early in the season creates a mosaic of burnt areas so that when a fire starts under dangerous conditions it rarely travels far before running into a recently burnt area or an area of light fuel.

The Forestry Department has been trying to place a completely protected forest, with its associated heavy fuel build up, into this environment. Up to now, the plantations have been small and fairly heavily staffed, so that the areas have been closely patrolled during the fire season. Added to this most of the people living close to the plantations have been associated with the Forestry Department and have probably been more careful with fire than the average person.

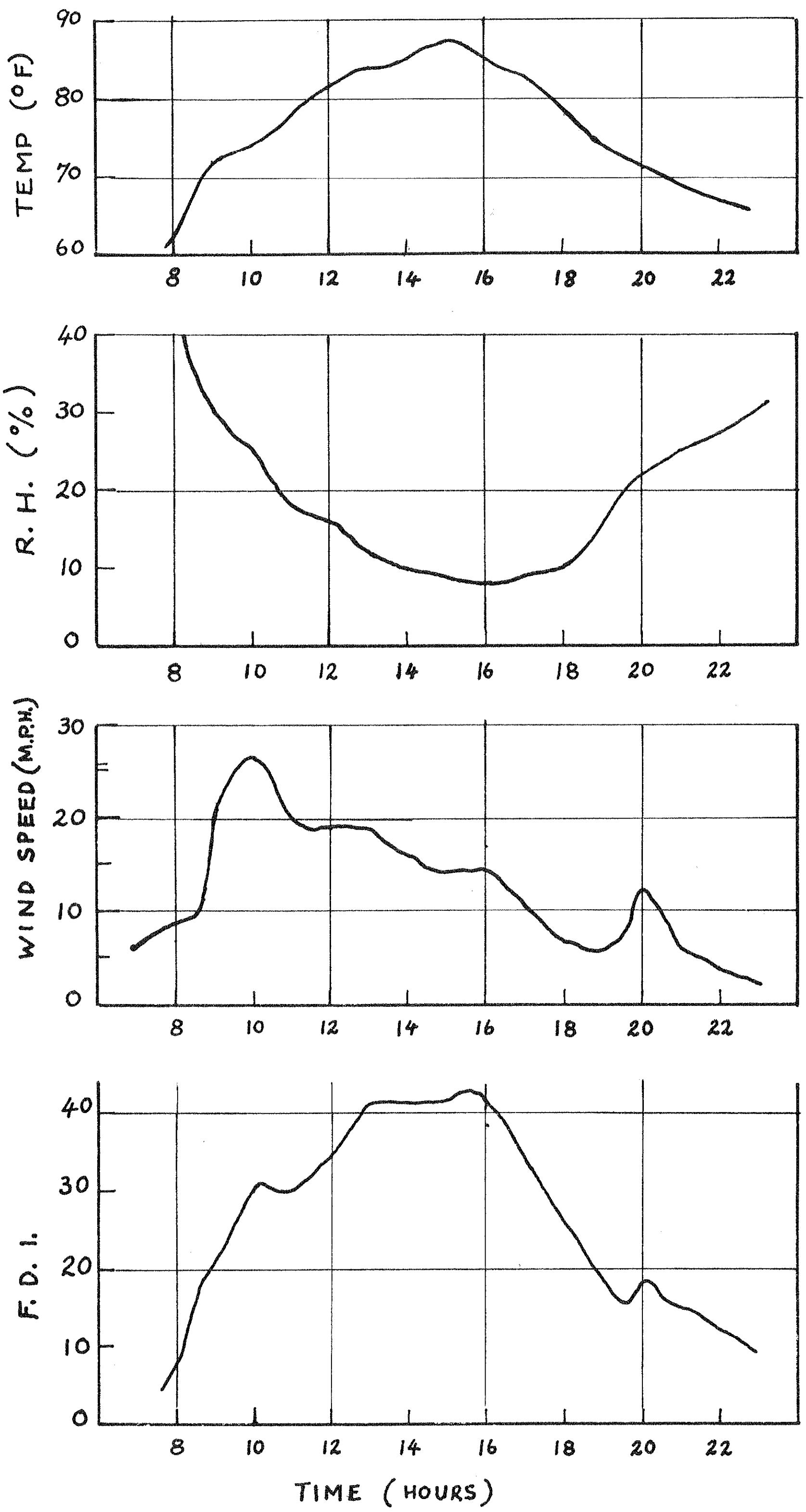


FIGURE 4. Fire Weather factors, Temperature, Relative Humidity (R.H.), and Mean Wind Speed; and Fire Danger Index (F.D.I.) recorded at Ndola Airport, 9th September, 1969.

Now that the plantation areas are rapidly expanding the forest will be less heavily patrolled and more people outside the Forestry Department will come into the plantations. It can be expected that the number of fires occurring in the plantation, through human agencies, will increase. The protection of the plantation will rapidly involve more than the protection from fires coming from outside the plantation area, and it will take considerable time before the general public is aware of the real need to protect the plantation areas from wild fires.

SECTION 2. HAZARD REDUCTION WITHIN COMPARTMENTS

2.1. General

The rate of spread of a fire and its intensity are directly proportional to the weight of fine fuel on the ground (i.e. fuel less than ¼ inch diameter). The weight of heavy log fuels on the ground adds indirectly to the fire intensity, but adds very significantly to the duration of heat output, and to the difficulty of fire line construction, and fire suppression generally.

The distribution of the fuel affects the flame height and, to a certain degree, the tendency for the flames to spread into the crowns of the trees and develop into a crown fire. In a forest where there is a distinct break between the ground and the crown of the tree, a crown fire cannot develop unless there is sufficient fuel on the ground to raise the flames into the tree crown. The amount of fuel required to produce a crown fire depends, of course, on the hieght of the crown above the ground. In a mature forest with the bottom of the crown 60 ft. above the ground, a fuel in excess of 5 tons/acre will produce a crown fire under severe burning conditions. If the fuel quantity if less than 2 tons/acre it is impossible to produce a crown fire in a mature forest, even under the worst burning conditions.

The quantity of fuel on the ground and the distribution of the fuel is the only fire behaviour factor over which man has any control.

If the area severely damaged by wild fire each year is to be kept to an acceptable limit, (generally considered to be 0.01 per cent of the total protected area for intensively protected plantations), then a policy of area fuel reduction will have to be undertaken.

The cheapest, most economical way to reduce the fuel over large areas is by theprescribed application of low intensity fires, or area control burning.

However, before control burning can be carried out, there are several current practices which will have to change to reduce the fire hazard.

2.2. Piling of Slash

Piling of slash in from the edge of the compartment should cease. This practice only reduces the fire hazard if the area cleared is kept free of all fuel and this is not feasible. On the other hand, it complicates fire fighting by leaving a mass of slash which fire fighters have to cut through and further complicates control burning by increasing the duration of fire at the pile, and trees either side of the slash pile are liable to butt damage.

2.3. Silvicultural Requirements

Certain silvicultural requirements are required for hazard reduction. These should not conflict with the requirements of the management branch.

1. Pruning

Prune all trees to 7 feet including double leaders and deformed stems. As burning will be carried out soon after the first thinning, the pruning should be delayed until the average height of the stand has reached 35 feet. While the current prescription of pruning when the tallest 10% of the trees are 35 feet would be satisfactory if the trees were uniformly distributed throughout the compartment, in practice, at Chichele, there are large areas in some compartments where the trees are all much smaller than the prescribed height for first pruning.

2. Uncommercial Thinning

At present the very heavy uncommercial thinning in the early stages of the pine plantations leaves a mass of log and fine fuels on the ground. These thinnings make the job of fire line construction very difficult and drastically increase the fire intensity.

It is recommended that these thinnings be killed and left standing.

The trees could be best killed by poisoning and experiments should be initiated to determine techniques for doing this type of thinning. Although these thinnings look hazardous, from a fire protection point of view it is far better to have the fuel standing in the air rather than lying on the ground.

Certainly the most desirable answer to this problem would be a market for small size thinnings. However, there appears to be no possible market within the next 5 years. Fuel reductions must commence NOW.

2.4. Area Control Burning

1. Principles of Control Burning

Control burning is similar to early burning only in as much as it is to be carried out towards the end of the wet season and in the early part of the dry season.

Control burning differs from early burning in that the behaviour of the fires prescribed for a particular area is defined so that no damage to the standing crop occurs. The burning is carried out under accurately defined weather conditions to achieve the prescribed fire behaviour.

Control burning should not aim at the complete removal of fuel in one operation as the conditions required to do this will cause the fire to be too intense and will result in damage to the trees. However, very heavy fuels can be removed by several successive burns over the same area - each burn removing a proportion of the fuel bed.

Control burning should be carried out after the hottest part of the day when the burning conditions are becoming milder and the burn should be planned to extend over the maximum period available for burning.

2. Fire Intensity for Control Burning

The type of fire prescribed for control burning is usually defined in terms of "Fire Intensity" or the heat out-put of the fire per foot of fire front.

Fire intensity is given by the formula:-

$$I = H.W.R.$$

where I = Intensity (B.T.U./sec/ft)

H = Heat yield constant (B.T.U./lb) usually between 6000 and 7000 for pine fuels

W = Weight of fuel (lb/ft^2)

R = Rate of spread of the fire (ft/sec)

Experiments carried out in 5½ year old pines revealed that these could withstand a fire intensity of 50 BTU/sec/ft without causing damage. This represents a fire burning 5 tons/acre of fuel and spreading at 2 ft/minute. However, this must be considered as the maximum limit for this age pine and the optimum intensity would be more like 25 BTU/sec/ft, which means that the fire should be spreading at half the rate or consuming half the amount of fuel.

In mature pines or rough barked eucalypts the absolute maximum fire intensity prescribed is 100 BTU/sec/ft. As yet the fire intensity for burning young E. grandis has not been defined but current research in Australia indicates that the intensity will have to be below 20 BTU/sec/ft to avoid damage to trees with a diameter of 6 inches b.h. Until considerable precision in control burning is developed, it is recommended that burning of E. grandis is not attempted.

Since flame height is roughly correlated with the rate of spread and fuel consumed, it can also be used to define the type of fire applied. Flame height is correlated with scorch height. As a rough rule of thumb, the scorch height will be 5 times the flame height. If a stand 35 feet high can withstand a scorch height of 15 feet the maximum flame height will be 3 feet.

3. Predicting Fire Behaviour

Very accurate fire behaviour prediction tables have been developes for control burning in Australia. These are designed to cover the maximum possible range of burning conditions without causing damage to the stand. If conservative limits are set on the weather factors and the fire intensity applied, then burning can be carried out safely with unsophisticated techniques.

However, certain fire behaviour knowledge will have to be gained by carrying out a number of small experimental fires and measuring the fire behaviour and recording the major variables affecting fire behaviour. These variables are:-

(i) Temperature

(ii) Relative Humidity

(iii) Wind velocity

(iv) Fuel quantity

(v) Drought index

(vi) Grass curing stage : i.e. the percentage of grass which has dried off.

A booklet entitled "Techniques for Carrying Out Experimental Fires for Fire Behaviour Studies" is in the process of publication by the writer and should be available early next year. Information regarding experimental fire techniques is provided in Appendix 1.

Experimental fires should be started towards the end of the wet season, say in March for a normal season and carried through until the Drought index reaches a figure of 200, say about mid May. Control burning can probably be carried out at the end of the wet season one or two days after rain.

Initially experimental fires should be burnt to determine:-

(i) How soon after rain burning can be carried out.

(ii) The rate of spread of single fires under different weather conditions.

(iii) The time of night when fires are self-extinguishing. (During June-July, 1970 fires would burn throughout the night).

4. Guide to Control Burning

Although it is not possible to give a complete burning guide, Control burning can be carried out next year provided a few test fires are carried out and the following instructions are adhered to:-

(i) Carry out test fires to determine the rate of spread of the fire before each burn.

(ii) Do not burn if the forward spread exceeds 2 ft/minute.

(iii) Determine the time of night when fire is self extinguishing or when the spread is not effective.

(iv) Burn when the wind is calm or less than 5 mph in the open.

(v) Do not burn if the relative humidity drops below 35% during the day.

(vi) Commence burning in the afternoon when the relative humidity rises above 50%.

(vii) Do not burn when the drought index rises above 200.

5. Lighting Techniques

Control burning has already been attempted in the early part of the dry season. Several trees were examined in an area burnt at Chati, in May, and no damage to the bole of the trees was apparent even though they were severely scorched. In all cases the burning was carried out too rapidly and the areas lit up intensely.

An area should be lit up with a grid lighting technique so that the fires burn individually and join up when the conditions are such that the fires are almost self-extinguishing.

e.g. The test fire indicates the rate of forward spread is 1 ft/minute and the fires are circular in shape. Therefore total spread is 2 ft/minute.

It is planned to start the burn at 1700 hours and the fires will go out around 1900 hours, therefore the burning time is 2 hours.

The grid spacing = R.O.S. x B.T.

= 2 x (2 x 60)

= 240 ft.

If the block takes one hour to light, then the grid spacing for the last half of the block to be lit can be closed to 120 ft. This decision depends on the controller's assessment of the fire.

Lighting should commence on the down wind side of the compartment, making allowance for the fact that the wind usually swings towards the south during the evening. The lighters then walk in strip lines at right angles to the wind direction, the lines working progressively into the wind. (See figure 5). No attempt should be made to speed up the burn-out time of the area if the fires are burning steadily.

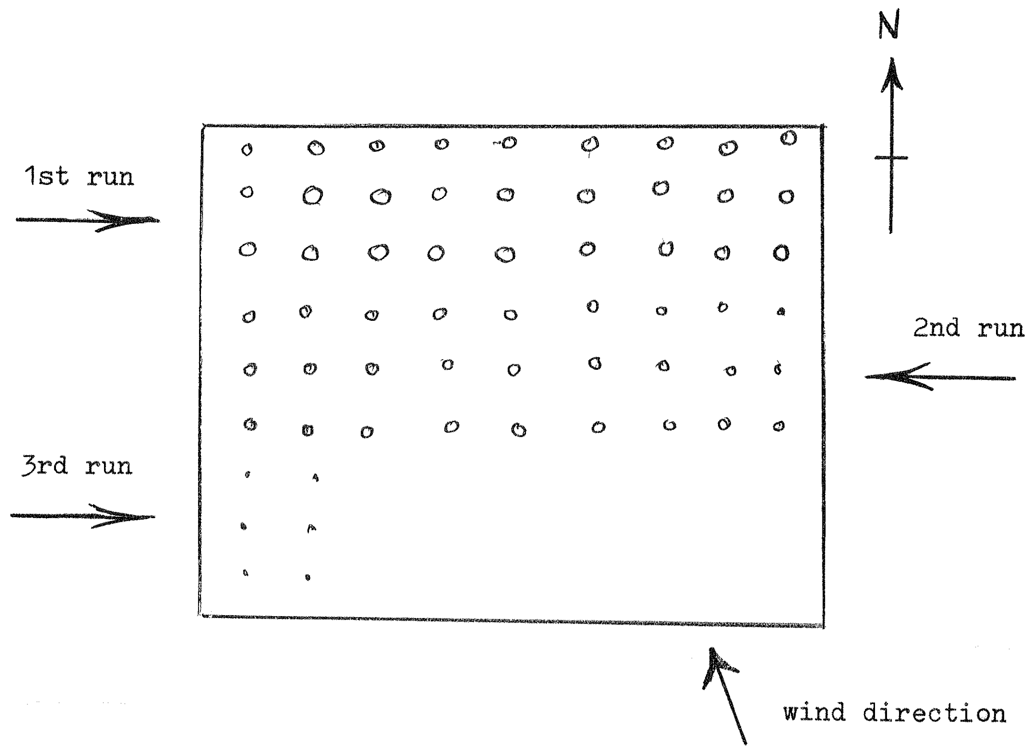


Figure 5. Grid Lighting Pattern for Control Burning.
Three man lighting team.

6. <u>Gang Size</u>

Lighting should be carried out by 2 or 3 men only. If the gang size is bigger than this, they can be difficult to manage. The Fire Control Officer should be in charge of all initial control burns.

Great care must be taken that the lighters are not disorientated by walking around anthills. Strict instructions must be given that they negotiate anthills by counting the rows of trees around the anthills.

Lighting should proceed rapidly and once a spot is lit the lighters should move on and not stop to see if the spot is burning.

The officer in charge of the operation must ensure that all men lighting come out of the area before another series of strip lines is commenced.

2.5. Damage by Control Burning

Low intensity control burning can be carried out so there is no physical damage to the trees. However, there are a number of beneficial results which can occur as well as reducing the fire hazard.

1. Lantana control. This can be achieved by 2 burns in close succession. The first burn kills the established lantana, and the second burn kills the seedlings before they have a chance to reseed.

2. Improved visibility and access, particularly for thinning and logging operations.

3. The reduction of soil moisture competition during the dry season by removing competing understorey shrubs.

4. Increased tree health by improving the microflora status of the soil. This is a direct result of increasing the pH and making the soil conditions more favourable.

SECTION 3. LAY OUT AND MAINTENANCE OF FIREBREAKS

3.1. Principle of Firebreaks

The purpose of firebreaks is twofold:-

(1) To provide access through the forest.

(2) To provide a fuel-free barrier to fire.

While this may appear to be stating the obvious, there are many firebreaks which provide neither access nor a fuel-free barrier.

Firebreaks which are maintained by ploughing are very often unsuitable. In the sandy soils at Chati plantations many of the ploughed breaks are trafficable only to 4 wheel drive vehicles and there is a distinct possibility that a heavily laden fire tanker could become bogged. This could be disastrous in the event of an emergency.

Ploughed firebreaks do not allow rapid access along them and rapid access is essential if initial attack is to be successful.

Heavy grass is generally not removed by ploughing, but is mixed in with the soil and provides fuel which will not stop a low intensity fire burning under very mild conditions. The firebreak between compartments 93 and 98 in Chichele plantation was ploughed to an average width of 40 feet but did not stop a low intensity fire at night, because of the heavy grass mixed in with the soil. This type of break is not even suitable for controlled burning.

Ideally a firebreak should consist of a clean graded road with trees planted up to the edge of the road formation. When the trees close canopy they will suppress grass growth adjacent to the road. If the trees are planted back from the edge of the road formation then grass will grow, and the strip either side of the road is committed to the expense of ploughing or mowing.

As a generality, unaided firebreaks cannot be relied upon to stop a fire in a severe situation and are not needed in an easy one. The only reliable defence in a severe fire situation is area fuel reduction.

3.2. The Problems of Wide Firebreaks

While wide firebreaks give one a feeling of security, particularly when the forest is young, they have several severe disadvantages:-

1. They are generally not wide enough to be effective against a high intensity fire which is throwing spot fires. While spotting is not a serious problem in pine forests (as compared with the stringy bark type eucalypt forests) one could expect spot fires to be thrown up to 10 chains ahead of the fire and possibly exceeding 20 chains.

2. They channel the wind flow along the firebreak and cause severe turbulence on the edge of the plantation. This often results in a fire increasing in severity as it approaches the firebreak and increases the chances of spot fires being thrown across the firebreak.

3. Wide firebreaks are expensive and costly to maintain. A wide firebreak represents a substantial loss of planting area and considering their dubious value, they considerably reduce the potential return from the forest area. Once the forest canopy is removed tall elephant grass (Hyparrhenia sp.) grows immediately and the area is committed to ploughing, grading, mowing or some form of clearing. Because ploughing is usually employed the firebreaks often become untrafficable and often contain fuel as mentioned earlier.

3.3. Green Firebreaks

A green firebreak should be an area with complete canopy closure to prevent grass growth and maintained free of litter by periodic burning. Because Gmelina arborea sheds it's leaves during the dry season it does not make a satisfactory green break as it requires burning several times during the fire season.

If a policy of controlled burning is carried out green firebreaks become largely redundant as they receive the same treatment as the plantation. However, there are some high hazard areas such as around compounds or African townships where green firebreaks may be useful.

There are several commercial species which would be suitable for green breaks and these should be used in preference to any non-commercial species. E. cloeziana and E. paniculata are both suitable for green firebreaks as they have a thick rough bark (figure 6) which will not cause spot fires. E. resinifera is less suitable as the rough stringy bark has a high spotting potential. However, the spotting potential of stringy bark is greatly reduced by controlled burning, and the E. resinifera firebreak at Chati will be quite effective if maintained by periodic burning.

Green breaks of fast growing eucalypts have an added advantage in pine areas as they act as wind breaks and reduce the wind speed in the forest areas particularly when the pines are young.

3.4. Orientation of Firebreaks

As the prevailing wind during the fire season is from the east and north-east (figure 3) firebreaks should be aligned either north-south or northeast-southwest. Particular attention should be given to the east and south boundaries of the plantation, especially where these are adjacent to African townships. Minimum attention is required on the western boundaries of the plantation.

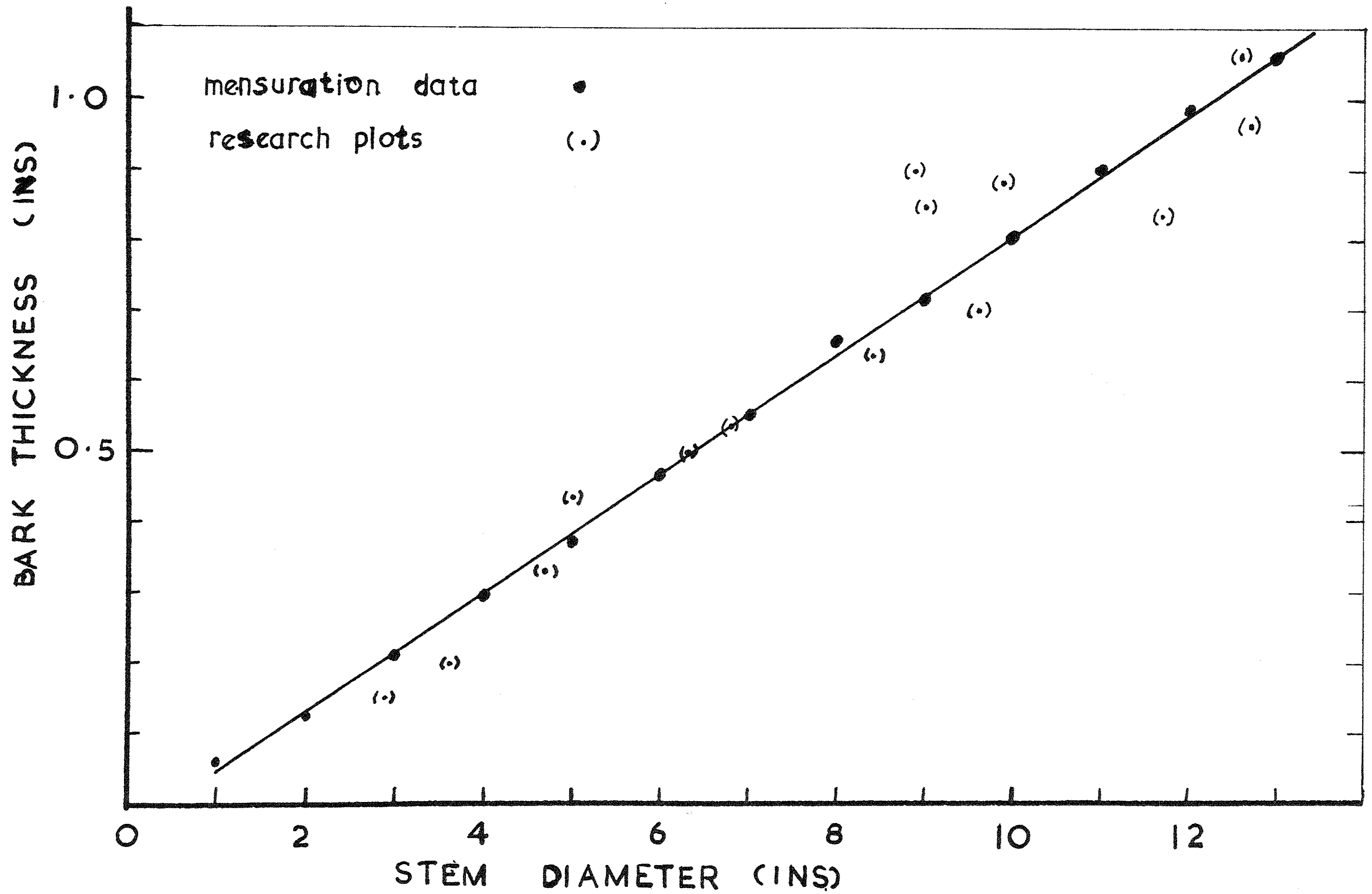


FIGURE 6. Relationship between Bark Thickness and Stem diameter diameter for _E. cloeziana_.

3.5. Recommendations

A. External breaks

1. On the northeast, east, southeast and south sides of the plantation place a clean graded road formation 25 feet wide immediately adjacent to the plantation; plough or mow a strip 25 feet wide between the road and the native forest. Where the forest has been cleared this strip may need to be wider.

2. On the remaining sides of the plantation maintain a graded road 20 feet wide.

3. Do not clear the native forest back from the firebreak, or open the canopy except to remove dead trees immediately adjacent to the firebreak.

4. Control burn (early burn) the native forest with a low intensity fire (see control burning techniques).

B. Internal breaks

1. Minor breaks Construct a formed road 20 feet wide, plant trees up to the edge of the road formation. Maintain the road clear of fuel by grading.

2. Major breaks Where a large road formation is required continue to plant trees up to the edge of the road formation. If the road is used during the wet season it is not feasible to plant trees so that their crowns will extend over the road surface. Water dripping from the crowns keeps the road surface saturated and the road rapidly becomes impassable. However if the road formation is wide enough there should be sufficient width on the crown of the road, unaffected by leaf drip, to be used during the wet season. During the dry season the remainder of the road is maintained by grading or mowing.

3. Wide breaks Plant existing wide breaks with *E. cloeziana* or *E. paniculata*, including anthills where possible, on a 10 ft x 10ft spacing. Retain a 15 ft or 20 ft road formation either side of the firebreak. Prune trees to 12 ft but do not thin. Maintain breaks clear of fuel by periodic control burning. Burning can probably commence when trees are 3½-4½ years old.

4. Break up continuous areas of pine by planting compartments of *E. cloeziana* and burn periodically.

5. Stop ploughing firebreaks in sandy soils. Create a trafficable road on all firebreaks by grading and spreading gravel where necessary. Maintain roads by grading and maintain existing verges by ploughing or mowing, whichever is cheaper.

SECTION 4. DETECTION AND REPORTING OF FIRES

4.1. General

The detection system, based on firetowers is working satisfactorily. The reporting of test fires at night was accurate and would allow rapid attack. Although no test fires were carried out during the day, the detection of fires close to the forest boundary appeared to be quite satisfactory.

4.2. Location of firetowers

Firetowers should be located to provide the maximum area seen from the least number of points. The selection of lookout points should consider the following factors.

1. Visibility. In the Copperbelt region the visibility can be reduced to as low as 5 miles due to smoke haze. However, a firetower network based on a visibility of 7 to 10 miles should provide adequate coverage. The detection system could include a number of secondary towers which are manned on days of particularly poor visibility, but not on normal days.

   The visibility range of the observers can be increased by using binoculars.

2. Topography. In the gently undulating country where the high points are not obvious a careful selection of sites should be made after examining aerial photographs and contour maps. The selection of the highest point on a ridge will be quite important when the trees reach maturity, even if it is only 25 feet higher than the surrounding country.

3. Triangulation. Care should be taken to avoid having the firetowers in a line across the plantation areas. Some towers should be set out from the plantations so that accurate cross bearings, intercepting at a reasonable angle, can be obtained.

4.3. Fire Tower Equipment

1. Alidade. A simple alidade is all that is required and the present equipment is quite satisfactory. However, sighting equipment consisting of a single vertical wire in the centre of the cabin and the bearings in degrees marked around the wall of the cabin may be easier to use if there is a rapid turnover of lookout men. The tower man stands behind the wire and lines up the smoke and reads the bearings off the wall.

2. Binoculars. Good quality, 10 magnification binoculars are a useful aid.

3. Radio/telephone. Radios should be mounted on a fixed stand with a power supply located at the base of the tower.

4. Anemometer. One tower in each district should be equipped with a simple direct reading anemometer to monitor wind speed. The "Dwyer" pressure tube anemometer, made in England, can be purchased at a reasonable cost and easily installed. The Meteorological Department should be consulted before purchasing this equipment.

5. Cabin design. Consideration should be given to operator comfort. It is suggested that the cabins should be fitted with louver type windows and the inside of the cabin painted light green to reduce glare.

4.4. Firetower manning hours

The hours that firetowers are manned depends entirely on the fire danger during the night. In the early part of the fire season there is probably little need to man the firetowers between 2100 hours and 0600 hours. During June and July there is probably little need to man the towers between 2400 hours and 0600 hours. During August and September it may be necessary to man some of the strategically located towers, particularly in areas of high risk, but certainly not all towers, throughout the night.

The times that the towers are manned should be determined by a series of small experimental fires throughout the night at various months in the season.

4.5. Reporting Procedure

At present the firetowers report frequently; every 15 minutes at Chichele and every 30 minutes at Chati. As the number of towers increase and the use of radio, both for management and fire control, increases, hourly tower reports should be sufficient.

Routine reports should include the wind direction, and the wind strength where anemometers are located.

Fire reports should include:

1. Bearing and estimated distance.
2. Wind direction and strength.
3. Colour of smoke (dense black smoke indicates a high intensity, rapidly spreading fire which will require immediate reinforcements to the initial attack crew).
4. Any other information as requested by the fire control officer.

4.6. Use of Aircraft for fire detection

In developed countries light aircraft patrols are replacing fire towers for detection purposes. Aircraft detection is not warranted at this stage. However, in several years time when the area of plantations is considerably enlarged, the use of aircraft for flying fire patrols on days of high fire danger or on days of particular poor visibility should be investigated.

SECTION 5. FIRE FIGHTING EQUIPMENT

In selecting fire fighting equipment two factors must be borne in mind - the job that is required of a particular piece of equipment and the people who are going to use it.

This section is not intended to cover all types of equipment that are available but rather a selection of equipment which is most suitable for fighting fires in heavy forest fuels and for use by unskilled men requiring a minimum of training.

Initially, equipment should be purchased to provide a rapid, mobile, initial attack force. However, as the area of plantations extend, consideration will have to be given to obtaining a range of heavy mechanical equipment for fire line construction and a number of large capacity water tankers for use on a fire of 1,000 plus acres.

5.1. Hand Tools

Hand tools provide the basis of fire fighting equipment in highly developed fire fighting organisations in Australia and the U.S.A. There is a lack of good hand tool equipment in Industrial Plantations. Immediate steps should be taken to purchase or make up the under listed equipment. A suggested list of manufacturers and price list is in Appendix 2.

Experience has shown that around 4-4½ lb is the optimum weight for tools with handles. Below 3½ lb for tool and handle, most tools are lacking in strength for robust work while tools weighing more than 5 lb are likely to cause rapid fatigue or prove clumsy in use.

McLeod Tool : The McLeod tool is a combination rake and hoe designed specifically for fire fighting in forest litter-fuels. It is standard equipment and is in general use throughout Australia.

Knapsack Sprays : Knapsacks consisting of a plastic container of 5 gallons capacity and a double action force pump are available in Australia. Plastic knapsack sprays have proved to be more robust, more comfortable and have a far longer life than the original metal types.

Back Firing Torches : It is desirable to have at least one back firing torch per tanker. A simple drip torch has been made up for prescribed burning. However, a better type of torch can be purchased in Australia, which is suitable for transport on fire tankers.

Drip torches will be required for prescribed burning and are generally fueled with 50:50 mixture of kerosene and diesel oil.

Comments on Existing Tools

Rakes : These have been purchased to provide a basic hand tool. They should be phased out with the purchase of McLeod tools.

<u>Shovels</u> : A shovel is a useful fire fighting tool and should supplement the McLeod tool. The best type is a light strong pointed shovel, about size 1, and set at about 25° to a long handle.

<u>Brush hook, Bill hooks etc</u> : These can be very useful for clearing a line through heavy undergrowth such as lantana. The recommended type would have a long handle and a curved blade, 12-15 inches long by 3 inches wide, and sharpened both sides.

<u>Axes</u> : A necessary piece of equipment. A slightly heavier axe (4 lb) would be favoured than those currently in use (2½ lb).

<u>Illumination equipment</u> : A supply of electric torches and several pressure lanterns should be kept in store for night fire fighting purposes.

<u>Miscellaneous tools</u> : A locked tool box containing hammer, pliers, wire cutters, shifting spanner or stilson wrench, files, sharpening stone etc. should be carried on each tanker.

<u>First Aid outfit</u> : A simple first aid kit for attending to minor cuts and burns should be available for field use.

<u>Water bags</u> : Personal water bags should be carried by each tanker.

5.2. <u>Stock and Maintenance of Equipment</u>

More equipment should be kept in stock than the number of personnel available to use them. It is quite useless bringing men to a fire unless each has an item of equipment to use. Although the final selection of hand tools will be decided after application in the field, the following proportions of equipment is recommended.

Type of Equipment	No.
McLeod tools	6
Knapsack sprays	2 or 3
Shovels	2
Axes	2
Brush Hooks	1

All cutting edges including the hoe side of the McLeod tool and the edges of the shovels should be kept sharp. All equipment should be checked and resharpened immediately after use.

Regarding care and maintenance the following should be attended to:-

1. Safe storage in the wet season.
2. Identification of G.R.Z. equipment by colour.
3. Arrangements for issuing equipment and returning it back to the store after use.
4. Systematic maintenance, sharpening and general repairs.

5.3. Pumps

The most suitable pump for general fire fighting purposes is the centrifugal type. Their advantages are that they are simple to operate, having a minimum of moving parts and no close tolerances; can handle dirty or abrasive material (although this should be avoided), and the fact that the output can be cut off abruptly at the nozzle without damage to the pump and without the need for pressure relief valves.

The main disadvantage is that they are not self priming. However, priming can be affected in different ways - by a hand operated piston pump, by filling specially designed pump housings or by an exhaust ejector operated from the engine.

Centrifugal pumps do not produce a very high pressure and this is an advantage for fire fighting as a high pressure stream can entrain air and actually fan the fire instead of extinguishing it.

The most trouble free pumps are those directly coupled to a four stroke petrol engine.

Power take-off pumps are not suitable for fire fighting equipment as they do not allow sufficient flexibility to move the primemover and vary the output of the pump. All tanker pumps should be directly coupled to a four-stroke petrol engine which has a variable throttle control, so that the pump can remain idling when the nozzle is shut off.

The "Hathaway" portable pump purchased by the Forestry Department is a single stage centrifugal pump which is quite suitable for fire fighting purposes, although better pumps are available (see Appendix 2.).

5.4. Water Tankers

A. Initial attack tankers. Tankers with a 200 gallon capacity should be used for initial attack. These tankers may be equipped with tanks and pumping equipment which can be removed but they should be fitted up at the start of the fire season and remain as a single purpose vehicle throughout the fire season. Each tanker should be equipped with:-

1. A 200-400 gallon square tank baffled to prevent surging in transit.

2. A single-stage centrifugal pump and priming equipment coupled to a four-stroke engine with a variable throttle.

3. A solidly mounted live-reel containing 200ft of ¾ inch high pressure hose.

4. An efficient spring-loaded shut off nozzle to which various nozzle outlets, or tips, can be fitted. The recommended type is the design used by the N.S.W. Forestry Commission, Australia.

5. An equipment rack containing a minimum of 6 McLeod tools, 1 axe, 1 shovel, 1 brush hook, 1 backfiring torch, 2 knapsack sprays. All equipment should be easily accessible but firmly and neatly attached to the tanker.

6. A length of suction hose equipped with a foot valve and a float strainer for refilling from dams.

7. A length of canvas hose for refilling from overhead water tanks.

8. A tool box containing various small tools, hose fittings etc.

It is important that the pump and live-reel are solidly mounted. If the vehicle is used for other purposes during the wet season this equipment can be mounted on a false floor on the tray of the truck.

Since the plantation areas are fairly flat there appears little necessity to have 4 wheel drive vehicles for all tankers, particularly in the Ndola plantation group. However, while the practice of ploughing fire breaks in sandy soils of the Chati areas persists, 4 sheel drive vehicles will be required in this area until solid roads are formed.

B. Large Tankers. Large tankers with a capacity of 600 gallons or over will need to be introduced as the plantation area is enlarged. These tankers should be designed as single purpose vehicles and not be used during the wet season. They should have a permanently mounted pump and motor. The pump can have the capacity for an independent suction line for refilling and outlet lines for ¾ inch and 1½ inch hose.

It is recommended that engineers consider the designs of standard fire fighting tankers used by the various Forest services in Australia and adopt what features are best suitable for conditions in the Industrial Plantations.

C. Slip on tankers. Various types of slip on tankers can be designed to fit on a vehicle not usually used for fire fighting. There are two important points which should be remembered:-

1. The slip on tank must be completely self contained with the pump and live-reel mounted on the tank.

2. The unit should not be so big that it becomes completely unmanageable. The optimum size of the unit is probably around 150 to 200 gallons designed for a light rear-wheel-drive truck.

5.5. Hoses and Nozzles

Hard rubber hose is recommended for initial attack vehicles and all live-reel installations on tankers. Canvas hose is not recommended because it has the following disadvantages:-

1. It is difficult to maintain in good condition and is easily damaged.

2. A length of hose must be completely laid out before water can be delivered.

3. Once the hose has been laid out it cannot be recovered quickly and used again.

4. A highly trained team is required for efficient use. Generally by the time a hose lay is completed, the job could be done by hand tools.

As mentioned above, all nozzles should be a spring loaded, shut off type with interchangeable tips. It is not necessary to have a nozzle which is infinitely variable but essential to have one which shuts off automatically when not held open.

5.6. Fire fighting Chemicals

1. Wetting Agents. All tankers should have a wetting agent or detergent added to the water. This gives a greater penetration into the fuel bed which is around 8 times better than plain water, and is essential to do a proper job of mopping-up. A variety of wetting agents are available which can be supplied in either powder or liquid forms. The amount which should be added should make the water froth slightly, but not excessively when applied, and is around 2 oz/100 gallons. Bought in bulk wetting agents should cost less than 10 ngwee/100 gallons.

2. Fire Retardant Chemicals. Fire retardant chemicals based on diammonium phosphate or ammonium sulphate, with corrosion inhibitors and thickening agents added are manufactured in the United States, and sold by various trade names. "Phoschek 259" is a very effective fire retardant designed for use in tankers but also very expensive, and would probably cost over 50 ngwee a gallon in Zambia. It would not be practical to use fire retardant chamicals at this stage.

5.7. Mechanical Equipment

1. A hydraulic operated blade mounted on the front of a rubber tyred tractor is a very useful piece of equipment for clearing

a fire line through the forest. Since there are numerous tractors idle during the fire season, two or three with blades at each district would be very useful in the event of a large fire.

2. Bulldozers are frequently used for fire fighting in other parts of the world. However, the fuel accumulation in the plantations should not be very heavy if the proper fuel reduction techniques are carried out and should not warrant the use of this heavy equipment.

SECTION 6. ASSESSMENT OF FIRE DANGER

6.1. Fire Danger Rating

A fire danger rating system is the integration of the various fire danger factors to give an expression of the probable behaviour of a fire in terms of the chances of a fire starting, its rate of spread, intensity, difficulty of suppression and its potential for doing damage.

The "McArthur Fire Danger Rating System" integrates the 4 major meteorological factors affecting fire behaviour (temperature, relative humidity, wind speed, long and short term drought effects) to give a fire danger index.

The fire danger index is percentage of the worst possible conditions likely to be experienced anywhere. An index of one hundred (100), or worst possible, means that the fires will burn so fast and hot that control is impossible. An index of one (1) means that fires will not burn, or burn so slowly that control presents no difficulty.

The four fire behaviour factors are integrated on a circular slide rule, the "Forest Fire Danger Meter". (See meter attached at back of report). The system is equally applicable in Zambia as it is in Australia, so the Forest Fire Danger Meter can be used, immediately to forecast fire danger in the Industrial Plantations.

The meter is designed for general forecasting and is based on the expected fire behaviour of fires burning for an extended period in a high (mature) eucalypt forest carrying a fuel quantity of 5 tons per acre over flat or undulating country. The behaviour of an individual fire can be predicted with reasonable accuracy and a table on the back of the meter gives the expected behaviour of eucalypt fires burning different quantities of fuel.

Experiments in Australia have shown that there is little difference between the behaviour of eucalypt and pine fires except in the very high to extreme category when spotting becomes an important factor in the spread of eucalypt fires.

It would be expected that the fire behaviour in both eucalypt and the pine fuels in Zambia would be slightly less than that predicted by the table. Since neither the eucalypts nor pines grown in Zambia have a high spotting potential the spotting distances will be shorter and the rates of spread will be slightly slower for a particular fire danger index and fuel quantity.

Accurate predictions of fire behaviour for a particular fuel type can only be determined by carrying out fire behaviour experiments in that fuel type and carefully detailing the behaviour of wildfires and noting the weather conditions under which the fires are burning.

6.2. Factors used in the Forest Fire Danger Meter

1. Drought Index. The drought index is a measure of long term drying of the larger fuel components as the fire season progresses. Early in the season (April-June) large logs still contain considerable moisture and will not burn, whereas late in the season (August-September) the large logs have dried out and will burn almost completely away.

The combustion of large logs adds considerably to the heat output of the fire and so to the damage done by the fire. Fires late in the season are generally much hotter and more difficult to control.

The drought index is calculated from daily rainfall and daily maximum temperature. A set of drought index tables, and examples of drought index curves for 1967, 1968 and 1969 are given in Appendix 3.

2. Recent Rainfall. Recent rainfall combines with the drought index to give the drought factor. This will only be important in the early part of the dry season.

During most of the fire season, from the end of June onwards in a normal season, the drought index will be above 400 and the maximum drought factor of 10 should be used. However, in an unusual season when the rains finish early the drought index could be above 400 from the end of May onwards.

The identification of unseasonably dry conditions is the most important function of the drought index.

3. Temperature and Relative Humidity. These two factors combine to give the moisture content of the fine fuel (less than ¼ inch diam.). Diurnal changes in temperature and relative humidity reflect the diurnal change of fuel moisture.

The uptake and loss of moisture from needle litter-fuels will lag 2-3 hours behind the change in relative humidity, so it must be remembered that in the early part of the evening the fuel will be drier and the fire danger will be higher than indicated by the meter.

The uptake of moisture for fine fuels, such as grass and bamboo leaves, will lag only about 30 minutes behind the change of relative humidity. As a result these fuels will burn better than the pine (or eucalypt) litter in the morning when the relative humidity is falling and more quietly during the evening when the relative humidity is rising.

4. Wind Speed. During the dry season the temperature and humidity patterns are very similar, but the wind speed can vary greatly from day to day. Wind speed is most important in determining the daily fire danger rating, and efforts should be made to install an anemometer in the fire towers to get an accurate daily reading of wind speed.

The wind speed used in the fire danger meter is average wind speed at 10 meters (the standard meteorological height) in an open location. However, the wind speed taken from a fire tower (at 100 ft) above the forest will not vary greatly from the standard meteorological observation.

6.3. Use of the Fire Danger Meter

1. Daily Fire Danger Forecasting. Daily forecasts of temperature, relative humidity and wind speed can be obtained from the Meteorological Department and a daily forecast of fire danger rating can be obtained from the Fire Danger Meter.

Forecasts for 1500 hours (3.pm.) should be obtained, at 1500 hours on the day before and at 0900 hours on the same day. These forecasts should be checked against the actual readings obtained on the day for which the forecast was made.

A table for recording fire weather forecast may be as follows:-

Daily Fire Danger Forecast

Date	Forecast for 1500 hrs.								Actual Weather at 1500 hours			
	Previous Day @ 1500 hours				@ 0900 hours							
	T.	R.H.	W.	F.D.I.	T.	R.H.	W.	F.D.I.	T.	R.H.	W.	F.D.I.
20/7/70	80	20	10	22	82	20	15	27	82	23	18	28
21/7/70	83	18	12	27	83	18	12	27	83	18	6	21
22/7/70												

2. Daily Fire Danger Measurements. At each district fire headquarters a small weather station can be installed to measure the daily weather at that station.

Each station should consist of a small stevenson screen situated in an open location over mown grass. The stevenson screen should contain:-

(1) A wet and dry bulb thermometer.

(2) A maximum and minimum thermometer

(3) A thermohygrograph (say "Cassella" type).

Wind measurements can be taken from a fire tower using a pressure tube anemometer of the "Dwyer" type.

The local Meteorological Department should be consulted to advise on the purchase and installation of this equipment.

6.4. Conclusion

Assessment of fire danger is not difficult. However, it does require a reliable man in charge of the fire control section to ensure that the readings are taken correctly and accurately. Considerable training would be required before the Zambian Foresters could do this job.

The assessment of fire danger does have the advantage that it makes the foresters aware of the factors which control the behaviour of a fire.

A stevenson screen containing the above mentioned instruments has been installed at Dola Hill. If accurate records are maintained it will provide valuable information for both assessing daily fire danger, and assessing the fire weather conditions for carrying out controlled burning or during a wild fire.

An immediate requirement is that accurate wind direction readings are maintained from the firetowers and that a simple anemometer is installed to measure wind speed.

SECTION 7. FIRE CONTROL ORGANISATION

Unhappily, a sad truth of history is that in most places an efficient fire control organisation does not become established until after a disastrous fire. This is mainly because nothing teaches as well as experience and it is only when a forester is faced with the task of stopping a fire raging out of control in heavy fuel and in bad weather that he realises the need for an organisation that works as a co-operative unit, and responds calmly and automatically in the event of a crisis. It is also the time that he realises the need for hazard reduction, preplanning for the event of a large fire, and the need to train his men in the use of equipment and firefighting techniques.

The fire hazard in the Industrial Plantations is severe enough to warrant the formation of a fire control section. This section must have equivalent status to all other sections in the Forestry Department and have the power to close the forest areas and stop fire hazardous operations on a day of very high fire danger. The personnel in the fire control section will be employed full time on fire control duties, including hazard reduction, during the fire season.

The following sub-sections are a suggested organisation. As the organisation develops, various modifications will become apparent and be developed astrained personnel becomes available.

7.1. Functions of the Fire Control Section

The functions of the fire control section will be:-

1. To carry out fire fighting activities and to supervise men co-opted into fire fighting in the event of a major fire.

2. To carry out hazard reduction burning and other hazard reduction measures.

3. To supervise the maintenance of firebreaks.

4. To take fire weather observations and obtain fire weather forecasts, and calculate the drought index.

5. To maintain the fire fighting equipment in first class condition.

6. To supervise the training of foresters and uniform staff, who are likely to be called out to fires, in the use of equipment and in fire fighting techniques.

7. To take charge of radio communications.

8. To make out fire reports and to assess fire damage.

7.2. Personnel

1. Chief Fire Control Officer: To be of Professional Forester rank and to have the following duties:-

(i) To draw up a Fire Plan for the fire control sections and designate the duties of the personnel of the fire control section.

(ii) To introduce new equipment and fire fighting techniques and to supervise the training of foresters in the use of equipment and in fire fighting techniques.

(iii) To carry out experiments to determine the best time of the year to do control burning.

(iv) To supervise hazard reduction burning.

(v) To supervise the overall running of the fire control section.

(vi) To establish liaison with the Meteorological Bureau, Police Department, and other outside organisations whose services may be required in the event of a major fire.

(vii) To direct fire fighting activities in the event of a major fire.

2. Deputy Fire Control Officer: To be of Forester rank and to have the following duties:-

(i) To supervise the daily running of the fire control section.

(ii) To attend all fires and, where necessary, direct the fire fighting activities until the arrival of the Chief Fire Control Officer.

(iii) To supervise the taking of fire weather observations and make fire danger forecasts.

(iv) To assess fire damage and make out fire reports for submission to the Chief Fire Control Officer.

(v) To carry out hazard reduction burning and other hazard reduction measures as outlined in the Fire Plan.

(vi) To train the fire crew in the use of fire fighting equipment, fire line construction and elementary fire fighting techniques, such as the economical use of water on fires and the correct procedure for mop-up and patrol.

It is essential that this man gets as much fire control experience as possible, hence the instruction to attend all fires, even if they are considered under control before he gets there. He must be a natural leader, of strong character, be able to make quick decisions and be able to get men to act without delay.

3. Fire Controllers: These will be the foresters supervising the forest stations and any other foresters who could be called out on to fire duty. They should have a thorough understanding of the principles of fire behaviour and fire fighting techniques. They will be expected to attend all fires in their sub-district and take charge of fire crews under the direction of the Deputy Fire Control Officer.

The Fire Controllers will instruct workers in their forest sub-district in techniques of hand line construction, mop-up and patrol.

4. Dispatcher or Radio Controller: This man will be in charge of the radio control in the fire control headquarters. His duties will be:-

(i) To supervise the radio traffic and in the event of a fire ensure that the radio is kept open for fire messages only.

(ii) To maintain communication with the firetowers and fire control personnel.

(iii) To keep a record of the fire danger forecast and to keep a record of the wind direction and strength as reported by the firetowers.

(iv) To know the exact location of the fire crews if they are working in the forest and the location of the fire tankers and other equipment.

(v) To pass messages as directed by the Fire Control Officer.

(vi) To keep a log of all fire messages transmitted during a fire. In the event of a fire call the controller will:-

  (a) Record the bearing of the fire, colour of smoke, wind strength and direction as reported by the firetowers.

  (b) Plot the position of the fire on the fire map.

  (c) Direct the nearest fire tanker and fire crew to the fire.

  (d) Inform the Fire Control Officers.

5. Store Boss: Initially this man should be in charge of the issuing and maintenance of fire equipment. Eventually he should take charge of logistics, i.e.

(i) Organisation of extra men and equipment and arranging transport.

(ii) Organisation of relief crews.

(iii) Arrange for catering facilities to feed the men on the fire line should a fire burn over a long period.

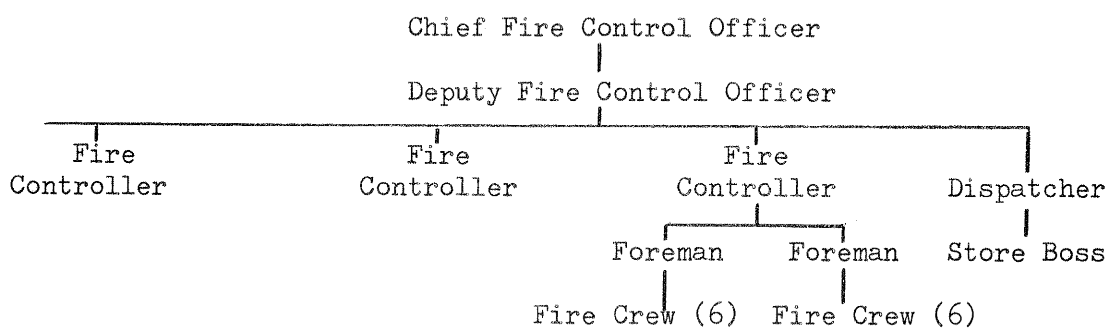
(iv) Arrange for fuel for fire fighting vehicles.

6. Permanent Fire Crews: In the initial stages of the organisation where training is the most important job to be carried out it is essential to build up a permanent fire crew of fit young men who will be on fire fighting duties full time during the fire season.

At this stage it is recommended that each district have 2 six man crews, who will carry out the initial attack.

All men in the crew should be trained to operate the fire tankers and be trained in fire fighting techniques. These men should also take part in all controlled burning operations.

During the fire season these men should not be waiting around the depot but should work in the forest on hazard reduction duties such as clearing hazardous anthills along firebreaks, removing heavy log fuels from the compartments in areas of high fire risk such as near compounds or along rights of way. The crew must be in continuous radio contact with the dispatcher. During periods of high fire danger the crew should be working in areas of high fire risk where there is the greatest need for speedy initial attack. The organisation of the fire control section is illustrated below:-



7.3. Communications

Good communications are essential for efficient fire fighting and forest management. As the plantation areas increase it can be expected that there will be an increasing use of radios for both fire control and management. It will be essential that the radios are reliable and require the minimum of maintenance.

1. Equipment. The most successful radio equipment for fire control purposes is V.H.F. equipment in the 70 to 80 Megacycle frequency. There are a variety of different systems which can be used and as the present sets come up for replacement it is recommended that the whole system of communications be re-examined.

(a) The communication system should be examined by a person who is experienced in forestry requirements for radio communications and has experience in communications over flat latterite terrain.

(b) Before purchasing another system, get several radio companies to carry out a customer survey which involves the field testing of various frequencies and systems.

2. Mobile Radios. All radios now in use should be mounted in a permanent position.

Portable radios are of limited value and in many organisations are rarely used, if at all. They have the disadvantage that they are easily damaged by careless handling or in transit; the power supply is unreliable and is generally discharged when needed most; if the operator is in a "dead spot", where it is not possible to receive (or transmit) it is difficult to shift to a more favourable location. Furthermore, the fire control organisation is not developed to a degree where portable radios have any application on the fire line.

It is recommended that radios are mounted in vehicles (mobile radios) and to be used by the following people:-

(a) Fire control officers and fire controllers.

(b) Fire crews - radios to be mounted in tankers.

(c) Senior management officers who are likely to be called upon to assist in fire control.

3. Firetower Radios. These should be mounted in the firetower with an outside aerial and a power supply at ground level.

4. Radio Procedure. A standard radio procedure must be drawn up and made available to all people using radios. Radio messages must be kept brief and it will be the duty of the dispatcher to ensure that radios are not used for casual chatter. A list of call-signs for the people using the radios should be drawn up and carried with all sets.

Some examples of radio procedure are given below:-

(a) Call Up. In most countries the Post Office department (or the department allocating radio frequencies) require the control

centre to identify itself fully, stating its complete call sign and its transmitting frequency, on the opening or closing down of the station. This is generally done at the same time each day when routine messages are passed. e.g. "This is VL2AB Control transmitting on a frequency of 78.4 megacycles. The weather forecast will be given in one minute.....". For other messages the complete call sign is not required. The usual convention is that the station requested is said first followed by the call sign of the station transmitting.
e.g. Mobile 10:- "Control, this is (mobile) one-zero, over."

(b) Test Call Procedure. If a mobile is in doubt about the quality of his transmission he may ask for a test call. A general convention is to identify the message in terms of loudness and clarity on a scale of 1 to 5.

Loudness		Clarity	
5	Loud	5	All words clear
4	↓	4	4 words in 5 clear
3	↓	3	3 words in 5 clear
2	↓	2	2 words in 5 clear
1	barely audible	1	1 word in 5 clear

e.g. Mobile 10 :- "Control, this is one-zero. Test Call. How do you receive, over."

Control :- "One-zero, this is control, receiving you five-five, over."

Mobile 10 :- "(Thank you) One-zero, out."

SECTION 8. FIRE FIGHTING TECHNIQUES AND TRAINING

8.1. Point of Attack

1. On arrival at a fire, the first crew should immediately attack the head fire (the most rapidly moving part of the fire) and then having controlled this they should attack the side of the fire which will become the head fire if the wind changes. In the Copperbelt region there is a diurnal change in wind direction, as outlined in Section 1, where the wind starts blowing from the east or north-east and, as the day progresses the wind will swing around towards the south.

Once the head fire is controlled the fire crew must immediately control the northern flank.

This is a fundamental principle of fire fighting and must be properly understood by all Fire Controllers and fire crews.

2. If the head fire is moving too fast and is too hot to control, one crew should start immediately on the northern flank. The tanker will attempt to stop the head fire on the nearest fire break or road and additional crews will be brought in to control the northern and southern flanks.

8.2. Methods of Attacking Fires

1. Direct Method. The fuel is pushed directly into the fire so that the fire edge becomes the established fire line. This is used on small fires or low intensity fires. The disadvantage of this method is that it is tiring to work close to a hot fire.

2. Parallel method. This method involves constructing a fire line parallel to the general edge of the fire, at a distance of from 4 to 20 feet (larger distances may be required to short cut irregularities in the fire edge or deviate around anthills). The fire must be allowed to burn up to the edge of the fireline. Where the fire line deviates some distance from the fire edge, the intervening area should be burnt out. (figure 7).

The advantages of this method are that men can work in comfort at a distance from the fire and yet remain fairly close to the fire edge, and it allows men to use efficient methods of fire line construction such as the "jump up" method.

3. Back burning from Prepared Firebreaks. This is not generally recommended. It should only be used by men who have considerable fire control experience and it should only be used 2 or 3 chains directly in front of the head fire. In most cases back burning results in the fire becoming much larger than if it was fought directly.

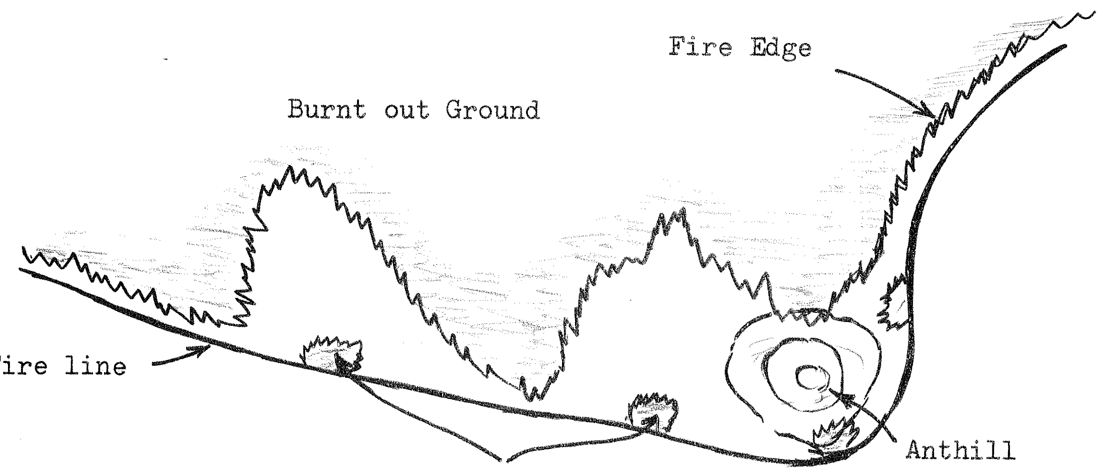


Figure 7. Location of Fire Line using the Parallel Method.

8.3. Fire line construction with Hand Tools

It is recommended that all fire crews are trained in the "jump up" method of fire line construction.

"Jump up" Method:-

(1) Used by a crew of 6 men working as a unit. The first man carried an axe or brush hook. The other men have McLeod tools.

(2) The men space themselves 20 feet apart along the fire edge and commence raking a trail 3 feet wide.

(3) The first man with the axe selects where the trail will go and clears logs or large branches off the trail.

(4) When any individual reaches the end of the section available to him he says "jump up" and then the signal is repeated along the line, and each man moves forward until he has some fresh work to do.

(5) When a man is signalled "jump up" from the man behind he immediately stops working and moves up the line and signals to the man in front to "jump up".

(6) When several men move up onto new ground at the same time they again space themselves out 20 feet apart.

(7) Each man should properly construct his section of the trail and it should not require widening by another man. The last man does, however, check that the line is constructed properly.

(8) The last man should be the best worker and used to push the other members of the crew along.

(9) As the fire line progresses men should be brought up to patrol the constructed fire line.

8.4. Use of Water on Fires

Water is scarce and men must be trained to use it efficiently. Training in the use of water on fires should include:-

1. Proper use of the shut-off nozzle so that water is only sprayed on burning fuel.

2. Varying the nozzle tip and the pump speed so that only the required amount of water is used for each job, e.g. a straight stream and high pump speed might be required to knock down the head fire, low engine speed and a spray is required for mopping-up.

3. The nozzle man should work as close to the fire as possible to avoid wasting water. This is particularly important when mopping-up.

4. When extinguishing a fire edge the nozzle man should direct the stream of water parallel to the fire edge so that no water is wasted by shooting through the flames onto burnt out ground.

5. A tanker should have a team of 2. One man with the nozzle and the second man to pull out hose and keep the hose away from smouldering coals.

A fire can be quickly extinguished with water but the edge cannot be considered safe until a bare earth trail has been constructed around the edge of the fire.

If a fire line has already been constructed the fire must be allowed to burn up to the bare earth line and burn out all the fine fuels. Water should not be sprayed inside the fire line, unless a jump over is threatened, when it is used only to cool the fire. It is best to save water for dealing with spot fires which have crossed the control line.

8.5. Mop-up and Patrol

It is essential that all fire controllers are aware of the need for good mop-up and patrol until the fire is dead out.

Mop-up is the extinguishing of all burning and smouldering material within 60 feet of the control line. Proper mop-up procedure includes:-

1. Working close to the fuel. The nozzle should not be more than 1 ft from the smouldering fuel unless it is physically impossible to get closer.

2. Burning piles of logs should be pulled apart with rakes and axes and carried away from the fire edge.

3. Efficient use of the shut-off nozzle so that water is not wasted.

4. Log material is only safe when it can be handled by hand.

Between 60 and 300 feet from the fire edge (approximately 1-5 chain) mop-up should concentrate on hazardous hot spots, such as hotly burning piles of logs, burning snags or anything which is likely to throw a spot fire across the line. It is a waste of effort, and more importantly water, to mop-up well inside the fire area.

8.6. Training

Once fire crews have learnt the basic techniques of tanker operation a training exercise should be held once a month during the fire season.

Competitions can be held which test the fire crews ability and efficiency in fire fighting. Such a competition may include:-

1. Hand Line Construction. Points to be awarded for the length of line constructed in one minute by a 6 man crew, using the "jump up" method (1 point/ft). Points to be subtracted for every part of the line where it is less than 3 feet wide clear of all fuel.

2. <u>Tanker competitions</u>. This should be designed to test the mens' ability to use the equipment and not be a speed trial. Penalty points would be subtracted if the driver drives recklessly or moves off before the crew are seated etc. Such a competition might include:-

   (a) Using the suction hose to draw water from a drum at ground level.

   (b) Reversing through an obstacle course.

   (c) Unwinding the live-reel, filling a bucket with water and rewinding the reel etc.

3. Other training may include map reading, radio procedures, fire fighting principles etc.

Control burning is an excellent way to keep the fire crews trained for fire fighting as well as making them aware of some of the principles of fire behaviour.

SECTION 9. FIRE PLANS

A fire plan is the systematic documentation of all the activities of the fire control section. The fire plan outlines the procedures to be taken for fire prevention, hazard reduction and fire suppression. It is particularly important for suppression. There is no time to make preparations when a fire is reported. Quick initial action is essential and this must be followed by an automatic course of action which will ensure continuous follow up support for the fire crews as required.

The fire history of an area will form the basis of a fire plan. Accurate fire reports must be made so that the following information will be recorded:-

(1) Number of fires.

(2) Location of fires.

(3) Causes.

(4) Time of occurrence.

(5) Elapsed time between fire start, detection, initial attack and control.

(6) Fire behaviour, and fire spread patterns.

(7) Fire weather.

(8) Fire damage and cost of suppression.

A suggested fire report form is given in Appendix 4 and a set of tables of the value of stands at all ages is given to assist in the estimation of fire damage (Appendix 5).

A fire plan should be made up for each district which functions as a fire control unit, with a general fire plan for the Industrial Plantations Division. Fire plans should be revised each year.

An outline of what a fire plan should cover is as follows.

1. A regional or district fire control map showing:-

   (a) Road and firebreaks.

   (b) Forest headquarters.

   (c) Water supplies, dams and tanks.

   (d) Lookouts - with a protractor drawn at each lookout.

   (e) Equipment locations.

The map, of a suitable scale, should be gridded so that the location of fires can be referred to by co-ordinates.

A master map mounted on fibre board in the fire control headquarters could locate the position of tankers and fire crews working in the forest, or at depots, by placing suitably coloured pins at their position.

2. A map showing the fuel conditions in the forest (fuel map). This map could indicate:-

(a) Areas of very high fuel accumulations, such as recent thinnings, lantana, etc.

(b) Areas recently control burnt.

(c) Bare areas.

3. A fire occurrence map showing where fires have started and indicating areas of greatest risk.

4. A telephone directory giving the telephone numbers of Fire Control Officers, Fire Controllers, Police, Meteorology office, and all other individuals who may, at some time, form part of the organisation.

5. A record of all co-operative agreements that have been made. These should include:-

(a) Police Department: In the event of a serious fire crossing one of the main public roads through the plantations the police should be asked to control traffic and keep the public out of the area. The police should not be asked to take any other duties, it should be clearly understood that they are under the direction of the Chief Fire Control Officer.

(b) Meteorological Department: To supply fire weather information.

(c) Earthmoving Contractors and/or Roads Department: Who have equipment which may be co-opted for fire fighting.

6. Statements of the responsibilities of individual officers.

7. Location of all equipment and supplies.

8. A statement of the presuppression activities and fire prevention measures to be undertaken including:-

(a) Hazard reduction prescriptions.

(b) Firebreak standards.

(c) Training procedures.

(d) Care and maintenance of equipment.

(e) Standard fire fighting instructions.

(f) Radio procedures.

(g) Firetower reporting procedures etc.

No absolute standard can be given for a fire plan. The plan will change as the forest areas increase and as different priorities become apparent. What is important is that advance planning be carried out and that the plan is revised regularly.

APPENDIX 1. EXPERIMENTAL FIRE TECHNIQUES

The experimental fire techniques outlined in this section are designed to study the behaviour and spread of a single fire starting from a point ignition. It is possible only to give an outline of experimental fire techniques and analysis in this report but it is hoped that this can be a guide to anybody carrying out preliminary burning experiments.

Detailed measurements of the weather and fuel factors affecting fire behaviour must be made before, during and after the burning of an experimental fire. During the program of experimental burning the experimental areas are chosen selectively to keep such factors as total fuel quantity, slope, stand density etc. as constant as possible for the complete series of fires. The effects of slope (or fuel quantity) are determined either by burning a number of simultaneous fires and varying only the one factor, slope, or by carrying out another series of fires over a range of conditions on a new site where the particular factor, slope, is different.

After a fire is lit it has an acceleration period during its initial 10 minutes or so. After this acceleration period the rate of spread will remain constant provided all the fire behaviour factors remain constant. This is called the "steady state" period.

In practice it is possible to allow an experimental fire to run for 30 minutes and it can be assumed that factors such as temperature, relative humidity and fuel moisture content will remain constant over that period. Wind speed generally fluctuates greatly over a short period so a continuous record of wind speed must be kept throughout the fire.

To obtain satisfactory data for control burning conditions a series of experimental fires must cover a range of conditions far exceeding those under which control burning should be carried out.

Sequence of Events for an Experimental Fire

1. Select an experimental site which will have a uniform slope and a uniform fuel quantity over the expected duration of the fire.

2. Measure the fuel quantity on the area.

3. Take temperature, relative humidity and fuel moisture measurements before the fire and at half hourly intervals during a series of fires.

4. Commence the experimental fire at a marked origin and measure the fire perimeter spread and the fire behaviour characteristics at 2 minute intervals. Start an anemometer at the same time as the fire is commenced and measure the wind speed at 2 minute intervals during the fire.

5. Allow the fire to burn for 30 minutes where burning conditions permit.

6. When the area has cooled, measure the remaining fuel, survey the position of the perimeter markers, measure the slope, the scorch height up the tree crown and note any other relevant damage.

During the course of the experimental fire program the following factors must be measured.

1. Temperature and Relative Humidity.

Equipment: Aspirated psychrometer, or wet and dry bulb thermometers in a stevenson screen, or Hygrothermograph in a stevenson screen.

Temperature and relative humidity should be taken by measuring the wet and dry bulb temperatures of the air at a height of 4 feet above the ground, in the forest at the experimental site. Care must be taken that the measurements are unaffected by radiation from the sun or by the influence of the fire. A continuous record of temperature and relative humidity can be maintained with a hygrothermograph but these instruments require careful calibration.

2. Fuel Moisture Content.

Equipment: Air tight, heat resistant sample jars, Balances accurate to ± 0.05 gm., oven drying facilities.

Samples are taken for fuel moisture determinations at the same time as temperature and relative humidity are recorded. The samples are taken of dead fuel and should not include any green material. The samples are weighed and dried at 103°C. The fuel moisture content is expressed in terms of percentage oven dry weight. Two samples are generally taken:-

(a) Surface Moisture Content:- This sample is the very top layer of the litter bed: i.e. less than ¼ inch in depth.

(b) Profile Moisture Content:- This sample is taken through the whole litter bed from the surface to mineral soil.

The fuel moisture content of the surface litter is primarily a function of ambient temperature and relative humidity and is one of the fundamental factors which determine fire behaviour.

The fuel moisture content of the litter profile is a function of long term drying after rain and determines how much fuel will be consumed.

3. Fuel Quantity Consumed.

Equipment: Fuel sample quadrat, clippers, plastic sample bags, weighing and oven drying facilities, fuel moisture sampling jars (if required).

The fuel which is important in determining fire behaviour is the fine fuel, i.e. that which is less than ¼ inch in diameter. Samples are taken of the fine fuels and converted to an oven dry weight basis either by drying the whole sample or by weighing and determining the moisture content of sub samples.

The fuel consumed by the fire is determined by sampling before and after the fire. Care must be taken to ensure that the pre-fire sampling does not alter the burning characteristics of the fuel bed.

The size of the sample taken depends largely on the distribution and nature of the fuel. A sample may be as small as 1 square foot in very uniform litter fuels or 10 square feet or larger in irregular fuels containing irregular slash piles. In most fuels a sample of 4 square feet of 1/10,000 acre (4.35 square feet) is a convenient size.

4. Wind Speed.

Equipment: Sensitive cup anemometer, stop watch.

Wind is measured in the forest, near the fire site at a height of 5 feet above the ground. The anemometer is set up near the base of the fire but out of the direct influence of the fires' convection. Wind speed measurements are taken throughout the duration of the fire, at 2 minute intervals or at whatever interval the spread of the fire is being measured. Care must be taken that the operator does not interfere with the air flow to the anemometer.

Wind speed in the forest at 5 feet is an important fire behaviour factor. It is related not only to wind speed outside the forest but also to the height and density of the forest.

5. Rate of Forward and Perimeter Spread.

Equipment: Stop watch, markers - metal or other non-combustionable material, lumber crayon, compass, measuring tape.

Each fire is started from a clearly marked point of origin. At every two minutes the perimeter of the fire is located with metal markers, which have the time period they represent written on them. (e.g. At 4 minutes all the metal markers are identified with the figure 4.). The front of the fire is marked separately and identified as the front by using a different type of marker or by writing the letter "F" along with the time identification.

After the fire is completed and the area has cooled down the position of each marker is surveyed from the fire origin with a compass and tape measure.

Where there is insufficient manpower to mark the whole fire perimeter; the spread of the head fire alone provides much useful data.

6. Fire Behaviour Measurements.

Equipment: Stop watch, data recording sheets.

Fire behaviour measurements are generally made by the person in charge of the experiments, who records the following on a prepared form:-

(1) The fire number, date, locality, fuel type, cloud cover and the time of commencement of the fire.

(2) At every two minutes he records -

(a) The flame height of the head fire.

(b) The flame depth of the head fire.

(c) The flame length.

(d) The angle of the flame to the horizontal.

(e) Other general fire behaviour characteristics such as the colour of smoke, any spot fires thrown, whirlwinds, shape of the fire, whether running upslope, cross-slope, with or against the wind and most importantly whether the head fire is burning in heavy, average or sparse fuel.

The flame height is the vertical height of the flame while the flame depth is the length of fuel in the head fire which is flaming at the same time, forming a continuous flame cover over the surface of the fuel.

Generally all these factors are a function of wind velocity, fuel moisture content and fuel quantity. e.g. the stronger the wind the more acute is the flame angle. At zero wind velocity the flames may be drawn back into the fire area so the flame angle will exceed 90°.

The observer makes occular estimates of these factors and it takes a lot of practice to make these observations quickly with reasonable precision. In initial stages the observer may be assisted by using a calibrated rod to judge flame height and flame depth.

7. Other Measurements.

(i) Slope Equipment: clinometer, compass.

Measure the maximum slope in the fire area and the slope from the origin to the most distant front marker.

(ii) Scorch Height - Clinometer, tape.

Measure the average height of the scorched needles along the path of the head fire.

(iii) Grass Curing Stage

Make an occular estimate of the grass curing stage. This estimate can be correlated with the drought index or the moisture content of grass samples to improve precision.

Man-power Requirements

An efficient experimental fire program requires a team of 5 men. During the course of the fire their duties would be:-

1. Booker: records fire behaviour and calls the time interval to the markers.

2. Front Marker: marks the position of the head fire precisely at the minute call. As this is the hottest and fastest moving part of the fire one man is assigned to this task.

3. and 4. Flank Markers: mark the position of either flank of the fire. As the fire increases in size each man may drop 3 or 4 markers on each flank to define the perimeter.

5. Wind Booker: records the wind speed at 2 minute intervals and makes notes on the wind direction, gustiness etc.

ANALYSIS.

For each fire:-

(1) Draw up a plot of the fire perimeter at each time interval as delineated by the markers.

(2) Calculate the "cumulative forward spread", i.e. the distance from the origin to the front marker, for each time interval.

(3) Calculate the "maximum forward spread," i.e. the maximum distance the fire spread in two minutes, for each time interval.

There are several ways that forward spread can be analysed. It is important that the fire has reached its steady state period before spread measurements are used for analysis.

One method of analysis has the following steps.

1. Correlate wind velocity with the steady state rate of spread for each fire.

2. Correlate fuel moisture content with temperature and relative humidity.

3. Correlate rate of spread with fuel moisture content in wind velocity classes.

These correlations give the fundamental multiple regression between rate of spread, wind velocity, temperature and relative humidity. As more data becomes available it is possible to add the effects of fuel quantity, slope and grass curing stage.

A control burning guide will require the data of 50 to 100 experimental fires.

APPENDIX 2. SUGGESTED EQUIPMENT AND SUPPLIERS

The following is a list of basic fire fighting equipment which is recommended for use in the Industrial Plantations. Prices are in Australian dollars (1 Kwacha = A$1.20)

1. McLeod Tools

Supplier:- Rider and Bell
Cavell Avenue,
RHODES, N.S.W. 2138 Australia.

Cost:- Heads only $1.55 each
Handles $7.06 per doz.

2. Knapsack Sprays 5 gallon plastic knapsack with double-action force pump.

Supplier:- Rega Pty Ltd,
Bryant Street,
PADSTOW, N.S.W. 2211

Cost:- $13.77 each.

3. Shut-off Nozzles

Specially designed unit complete with fog nozzle and 3 interchangeable tips.

Supplier:- Forestry Commission of N.S.W.
93 Clarence Street,
SYDNEY, N.S.W. 2000

Cost:- $19.00

4. Drip Torches - 3 pint.

Supplier:- Fire Fighting Equipment,
6 Hope Street,
ERMINGTON, N.S.W. 2115.

Cost:- $19.60

5. Single Stage Centrifugal Pumps

The unit most highly recommended would be the Tahatsu VE6 which has a maximum pressure of 150 p.s.i. and a maximum filling rate of 80-90 gallons/minute.

The Australian price of this unit is $600 but this would include a heavy protective tariff and the unit could probably be obtained directly from Japan at a much lower cost.

6. Multistage Centrifugal pumps

The Senior Forester 3, 4, or 5 stage centrifugal pump have been designed for forest fire fighting by the Forestry Commission of N.S.W.

The recently developed Senior Forester 5 stage waifer centrifugal pump has exceptionally good performance with a maximum pressure greatly exceeding 150 p.s.i. and a filling rate of about 90 gallons per minute.

A multi-stage centrifugal pump should be considered for use with tankers carrying more than 200 gallons.

Supplier: Fire Fighting, Agriculture and
Industrial Pumps Ltd,
6 Crammond Boulevarde,
CARINGBAH, N.S.W. 2229

Cost:- $500-540.

APPENDIX 3. DROUGHT INDEX CALCULATION

A drought index is a system of recording a "moisture deficiency" budget. It was initially designed to indicate a soil moisture deficiency and has now been adapted to indicate the dryness of large fuel components (logs etc.) and deep litter beds.

Without going into any great detail concerning the derivation of the index, the system makes several basic assumptions. These are:-

1. Soil moisture depletion has an exponential curve form, i.e. as the soil dries it becomes progressively more difficult to remove further moisture.

2. The rate of moisture loss from the soil is a function of air temperature. In fact the precise measurement of drought for a particular area involves complex evapotranspiration formulae and the measurement of many meteorological elements and soil characteristics. The Penman evapotranspiration formula requires the measurement of mean ambient air temperature, mean vapour pressure, duration of bright sunshine and mean wind speed. However, air temperature is the most important function of these and a good simple correlation can be obtained between daily moisture loss and daily maximum temperature.

3. The Drought Index is on a scale of 0-800. Originally, the 800 points (or 8 inches rainfall equivalent) represented the amount of moisture held in the average soil that was available for evapotranspiration. However, since the moisture capacity of soils varies greatly it is better to consider the 800 points as an arbitrary scale and relate various drought effects to the drought index when the effect occurs. A drought index of 800 is the maximum drought that is possible anywhere.

4. The index is reduced by a simple subtraction of the amount of rain which falls less 20 points (.20 inches) in any one fall, which is assumed as being intercepted by the vegetation and does not reach the soil (or litter) surface. Thus if the index today is 480 and 200 points of rain is recorded the index is reduced by 180 to 300.

The drought index is most useful to identify unseasonably dry conditions.

Computation of the Drought Index

The only meteorological measurements required for the computation of the drought index are:-

(1) Daily maximum air temperature.

(2) Total rainfall for the past 24 hours.

The set of Drought Factor Tables and instructions for the use of the tables are at the end of this appendix.

It is most important to determine a reliable zero point when commencing the drought index readings. In the Copperbelt region the index will be zero during most of January and February although it may start to rise rapidly during February. The record should be brought forward day by day during the dry season.

Use of the Drought Index for Fire Control

The drought index gives a good indication of the fuel available for combustion. As the index rises moisture is lost from deep litter beds and large log material and, eventually, when the index is high enough the moisture content of the living vegetation is significantly reduced until it reaches the wilting point where it wilts and dies.

Since the rate of spread of a fire is directly proportional to the fuel quantity consumed, fires will burn faster and hotter at a high drought index and will be far more difficult to control.

The following table outlines the effects which can be expected at various drought indexes in Australia. There may be some differences in Zambia although the drying of dead fuel is not expected to vary greatly. The droughting of live vegetation depends on other factors such as tree species, soil type, and availability of sub-surface moisture, and can vary greatly even from district to district.

Drought Index	Effect
100	Most fine fuels (less than ¼ inch) readily available. This is generally the upper limit for control burning in Australia.
200-250	Annual grasses become fully cured and dried (Recommended upper limit for control burning in Zambia).
400	Large log material completely dry and there is total consumption of the fuel by fire. Above this value fire control becomes particularly difficult and the worst bush fires have generally occurred.
500	The moisture content of shrubs and perennial understorey vegetation drops rapidly and becomes highly inflammable.
600+	Tree vegetation on shallow soils wilts and dies. Heavy bark shed occurs from smooth bark eucalypts and crown fires develop very rapidly under high burning conditions.

Drought Index curves for the years 1967, 1968 and 1969 are given in Figure A. The curve for 1969 follows very closely the curve drawn using the long term average monthly temperatures starting from the first of April without further significant rain.

During 1968 and 1969, conditions suitable for control burning pines probably existed during February and March.

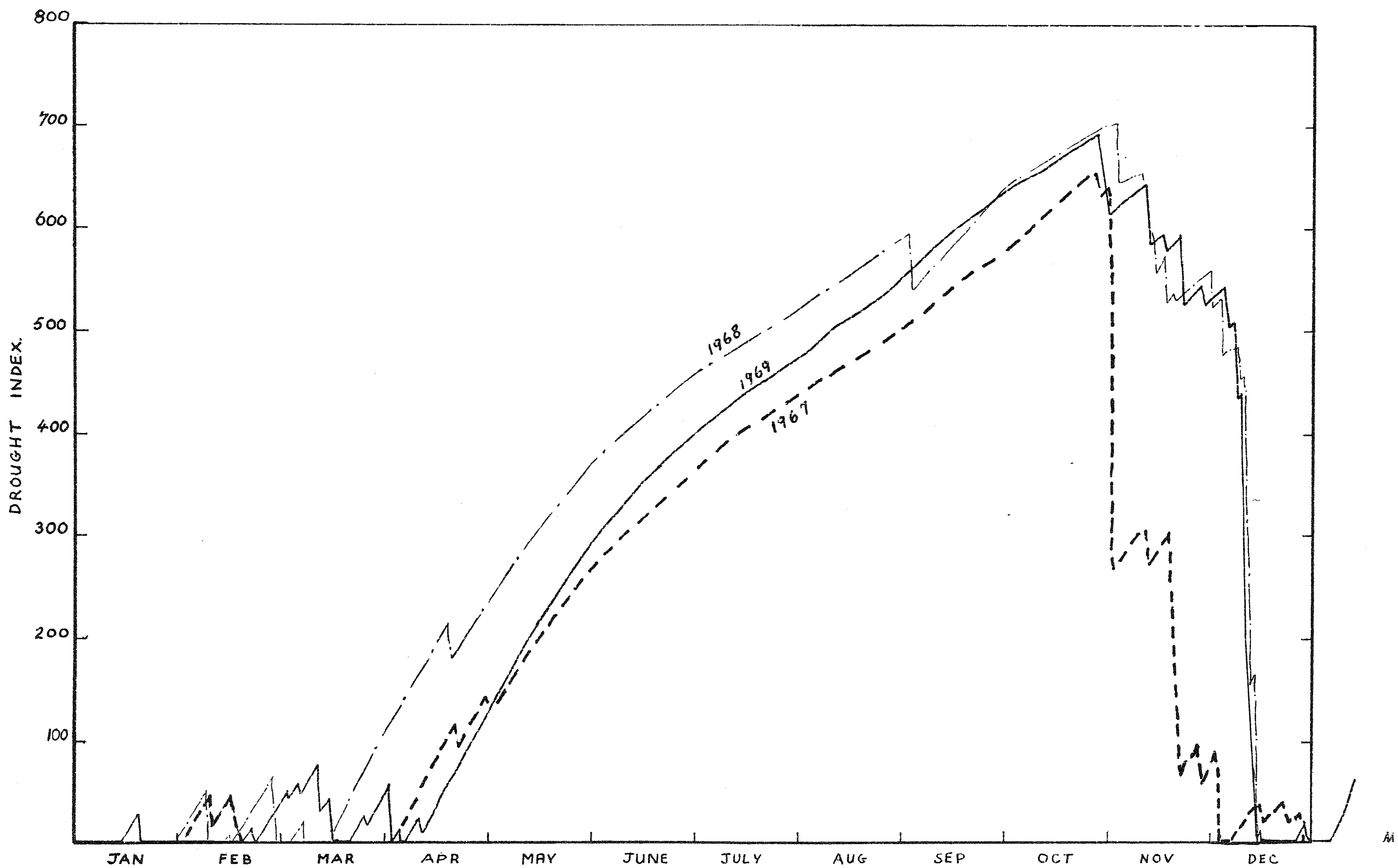


FIGURE A. Drought Index curves 1967-1969 Ndola Airport.

DROUGHT FACTOR TABLE

MAXIMUM TEMPERATURE (°F)	DROUGHT INDEX YESTERDAY (or as reduced by precipitation) [1] 0 to 49	50 to 99	100 to 149	150 to 199	200 to 249	250 to 299	300 to 349	350 to 399	400 to 449	450 to 499	500 to 549	550 to 639	640 to 699	700 to 759	760 to 799	800
	DROUGHT FACTOR															
107+	32	30	28	26	24	22	20	18	16	14	12	8	5	3	1	0
104-106	25	23	22	20	18	17	15	14	12	10	9	6	4	2	1	0
101-103	22	20	19	17	16	15	13	12	10	9	8	6	4	2	1	0
98-100	18	17	16	15	14	12	11	10	9	8	7	5	3	2	1	0
95-97	16	15	14	13	12	11	10	9	8	7	6	4	3	2	1	0
92-94	13	13	12	11	10	9	8	7	6	6	5	3	2	1	1	0
89-91	11	11	10	9	9	8	7	6	6	5	4	3	2	1	1	0
86-88	10	9	8	8	7	7	6	5	5	4	3	3	2	1	0	0
83-85	8	8	7	7	6	6	5	5	4	4	3	2	1	1	0	0
80-82	7	6	6	6	5	5	4	4	3	3	3	2	1	1	0	0
77-79	6	5	5	5	4	4	4	3	3	2	2	2	1	1	0	0
74-76	5	5	4	4	4	3	3	3	2	2	2	1	1	1	0	0
71-73	4	4	4	3	3	3	2	2	2	2	2	1	1	1	0	0
68-70	3	3	3	3	2	2	2	2	2	1	1	1	1	1	0	0
65-67	3	2	2	2	2	2	2	1	1	1	1	1	1	0	0	0
62-64	2	2	2	2	2	1	1	1	1	1	1	1	1	0	0	0
59-61	2	2	1	1	1	1	1	1	1	1	1	1	0	0	0	0
56-58	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0
53-55	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
50-52	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0

1. The Drought Index expresses moisture deficiency in hundredths of an inch. It is reduced one point for each one hundredth inch of rain in excess of .20". Thus a 24 hour precipitation of .52" will reduce the Drought Index by 32 points.

INSTRUCTIONS FOR THE USE OF DROUGHT FACTOR TABLES

The necessary data should be recorded in the following form:

1. Date	2. Max. Temp. (°F)	3. Rainfall to 9 a.m. (Pts)	4. Nett Rain (Pts)	5. Yesterday's Drought Index Corrected to today's nett rainfall	6. Drought Factor today	7. Drought Index today

Column 2. Record maximum air temperature for the day.

Column 3. Record 9 a.m. rainfall in points.

Column 4. Subtract 20 points from the amount entered in Column 3 to obtain the nett rainfall. If rain in Column 3 is 20 points or less record zero (0) rainfall in Column 4.

Exception

If there has been a series of days with little or no drying between showers, subtract 20 points only once on the first day. Thereafter copy all the rain from Column 3 to Column 4.

Consider a wet spell ended on the first day that the rainfall is 10 points or less.

Column 5.

Subtract nett rainfall from yesterday's drought index (Column 7 previous day). If no rainfall has been recorded, yesterday's drought index transfers to Column 5.

Column 6.

Determine the drought factor from the drought factor table, e.g. If the temperature in Column 2 is 87, the drought index in Column 5 is 290, then the drought factor is 7.

Column 7.

Add the drought factor in Column 6 to the drought index in Column 5 to obtain the drought index today.

DROUGHT INDEX   Station....................   Year...........

DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
MONTH............ MAXIMUM TEMPERATURE (°F)																															
RAINFALL																															
NETT RAINFALL																															
YESTERDAY'S DROUGHT INDEX RED.																															
DROUGHT FACTOR																															
TODAY'S DROUGHT INDEX																															
MONTH............ MAXIMUM TEMPERATURE (°F)																															
RAINFALL																															
NETT RAINFALL																															
YESTERDAY'S DROUGHT INDEX RED.																															
DROUGHT FACTOR																															
TODAY'S DROUGHT INDEX																															
MONTH............ MAXIMUM TEMPERATURE (°F)																															
RAINFALL																															
NETT RAINFALL																															
YESTERDAY'S DROUGHT INDEX RED.																															
DROUGHT FACTOR																															
TODAY'S DROUGHT INDEX																															

APPENDIX 4. FIRE REPORT FORM

INDUSTRIAL PLANTATIONS DIVISION

FIRE REPORT FORM

District .... Fire Season ....

Fire No. .... Date. ....

Location of Fire. ....

....

Fire Cause:

Details	Tick appropriate cause			
....	Burning Off	☐	Incendiarism	☐
....	Smokers	☐	Children	☐
....	Mechanical Equipment	☐	Forest Workers	☐
....				
....	Other Known	☐	Unknown	☐

Area Burnt within the Plantations

Species	Acres
Pine	
Eucalypt	
Other	
TOTAL	

MAP

	Scale 1"	= ...	

N ↑

Sketch area of Fire and show following details.

1. Area of fire when first attacked (e.g. ....)
2. Hourly perimeters of fire if known (e.g. —1600—)
3. Final Perimeter (e.g. ▬▬▬
4. Wind direction (indicate with arrow)
5. For large fires attach separate map.

Time Fire Started. .... Time Detected. ....

Time Initial Attack. .... Time Controlled. ....

Finish Mop-up and Patrol:- Date. .... Time. ....

Fire Behaviour

Flame Height........................ Rate of Spread..................

Fuel Type..

....

Means of Control...

....

....

....

Comments...

....

....

.....................................Report by......................

Office Use

Fire Weather

Time	Drought Index	Temp. (^{o}F)	R.H. %	Wind Vel.		F.D.I.	F.D.R.
				Speed m.p.h.	Dir.		

Fire Damage : (See Fire Danger Tables).

Species	Age (Years)	Area damaged (acres)			Loss Value (Kwacha)
		Killed	Not Killed		
			Severe Scorch	Light Scorch	

Total Loss Value K

Cost of Suppression : K..........

Comments:-...

....

....

....

...........................Chief Fire Control Officer..............

APPENDIX 5. APPRAISAL OF FIRE DAMAGE

The appraisal of fire damage is a highly contentious subject and one on which many organisations will not be committed. However, it is considered very necessary to put a monetary figure on fire damage as this can be used as a strong argument for improving the fire protection services for the plantation. A monetary figure is also useful for public relations to impress on people the value of the forests and the necessity to take care with fire.

A simple damage appraisal system is given, based on cost values discounted forward at two interest rates. When market values of the final crop can be assessed a better damage appraisal system can be drawn up.

KILLED TREES

When trees are killed outright the loss can be considered as the cost value of the stand less any salvage values which may be recovered. Using the annual expenditure per acre for pines and eucalypts given in table 1, the value of pine stands from 1 to 30 years of age and eucalypt stands from 1 to 12 years, are given in table 2.

These tables assume that there has been no income from thinnings and so will overestimate the value of any stand which has had any commercial thinnings taken from it. If the value of commercial thinnings are known then the table can be adjusted accordingly.

The table does not include overhead expenses which can be included or omitted as desired.

SEVERELY SCORCHED TREES

Trees in this category can be considered as losing 2 years increment. One way of valuing this damage would be to say that the stand would have to wait an extra two years to reach its rotation size. This would cost an extra 100 Kwacha per acre, for a *P. kesiya* plantation with a 30 year rotation and costed at an interest rate of 6¼%.

Obviously, in practice the rotation age would not be extended and the difference between the market value of the burnt and unburnt stand at rotation age would be the damage value. As this is likely to be small a nominal value of K10 per acre could be given to stands in this category.

This figure would apply to *P. kesiya* and *E. cloeziana* stands. *E. grandis* which can suffer severe stem degrade when only lightly burnt would sustain much greater damage. The value of this damage can only be assessed by a milling study.

LIGHTLY SCORCHED TREES

P. kesiya and *E. cloeziana* would not suffer any degrade or loss of increment. *E. grandis* would probably suffer some degrade but the damage rate will have to be determined.

Obviously there are many ways to assess the value of a standing crop before it can be marketed and an economist would probably require a cost benefit analysis before deciding on a system. However, what is important is that a figure is put on fire damage and can be quoted when fire statistics are required for publicity or for fire control planning.

TABLE 1.

INDUSTRIAL PLANTATIONS.
ANNUAL EXPENDITURE PER ACRE.

YEAR	PINES		EUCALYPTS	
	Exp. (K.)	Remarks	Exp.(K.)	Remarks
0	50.0	Land clearing to ploughing	50.0	Land clearing to ploughing.
	0.8	Discing	0.8	Discing
	15.2	Nursery	4.2	Nursery
	3.9	Planting @ 10'x10'	3.3	Planting @ 12'x12'
	0.3	Blanking	4.9	Fertilizer (Borate)
			0.3	Blanking
1	0.3	Beating up	12.5	Weeding 8 times
	12.1	Weeding 8 times	0.1	Clearing
2	8.2	Weeding 6 times	6.4	Weeding 7 times
	0.1	Clearing	1.4	Pruning to 10'
3	4.8	Weeding 4 times	1.7	Marking and thinning (uncommercial)
			1.6	Maintenance and Fire Control
4	0.2	Weeding	2.5	Pruning to 20'
	1.6	Maintenance and fire control	1.6	Maintenance and Fire Control
5	2.5	Pruning to 7'	3.8	2nd thinning (returns unknown)
	1.6	Maintenance and fire control	1.6	Maintenance and fire control
6	1.6	Maintenance and fire control	1.6	Maintenance and fire control
	2.8	1st thinning (uncommercial)		
7	1.6	Maintenance and fire control	10.0	3rd thinning (returns unknown)
			1.6	Maintenance and fire control
8	2.2	Pruning to 12'	1.6	Maintenance and fire control. Clear falling between 8 and 12 years returns not known
	2.1	2nd thinning (uncommercial)		
	1.6	Maintenance and fire control		
9	1.4	Pruning to 18'		
	1.6	Maintenance and fire control		

10-11	1.6	Maintenance and fire control
12	5.1 1.6	Third thinning (uncommercial) Maintenance and fire control.
13-30	1.6	Annual expenditure for maintenance and fire control

Proposed clear felling of pines at age 30 years but returns are not known.

TABLE 11.

INDUSTRIAL PLANTATIONS FIRE DAMAGE TABLE

Value of *P. kesiya* and *E. grandis/E. cloeziana* in Kwacha per acre based on costs compounded at interest rates of 5% and 6¼%.

	P. kesiya		Eucalypts	
AGE	Value @ 5% (K)	Value @ 6¼% (K)	Value @ 5% (K)	Value @ 6¼% (K)
1	74	75	67	67
2	90	92	83	85
3	104	107	95	99
4	114	118	104	108
5	121	128	113	119
6	132	140	125	133
7	143	154	133	143
8	152	165	151	164
9	166	182	160	176
10	177	196	170	189
11	187	210	180	202
12	198	225	191	216
13	215	246	202	231
14	228	264		
15	241	282		
16	255	301		
17	269	321		
18	284	343		
19	300	367		
20	317	391		
21	335	417		
22	353	445		
23	372	475		
24	393	505		
25	414	539		
26	436	575		
27	460	612		
28	485	652		
29	510	694		
30	538	739		

\- Does not include any returns from thinning

Overhead expenses are not included. As a rough guide 50% of each figure could be added to the value per acre for any particular year to account for overheads.