Prescribed Burning under Pinus caribaea

for Wildfire Hazard Reduction

A joint research project between the

Centro Agronómico Tropical de Investigación y Enseñanza

TROPICAL AGRICULTURAL RESEARCH AND TRAINING CENTER

and the

BELIZE FOREST DEPARTMENT

Trial Establishment -1976

CONTENTS

TABLES

MAPS

1. Map of Belize indicating location of M.P.R.
2. Map of M.P.R. indicating location of replicates.

PHOTOGRAPHS

1. An indication of the height of fern (*Dicranopteris pectinata*) in plot D3 before burning. (Fireline visible close to live fern)
2. *Bulbostylis paradoxa* flowering within two days of burning
3. Plot A6 prior to burning
4. Plot A6 after burning
5. Plot A15 prior to burning
6. Plot A15 after burning
7. Plot C10 prior to burning
8. Plot C10 after burning
9. Plot A24 prior to burning
10. Plot A24 after burning

APPENDICES

I. Location Maps of the Four Replicates

II. Basal Area and Stocking of Pine

III. Basal Area and Stocking of Hardwood Species

IV. Ground Cover

V. Meteorological Observations for Bent Pine and Augustine March - May 1976

VI. Meteorological Observations during each burn.

VII. Rates of Spread and Fire Intensities

VIII. Forest floor fuel weights before and after burning and percentage fuel reduction

IX. Scorch data summary

X. Personnel involved

Introduction

This report outlines the progress made in the first year of the joint research project between the Tropical Agricultural Research and Training Center (CATIE) of Costa Rica and the Forest Department of Belize (BFD) to study the use of prescribed burning for wildfire hazard reduction in the Mountain Pine Ridge Forest Reserve (MPR)of Belize.

The background to the problem faced and the objectives of the project are recorded in the document "Proposal for a joint research project between the Tropical Agricultural Research and Training Center and the Belize Forest Department". However, in summary, the problem is that after many years of fire protection, fuels have accumulated to the point where they support wildfires of great intensity which are very difficult to suppress and which cause severe damage. It is the purpose of this project to assess the use of prescribed burning to maintain low fuel levels whilst causing minimal damage to the pine crop and thus prevent the occurrance of disastrous wildfires.

This report describes the establishment of the trial and the results of the initial fuel reduction burns carried out in March to May 1976.

The Project Area

The MPR Forest Reserve is an upland pine savanna of some 560 km^2., completely encompassed by broadleaved forest in the SW of Belize.(See Map 1)

The area experiences a marked dry season from February to May which in exceptional years is prolonged to as late as August. The wet season is introduced by hot sultry weather with numerous dry electrical storms. Such storms may pass over the area for a month prior to the commencement of heavy rains and present a severe fire risk. A brief summary of meteorological observations within the reserve, recorded at two elevations, which serves to indicate the range of conditions within the Reserve, is given in Table 1 below.

Table 1. Summary of Meteorological Observations

Recording station	ELEVATION m.a.m.s.l.	Mean Ann. Rainfall mm	Mean Ann. Max. Temp. °C	Mean Ann. Min.Temp °C
Augustine	500	1631	29	19
Cooma	900	2101	24	18

Source for Table 1 - BFD. Augustine 1951-1970 Cooma 1962-1970

The reserve forms part of the dominant topographical feature of Belize, the Maya Mountains which rise to 1100 m.a.m.s.l. The central and southern area of the Reserve, where forest management began some thirty years ago and within which the present project is located, consists of a granite plateau of mean elevation of 500m. To the west and north karstic limestone, which previously covered the central plateau, remains and supports broadleaved vegetation. To the east steeply folded metamorphosed sediments present a rugged and spectacular landscape. (Johnson and Chaffey, 1973).

The soils of the region have been studied by several authors (Birchall 1973, Charter1941, Furley 1968, Romney 1959). Those of the central plateau, of granitic origin are acidic and highly infertile. According to Birchall (1973) water retention of the top soil is low and the subsoil is generally impermeable so that the vegetation which is supported experiences drought for a large part of the year.

The principal vegetation type of the area, found on the non-calcareous parts of the Reserve, and to which management activities have been directed in recent years is known as "Pine Ridge". This vegetation has been classified by several writers (Bartlett 1935, Hunt 1970, Lundell 1940, Romney et al 1959) and a summary of these classifications appears in "A Forest Inventory of Part of the Mountain Pine Ridge" (Johnson and Chaffey, 1973) Hunt (1970) describes three vegetation types within the MPR pine forest and marginal vegetation. The first type, savanna, is the most extensive and it is within this vegetation type that the present study is located.

Experimental Design

A randomised block design with four replicates of twenty factorial treatments (5 burning cycles x 2 burning seasons x 2 burning intensities) and 5 check plots was established in March 1976. In May 1976 all 100 plots received initial fuel recuction burns and in subsequent years plots will be treated as programmed in the schedule below.

Table 2. Schedule of Treatments

	Plot N°																								
	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
1	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2						x	x	x	x																
3						x	x	x	x	x	x	x	x												
4						x	x	x	x					x	x	x	x								
5						x	x	x	x	x	x	x	x					x	x	x	x				
6						x	x	x	x													x	x	x	x
7						x	x	x	x	x	x	x	x	x	x	x	x								
8						x	x	x	x																
9						x	x	x	x	x	x	x	x												
10						x	x	x	x					x	x	x	x								

Plot N°									
1- 5	Check plots								
6- 9	1 year cycle	6	S/H	7	S/B	8	W/H	9	W/B
10- 13	2 year cycle	10	"	11	"	12	"	13	"
14- 17	3 year cycle	14	"	15	"	16	"	17	"
18- 21	4 year cycle	18	"	19	"	20	"	21	"
22- 25	5 year cycle	22	"	23	"	24	"	25	"

S/H = Summer Headfire S/B = Summer Backfire

W/H = Winter Headfire W/B = Winter Backfire

Check plots will remain untreated after the initial burn to permit study of undisturbed patterns of fuel accumulation.

Site description

Location

Four areas were chosen for the location of replicates in the south west of the Mountain Pine Ridge on the basis of stand and fuel characteristics which were considered representative of the fuel management problem in the area as a whole. (See map 2)

Twenty five 0.1 ha. plots (40m x 25m, long axis N/S) were demarkated per replicate and stand inventories and percentage cover assessments carried out for each plot.

The areas chosen for replication are as follow:

A. On both sides of the A10 Road between Mahogany Creek and the Brunton Trail Junction at an elevation of 500 m. a.m.s.l. This site, as indeed the other three, can be considered to have been under effective fire protection for 20 years. There are no records of wildfire occurrence in this particular area which was thinned in 1964. (See appendix I for maps of the 4 replicates)

B. On both sides of Castillo Road at an elevation of 500 m. Records indicate a wildfire occurrence in 1972. Some basal charring is evident but crowns are full and healthy. The area was thinned in 1973.

C. On both sides of Bailarina Road at an elevation of 570 m. There are no records of fire occurrence in this area which was thinned in 1973.

D. On both sides of Bailarina Road, to the east of Espat Road Junction at an elevation of 600 m. Again there are no records of wildfire occurrence and the area was thinned in 1973.

Stand Data

Diameter at Breast Height (DBH) of all stems of Pinus caribaea taller than 2m and DBH of all hardwood species of diameter greater than 2 cm were recorded and are summarised below.

Pinus caribaea Morelet

Table 3 Basal Area and Stocking of pine

Replicate	Mean Stocking Stems/ha.	Range of Stocking Stems/ha.	Mean B.A. m^2/ha.	Range B.A. m^2/ha.
A	924	1550-350	16.487	21.507-10.514
B	470	690-290	7.627	11.140- 4.759
C	647	1130-310	11.341	21.217 - 7.051
D	628	1210-360	13.910	19.880- 9.349

A few stems of Pinus oocarpa Schiede var. ochoternai were identified in the "D" plots. However, as no more than two stems per plot were found they have been included here as Pinus caribaea.

Basal area and stocking of pine for each plot is given in Appendix II.

On the basis of the mean diameter class for all plots five trees in the 10.1-15.0cm class and 5 trees in the 15.1-20.0cm class were selected for height measurement to the nearest 0.5 m. The ten trees selected per plot were those nearest the plot center.

Hardwood Species

Table 4. Basal Area and Stocking of Hardwood Species.

Replicate	Mean Stocking Stems/ha.	Range of Stockings Stems/ha.	Means B.A. m^2/ha.	Range of B.A. m^2/ha.	% of total Plot Basal Area. Mean	% of total Plot Basal Area. Range
A	516	1270-130	2.084	5042-461	11	27-2
B	154	670-0	.566	2385-0	6	22-0
C	40	140-0	.089	325 0	1	3-0
D	5	40-0	.038	367-0	1	2-0

Table 5. Distribution and Composition of Hardwood Species

Replicate	Frequency of occurrence of Hardwood Species %				% of basal area of all Hardwood Species			
	A	B	C	D	A	B	C	D
A	96	92	64	64	33	48	7	12
B	72	68	52	24	23	59	12	6
C	24	4	64	12	13	1	78	8
D	16	12	12	0	19	23	58	0

N.B. A= *Byrsonima crassifolia* B = *Quercus* spp. C = *Clethera hondurensis*

D = Others

Other hardwood species encountered, of greater diameter than 2 cm included: Acoelorraphe wrightii, Calophyllum brasiliense, Cecropia peltata, Heliocarpus mexicanus, Inga lindeniana, Myrica cerifera and Xylopia frutescens. Basal area and stockung of hadwood species for each plot is given in Appendix III.

Ground cover

Percentage ground cover was subjectively assessed on a 10% scale by means of five, 5 m^2 circular samples per plot, located at plot centers and midway between plot centers and plot corners. Ten cover types were included and a summary of the percentage cover and frequency of each type is summarised below by replicate. (A summary by plots is given in Appendix IV).

Of the four sites A and D represent extremes. Site A, nearest the periphery of the savanna vegetation - closest to the hardwood forest on limestone derived soils and presumably less affected by fire than the other sites -- supports a good stocking of pine with a vigorous understory of hardwood species. Ground cover was a composite of live and dead graminoid vegetation and hardwood and pine litter. Site D supports a lower stocking of often quite large pine with virtually no hardwood species and a more homogeneous ground cover of predominately gaminoid vegetation with pine litter and some patches of fern. (Dicranopteris pectinata).

Pine regeneration counts made at the time of cover assessments within the circular samples showed no significant differences between sites. Although no account of the density of seed producing trees was taken in was noticeable that the highest densities of regeneration recorded, of seedlings one meter or less in height, of 10,400 per ha on plot B5 and 15,000/ha on B19 were found on plots with light ground cover and high light levels reaching the forest floor. Plots B5 and B19, with 7034 and 7808 kg per ha of oven dry forest floor fuel weight respectively, were both burnt in 1972.

Methods and Results

Burning Procedures

The 1976 dry season in the MPR was unusually severe. Only .25 mm of rain was recorded at the Bent Pine Station in the months of March and April and nothing at all at Augustine and Cooma. Rain began, however, on May 1st and after three days of rain during which 62 mm fell, the decision to begin burning was made. (A summary of Met. observations for the period March to May is given in Appendix V). Burning began on May 4 and was completed by 26 May after 12 burning days.

A backfire technique was used on all occasions after direction of spread had been confirmed by igniting and extinguishing a small test fire and when wind direction and velocity were considered stable. Ambient temperature, relative humidity and wind direction were recorded during each burn. Wind velocity was not recorded for all burns as the anemometer broke beyond local repair.

A mobile fire-tender and crew of 4 men were stationed at the site of each burn as a precaution against the fire spreading beyond the confines of the plot which had been secured by ploughed firelines. The same crew extinghished all burning embers before the site was abandoned.

Burning was carried out at various times of the day with individual fires being started as early as 0546 hours and as late as 1402 hours. Ambient temperatures during the burning period ranged from 22.5 to 35° C, relative humidity from 88-48% and wind velocity from gusts of 6.0 m per sec. to negligible. A summary of meteorological conditions during

Cover Type	Replicate							
	A		B		C		D	
	% Frequency	Mean % Cover	% Frequency	Mean % Cover	% Frequency	Mean % Cover	% Frequency	Mean % Cover
Live Graminoid Vegetation	100	28.8	100	36.1	100	32.7	100	28.0
Hardwood Veg.	100	17.6	100	16.0	100	6.1	100	6.6
Pine Veg.	100	2.8	60	1.0	84	1.9	88	1.5
Fern. Veg.	16	.6	12	1.0	44	1.0	48	3.6
Dead Graminoid Vegetation	100	8.7	100	12.7	100	31.6	100	27.5
Hardwood Litter	100	15.2	96	8.4	84	2.7	80	3.2
Pine Litter	100	26.0	100	13.3	100	19.3	100	24.7
Exposed Soil	72	1.4	92	5.1	72	1.6	60	1.3
Rock	8	.2	24	.7	12	.2	16	.2
Wood	96	2.6	92	5.1	100	6.2	100	5.0

each burn is given in Appendix VI.

Wind dirction in the MPR during the transition period from dry season to wet season is generally less consistent than at other times of the year, and inconsistency increases as the day progresses from late morning to late afternoon. During the burnings in May, although wind direction was predominately from NE to E, of the 100 fires intended to burn slowly into the wind part of the burns became fast moving headfires because of changes in wind direction.

These headfires produced greater scorching of pine foliage than backfires but no actual consumption. Depth of convective activity was shallow in all but the must intense fires. Crowing occured very infrequently in small, isolated patches of Palmetto palms (*Acoelorraphe wrightii*) when ladders of dried leaves still attached to the stem, carried flames upwards.

Backfires were characterised by low flame heights in the range of 2o-25 cm with a maximum of about 1 m and narrow burning zones of 15-50 cm. Flame heights were lower and burning zones narrower in pine and hardwood litter fuels than in grass fuels. Flame heights were much higher in head fires and a maximum of 4 cm was observed in the B3 plot burn.

Rates of spread, which are summarised in Appendix VII, ranged from .29 m per minute (.17 km/hr) for the slowest backfire to 3.3 m per minute (.198km/hr) for the fastest, unintentional, head fire. Rate of spread was significantly correlated with moisture content of the profile of the forest floor fuel but no correlation, as found elsewhere (Mc Arthur 1962) was established with wind velocity. Highest rates of spread were recorded in predominately grass and fern fuels. (Photo N° 1 shows height of fern burnt in plot D3). Slower rates of spread were observed in compact pine litter fuels and the slowest in hardwood litter. Under small patches of hardwood species where all vegetation had been suppressed and the forest floor fuel was composed only of a thin layer of hardwood litter firewould often not sustain itself.

It was readily apparent that the most important fuel component, the grass and sedges, were highly responsive to changes in meteorological conditions. Difficulty was experienced in igniting plots in the early morning (before 0700 hours) when fuel moisture content was greater than 25% due to dew fall, yet fires of unacceptably high intensity such as B3 occurred within 30 hours of four rainy days during which 66mm of rain fell, by which time fuel moisture content had fallen to 10.7%. Indeed on one occasion light drizzle in the middle of a burn reduced the rate of spread from .77 m per min. to .38 m per min. but failed to extinguish the fire before it reached the plot perimeter.

The fire intensity of each burn was calculated, after Byram (1959) from the product of the heat yield, the fuel consumed and the rate of spread.

$I = HWR$

I = Fire Intensity (Btu per sec per foot of fire front or Kilojoules/sec/M)

H = Heat Yield (Btu per pound of fuel or KJ/Kg.)

W = Weight of fuel consumed (pounds per square foot or Kg/m^2)

R = Rate of spread (Feet per second or m/sec.)

Using Byran's heat yield value of 15087 KJ/Kg (6500 Btu/lb) for forest fuels of low moisture content the range of fire intensities varied from 220685 KJ/sec/m (6-198 Btu/sec/ft). Byram states that the range of intensities to be expected from backfires probably ranges from 19-58 Btu/sec/ft (65-198 KJ/sec/m). If those burns, part of which developed into headfires, are excluded from consideration, 84% of the estimated fire intensities experienced during this study fell within this range: 14% were lower and 12% higher.

A significant correlation was established between fire intensity and moisture content of the profile of the forest floor fuel. (Appendix VIIgives Fire Intensities for each burn).

Fuel Reduction

Forest Floor Fuels

Forest floor fuel weights were determined from 10 randomly located 0.1 m^2 (40cm x 25 cm) samples per plot. All organic matter less than 0.5 cm in diameter, within an open-ended quadrat, between mineral soil and the boundary between the forest floor and the shrub layer if present, was collected, stored in sealed polythene bags and weighed. No attempt was made to classify this fuel layer in terms of live or dead material or to describe it quantitatively in terms of it's constituents of grasses, sedges, fern and pine and hardwood litter, etc.

A composite sample was taken from the 10 weight samples and oven dried for moisture content determination.

Due to the irregular spatial distribution of fuels, high sampling errors of 15- 23% were recorded at this low sampling intensitiy. In subsequent seasons when less plots will be treated, the work load lower and more precision required to determine if differences exist between treatments, the sampling intensity will be raised to achieve a sampling error of less than 10%.

The procedure outlined above was repeated after burning to determine the weight of fuel consumed by the fire. (Forest floor fuel weights before and after burning and percentage fuel reductions are given in

Appendix VIII).

Shrub layer fuels

An attempt was made to determine the weight of fuel in the shrub layer. This fuel component was absent in some plots and distributed irregularly in the others. The melastome Miconia albicans was the most conspicuous component of the shrub layer which also included other melastomes, pine regeneration and species present in the tree layer.

All leaves and twigs of diameter less than 0.5 cm within an open-ended quadrat of 0.1 m^2, between the forest floor/shrub layer boundary and 2 m above ground level were cut with scissors, stored in sealed polythene bags and weighed. This procedure was repeated at the same intensity of 10 samples per plot with 1.0 m^2 quadrats. Both procedures, however, gave high sampling errors and in some cases because of the insensitivity of the sampling procedure estimated fuel weights were higher after burning than before. Post burn surveys revealed that very little of the shrub layer was actually consumed and shrub layer fuel weight estimates were therefore excluded from consideration.
In the 1977 season a more elaborate double sampling technique will be assessed.

Forest floor fuel weights prior to burning were found to range from 25.722 kg per ha of oven dry fuel to 6212 kg per ha. The heaviest fuel accumulation was found on plot D3 and was largely composed of fern with a deep layer (up to 25 cm) of slowly decomposing fern and pine litter beneath it. The lowest fuel level, on B23 was composed of a fairly homogeneous layer of grasses and sedges with virtually no litter layer. In general the highest fuel levels were found on the D and C plots (means of 14981 and 12972 kg/ha respectively and thelowest on the B and A plots (means of 8526 and 10614 kg/ha repectively). Black and white photographs were taken before and after burning of approximately half of the plots and those of plots A6, A15, C10 and A24 are included in this report.

Burning under the variety of conditions mentioned earlier resulted in fuel reduction of from 15.5% (1400 kg/ha consumed) to 92.3% (21.995 kg/ha consumed). Of the 100 burns 54% resulted in moderate fuel reductions (60 - 85%), 24% in low fuel reductions (60%) and 22% in high fuel reductions (85%).

A significant negative correlation was established between percentage fuel reduction and moisture content through the profile of the forest floor as expected. As earlier mentioned poor fuel consumption was experienced in the early morning burns. When fuel moisture was high a protective mantle of litter and the lower parts of grass bunches was invariably left. The more intense fires in predominately grass fuels however left virtually no protection of the soil surface.

Shrub fuels were rarely consumed but generally severely scorched to the 1.5 - 2.0 m level. Individual specimens of Quercus oleoides and Myrica cerifera, however, if sufficiently pre-heated emitted volatile gases which ignited in a brief flash and consumed a large proportion of the lower leaves but very few twigs. The sparcity of grass fuels under the intense shade of small groups of hardwood shrubs did not permit the entry of fire and the shrubs remained undamaged.

Response to fire damage was rapid. The sedge, Bulbostylis paradoxa, noted by Hunt (1970) as flowering within 36 hours of the passage of fire, was observed in flower two days after burning. (See photo N^{o} 2) Craboo (Byrsonima crassifolia)and oak (Quercus spp.) exhibited development of secondary buds on damaged branches and vigorous basal sprouting within 10 days of burning.

In all plots but particularly in the B and C plots additional fuel was present in the form of logs and branches as a result of thinning and mortality. Although the weight of these heavy log fuels added indirectly to fire intensity their contribution has not been considered here. Those logs which did ignite and were smouldering after the passage of the fire front were extinguished with water.

Effect upon pine overstory

Several days after burning, when scorched pine foliage was a clearly visible orange, the degree of scorch damage was assessed. The number of scorched trees taller than 2 m was counted, the maximum scorch height in the plot measured and the height of the mean scorch line assessed. In addition the scorch heights of the ten trees per plot selected for height measurement were measured and the percentage of crown volume scorched assessed and placed into one of four classes (5-15, 25-40, 55-70, 85-100%).

Maximum scorch heights were generally associated with localised heavy fuel levels, crowning of palmettos or brief wind changes and the mean scorch height was considered a more effective measure of scorch height throughout the plot. (Scorch data is summarised in Appendix IX).

If the product of mean scorch height in meters and the number of trees scorched as a percentage of total stocking is used as an index of scorch severity, a wide range of values from 0-1131 in found. Four categories of scorch severity were distinguished after a survey of the plots, nil and negligible, low, moderate and high. A summary of the occurrence of each category is given below.

Table 7. Scorch Severity

Scorch Category	Scorch Severity Product of mean scorch ht (m) X scorched trees as % of total stocking	N° of plots per Category
1. Negligible	0 - 40	31
2. Low	41 -100	23
3. Moderate	101- 200	24
4. High	200	22

Categories 1, 2 and 3 were considered acceptable for an initial fuel reduction burn. 22% of all burns thus caused unacceptable scorch.

Scorch severity was strongly correlated with fire intensity.

Mortality is expected to be very low and restricted to pines under 3m. Cambium damage was not assessed but it is expected that any mortality which will become evident from next year's inventories will be due to complete crown scorching. Many small saplings and seedlings will however survive. It appears that if excessive preheating is avoided by employing controlled low intensity backfires the sheath of needles around the apical bud provides adequate protection.

Some of the A plots contained one or two pine trees being tapped for oleo-resin. Prior to burning the fuel was raked away from the base of the trees to a distance of about 50 cm. One resin tree was left untouched. None of the protected trees were damaged during the burning but the resin face of the unprotected tree ignited easily and burnt fiercely until extinguished.

Discussion and Conclusions

Fire is anathema in the Mountain Pine Ridge and every effort in the past has gone into excluding it. The prospect of deliberately started fires soon after the end of the dry season was thus viewed with some unease. It was feared that fires would escape and cause serious damage. This did not happen and perhaps the most important result of the first year of this trial has been psychological. It has been shown that fire can be used as a tool and controlled, as it has been elsewhere, and a greater willingness to look at the fire management problem afresh is evident.

There are two sets of conditions which are of interest when planning prescribed burning for hazard reduction; a lower set of conditions below which fuel consumption is unsatisfactory and the area retains the ability to sustain high intensity wildfires during the height of the dry season and an upper set of conditions above which excessive damage is caused to the overstory and undesirable environmental effects may be caused.

The factors which make up these sets of conditions are the quantity, type and distribution of fuel, temperature, relative humidity, wind velocity and fuel moisture content as influenced by prevailing atmospheric conditions and the recent history of precipitation and dew-fall.

Conditions experienced during the course of the initial fuel reduction burns of this trial gave a spectrum of results beyond and between both extremes.

It was apparent that early morning burns, ignited before the dew had started to lift resulted in poor fuel reduction. It appears that some two hours of daylight are needed before good fuel reduction is achieved. Precipitation over the few days preceding burning after a long dry period did nor prevent satisfactory fuel reduction when the site was exposed to the sun and drying winds for only a few hours. After a period of rain, burning may be extended for most of the day without undue risk of damage to the overstory.

In the period May to June wind direction becomes more unstable and limits the ability to set controlled backfires. Wind instability increases as the day progresses and is most pronounced between 1100 and 1600 hours, at which time temperatures are also at a maximum. Burning between these hours,after an uninterrupted dry spell in May or June of as short as two days, depending upon the nature and amount of fuel and the height of the pine, will often have undesirable results. Burning at this period should therefore be carried out between 0700 hours if no rainfall has been recorded for two days. It may also be continued from around 1500 hours on into the night when logistical problems are however of course increased.

Fuel moisture content of the profile through the forest floor fuel, which is a function of long term drying after rain, was demonstrated to be related to fire intensity and fuel consumption. The desired moisture content of the profile of the forest floor fuel would appear to be 10-25%. No relationship was established between ambient tempreature and fire intensity or scorch severity but in view of the fact that the higher the ambient temperature the lower is the heat input necessary to raise plant tissue to lethal temperatures (see Mathven 1971) ambient temperatures below 30°C are recommended.

Fuel moisture content of the surface litter is primarily determined by ambient temperature and relative humidity. No assessment was made of this moisture content during this study but as it is one of the fundamental factors governing fire behaviour it will be investigated in subsequent seasons. Satisfactory results were achieved with relative humidities in the range of 50-70%.

Rate of spread is a highly important fire behaviour variable which determines costs of burning in addition to intensity. McArthur (1963) demonstrated that rate of spread is directly proportional to fuel quantity and wind velocity. Wolffsohn (1974) considers wind velocity the most important factor to be taken into account when prescribed burning and a moderate wind, 1.7-4.5 m/s (6-16 km/hr) is generally recommended to disperse smoke and prevent heat rising to tree crowns . Gusts of wind up to 6.0 m/s (22 km/hr) were experienced in this trial and considered quite acceptable if against the direction of fire spread. The subject of rate of spread, wind velocity and it's effect upon burning times and costs will receive further study from 1977 onwards when both backfires and headfires will be assessed.

The range of fire intensities within which objectives were achieved was 50-200 kj/sec/m (14-58 Btu/sec/ft). Intensities greater than 200 Kj/sec/m should be avoided when the objective is wildfire hazard reduction under mid-rotation age <u>Pinus caribaea</u>. Younger stads will require lower intensity fires and fuels should be gradually reduced in two or more seasons. The height of pine overstory at which prescribed burning may begin is dependent upon the degree of scorch which can be tolerated. Prescribed burning should begin sooner and a greater degree of scorch damage can be accepted where the risk of wildfires is high. Wolffsohn (1974) suggests that burning, with low intensity fires, can begin at the height of 4 m (5-12 years after seed fall on most savanna sites) and Hancock (1975) considers that 7 year old regeneration can with stand light fires. An unpublished report by INFONAC personnel in Nicaragua (Reporte de Fuego Controlado 4/4/76) comparing the effect of prescribed burning on height and diameter increment of pine regeneration of different heights indicated that regeneration less than 3 m was severely damaged but that regeneration in the 3.0 - 4.5 m class, although severely scorched recovered by the fourth year to show increment similar to the control. Regeneration taller than 4.5 m was less severely damaged and recovered quicker. It is apparent that the decision whether to begin burning when the crop reaches 4, 6, 8 or 10 m can only be made after assessment of fire risk and the rate of fuel accumulation in the area under consideration.

Fire intensities must be low, however, with a ceiling perhaps of 100 KJ/sec/m. (29 Btu/sec/ft).

From a knowledge of the critical fire intensity and an idea of rates of spread likely to occur under dry season conditions, maximum fuel loadings which can be tolerated before a subsequent burn is prescribed may be suggested. Further results of this trial will indicate rates of fuel accumulation and refine acceptable fire intensity limits but at this stage it would appear that fine fuels should be reduced to around 3000 kg/ha and that a repeat burn should be prescribed when fuel loadings reach about 8000 kg/ha. The burning cycle to achieve is likely to be less than four years.

Summary

This report covers the establishment and initial fuel reduction phase of a trial to evaluate the use of prescribed burning for wildfire hazard reduction under Pinus caribaea. The trial which is long term will look for suitable combination of frequencies, seasons and

intensities of burning which, with minimum damage to the pine crop, will maintain fuels at levels unable to sustain wildfires of great intensity.

The objective of the first phase of the trial was not only to yield useful information on the behaviour and effects of fire under Pinus caribaea but to establish suitable working methods. Experience has indicated that:

a. a more sensitive sampling system is required to fully evaluate the role of hardwood vegetation in fire behaviour.

b. wind velocity, rate of spread relationship should be examined more closely.

c. moisture content of different layers of the forest floor fuel should be determined to predict more accurately fire behaviour and retention of protective lower litter layers.

Observation of fire behaviour and fire effects permit the following preliminary suggestion to be made for prescribed burning practice for hazard reduction in the summer (end of dry season) period:

a. Begin burning when dew has lifted after 2 hours of day light.

b. Do not burn if wind direction is variable.

c. Burn when moisture content of the profile through the forest floor is between 10-25%, ambient temperature less than 30°C and relative humidity 50-70%.

d. If rain has not fallen for 2 days stop burning around 1100 hours and begin again around 1600 hours.

REFERENCES

1. BARRLETT, H.H. 1935. A method of procedure for field work in tropical American phytogeography based upon a botanical reconnaissance in parts of British Honduras and the Peten Forests of Guatemala. Publs. Carnegie Instr. N° 461,1-25

2. BIRCHALL, C.J. 1973. (Appears in the report by Johnson and Chaffey referred to below).

3. CHARTER, C.F. 1941. A reconnaissance survey of the soils of British Honduras north of the central metamorphic and igneous massif with special reference to their utilization in agriculture. Port of Spain: Government Printer.

4. FURLEY, P.A. (ed). 1968. General report of the expedition to British Honduras - Yucatan 1966. University of Edinburgh.

5. HANCOCK, M.J.D. 1975.Plan de ordenacion: Capítulos Protección Forestal y caminos. Distrito Forestal Demostrativo de Jutiapa D.F.D. Documento de Trabajo N° 6. Proyecto de Desarrollo Forestal HON-71-511 (FAO)

6. HUNT, D.R. 1970. Some observations on the Pine savannas of British Honduras. Internal Report R. Bot. Gdns., Kew.

7. JOHNSON, M.S. and CHAFFEY. D.R. 1973. A Forest Inventory of Part of the Mountain Pine Ridge, Belize. Land Resource Study N° 13 . Land Resources Division, England.

8. LUNDELL, C.L. 1940. Botany of the Maya area: Miscellaneous papers XVI the 1936 Michigan - Carnegie botanical expedition to British Honduras. Publs. Carnegie Instr. N° 522-1-57.

9. METHVEN, I.R. 1971. Prescribed fires, Crown Scorch and Mortality: Field and Laboratory Studies on Red and White Pine: Information Report PS-X-31 Petawawa For. Exp Sta., CAN.FOR.SER.

10. McARTHUR, A.G. 1961. Fire danger rating table, for annual grass-lands. Annual Report 1960- Forestry and Timber Bureau.

11. _________. Revised Forest Fire danger tables. Annual Report 1962- Forestry and Timber Bureau. (See Fire in Tropical Forests and Grasslands (1966) by Batchelder, R.B. and H.F. Hirt).

12. ROMNEY, D.M. *et al*. 1959. Land use in British Honduras. London : HMSO.

13. WALKER, S.M. 1972. Summary of climatic data for British Honduras. Suppl. Rep. Land Resour. Div. O.D.M. N° 3.

14. WOLFFSOHN, A.L.A. 1974. Silvicultura - Ensayos y Entrenamiento: Investigación sobre el fomento de la producción de los bosques del noreste de Nicaragua. Informe técnico N° 6 FO:SF/NIC O.