FIRE SPREAD AROUND A FOREST CLEARING SITE IN THE BRAZILIAN AMAZON REGION

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1. INTRODUCTION

This paper describes the characteristics of fire spread around a forest clearing site located in the Amazonian arc of deforestation. The experiment was carried out in 2001 at the Caiabi Farm, near the town of Alta Floresta, state of Mato Grosso, Brazil, in the Amazon Arc of Deforestation as part of a set of tests that have been performed in the same area since 1997. So far, six test plots were burned. The main goal in the experiments of the first five plots was to determine biomass fire consumption and carbon release rates under different conditions of size of burned area and period of curing. The results regarding these tests were already published (Carvalho et al., 2001).

Special care had to be taken to prevent fire from escaping the clearing site into the adjacent forest in all five experiments. This procedure had not been necessary in previous experiments conducted by the group in Manaus, state of Amazonas (Carvalho et al., 1995, 1998), and in Tomé Açu, state of Pará (Araújo et al., 1999). Therefore, during 2001 a site was prepared and burned to investigate under-story fire generated by the forest clearing process, and results of this work are presented here.

2. TEST SITE AND PROCEDURE

The experiments reported by Carvalho et al. (2001) were conducted in five plots, denominated A, B, C, D, and E. Biomass fire consumption and carbon release rates were determined in the central 1-hectare area of each plot. In 2001, plot F was felled in May and burned on August 20, to investigate the spread of understory fire in the adjacent standing forest. Figure 1 shows the location and dimensions of plots A to F. The times of vegetation felling and burning of each plot are presented in the figure legend.

Fire spread rates were investigated with a thermocouple grid in one of the adjacent areas of plot F and using calibrated stakes, tapes, and a chronometer in the other three adjacent areas. The nomenclature for each of the sides is shown in the scheme of Figure 2.

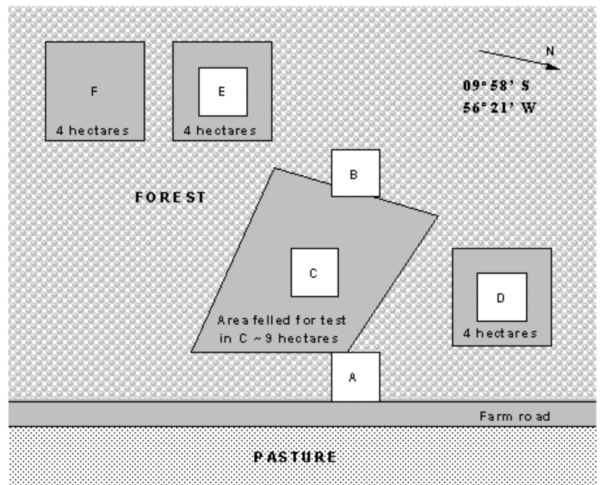

Figure 1 - Location of test plots in Caiabi farm. A, B: felled and burned in 1997; C: felled and burned in 1998; D: felled in 1998 and burned in 1999; E: felled and burned in 1999; F: felled and burned in 2001.

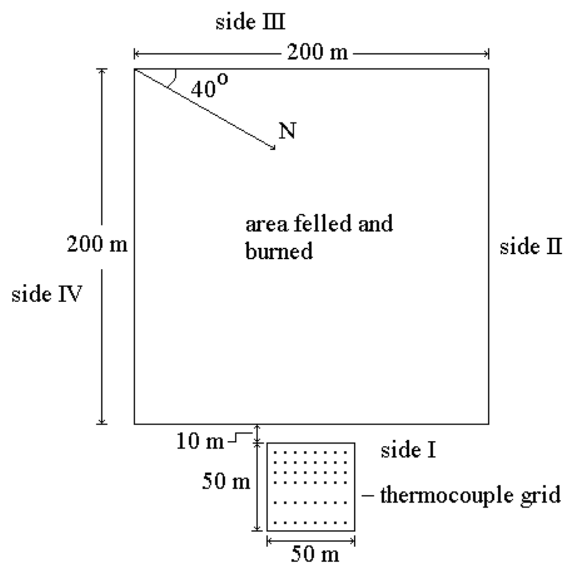

Figure 2 - Test plot F and the location of the thermocouple grid.

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The air relative humidity and temperature at 1 m from the ground, in the plot area, were 31 % and 39 ^oC, respectively, just before ignition on August 20, 13:47 h, local time. Ignition was done with drip-torches, from the central point of side III, progressing towards side IV. At 14:04 h, the central area was burning, dark smoke was raising from fire, the flames were 15 to 20 m high, and the flame front was approximately 120 m long, parallel to and approximately at 70 m from side I. At 14:23 h, fire definitely reached the border of side I and continued burning slowly near the border until 14:35 h. At 14:40 h, under-story fire started along the border of side I.

3. DISCUSSION

The thermocouple networks functioned as expected. The passage of the flame front was recorded in all cases in which the flames actually occurred. However, there were several flame fronts and, with the data obtained, we had difficulty to visualize practical results relative to flame front progression rates. Probable reasons for such behavior are: a) the fact that the soil was stepped on during the placement of thermocouples, which altered the litter layer depth and degree of compactness, b) the fact of the area being occupied by heterogeneous species, which leads to variable litter moisture content, and c) the characteristic scale of heat transfer and patterns of fire spread were shorter than the thermocouple grid spacing.

Figure 3 presents a scheme of the burned and unburned regions inside the primary net area, considering that the fire stopped at the last reached thermocouple. In reality the border between the burned and unburned regions is further right that that shown in the figure. Considering that at 14:40 h the fire reached side I and around 16:00 h there was fire at 40 m inside the thermocouple area, the average rate of spread at which the fire reached this distance was 0.29 $m.min^{-1}$, that is considering propagation in a direction perpendicular to side I, which, in fact, did not occur.

Results obtained with the procedure conducted with stakes and tapes are presented in Table 1. We can observe that the average flame front rate of spread varied between 0.16 and 0.26 $m.min^{-1}$. The maximum observed spread was 0.35 $m.min^{-1}$ and the second highest value was 0.33 $m.min^{-1}$, which occurred across side I, the place where the thermocouples were installed. These measurements were conducted in the area starting from the primary thermocouple network and going in direction to side IV.

In relation to the differences between measuring with stakes and tapes, those measurements performed with stakes covered smaller distances and occurred in a more homogeneous litter material. For the larger distances that were measured with tapes, the flame front passed by natural obstacles, such as the standing trees, and consequently it also propagated through variations in the litter material characteristics.

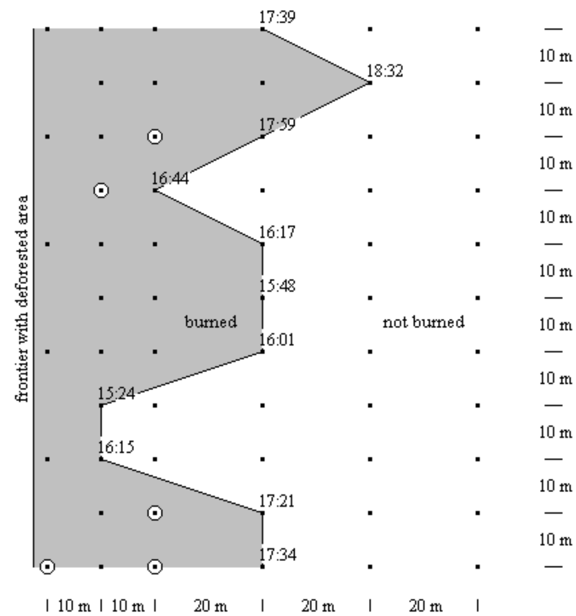

Figure 3 - Burned and unburned regions inside the primary thermocouple net area.

Table 1 – Flame front propagation rates obtained with stakes and tapes.

Side	Method	Distance (m)	Time (min)	Speed (m. min^{-1})	Observation
I	Stake	1.47	9.00	0.16	Flame not tilted toward burned area*
I	Stake	1.47	6.62	0.22	
I	Stake	2.33	10.45	0.22	Slight terrain inclination
I	Stake	2.13	6.43	0.33	
I	Stake	1.50	4.23	0.35	
II	Tape	10.5	74	0.14	
II	Tape	16.9	75	0.23	
II	Tape	7.60	76	0.10	
II	Tape	----	----	----	Fire stopped
II	Tape	----	----	----	Fire stopped
III	Tape	6.45	78	0.08	Fire stopping**
III	Tape	13.40	78	0.17	
III	Tape	19.70	79	0.25	
III	Tape	13.35	63	0.21	
III	Tape	----	----	----	Fire stopped
III	Tape	11.31	81	0.14	
III	Tape	13.40	81	0.17	
IV	Stake	1.70	9.08	0.19	
IV	Stake	1.77	6.58	0.27	Propagation at the base of bamboo
IV	Stake	2.02	----	----	Fire stopped in 6 min
IV	Stake	1.70	7.75	0.22	
IV	Stake	2.02	8.40	0.24	

* Only case; ** Fire stopped following measurement of time (we did not consider this measurement).

The above values are estimates, but illustrate the order of magnitude for flame front velocity. For comparison, Cochrane et al. (1999) reported a rate of spread of 0.25 m.min^{-1} by direct observations of fires at scattered locations within a 150-km^2 area south of Tailândia, state of Pará, Brazil.

Flame length of the observed propagating front varies between 15 and 30 cm. Flame thickness was on the order of 10 to 15 cm. For comparison, Cochrane et al. (1999) reported flame heights varying from 13 to 46 cm and flame depths varying from 8 to 20 cm. The flames, in all but one case, were always tilted towards the burned area, due to air convection effects and absence of winds inside the forest. We never had fire propagation to the crowns. Crown fires were observed only in some trees at the border of the burned area, which were subject to intense heating by the clearing fire. In previous experiments, we also observed isolated crown torching of palm or banana trees.

With the objective of investigating the effect of litter moisture content on fire propagation, we measured the average moisture content in several points along the four sides of the area. The samples were collected a couple of hours before the burn. The points in which litter moisture content was determined are shown in the scheme of Figure 4. Three samples were used for each average. The results of moisture content, M, in terms of mass of water per mass of dry biomass, are presented in Table 2. In the central point of the slashed area, the moisture content was 3.8 %.

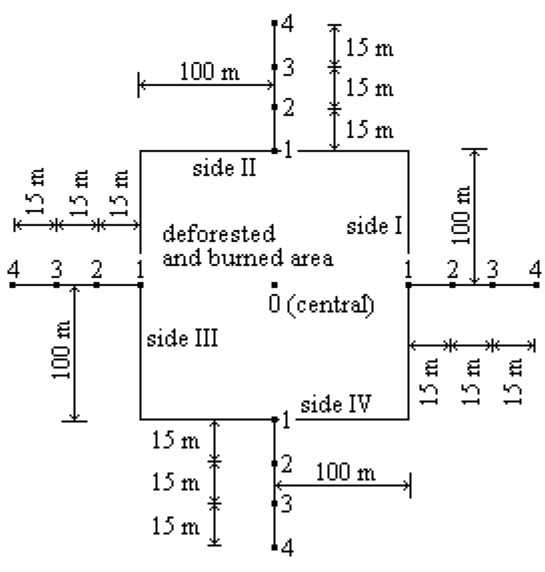

Figure 4 - Points where average litter moisture contents were determined just before fire.

In relation to the observed moisture contents, side II was more humid than the other three. Nevertheless, fire propagation across side II occurred, however at lower rates. Sides I and III were in general drier. The fastest fire rate of spread on these later sides was observed.

Fire advanced heterogeneously up to 60 m from side I. Along side III, there was a spread of at least 20 m. On side II we observed around 17 m of fire propagation. Taking into account the moisture dada of Table 4, we can affirm that there is possibility of fire propagation in forest litter with moisture contents as high as 13.5 %. On the other hand, we did not observe fire propagation in litters with moisture contents higher than 15 %.

Table 2 – Average litter moisture contents determined in the date of the experiment.

Point *	M (%)	Point *	M (%)	Point *	M (%)	Point *	M (%)
I1	8.6	II1	13.6	III1	7.2	IV1	11.3
I2	13.8	II2	13.5	III2	12.4	IV2	33.5
I3	11.7	II3	14.7	III3	15.4	IV3	11.2
I4	17.3	II4	14.5	III4	26.0	IV4	31.8

*Roman character means corresponding side, see Figure 4.

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