# Fire spread around a forest clearing site located in the Amazonian arc of deforestation

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## INTRODUCTION

The characteristics of fire spread around a forest clearing site located in the Amazonian arc of deforestation are presented. The experiment was carried out in 2001 at the Caiabi Farm, near the town of Alta Floresta, Mato Grosso as part of a set of tests that have been performed in the same area since 1997 (Fig.1), where six test plots were already slashed and burned. The main goal of the first five tests. (plots A, B, C, D, and E) was to determine biomass fire consumption and carbon release rates under different conditions of size and period of cure of the slashed and burned plots (Carvalho et al., 2001). This were also the objectives of previous experiments conducted by the group in the Manaus, Amazon area (Carvalho et al., 1995, 1998), as well as in Tomé Açu, Pará (Araújo et al., 1999). In all cases, special care had to be taken to prevent the fire from escaping from the slashed site into the adjacent forest Thus, to investigate the under-story fire generated during the burning of the slashed forest, in 2001 a test was made in plot F, and its results are here presented. The 4 ha plot was felled in May, and burned on August 20, starting at 13:47 LT.

## METHOD

The fire spread rates were investigated (i) with a 61 thermocouple grid in the side I (Fig. 2) of the area adjacent of the plot; (ii) with the use of fixed stakes, on sides I, II, III and IV, for smaller areas with more homogeneous litter material: and (iii) with tapes, on sides II, III and IV, for larger areas, where the flame front passed by natural obstacles such as standing trees, which caused variations in the characteristics of the litter. The high temperature pulses caused by the passage of the flame front in the thermocouple grid, which were distributed as shown on Fig. 3, were registered with buried Campbell CR10X data loggers. Chronometers were used to measure the propagation times determined through procedures (ii) and (iii). Figures 4 and 5 show details of the installation.

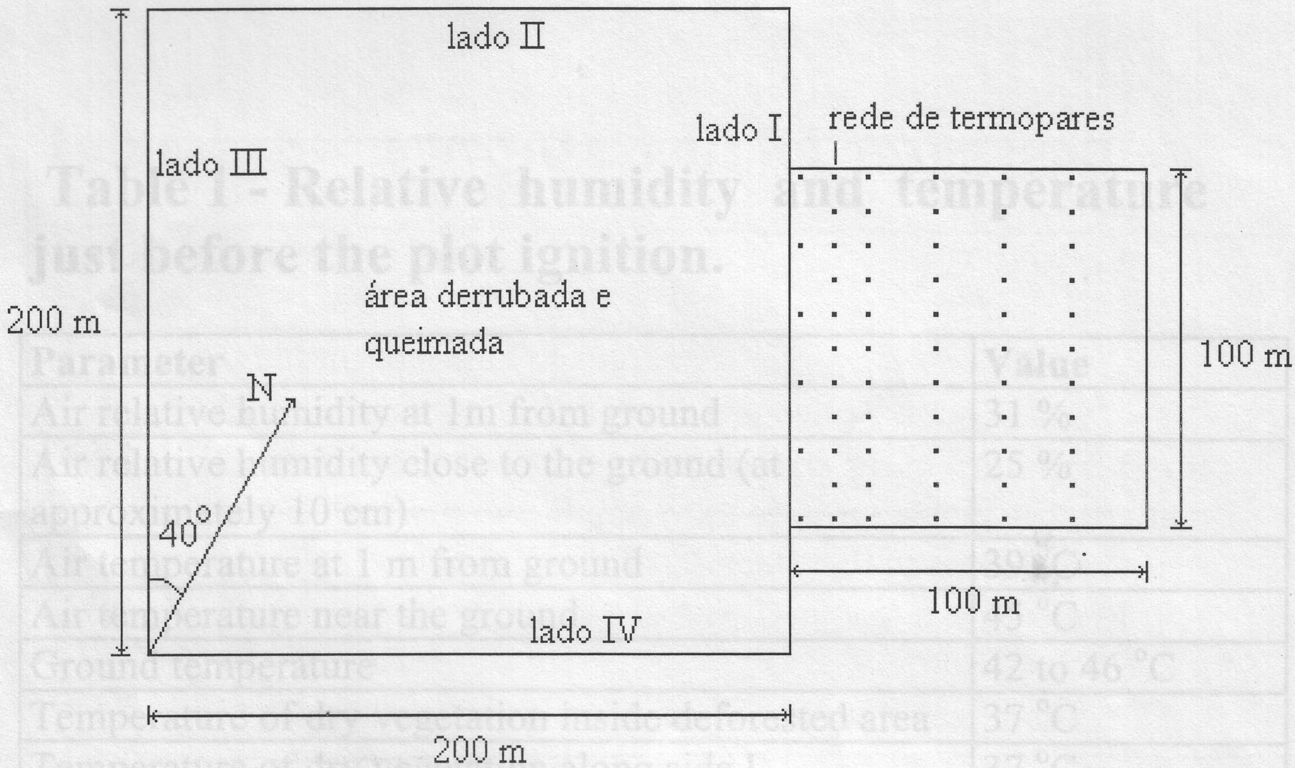


**Fig. 2 Test plot F and the thermocouple grid.**

**Table 1 - Relative humidity and temperature just before the plot ignition.**

| Parameter | Value |
|---|---|
| Air relative humidity at 1m from ground | 31 % |
| Air relative humidity close to the ground (at approximately 10 cm) | 25 % |
| Air temperature at 1 m from ground | 39 $^{o}$C |
| Air temperature near the ground | 45 $^{o}$C |
| Ground temperature | 42 to 46 $^{o}$C |
| Temperature of dry vegetation inside deforested area | 37 $^{o}$C |
| Temperature of dry vegetation along side I | 37 $^{o}$C |
| Temperature of large log inside deforested area | 38 $^{o}$C |
| Temperature inside adjacent forest | 33.5 $^{o}$C |

## Table 2 - Sequence of events following ignition.

| Local time (h) | Event |
|---|---|
| 13:47 | Ignition; first spot of smoke. |
| 13:48 | Flames become visible from opposite side. |
| 14:04 | Central area is burning; dark smoke raises from fire; flames are 15 to 20 m tall; flame front approximately 120 m long, parallel to side I; flame front nearly 70 m from side I. |
| 14:08 | Flames proceed coming to side I, now at a distance of approximately 50 m. |
| 14:12 | Ignition proceeds along side IV, coming near side I. |
| 14:18 | Fire starts reaching the border of side I. |
| 14:23 | Fire definitely reached the border of side I. |
| 14:35 | Fire continues burning slowly along the border of side I. |
| 14:40 | Under-story fire starts along border of side I. |

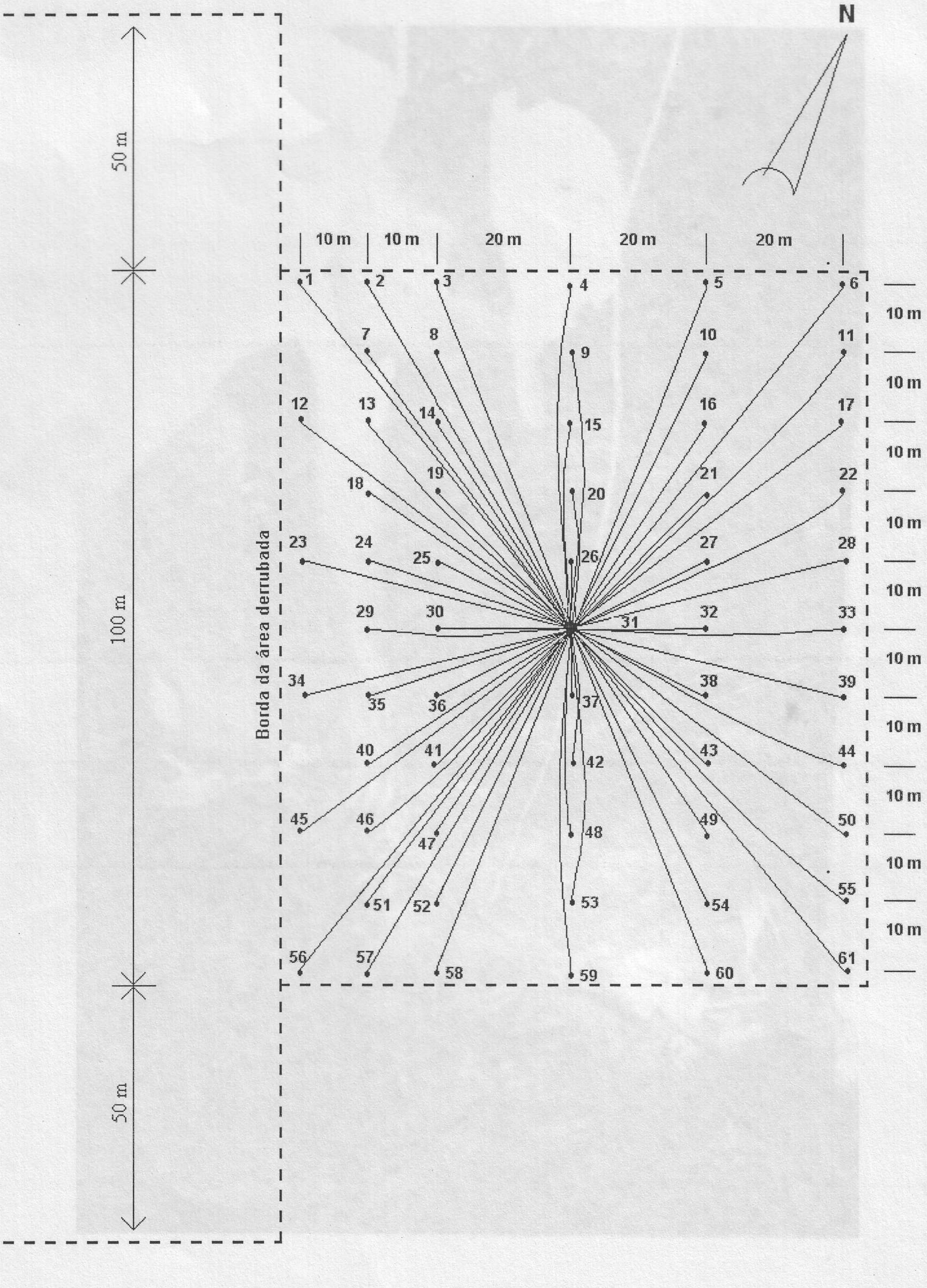


**Fig. 3 - Grid location of the thermocouples.**

**Fig. 4 - Collocation of a thermocouple.**

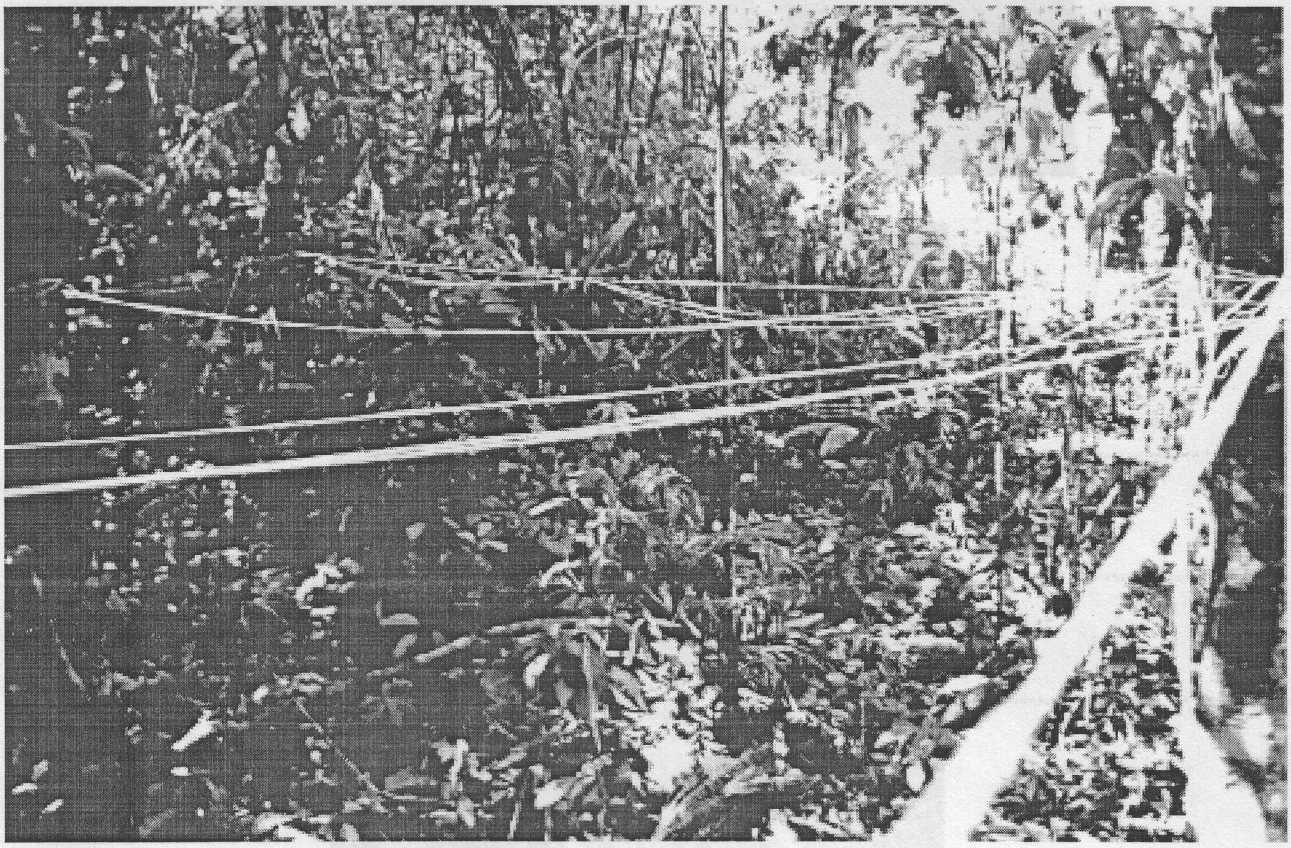

**Fig. 5 - Thermocouple wires.**

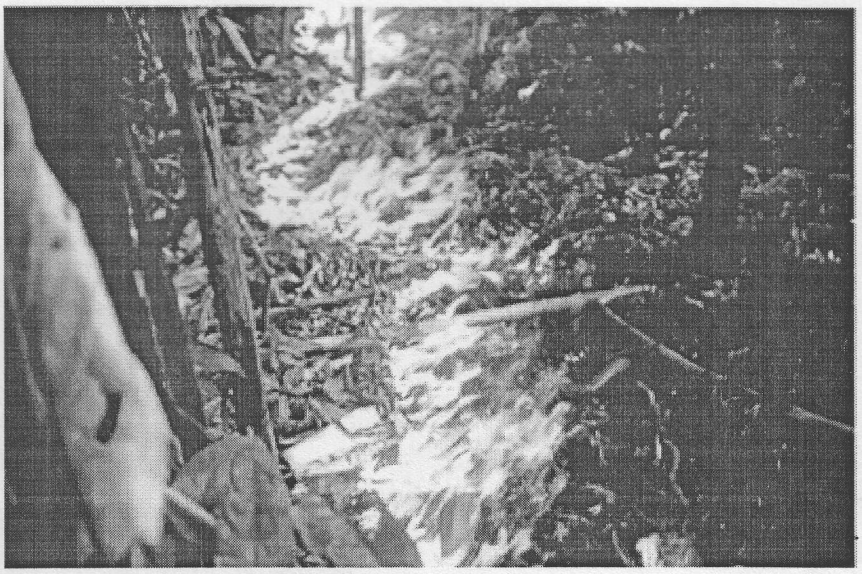

**Fig. 6 - Flame fronts of high and low intensities.**

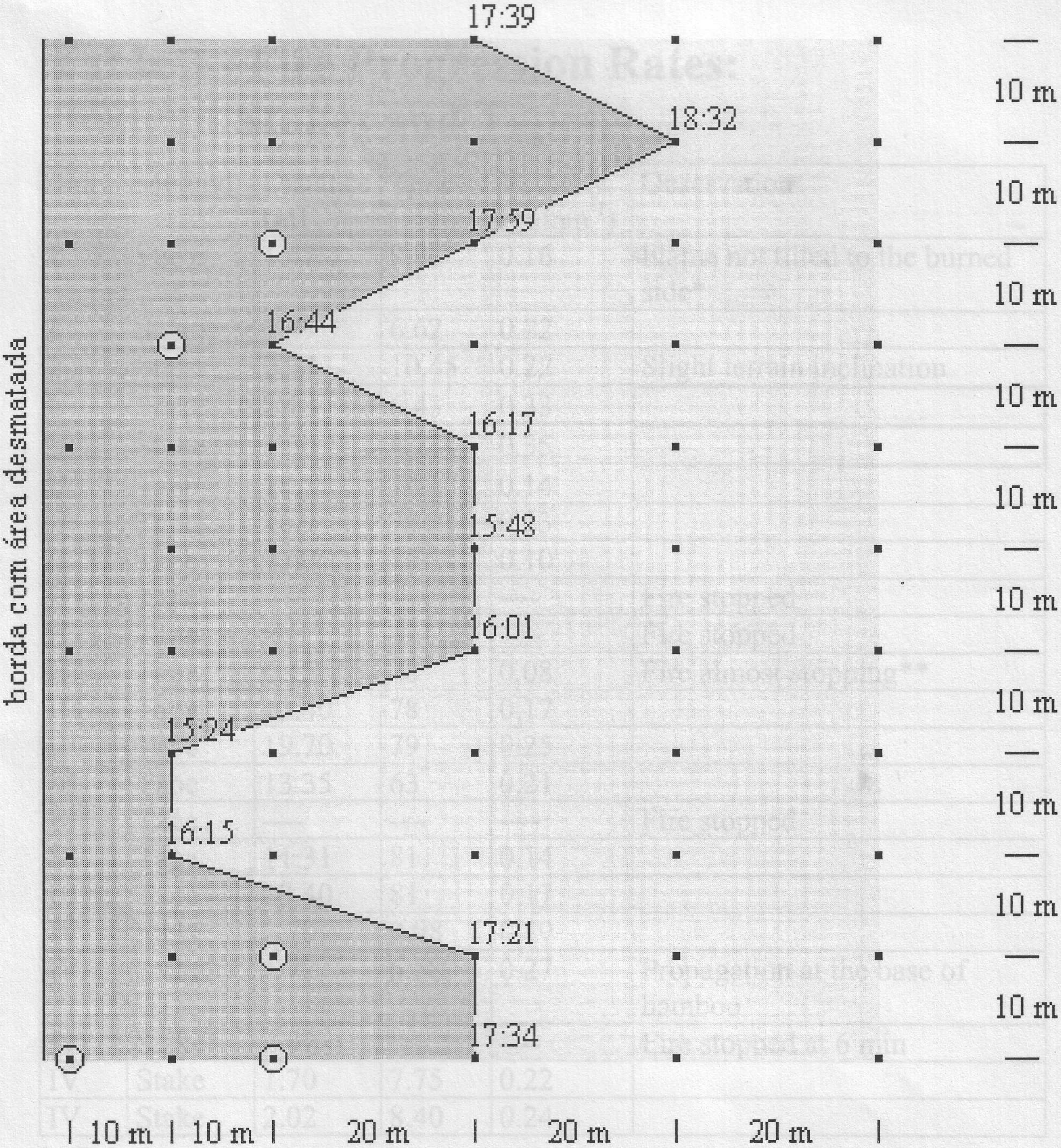


**Fig. 7 - Thermocouple grid area**
**Local Time of burning.**
**Burned - gray**
**Unburned - green**

## Table 3 - Fire Progression Rates: Stakes and Tapes.

| Side | Method | Distance (m) | Time (min) | Velocity ($m.min^{-1}$) | Observation |
|---|---|---|---|---|---|
| I | Stake | 1.47 | 9.00 | 0.16 | Flame not tilted to the burned side* |
| 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 almost 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 at 6 min |
| IV | Stake | 1.70 | 7.75 | 0.22 | |
| IV | Stake | 2.02 | 8.40 | 0.24 | |

* Only case
** Fire stopped following time measurement (measure not considered)

**Average Side I: 0.26 $m.min^{-1}$ (five measures)**
**Average Side II: 0.16 $m.min^{-1}$ (three measures)**
**Average Side III: 0.21 $m.min^{-1}$ (five measures)**
**Average Side IV: 0.23 $m.min^{-1}$ (four measures)**

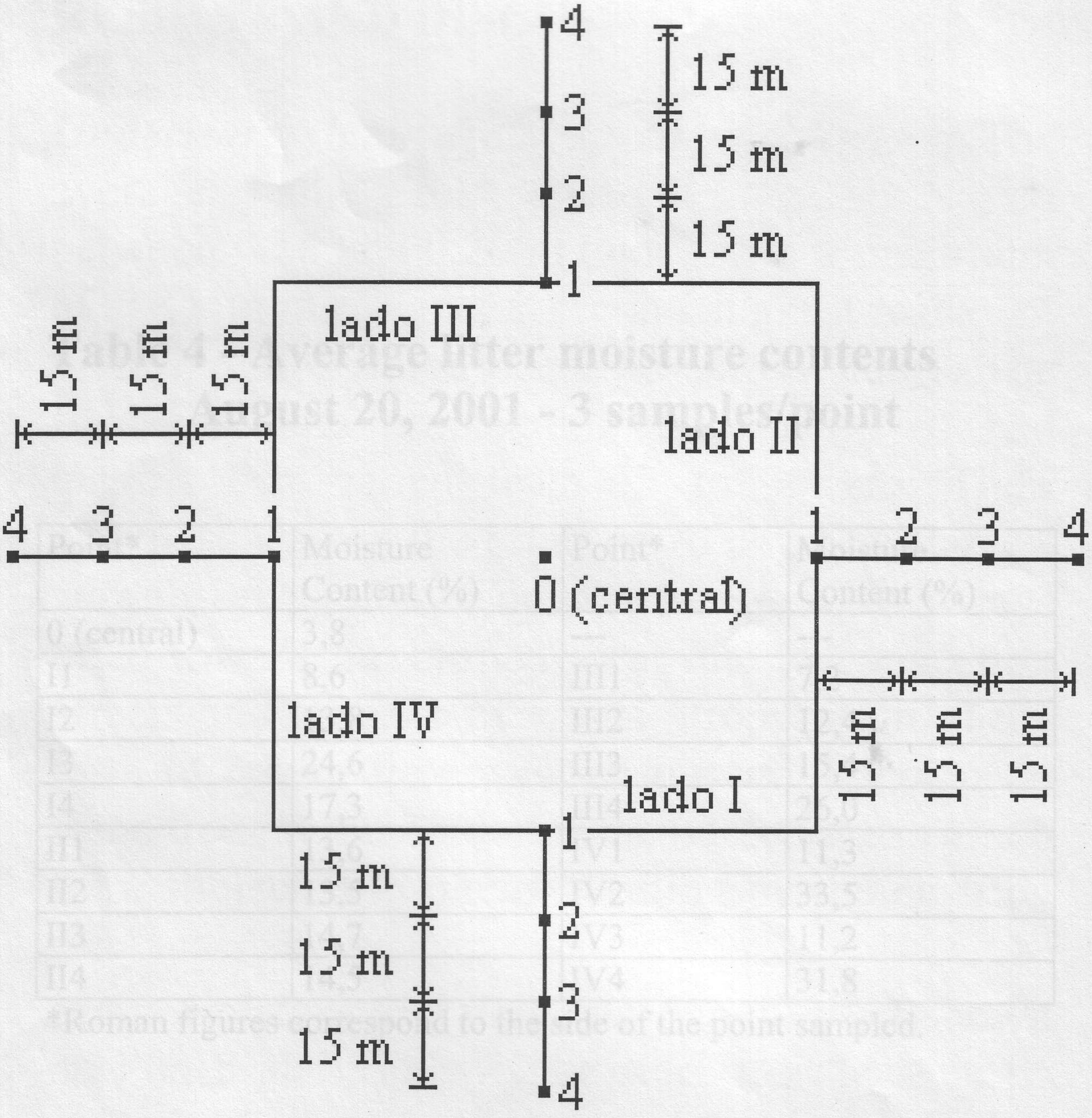


**Fig. 8 - Average litter moisture sampling points.**

## Table 4 - Average litter moisture contents August 20, 2001 - 3 samples/point

| Point* | Moisture Content (%) | Point* | Moisture Content (%) |
|---|---|---|---|
| 0 (central) | 3,8 | --- | --- |
| I1 | 8,6 | III1 | 7,2 |
| I2 | 13,8 | III2 | 12,4 |
| I3 | 24,6 | III3 | 15,4 |
| I4 | 17,3 | III4 | 26,0 |
| II1 | 13,6 | IV1 | 11,3 |
| II2 | 13,5 | IV2 | 33,5 |
| II3 | 14,7 | IV3 | 11,2 |
| II4 | 14,5 | IV4 | 31,8 |

*Roman figures correspond to the side of the point sampled.

## RESULTS AND DISCUSSION

***Understory flame front speed and height***: The average flame front speed (Table 3) varied between 0.16 and 0.26 $m.min^{-1}$, with a maximum of 0.35 $m.min^{-1}$ and a second highest value of 0.33 $m.min^{-1}$, which occurred across side I. The flames of the propagation front (Fig. 6) had lengths that varied from 15 to 30 cm. Their thickness was on the order of 10 cm. The flames, with the exception of only one case, were always tilted toward the burned area, due to convection effects and absence of winds. Propagation in the form of crown fires was not observed, except in some trees at the border of the burned area, which were subjected to intense heating by the clearing fire.

***Litter moisture and flame propagation***: as shown on Fig. 8 and Table 4, the side II, at least in its central point, was more humid than the other three; nevertheless, the propagation of the fire across this side occurred, even though at lower rates. Sides I and III were drier, at least in their central points, and across these sides the highest flame front propagation rates were determined.

***Understory fire extension***: Even trough in a very irregular manner, the fire advanced up to 60 m from side I (Figure 7). Across side III, there was an advancement of at least 20 m, while across side II it was around 17 m of fire. Considering the moisture data (Table 4), one may affirm that there is a possibility of fire propagation in the forest litter with moisture contents as high as 13.5 %, while no propagation was observed with moisture contents higher than 15 %.

***Special remarks***: It is not possible to guarantee that, during the period of time of fire spread around plot F, the moisture contents retained the values determined before the ignition. Another limitation is that the fire propagation in forest litters depends strongly on other parameters, such as the material degree of compaction and average size of the litter layer, and its depth. The material is highly heterogeneous in size, and it is composed mainly of small branches and leaves. Thicker litter layers tend to propagate the fire more rapidly.

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