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Institute of Hydrology

Overseas Development Report

Natural Environment Research Council

(First Draft - prior to revision by INPE)

ANGLO-BRAZILIAN AMAZONIAN CLIMATE PROJECT

(Proposed September 1990, as the
'Anglo-Brazilian Amazonian
Climate Observational Study' [ABRACOS])

INTERIM REPORT NO 2 (1 July 1990-30 December 1990)

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ABRACOS: PROJECT OVERVIEW

1.1. **Progress** in the period 1 July 1990 to 31 December 1990.

(a) the equipment and vehicles required for Manaus were requisitioned and shipped;
(b) an 11 week Mission (M1) was successfully carried out, which involved 10 Institute of Hydrology scientists, along with 19 collaborators from 9 Brazilian institutions;
(c) the damaged tower in Ducke forest reserve was dismantled, repaired and reassembled;
(d) data was collected from a range of micrometeorological and soil physics instrumentation deployed at a cleared pastureland site 80 km from Manaus, which demonstrated that in comparison with natural forest it has reduced ability to capture solar energy, and experiences a more rapid fall in evaporation in dry periods;
(e) automatic weather stations were installed at cleared, forested and urban sites near Manaus, and large differences observed between the average daily weather pattern for forested and cleared areas;
(f) a typical 20m x 20m plot of forest was selected, the trunks and branches removed and weighed, and the area of the leaves measured, thereby providing the basis for an estimate of the leaf area index of the forest, and of the potential contribution to global CO_2 increase from Amazonian deforestation;
(g) potential sites and collaborators for subsequent phases of the project were identified in Rondonia and Para.

1.2. **Problems** remain unresolved in three areas, thus

(a) the radio transmitters required for the satellite capture of weather station data have not yet been delivered;
(b) the infra red gas analysers instruments required for plant physiology failed under field conditions, and will require modification;
(c) cost-effective provision of intersite and intervehicle radio communication around Manaus was not addressed.

1.3. **Plans** for the next 6 months are

(a) ongoing data collection from the climate and soil monitoring systems installed at the Manaus sites;
(b) installation in Brazil of the satellite transmitters, as soon as they become available and can be shipped;
(c) requisition and shipment of equipment and vehicles for the sites in Rondonia and Para;
(d) analysis of results from Mission M1 and their submission for publication in scientific journals;
(e) a workshop in São Josė dos Campos, to co-ordinate publications and define plans for Mission M2;
(f) a training visit to Wallingford of approximately 3 months' duration by a Brazilian participant;
(g) preparation of an overview of progress and first results in a form suitable for public dissemination as a handout in English and Portuguese, and as a video.

2. REQUISITION AND SHIPMENT

2.1. Land Rovers

Two vehicles were purchased by ODA directly from Land Rover UK and shipped to Manaus. Both vehicles were 127" Crew Cab type in left-hand drive configuration and fitted with 2.5 litre Turbo Diesel engines. In addition to Land Rover "Rest of the World" specification, they have an electric winch at the front, inertia reel front seat belts and belts on other seats, towing kit with 50 mm ball, and lamp-guards front and rear. The vehicles were sea freighted directly to Manaus on the same vessel as the sea freighted equipment, arrived in good condition and were ready for use at the beginning of Mission M1.

2.1.1. The vehicles are owned by the British Embassy and their registration was handled in Manaus by Mr George Clarke, the British Honorary Consul. Initially the vehicles received temporary registration plates and documents but they were permanently registered by Mid-October 1990. The vehicles have insurance cover for third party claims under a FCO global policy with the Guardian Royal Exchange Group. Additional local insurance for third party claims has also been taken in Brazil with Previdencia do Sul. To satisfy legal requirements in Brazil, vehicles must be provided with fire extinguishers and red warning triangles. Registration documents must be carried in the vehicle at all times.

2.1.2. No serious problems were encountered with the vehicles during Mission 1. One rear shock absorber failed on each vehicle, these being replaced from spares sent with the vehicles. Three punctures occurred during the first Mission (total vehicle mileage 22,000 km at end of mission on 10 November). The tyres fitted by the factory (Michelin MXL) were not considered ideal for the dirt road conditions which constitute the majority of the vehicle usage. However, Michelin XC4 tyres were included in the equipment sea freighted by IH and will replace the original tyres in due course.

2.1.3. All the vehicle lubricants in both Land Rovers were changed on 16 September 1990 by Mr Kevin Marshall, Land Rover UK. The work was carried out at the premises of MOPEL, Rua Belo Horizonte 55, Manaus. Mr Marshall and Dr John Roberts (IH) subsequently discussed future warranty repairs that may arise in the 12 months' warranty period, with Senhor M Izidro Filho of MOPEL. MOPEL agreed to undertake such warranty work, and Land Rover will pay for the repairs via the ABRACOS project account. The first routine service (10,000 km) was carried out on both vehicles by MOPEL in mid-November at the end of Mission 1, their account being rendered directly to Dr Clarke for payment. One of the Land Rovers is required in between major missions for routine visits for equipment servicing and readings. The remaining vehicle has been taken off the road.

2.1.4. At least two further vehicles are required for the project, one each to be located in Rondonia and Para. The intention is to purchase identical vehicles to the first two, but to also request long-range fuel tanks and passenger grab-handles. It is understood that the engines in the new vehicles will differ from those in the originals, so engine spares and consumables (e.g. oil filters, etc.) cannot be regarded as interchangeable with stock at Manaus.

2.2. Equipment

2.2.1. Most of the equipment known to be required by the project was ordered as soon as ODA gave the Institute of Hydrology authority to proceed with purchase but some small provision was made for carry forward in certain areas of activity (Budget lines 1.1.1., 1.1.2 and 1.2.2.) where equipment may be site specific to the new Para and Rondonia sites. This carry forward is is reflected in the Rolling Project Budget in section 7.2.

2.2.2. The complete satellite transmitting and receiving system for the automatic weather stations has not yet been delivered to the Institute of Hydrology. The satellite dishes and receiving systems were supplied in time for shipping for Brazil this year, and were installed and tested during Mission M1. However, the transmitters are still being manufactured. Didcot Instrument Company expects to send them to Bradford University for final assembly and testing during the first week of January 1991. They will then have to be sent to the European Space Centre at Darmstadt, Germany for further testing before being registered with Meteosat.

2.2.3. With the exception of the transmitters described in the previous paragraph, all of the equipment required for Mission M1 was successfully requisitioned and delivered, though some items arrived too late for the main shipment and were sent to Brazil as air freight.

2.2.4. The primary equipment requirements for Mission M2 are the forest towers, the Land Rover vehicles and the soil moisture monitoring instrumentation for the new Para and Rondonia sites. These are on order, and delivery sought in the present financial year - with sufficient time for shipment to Brazil to allow Mission M2 to begin in June.

2.3. SHIPMENT

2.3.1. The vast majority of the equipment and both Land Rovers were sent sea freight to Manaus. The satellite receivers for São José dos Campos and Porto Alegre were air freighted to São Pãulo. Equipment delivered late was air freighted to Manaus as it became available. The soil moisture (neutron) probes were deliberately air freighted separately in case any importation delays generated by their radioactive nature jeopardised the whole shipment.

2.3.2. Importation of the vehicles was handled by Mr Clarke, the Honorary Consul in Manaus, and went smoothly.

2.3.3. Importation clearance for the equipment was required urgently and was successively secured for each shipment on a temporary basis, independent of the Memorandum of Understanding. This was achieved only through the good offices, local knowledge and influence of INPA staff, and the persistence of IH's Brazilian-based consultant.

2.3.4. Long-term clearance of the equipment is now proceeding through formal channels in Brasilia, and is being handled by the British Council in consultation with ABC.

2.3.5. Considerable unforeseen expense was incurred in importing the equipment to Brazil. This was mainly generated by the standard practice of Port Authorities and Airlines in that country who levy importation charges which are approximately 5-6 percent of the declared value of the shipment (this is normally a comparatively small addition to heavy importation taxes). Attempts were made to negotiate lower charges and in some cases these were successful. There are additional charges (typically 1000=2000 US$) levied by importation agents ('despachantes') who handle the considerable formalities involved. These last charges could be minimized by reducing the number of named items in the shipment since each item requires a separate form.

2.3.6. The freight component of the project budget for 1990/91 is over budget in consequence of the heavy importation costs described above, and estimates for future freight costs in the Rolling Project Budget in Section 7.2 has had to be increased to allow for them.

2.3.7. The two Hydras due to return to the UK for repair and recalibration were imported at the beginning of M1 as a temporary import. These were repacked and the matter put in the hands of the INPA despachante. They have not yet left Manaus.

3. SCIENTIFIC RESULTS

3.1. Micrometeorology

The rôle of the micrometeorological measurements within the ABRACOS project is to provide surface parameterisations for use in General Circulation Models (GCMs) from measurements of evaporation rates and surface energy partitioning. During Mission 1, commencing on 15 September, measurements were made at the ranchland site, Fazenda Dimona, covering a 50 day period in the dry season. During the Mission, a fortuitous period of low rainfall yielded an invaluable record of progressive soil moisture depletion, and, as moisture availability receded, the resultant changes in surface energy balance were successfully monitored.

3.1.1. Site and Instrumentation

Fazenda Dimona (2°18'S 60°5'W) was created as cattle ranchland by felling and burning the primary forest and sowing the clay soil with hardy pasture grass (Amazonian Kikuyu). The site is regularly burnt to discourage regrowth but many of the larger trunks and tree stumps still remain. Some small bushes had regrown at the time of the measurements.

The area covered by the various surface components was measured along 12 radial transects, centred on the instrument tower, and are as follows:

Component	Percentage Area
Grass	83.63
Bare Soil	10.99
Trunks	4.94
Bushes	0.44

The instrumentation installed was as follows:

two 'Hydras' at 3.5 m (one net radiometer), designed, built and calibrated by the IH Instruments Section

a Campbell Scientific Inc. (CSI) Bowen Ratio System

a nine metre profile tower with instruments measuring wet and dry bulb temperature at six logarithmically spaced levels (designed at IH and engineered by the IH Instruments Section)

one each supplementary net radiometer and reflected solarimeter at 9 m

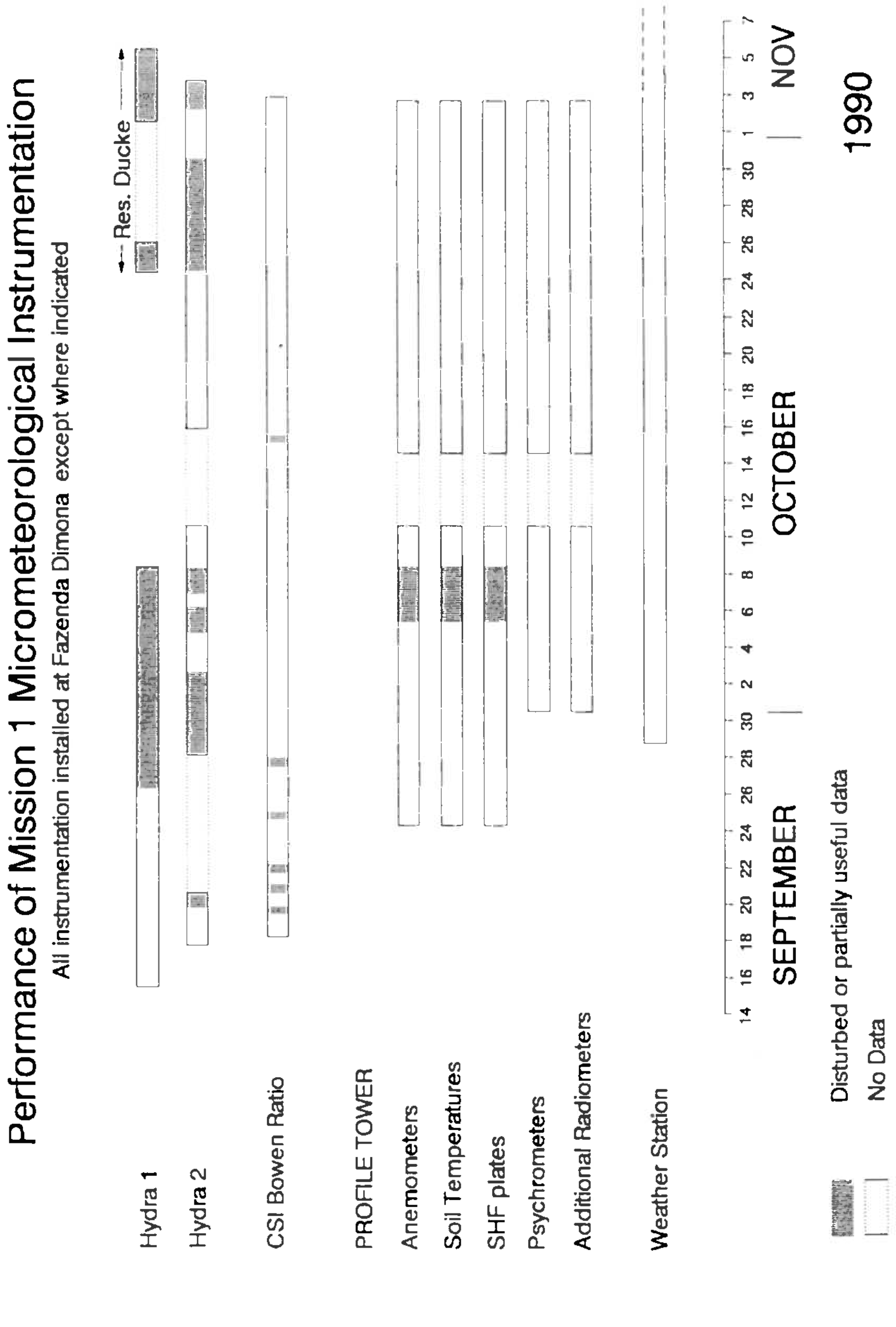
nine (total) soil heat flux plates at 5 mm depth under grass and bare soil

six soil temperatures at 5 mm to 400 mm depth under grass.

One of the Hydra instruments was operated at Fazenda Dimona for 23 days, and then installed on the forest tower at Reserva Ducke for 12 days.

The periods of operation for individual systems are shown in Figure 3.1.1, together with an indication of the system performances.

Figure 3.1.1


Performance of Mission 1 Micrometeorological Instrumentation
All instrumentation installed at Fazenda Dimona except where indicated
Hydra 1
Hydra 2
CSI Bowen Ratio
PROFILE TOWER
Anemometers
Soil Temperatures
SHF plates
Psychrometers
Additional Radiometers
Weather Station
Res. Ducke
14 16 18 20 22 24 26 28 30 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 1 3 5 7
SEPTEMBER
OCTOBER
NOV
1990
Disturbed or partially useful data
No Data

3.1.2. Preliminary Results

Latent heat flux was chosen as a suitable parameter with which to compare the three main measurement systems. Not only is it readily available from two of the systems (Hydra and CSI Bowen Ratio) but it also utilises data from nearly all instruments.

Figure 3.1.2 shows latent heat fluxes for a single day, measured by the three independent systems. The figure shows that the systems are capable of remarkably good consistency and provides confidence in the measurements. On the day illustrated, the Bowen Ratio ranged from 0.6 to 0.9, and the CSI Bowen Ratio system was resolving humidity gradients of typically 0.033 mb m^{-1}. The total evaporation for the day was 2.8 mm, which is amongst the lowest daily evaporation rates measured during the campaign.

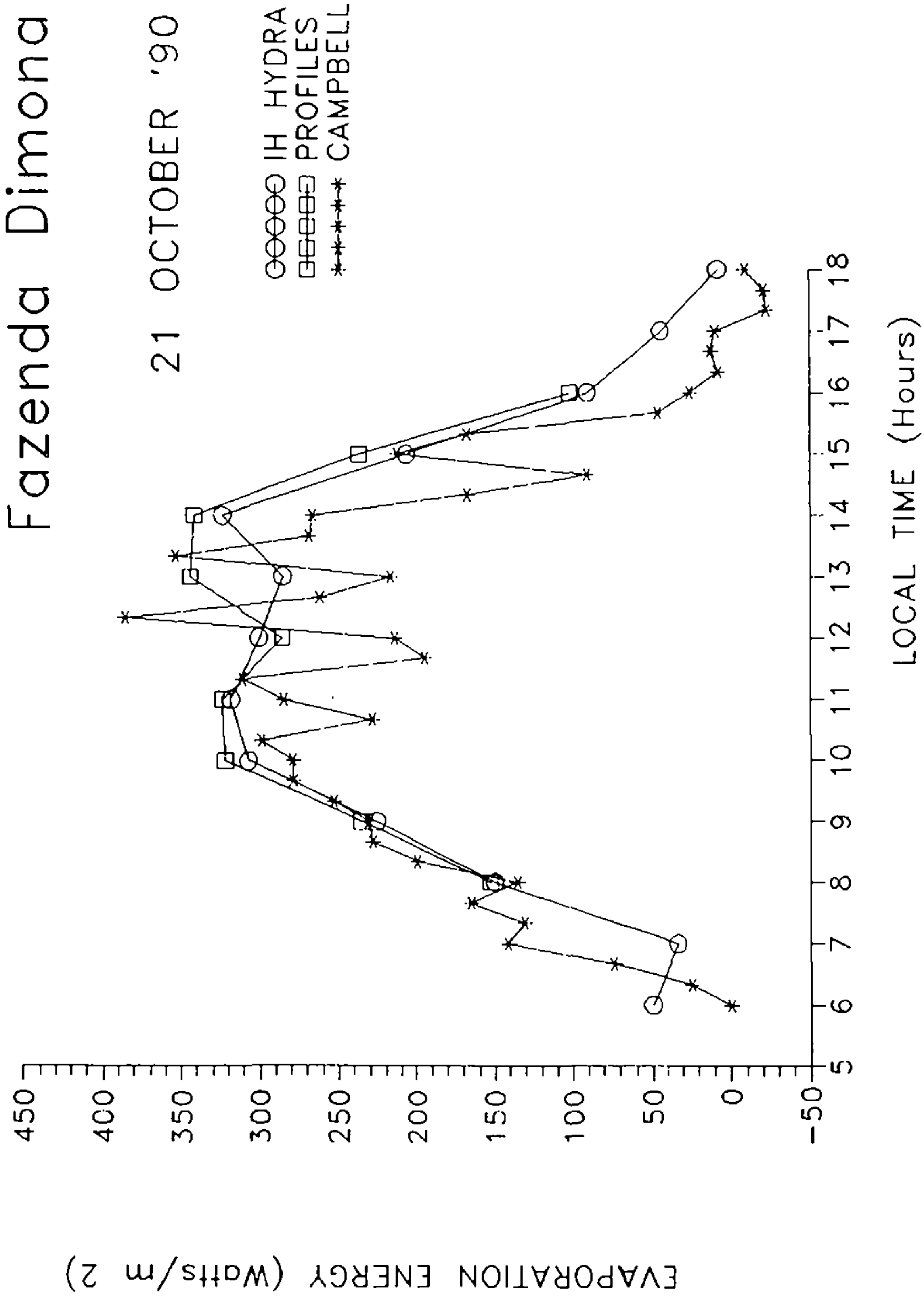
The CSI Bowen Ratio system provided the most readily available record of longer term water use and some of these data are shown in Figure 3.1.3a, as daily evaporation totals, and in Figure 3.1.3b, as evaporation normalised to the available energy. The figures include the 20 day period in which rainfall was insuffient to maintain evaporation. Evaporation diminishes (Figure 3.1.3a) from the 4th to the 24th of the month in response to the decreasingly available water in the soil, both from the soil surface and in the root zone, stressing the grass and reducing transpiration. The rapid increases and partial recovery of evaporation in response to rainfall can also be seen. The proportion of energy going to evaporation after a large storm, about 70%, (4.10.90 Figure 3.1.3b) is similar in magnitude to the measured transpiration rate over primary forest in the earlier work by Shuttleworth et al. (1984). However, unlike the forest, the ranchland soon loses available moisture and within 20 days is consuming only 55% of energy as evaporation. The two small storms on 10.10.90 and 24.10.90, totalling 8 mm, are only partially capable of refilling the moisture store, but it is not yet clear why these two storms (of similar magnitude) have markedly different effects upon the diminishing evaporation. Rainfall for the period is shown in Table 3.1.1.

TABLE 3.1.1. Rainfall for the period 3.10.90 to 29.10.90

Date	mm
4.10.90	32
10.10.90	4
17.10.90	Trace
22.10.90	Trace
24.10.90	4

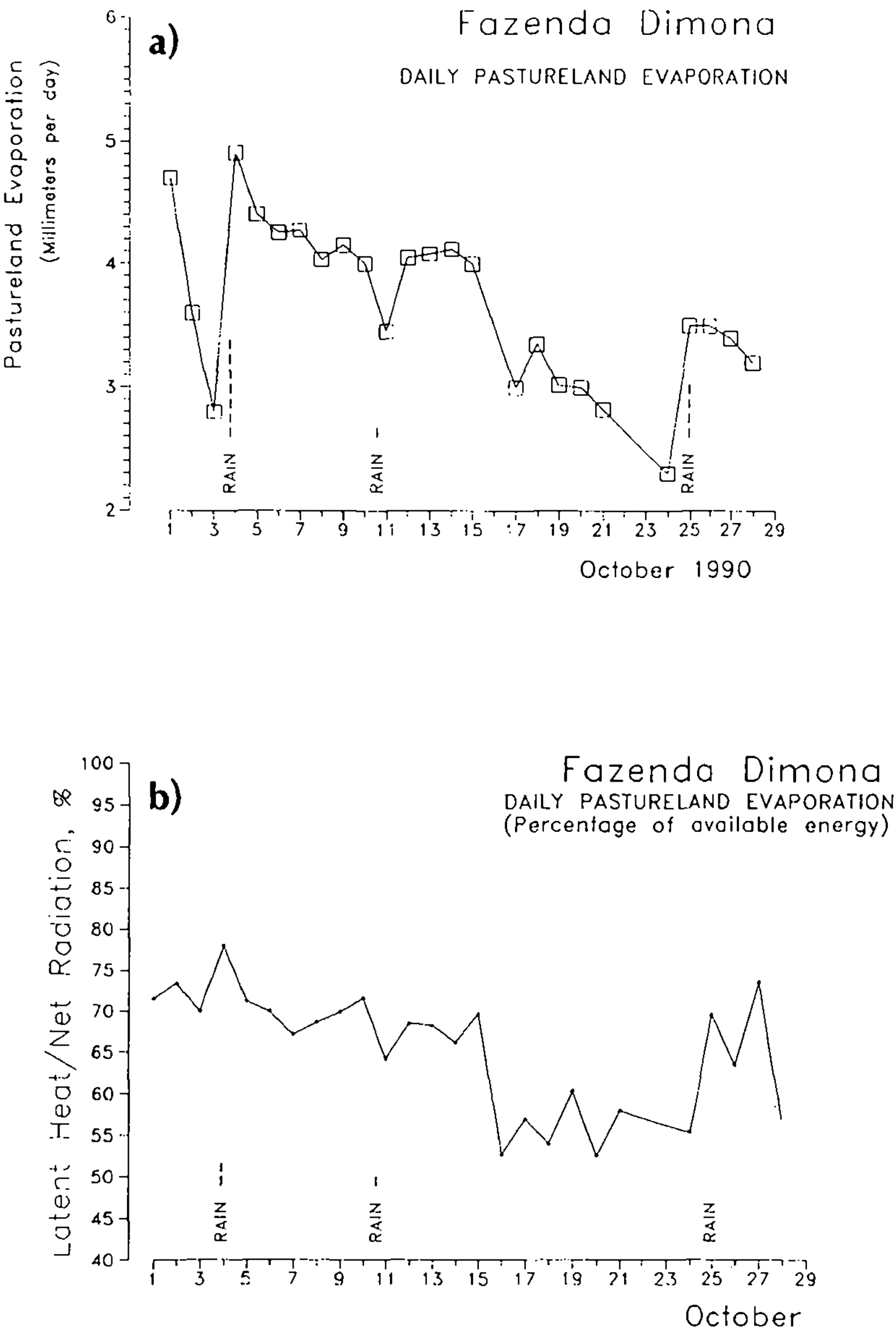
Figures 3.1.4a and b show the partitioning of available energy for two contrasted days, 10.10.90 and 17.10.90, during the dry period. Statistics for the two days are given in Table 3.1.2. In the seven days between these two dates a noticeable change in the partitioning has occurred, with increased sensible heat flux and reduced latent and soil heat flux. The reduced soil heat flux indicates a decrease in soil conductivity as the soil dries out. Clearly, more energy must go into heating the air.

Figure 3.1.2



Fazenda Dimona
21 OCTOBER '90
IH HYDRA
PROFILES
CAMPBELL
EVAPORATION ENERGY (Watts/m 2)
LOCAL TIME (Hours)
450
400
350
300
250
200
150
100
50
0
-50
5
6
7
8
9
10
11
12
13
14
15
16
17
18

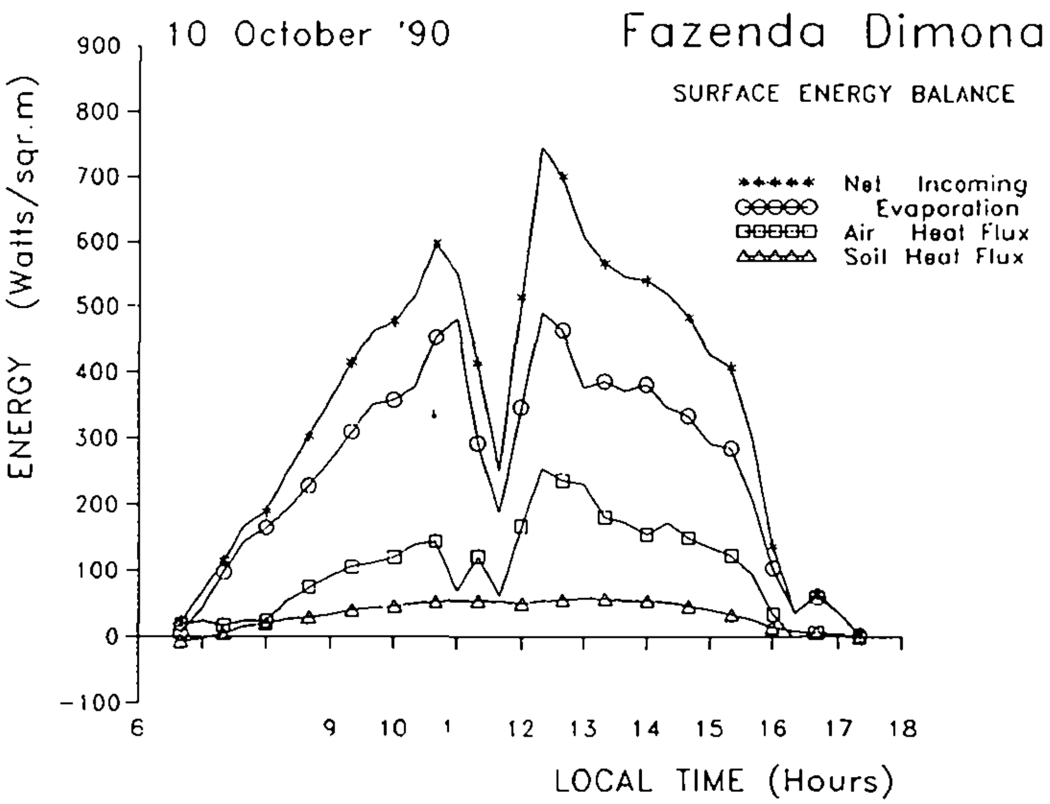
Figure 3.1.3



a)
Fazenda Dimona
DAILY PASTURELAND EVAPORATION
Pastureland Evaporation
(Millimeters per day)
6
5
4
3
2
RAIN
RAIN
RAIN
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
October 1990
b)
Fazenda Dimona
DAILY PASTURELAND EVAPORATION
(Percentage of available energy)
Latent Heat/Net Radiation, %
100
95
90
85
80
75
70
65
60
55
50
45
40
RAIN
RAIN
RAIN
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29
October

Figure 3.1.4

a)



b)

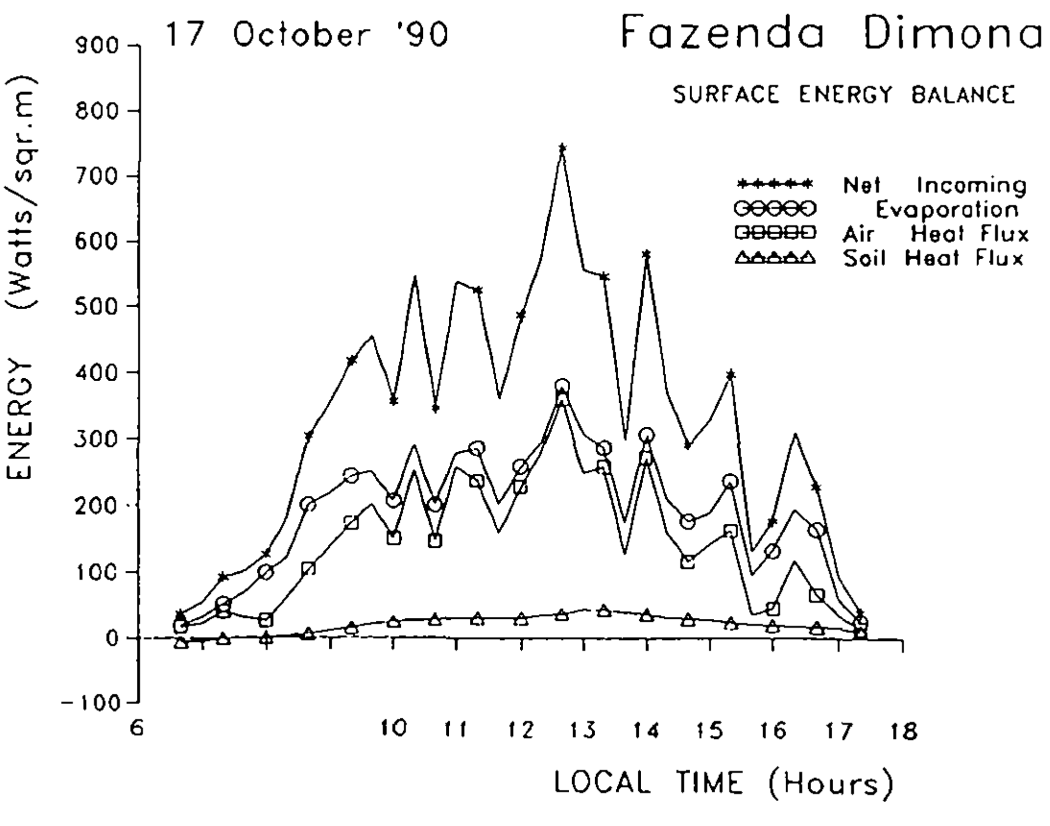


TABLE 3.1.2. Energy partition totals for the 12 daylight hours on 10.10.90 and 17.10.90 (See also Figures 3.1.3 and 3.1.4)

Date		10.10.90	17.10.90
Days since rain	32 mm storm	6	13
	4 mm storm	0	7
Total Energy (Net Radiometer)	MJ m^{-1}	14.27	13.32
Latent Heat Flux (via Bowen Ratio)	MJ m^{-1}	10.07	7.53
Sensible Heat Flux (via Bowen Ratio)	MJ m^{-1}	3.98	5.64
Soil Heat Flux	MJ m^{-1}	0.22	0.15
Latent Heat Flux	%	70	57
Sensible Heat Flux	%	28	42
Soil Heat Flux	%	2	

3.1.3. Overview of Results

Micrometeorological data are available from Mission 1 (1990) representing 50 days from 15.9.90 to 4.11.90, with full instrumentation from 1.10.90. All systems have made a significant contribution to the potential of the data base, both as an extended record and as detailed data for further research on physical processes. The agreement between systems is very encouraging.

The data from Mission M1 are already showing clear differences between the forest and ranchland meteorology. The different surface characteristics alter the amount of energy that is available to the two land surface types, but of particular interest is the influence on the diurnal micrometeorology (discussed in section 3.3.3), and longer term water use. When water is readily available evaporation proceeds at about 4 mm day $^{-1}$, consuming 70% of the available energy and very similar to the expected rates from the nearby primary forest. Whereas the forest might be expected to respire at similar rates in dry spells, the grass land responds quite quickly to soil moisture depletion. Notwithstanding 8 mm of rainfall, the evaporation fell to 2.5 mm day $^{-1}$ and 55% of available energy within 20 days.

3.1.4. Plans for 1991

Micrometerological measurements will be made at Fazenda Dimona for a further intensive period during 1991. The original experimental design appears very satisfactory and only minor alterations are proposed. The main objective of the project in 1991 is to establish the climatology sites in Rondonia and Para;

therefore time and manpower resources will need to be carefully managed to ensure a successful micrometeorological mission at Fazenda Dimona. Fortunately reconstruction of the instrumentation will be rapid with the help of the counterpart micrometeorologists who now have working experience with the equipment. Weekly servicing of the site will largely be carried out by local Brazilian scientists.

3.2. **Soil Physics**

The objective of the ABRACOS soil moisture measurement programme is to satisfy the needs of climate modelling by providing understanding of the physical processes of soil water movement for representative study areas vegetation types, and how they may be described in models; and to provide estimates of total evaporation independent of other techniques.

During Mission 1, the soil moisture programme focussed on the ranchland site, Fazenda Dimona. The primary objective was to install sufficient instrumentation to measure and compare moisture storage changes under cleared forest ranchland and nearby primary forest. As the local topography is incised by many seasonal water courses, the areas covered by the two vegetation types were further subdivided into plateau, slope and valley bottom categories. A neutron probe was used to measure water storage changes to a depth of 2 metres below the ranchland and the forest. Also, soil matric potential was monitored with three arrays of tensiometers, and water table levels were measured where necessary.

3.2.1. Installation and instrumentation

A schematic diagram of the arrangement of instruments is shown in Figure 3.2.1.

Thirty neutron probe access tubes were installed, using equipment developed at IH, to encompass all categories of vegetation and terrain to a depth of two metres. Installation commenced on 13 September 1990, giving the first measured changes under ranchland by 21 September 1990. All access tubes were operational from 27 September 1990. In the forest valley, where the water table is less than 2 m below the soil surface, piezometer tubes were installed, paired to the affected access tubes, to monitor the depth of the water table.

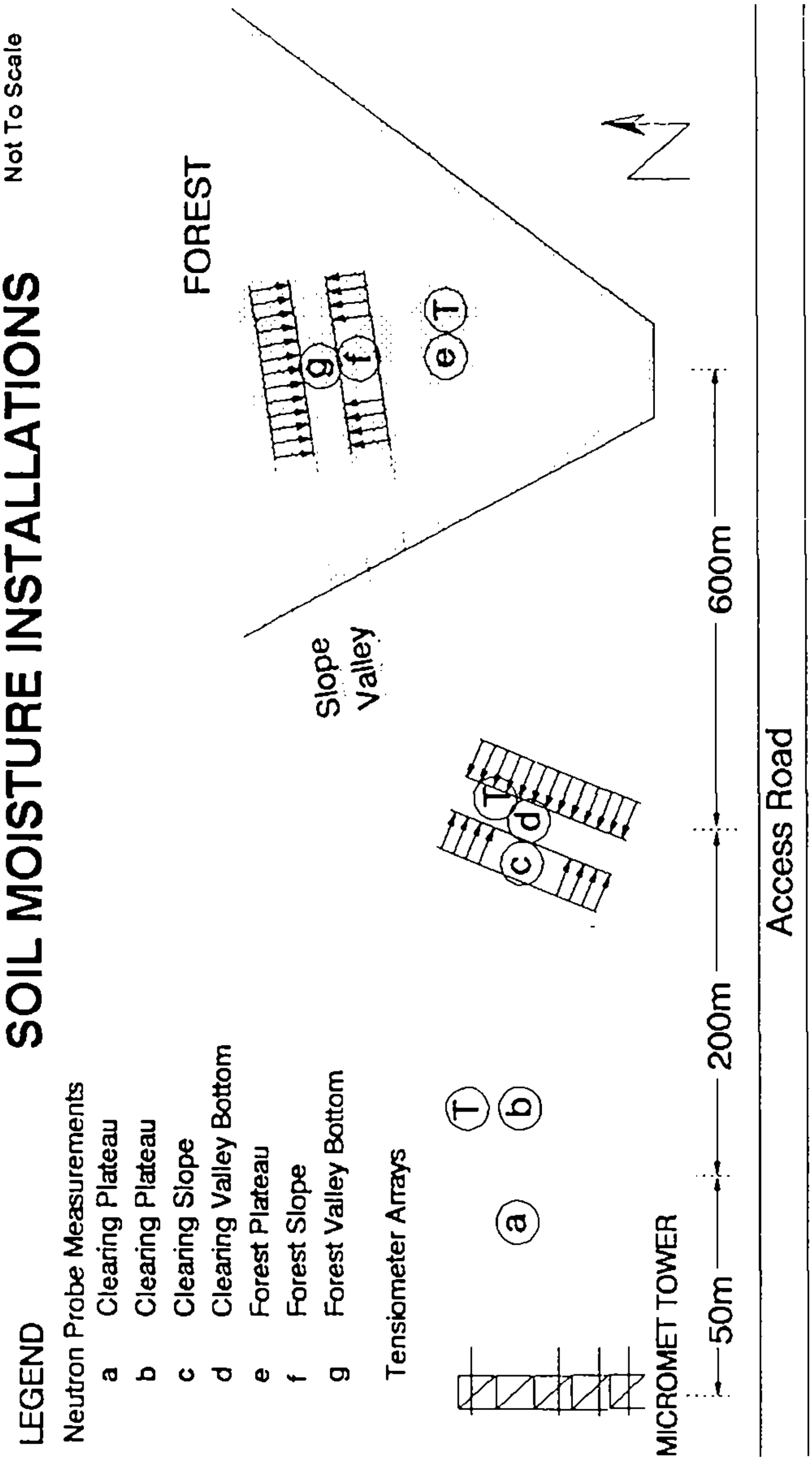
Three purpose-built tensiometer arrays were installed to facilitate comparison of soil matric potential between plateau ranchland, plateau forest and the forest valley. These arrays became operational between 30 September and 8 October 1990 and potentials were recorded until tensions became too high, (< 650 mm mercury, in later October 1990). The tensiometers remained operational in the forest valley.

Soil samples were taken from 0.6 m and 0.1 m within the soil profile for calibration of the neutron probe.

3.2.2 Preliminary Results

A plausible temporary calibration for the storage capacity of the soil has been applied while soil samples are still being analyzed

Figure 3.2.1


SOIL MOISTURE INSTALLATIONS
Not To Scale
LEGEND
Neutron Probe Measurements
a Clearing Plateau
b Clearing Plateau
c Clearing Slope
d Clearing Valley Bottom
e Forest Plateau
f Forest Slope
g Forest Valley Bottom
Tensiometer Arrays
FOREST
Slope
Valley
MICROMET TOWER
50m
200m
600m
Access Road
a
b
c
d
e
f
g
T

for the true calibration. The data presented here are therefore provisional, pending the establishment of the true calibration.

Figures 3.2.2a and b show moisture changes from individual access tubes, measured by neutron probe, under ranchland and forest plateau respectively. In the absence of any true common point of reference, i.e. field capacity during the wet season, these data have been normalised to the 4 October 1990, when measurements were recorded just after the largest storm of the period (32 mm). Even so, there is evidence of the limitations of this assumption: not all tubes are indicating their highest storage at this time (Figures 3.2.2a and 3.2.3a) and (shown later) the moisture tension is considerably higher under the forest area, indicating greater soil moisture depletion, which must have occurred before these data commenced.

Figure 3.2.2.a shows the large variability in moisture content under the ranchland, with profiles having both greater and smaller extraction rates than any of the forest tubes (Figure 3.2.2b). Forest and ranchland slope sites have similar variability, with more water extraction from the forest soil (Figure 3.2.3a and b). Depletion rates are generally greater on the slopes than on the plateau. Valley bottom data are not compared in this way due to the interference of the forest water table.

When the slope and plateau data are brought together as averages for the two vegetation types, (Figure 3.2.4.) the forest appears to have extracted 7 mm more water from the soil profile than the ranchland grass in the 25 days since the last rain. This represents 2.36 mm day^{-1} and 2.08 mm day^{-1} from the forest and ranchland respectively. The two small rainstorms of 10 October and 24 October produced only very small perturbations in the continuing depletion of soil water content.

When correct calibrations and normalisation are applied to these data, these extraction rates would not be expected to be very different. These rates are significantly lower than those produced from the micrometeorological measurements, and this is of considerable interest. But it should be remembered that, for reasons of quality control, data in Figure 3.1.3a do not include several days of particularly low evaporation rate, and that the soil water depletion measurements do not allow for re-evaporation of dew.

Soil matric potentials, as measured by the tensiometer arrays are shown in Figure 3.2.5. There is a marked difference between the forest and grassland profiles at depths greater than one metre. The forest has extracted very much more water from lower in the profile against considerable tension, whereas the grass has only influenced the lower profile moderately. The tensions in the forest valley indicate the level of the water table at the point of intersection with the neutral potential line, i.e. at about 1.05 m depth.

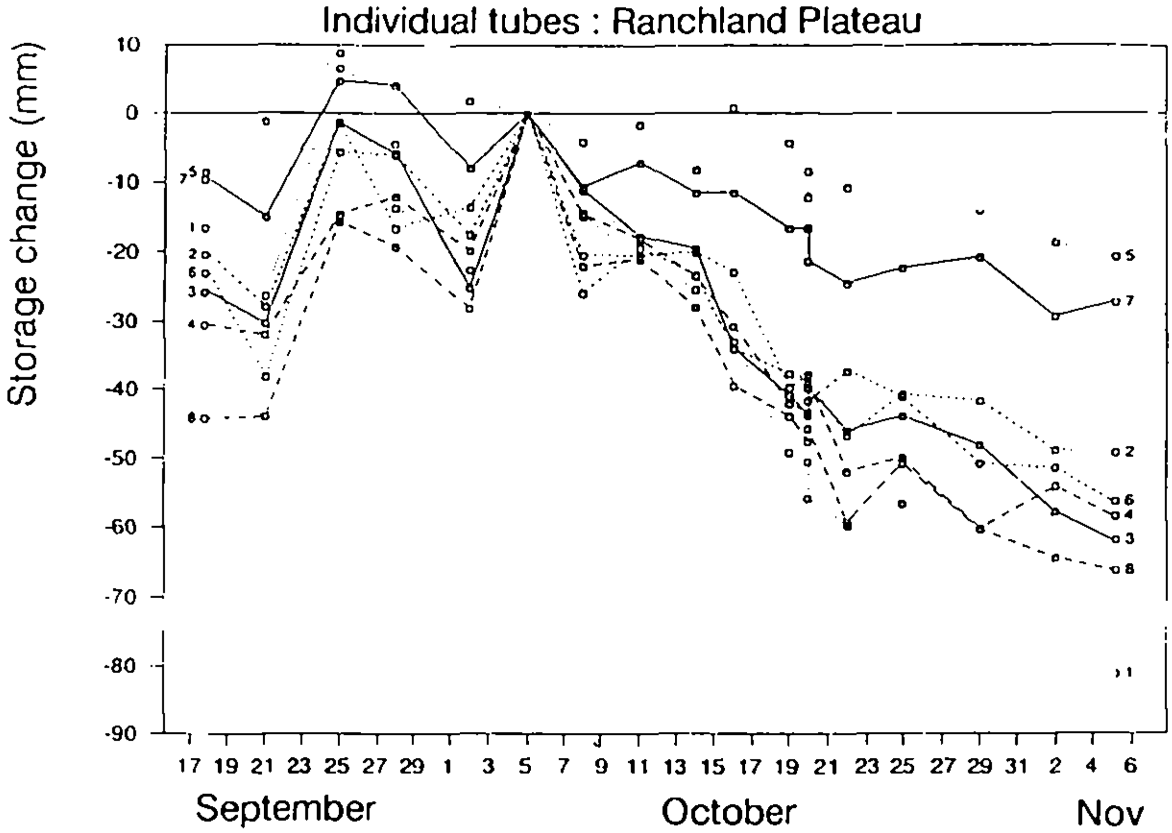
3.2.3. Overview of results

Neutron probe access tubes and tensiometers arrays were installed and became operational at Fazenda Dimona in the early stages of Mission 1, and provided a valuable record of an extended period of soil moisture depletion during the dry season.
Notwithstanding the limitations of short period moisture

Figure 3.2.2

Fazenda Dimona Profile Storage Changes

a)



b)

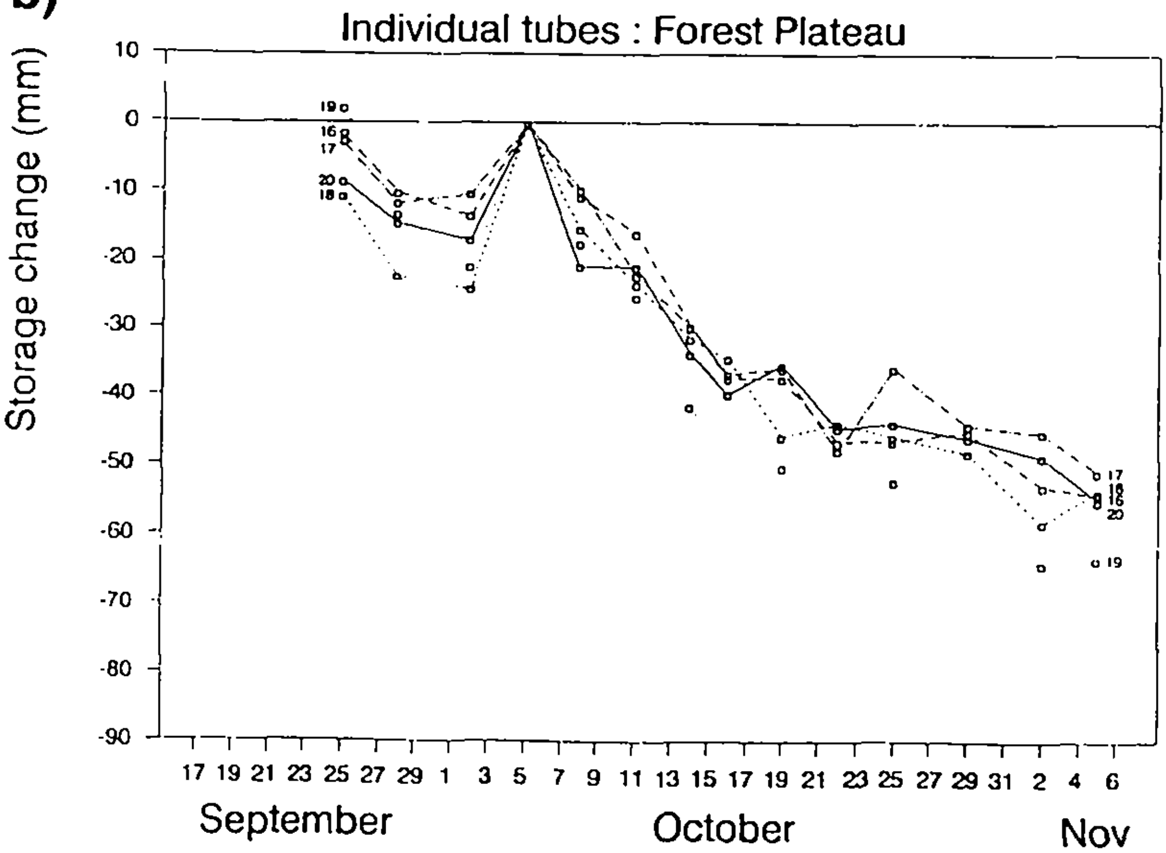
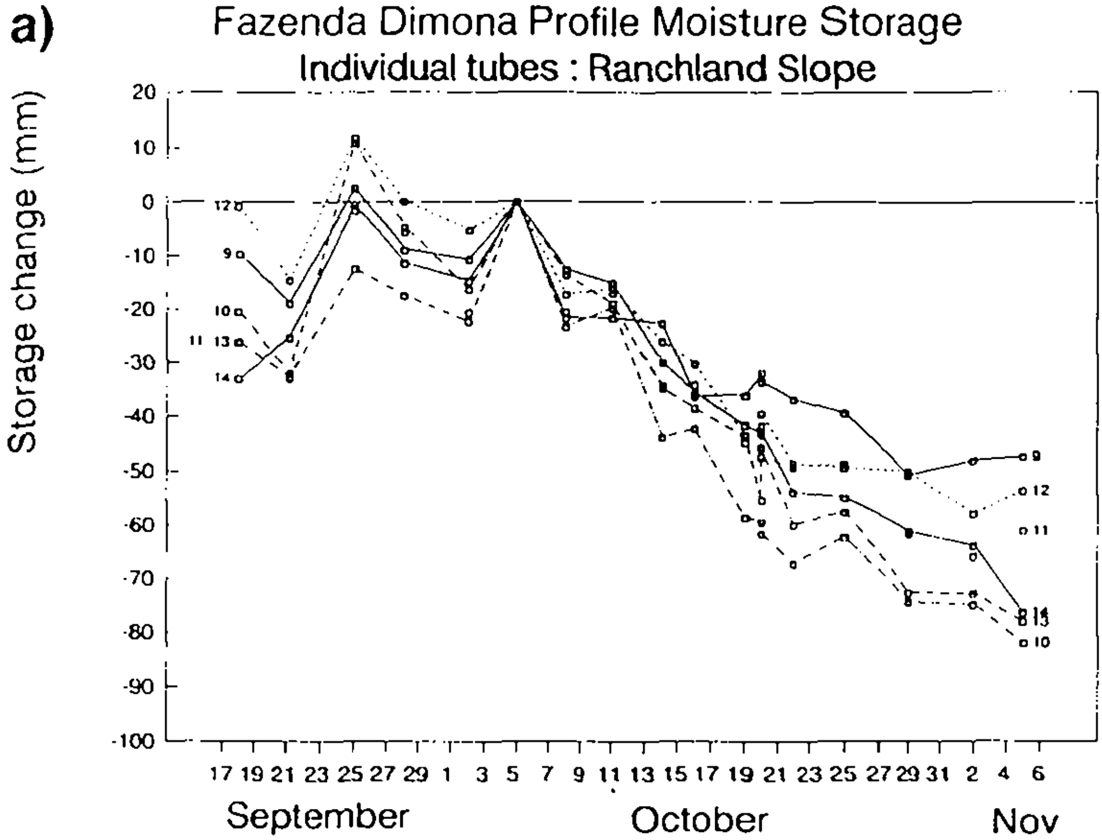


Figure 3.2.3

a)



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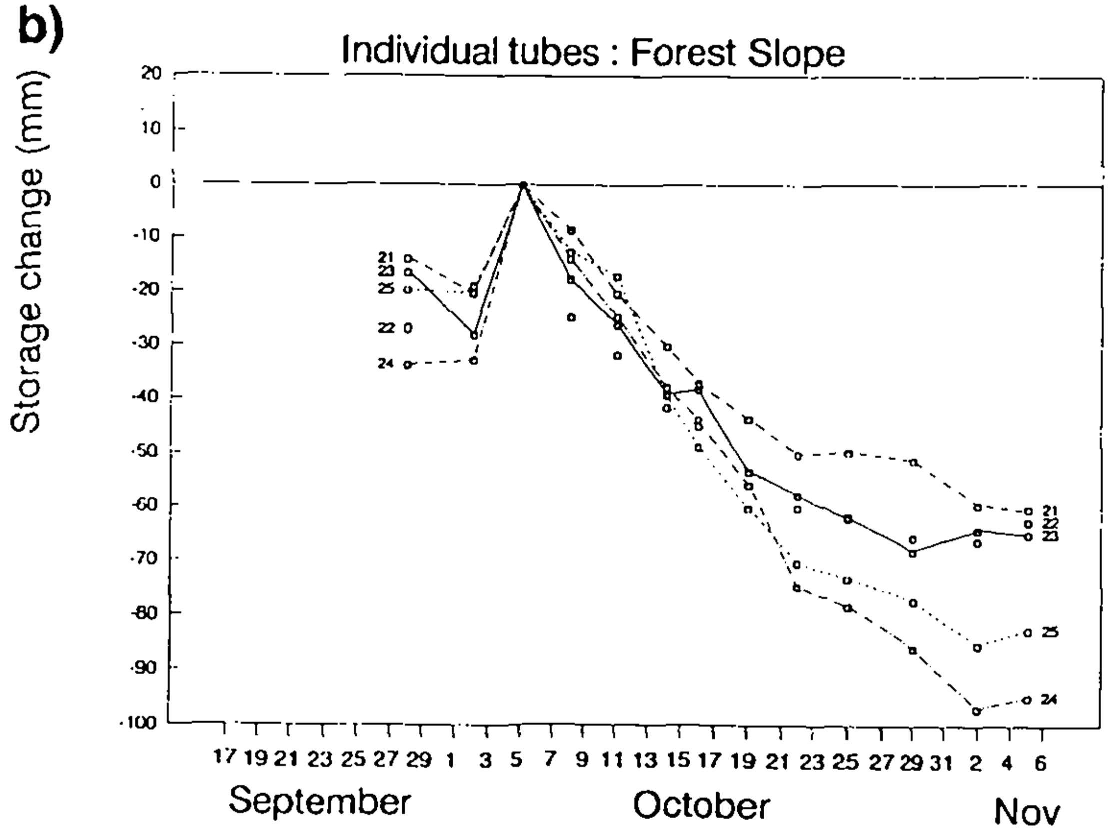


Figure 3.2.4

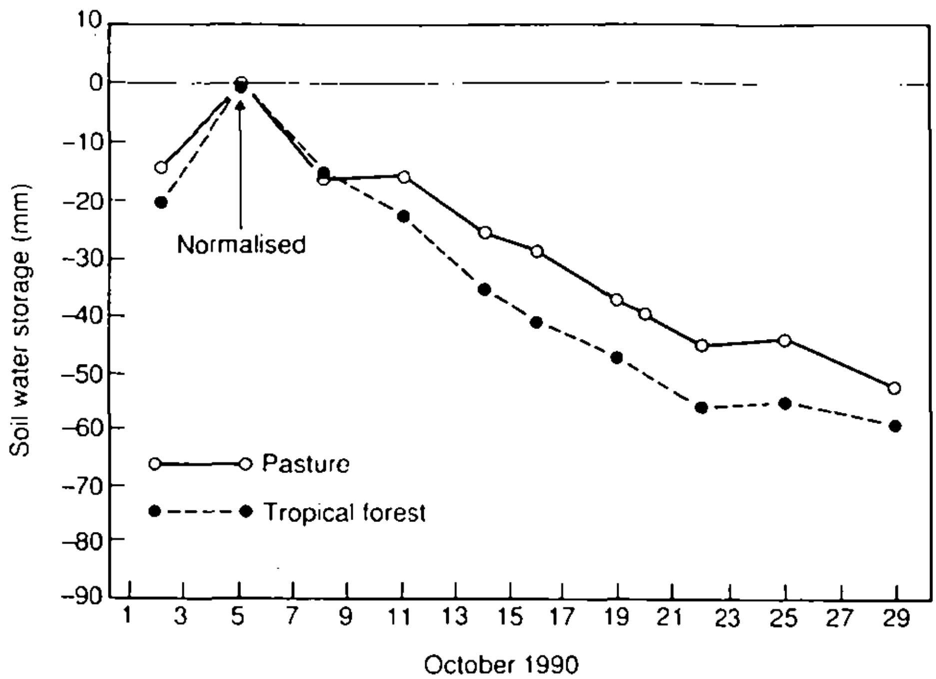
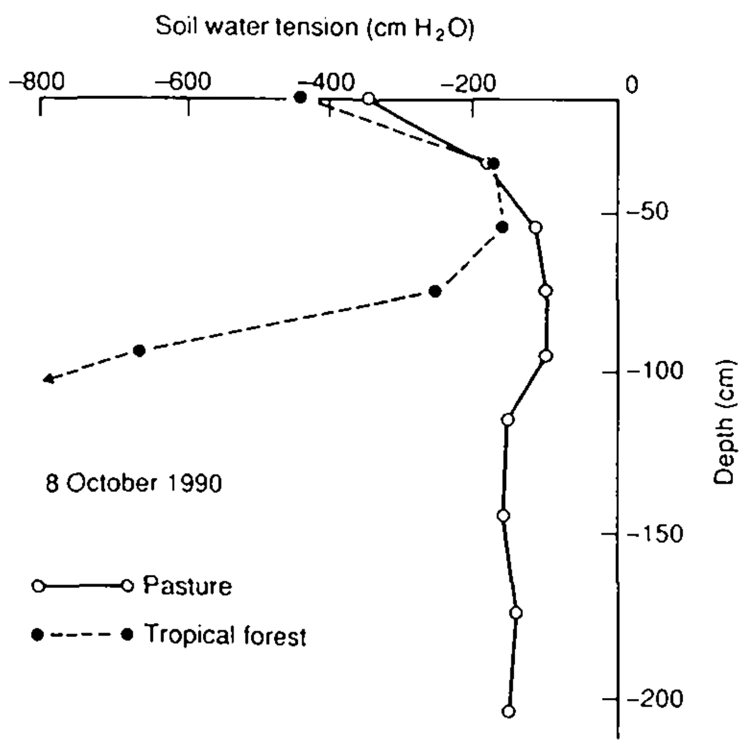


Figure 3.2.5



measurements, some conclusions can be drawn from the 50 days of data presented here.

Within the subdivisions of topography and vegetation cover, the soil moisture variability has been well sampled, particularly in the forested areas, though less so on the ranchland plateau. This is probably due to redistribution of runoff by the uneven microtopography, and uneven grass cover, bare patches and trunks. The ability of the forest to transpire more freely than the ranchland grass is already evident. The forest is accessing deeper water, extracting water under conditions of greater soil moisture tension and still maintaining a higher overall rate of water loss when compared to the ranchland grass.

3.2.4. Plans for 1991

Local Brazilian scientists have been trained to continue the operation of the neutron probe at Fazenda Dimona. All 30 tubes will be read at regular and frequent intervals to establish the long-term water balance of the soil and evaluate the wettest possible storages for calibration purposes. A short visit will be made to the site by an IH expert at the height of the 1991 wet season, to lead this calibration exercise. The tensiometer arrays will be reinstated when the soil moisture tensions return to within the range of the instrumentation. Similar paired soil physics sites will be installed at both the Rondonia and Para climatology sites in 1991. Since installation of soil instrumentation is time consuming, these further installations will necessarily be on a smaller scale, compared to Fazenda Dimona, due to limitations of time and manpower.

3.3 Climatology

The objectives of the climatological component of ABRACOS are to provide data for the validation of global climate models, and to compare the climate of cleared and undisturbed forest and of riverside urban developments using automatic weather stations. The data from these automatic weather stations will be relayed via satellite to three receiving stations in Brazil and one in the UK. In addition, the data will be stored on site by solid-state loggers, these being interrogated by portable computer.

3.3.1. Observational Systems

Automatic weather stations were installed at three sites in Amazonia during Mission M1. The first was at the cleared forest site of Fazenda Dimona. The second weather station was installed on the top of the 45 m tower above undisturbed forest at the Reserva Ducke site. The third was in the urban area of Manaus on the northern bank of the River Amazon. Each weather station records hourly averaged values of the following variables; incoming solar radiation, reflected radiation, diffuse radiation, net radiation, aspirated wet and dry bulb air temperatures, wind speed and direction, soil heat flux and rainfall.

Three receiving stations were also installed in Brazil during Mission M1 but due to the supply problems with the transmitters (described in section 2.2.2.), they are not yet receiving data from the weather stations already running in Amazonas. However, the Institute of Hydrology does have a weather station with a transmitter running at Wallingford, UK and the receivers were set to capture these data for testing and training purposes. The first of the receiving stations was installed at INPA in Manaus, the second at INPE in São José dos Campos and the third at IPH in Porto Alegre. The two stations in the south of Brazil (INPE and IPH) are working well, but we are experiencing problems with the receiver in Manaus. At Manaus the signal strength is not good, resulting in only about 50% of transmitted files being captured.

3.3.2. Data

The data logging at Fazenda Dimona was initiated on 28 September 1990 and a near complete record was obtained at the site, interrupted for two days (6-7 October) when the site was damaged by cattle. The data record at Reserva Ducke starts on 2 October and this site ran continuously throughout the mission. The Manaus site was installed at the end of Mission M1 and has been logging since 8 November 1990.

Arrangements have been made with colleagues at INPA in Brazil to visit each weather station regularly to carry out routine maintenance and to download the data from the loggers. The data will then be sent to the Institute of Hydrology on a monthly basis.

3.3.3. Preliminary Results

In order to illustrate the major differences observed between the cleared forest and undisturbed forest sites, a preliminary analysis of the data from Mission M1 was undertaken involving the averaging of the hourly values over a 28 day observation period. This gave an 'average day' for the Mission at each of the sites.

It was found that on average 17% of the sun's energy was reflected back to the atmosphere in the clearing, compared with only 13.7% over the forest (Fig. 3.3.1.). This is illustrated well by the net radiation graph (Fig. 3.3.2.) which shows the forest absorbing more energy during the day but also releasing more back to the atmosphere at night. However, the total incoming solar radiation differed slightly between the two sites over this period due to differences in cloudiness. A clearer picture can be obtained by plotting net radiation against solar radiation for each site (Fig. 3.3.3.). This shows that when the incoming solar energy was 500 Wm^{-2} there was 50 Wm^{-2} more energy being absorbed by the forests than the clearing.

Dramatic changes after deforestation were also observed in weather variables such as temperature, humidity and wind speed. The range of temperatures through the day is twice as large over the clearings as over the forest (Fig. 3.3.4.). At night, close to the ground in the clearings, the atmosphere stabilizes, the wind virtually stops (Fig. 3.3.5) and the air saturates (Fig. 3.3.6.), often leading to early morning fog and mist.

3.3.5. Plans for 1991

The installation of four new automatic weather station sites is planned for the 1991 field mission. There will be two new study areas, one in the west near Ji-Parana in Rondonia and one in the east near Maraba in Para. Two sites will be set up in each

Figure 3.3.1

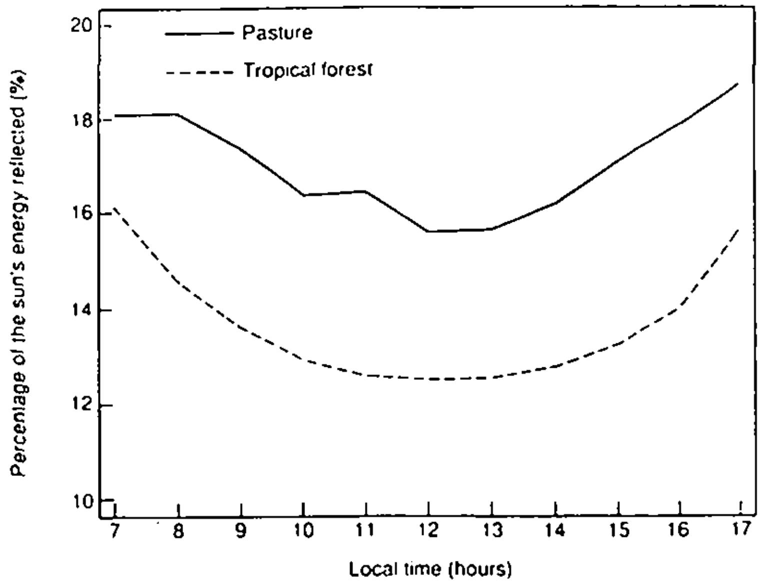


Figure 3.3.2

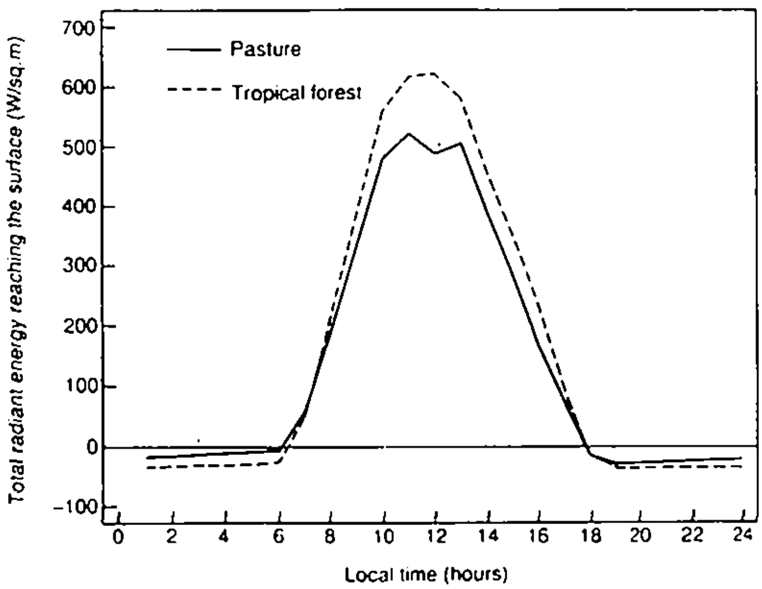


Figure 3.3.3

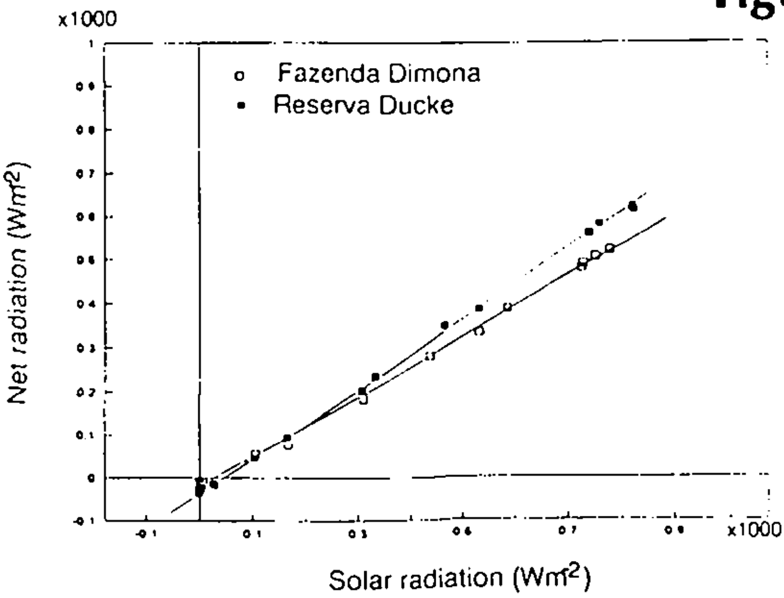


Figure 3.3.4

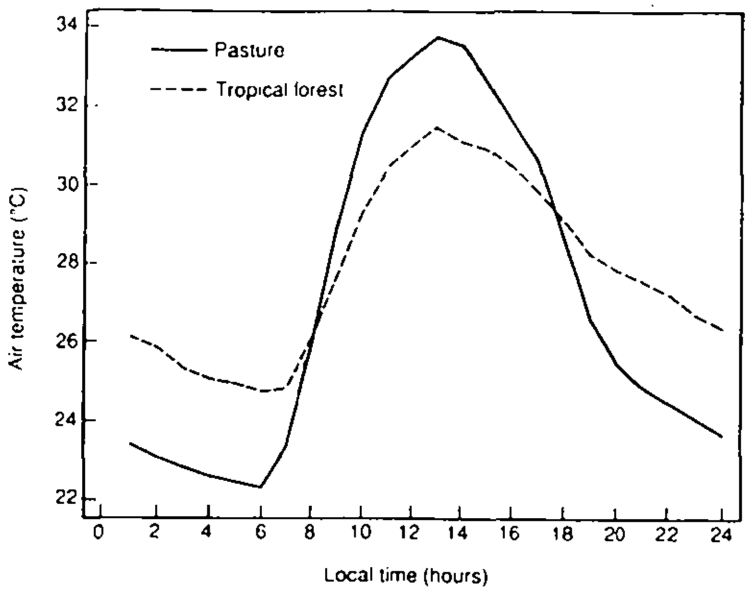


Figure 3.3.5

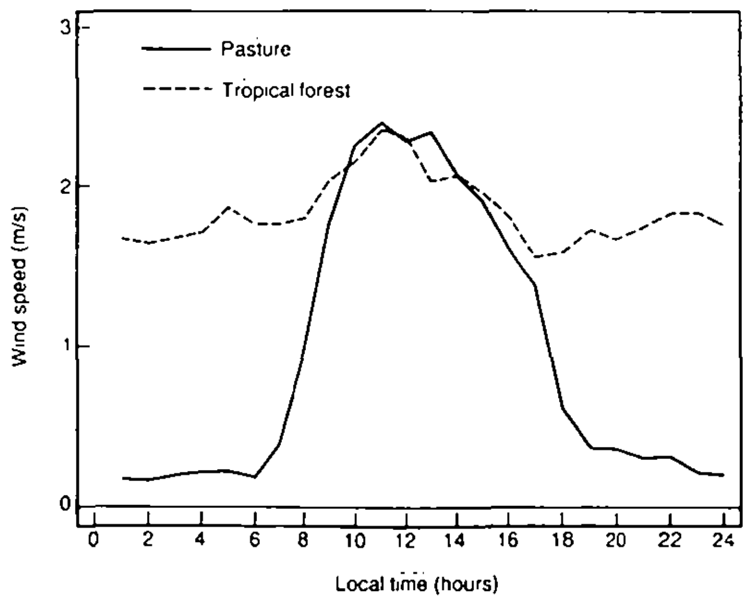
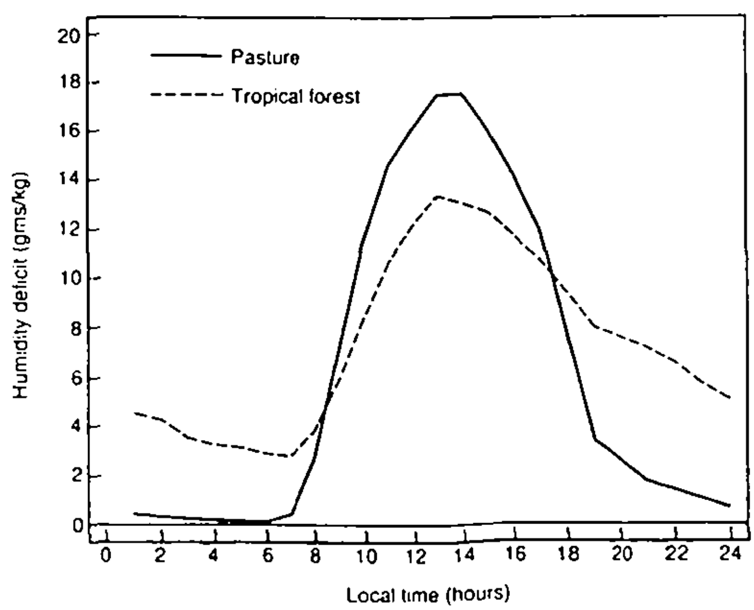


Figure 3.3.6



study area, one over undisturbed forest and one in a large clearing. The two forest sites require the construction of towers through the canopy, similar to that at Reserva Ducke. Also scheduled for 1991 is the installation of satellite transmitters, at both existing and planned weather stations, as soon as they are available.

3.3.6. Instrument damage

On the 6 October 1990 the Fazenda Dimona clearing site was invaded by cattle and considerable damage was done to the meteorological instruments there. The automatic weather station suffered a damaged net radiometer, lost soil heat flux plates and many of the cables were chewed through. The micrometeorological experiments also suffered and soil heat flux plates were lost and anemometer cups damaged.

Following this, the electric fence was replaced by a barbed wire and concrete post fence. However, in December our Brazilian colleague responsible for the maintenance of the site reported that cattle had again broken into that site and caused damage. The fencing around this station has now been further strengthened. The best information we have to hand indicates that, in addition to broken cables, soil heat flux plates have been lost and the net radiometer and a solar panel are damaged. The estimate for the replacement of these instruments is £3,100, but the budget allocation to this Budget Line is already spent. The Institute is therefore requesting additional resources to cover the loss of these instruments, and the Rolling Project Budget in 7.2 assumes these will be forthcoming.

3.4. Plant Physiology

The overall objectives of the plant physiological studies in ABRACOS are to provide insight into factors controlling transpiration in rainforest and clearings, and to give an independent estimate of transpiration for both. Studies will be made at all three sites, but during Mission M1 studies were concentrated in the central Amazon near Manaus. In the previous IH project at the Reserva Ducke, substantial data were obtained on stomatal conductance and its controls. The studies carried out in M1 aimed to fill gaps identified in the information for the forest (particularly the amount and distribution of foliage area) and to initiate parallel physiological studies in a clearing. The specific objectives were:

to estimate the vertical distribution of leaf area and biomass in rainforest and adjacent pasture;

to measure leaf gas exchange (photosynthesis and transpiration) and water relations in forest and adjacent clearing;

to measure within-canopy microclimatic factors contributing to transpiration.

3.4.1. Experimental Methods

Leaf area and biomass measurements

Twelve quadrats (0.5 m^{-2}) were sampled in the Fazenda Dimona pasture area. A quadrat was located at each of twelve compass directions and at a distance of 30 m from the meteorological tower (see Section 3.1.). All the vegetation in the quadrat was clipped at ground level and weighed. Ten per cent of this material was selected randomly and divided into green leaf, living stems and dead material. Leaf and stem areas were measured and all fractions then dried and weighed.

A representative area of forest was selected at a sufficient distance from an access road to avoid edge-effects. This 20 m x 20 m plot was divided into four sub-plots which were each destructively sampled. Prior to sampling, 20 sensors of photosynthetically active radiation (PAR) were installed on the forest floor. These sensors give transmission of PAR through the canopy above as it was successively removed: they should provide an independent estimate of Leaf Area Index (LAI) to that obtained from destructive sampling. In addition, prior to removal of each layer of forest, measurements were made with an SF80 Sunfleck Ceptometer from which a further estimate of LAI can be derived. The destructive sampling involved removing vegetation in 3 m layers for the lowest 9 m of the forest. Above this, individual trees were cut down, and their canopies divided into the appropriate canopy height category. The plant material in each 3 metre layer was divided into leaf and stem material and weighed in the fresh condition. A known ten per cent was then taken from each of the stem and leaf fractions, and leaf area measured before the subsamples were dried and reweighed.

Stomatal conductance and photosynthesis were measured in the clearing using an Infra-Red Gas Analyser (IRGA). In addition, stomatal conductances were also measured with a steady state porometer. Water potential was measured for foliage in the pasture area with a "Scholander" pressure chamber. Osmotic potential was measured on parallel leaf samples, and turgor potential estimated as the difference between leaf water and osmotic potential.

Forest Microclimate measurements.

Lightweight anemometers and psychrometers were used to measure windspeed, temperature and vapour pressure deficit at 5, 15, 20, 25, 30, 35 metres in a height profile from the forest floor on the tower in the Reserva Florestal Ducke.

3.4.2. Data Collected

The sampling of the pastureland vegetation was fully completed in the course of Mission M1. The sampling of the forest biomass was completed by the end of the Mission, and the fresh weight of tree parts, leaf area and leaf dry weight obtained. The complete drying of large woody material is a protracted process and it was decided to sea freight these to the UK to complete the drying. The sea freighting is now in progress following botanical identification of the samples at INPA. The measurement of photosynthetically active radiation on the forest floor were successfully made throughout the biomass removal.

Data collection on leaf gas exchange was severely limited by problems encountered with both Infra-red gas analysers. To supplement the gas exchange data for the clearing, measurements were made on five days with a steady-state porometer. No serious problems were encountered in monitoring plant-water relations in the Fazenda Dimona clearing, and five days' sampling were completed.

The profile of microclimate measurements was established by 15 October 1990 and satisfactory data were collected over the following 17 days.

3.4.3. Preliminary results

So far analysis has concentrated on leaf area and biomass data from the forest and clearing sites. Although large differences existed in the height distribution of leaf area index between the four 10 x 10 m forest quadrats, vertical distribution of leaf area is plausible (Fig. 3.4.1) and the total leaf area is 5.6 +/- 0.48. This is slightly lower than estimates for central lowland forests in Brazil, but the present study was carried out at the end of the dry season, which coincides with maximum leaf fall. A clear systematic pattern of specific leaf area has emerged. Values are highest close to the forest floor, 115 cm^2 leaf per gram of leaf dry weight, falling to 70 cm^2 gm^{-1} high in the canopy. Such information on specific leaf area is very useful, since it allows the conversion of simpler leaf dry weight measurements into the more valuable leaf area index.

Data from the above-ground sampling of the Fazenda Dimona clearing are tabulated below as means with standard deviations.

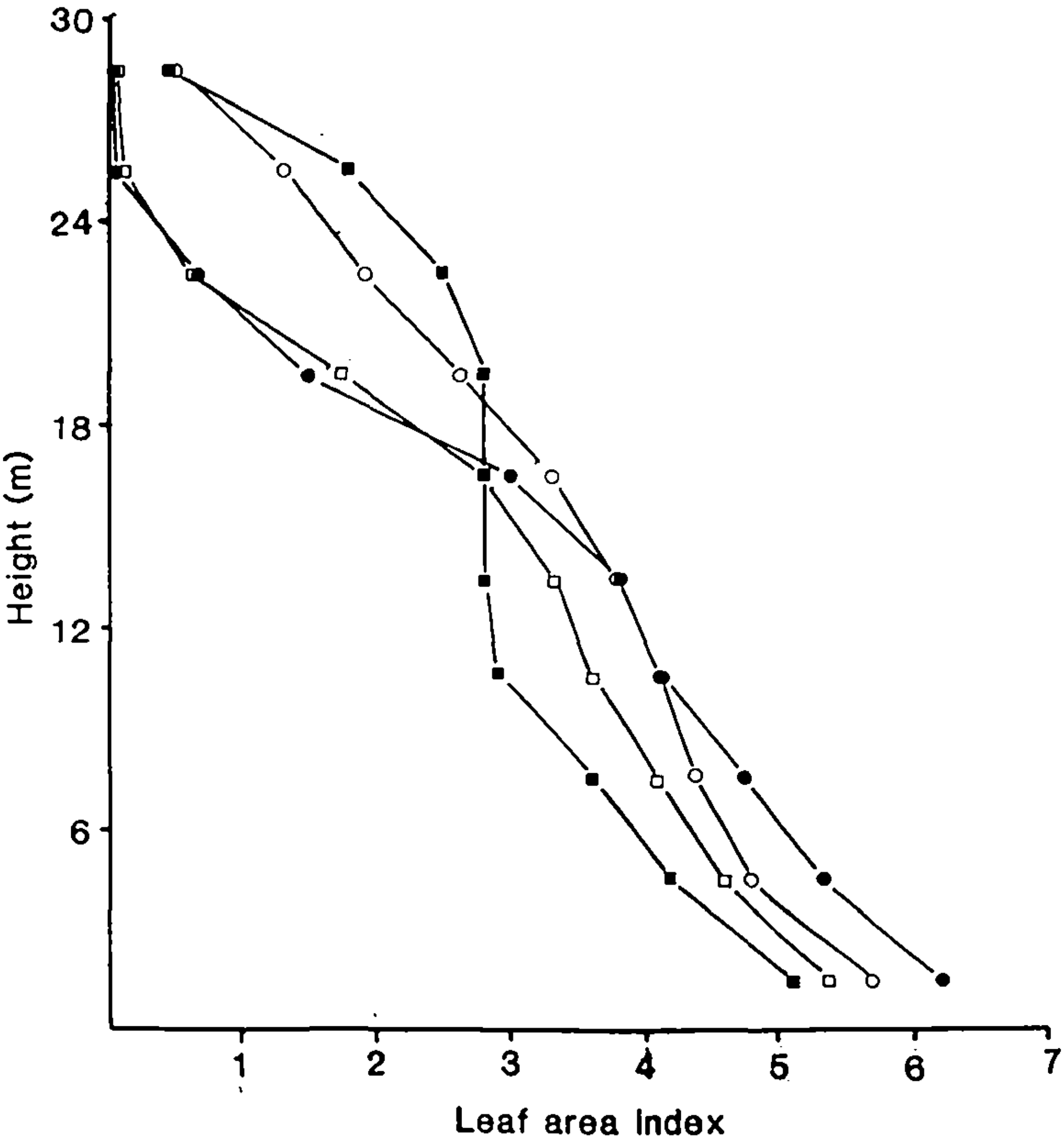
Leaf Area Index	=	0.83	+/-	0.39
Total Green Leaf Area	=	1.22	+/-	0.61
Leaf dry weight	=	109.3	+/-	45.5 kg ha^{-1}
Stem dry weight	=	128.7	+/-	71.5 kg ha^{-1}
Dead dry weight	=	334.2	+/-	153.6 kg ha^{-1}

3.4.4. Plans for 1991

The plans for physiological studies in Mission 2 are:

- to make leaf gas exchange and plant water relations at the Manaus forest and clearing sites;
- to extend leaf area and biomass measurements at the clearing site to provide information regarding its variation with position on hill slopes;
- to extend information on within forest canopy microclimate by including additional radiation sensors throughout the canopy space;
- to make leaf gas exchange and plant water relations studies at a new forest site in Para;
- to use sunfleck techniques to make preliminary studies of leaf area index at the forest site in Para.

Figure 3.4.1



4. TRAINING

The project involves a strong element of 'on the job' training through shared research endeavour. This has been modelled on previous successful experience between IH and Brazilian institutes.

4.1. Brazilian Activity

Nineteen scientific collaborators from nine different research institutes widely spread across Brazil worked alongside the ten British participants during Mission M1. Follow up guidance in analysis and interpretation of the data will proceed in the next six months through a workshop in São José dos Campos (and associated visits), and in parallel with experimental activity during future missions.

4.2. UK Activity

A Brazilian participant (Pedro Rubens de Carvalho) will make a visit of three months to the UK in the next six months for joint instrumental development and data analysis.

It has become apparent that the level of financial suppport normally provided by the British Council Technical Training Programme is insufficient for the purposes of the typically three month training visits to Wallingford by the mature Brazilian collaborators involved in ABRACOS, and alternative arrangements are currently under discussion.

5. DISSEMINATION OF INFORMATION

Although it was clear from the outset that the research to be undertaken in the ABRACOS project was likely to capture public attention, the level of interest it generates in Britain, Brazil and elsewhere is greatly in excess of that anticipated, to the extent that it requires recognition as part of project activity and as a significant demand on the project budget. Activity comprises propogating the project through talks at scientific meetings and learned societies; through interviews and press releases for articles in newspapers, and reports on radio and television; and through the production of handouts and videos, suitable for distribution to interested members of the public. All of these have formed part of the project activity during the period reported on here.

5.1. Dr Shuttleworth presented formal scientific talks on the project and its rôle in the global research programme in July at the International Geosphere-Biosphere Programme (IGBP) Workshop in Stockholm; in August at the Hydrology and Water Management of the Amazon Basin Symposium in Manaus; in October at the Global Energy Water Cycle EXperiment (GEWEX) Meeting in Washington; in October at the Royal Meteorological Society Meeting in Edinburgh; and in November at the Royal Society IGBP Meeting in London. He also gave informal talks in November at the Royal Geographical Society and the Anglo-Brazilian Society in London, and in October presented a poster display on the project to the First Anglo-Brazilian Environment Conference in Brasilia.

5.2. The UK Minister for Overseas Development, Mrs Lynda Chalker, attended this latter conference, accompanied by senior advisors, with the intention of travelling on to Manaus to view the progress of this proposal. Unfortunately her trip had to be cancelled at the last minute, when she was recalled for urgent parliamentary business. The project participants were, however, pleased to entertain Mr Richard Manning, ODA Permanent Under Secretary, in her stead.

5.3. Over the last six months, the ABRACOS project has been frequently reported by national newspapers in Brazil, by national and local newspapers in Great Britain, and has been featured on local radio in the UK and twice on the BBC World Service.

5.4. Two colour brochures have been prepared on the project over the period under review, one in English and one in Portuguese, and demand for these has been such that the first print runs are now almost exhausted. The project featured in the IH-produced ODA newspaper "Overseas" which was widely distributed at the First Anglo-Brazilian Environment Conference in Brasilia.

5.5. The first results from the project, based on the data collected during Mission M1 are being written up as scientific papers which will be submitted for publication in 1991. Meanwhile overviews of these results are being prepared in a form suitable for public dissemination early in 1991, both as a colour handout and as a VHS video cassette.

5.6. The level of demand for information and dissemination products described above has financial implications, as staff costs; travel expenses and recurrent costs for materials and production. These were not foreseen at the time of the project proposal, and because of this, the costs involved have largely been borne from Institute of Hydrology resources outside the project budget pending this report. However, such expense is clearly significant and ongoing, and the Institute therefore requests that it should be recognised as a legitimate additional component of project costs, and provision made for it in the project budget. The estimated annual costs are as follows:

Additional Staff Costs	equivalent to 6 weeks per year at HSO grade [to enter the budget through support specialist S9 in Budget Line 2.7].
Additional Travel Costs -	£5K per year [to enter the budget in Budget Line 2.5].
Additional Recurrent Costs	£5K per year [to enter the budget in Budget Line 2.1].

6. SITE SELECTION VISITS

The project plans to establish and instrument two 'paired site' studies during Mission M2 in 1991 in the states of Para and Rondonia. At each location this will involve erecting a tower over an extensive area of natural forest, and a similar (but shorter) tower over an adjacent, extensive cleared area. The two sites at each location will be instrumented for long term routine measurements of comparative climate and soil moisture status, and may well provide the focus of additional detailed study in future years. In the course of the six months under review here, a preselection of potential sites was made using remote sensing images provided by INPE, and preliminary visits to preferred areas made by leading Brazilian collaborators. At the end of Mission M1 a group of senior British and Brazilian participants made detailed inspection of the most likely potential sites, and they were accompanied in this by Dr Peter Rowntree, a UK climate modelling specialist from the Hadley Centre for Climate Modelling and Prediction.

6.1. Site Selection Visit to Rondonia

6.1.1. Personnel involved in this visit were:

Dr Nobre (INPE)
Dr Shuttleworth (IH)
Dr Gash (IH)
Dr Rowntree (Hadley Centre)

6.1.2. The itinerary was as follows:

6 November 1990: the party arrived in Porto Velho and visited the local office of EMBRAPA, the agricultural research organisation. The EMBRAPA scientists expressed interest in being involved in the project and suggested that a visit be made to the out station at Ouro Preto (40 km from Ji-Parana), which might form the possible base for the project. This station was visited en route to Ji-Parana. Ji-Parana is approximately 320 km from Porto Velho.

7 November 1990: visits were made to the offices of INCRA (Land Reform Agency), FUNAI (Indian Affairs Agency) and IBAMA (Environment Protection Agency). These visits were both to establish contacts and to obtain the necessary permission to visit the Indian reservations. In the afternoon a possible area of forest was visited within the Indian reservation at the eastern edge of the new agricultural clearings north east of Ji-Parana. Although a possible site, the forest was not totally undisturbed and the topography far from ideal. Access from Ji-Parana was almost two hours' drive.

8 November 1990: an alternative forest site was visited in the Indian reservation north of Ji-Parana. A suitable area for a site was located. Both the Indian chief and the resident FUNAI representative were in favour of siting the tower at this site. However, there are problems of access. It is a two hour drive from Ji-Parana, only suitable for 4 wheel drive vehicles. In the wet season it is likely that the road may become temporarily impassable and some of the bridges (essentially logs with planks on top) would need renovating if used regularly. In the afternoon a second visit was made to the EMBRAPA station and on

their advice a suitable farm site was located. However, it is clear that in this region pure pasture is rare there are almost always residual palms, which are fire resistant and are not removed. To get above these palms, a short (approximately 15 m) instrument tower will be required.

9 November 1990: to investigate the feasibility of operating the proposed site by boat, a boat was borrowed from IBAMA, and taken up river to the nearest accessible point close to the proposed site. This was a journey of 90 minutes. A further 30 minutes would be required to travel up the stream (only possible with wet season river levels) from the main river to the site. There is no advantage in using boat transport, but during the wet season it may on occasions be the only method of reaching the site. It will be possible to borrow boats from IBAMA but the availability of outboard motors is unreliable and a suitable motor should be bought for the project.

A visit was made to the State University Campus in Ji-Parana. There is a small staff and office space is available. They are interested in collaboration and it could make a suitable base for project operations.

10 November 1990: the party travelled to Belem.

6.1.5 Summary

The selected sites in the forest and clearing, illustrated in Figure 6.1, are ideal from a scientific standpoint. There are access difficulties with the forest site described above, which will necessitate some upgrading of the tracks to the Indian reserve and the purchase of an outboard motor to ensure access in the wet season. The required tower infrastructure is greater than expected at both forest and clearing sites.

6.2. Site Selection Visit to Para

6.2.1 Personnel involved in this visit were:

Dr Nobre (INPE)
Prof Carvalho de Moraes (University of Para)
Dr Shuttleworth (IH)
Dr Gash (IH)
Dr Roberts (IH)
Dr Rowntree (Hadley Centre)

6.2.2. The itinerary was as follows:

12 November 1990: the party assembled in Belem and departed to Maraba, there making a visit to the University of Para campus to inspect their local facilities being hosted by Prof. Anair, and then making contact with Sr José Ferreira Campos, the administrator at the local FUNAI office. In the afternoon the party visited an extensively cleared area near the town of São Raimundo, previously identified by satellite. This was confirmed as the ideal location for the cleared site data collection in Para. It is accessed via highway PA70, this being a dirt road which crosses the Mae Maria Indian Reserve which is north of Maraba. No attempts were made to establish contact with

Figure 6.1

proprictors of potential sites on this visit, but there are many options for suitable locations in this general area.

13 November 1990: an exploratory trip was made to areas of undisturbed forest south of Maraba, but this had to be curtailed due to problems with borrowed transportation. The party returned to Maraba and rented a car for the remainder of the visits.

14 November 1990: the party travelled south for approximately 70 km on the (metalled) PA 150 highway, and then east for about 30 km on good dirt roads, to reach **Fazenda Piranha.** This farm specialises in the collection of Brazil nuts over a large area of forest, and the administrator, Sr. Livio de Andrade Lima, proved amenable to siting the forest tower on this property. After returning north to a point approximately 45 km from Maraba on the PA 150, the party then went east on dirt roads to visit the **Reserva Florestal da Companhia Vale do Rio Doce.** This is a forest reserve of approximately 17,000 ha, but a visit into the reserve itself was not possible since there was no person available to give authorisation.

15 November 1990: a small plane was rented in Maraba, to overfly the Mae Maria Indian Reserve, the Fazenda Piranha and the Reserva Florestal da Companhia Vale do Rio Doce. A visit was made to inspect the Maraba meteorological site in the afternoon.

16 November 1990: further discussion at the FUNAI office in Maraba was followed by a visit to the India community in the Mae Maria reserve to meet Cacique, their chief spokesman. The Indian community expressed an interest in further information on the project, in particular its objectives, the infrastructure to be installed in the forest and what advantage there might be to the Indian community. Meanwhile their attitude to the proposal to construct a forest tower in their reserve remains neutral. Later in the day discussions were held with Sr Barbosa, a technician of the Companhia Vale do Rio Doce to gather information on the extent and security of their company reserve and the degree to which it has been disturbed.

17 November 1990: site selection party dispersed.

6.2.3. **Summary**

The potential sites are illustrated in Figure 6.2

São Raimundo Pasturelands There are plenty of opportunities for good pastureland sites in this area all with easy access. As with the Rondonia site, short towers will be required to raise the climate stations above the trees.

Fazenda Piranha is a site with good road access throughout the year and a co-operative farm management. However, the overflight suggested the forest was quite disturbed. The site is not ideal, but represents a third preference.

Reserva Florestal Companhia Vale do Rio Doce is a dense, continuous, undisturbed forest but there is rapid encroachment to the reserve boundary, such that the reserve itself could possibly be the only remaining forested area in the next few years. This, without the surrounding area, may prove too small from the climatological studies. No obstacles are foreseen in gaining

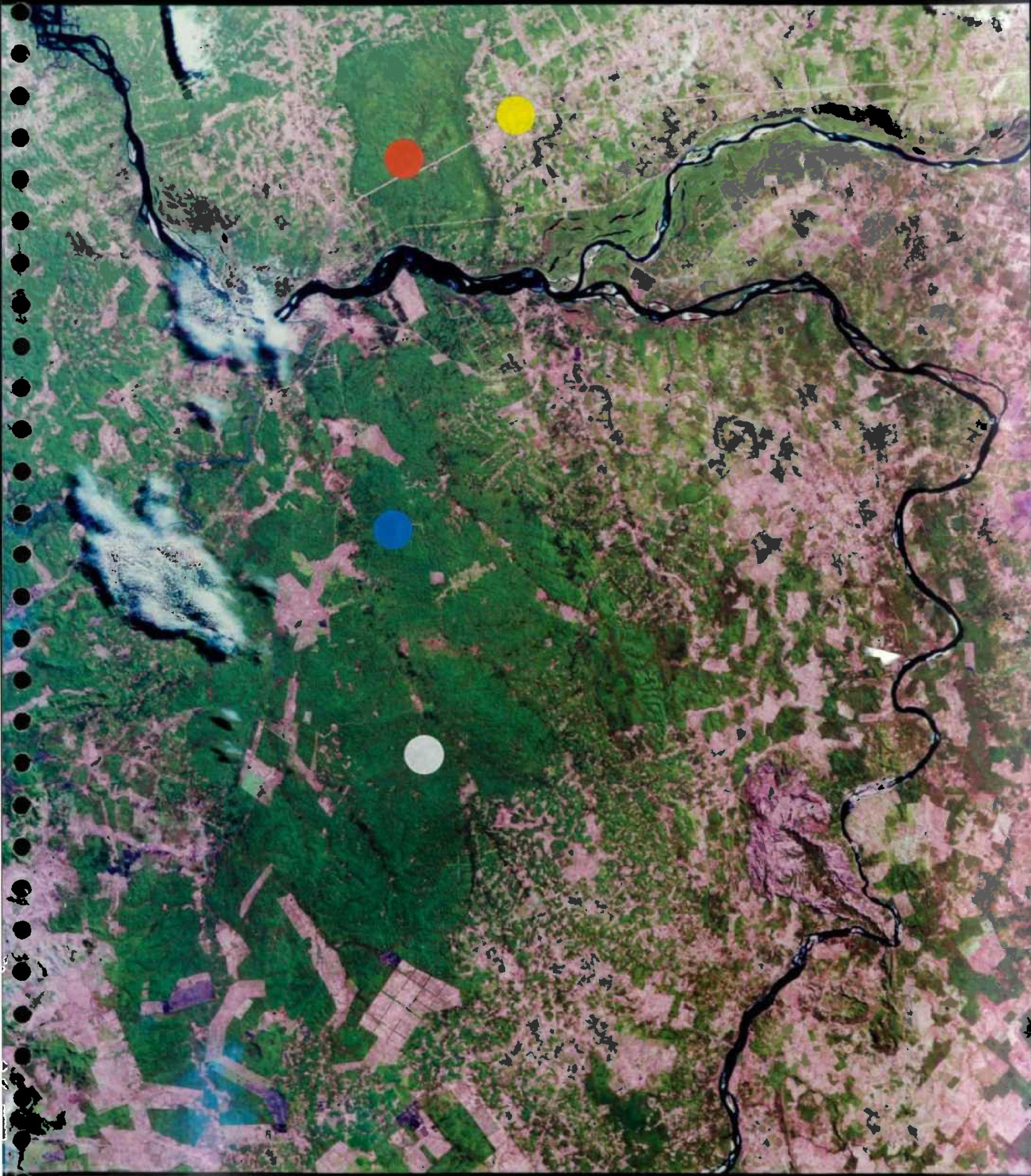


Figure 6.2

Sao Raimundo

Mae Maria

Vale do Rio Doco Reserve

Fazenda Piranha

permission to work at this reserve, but there could be access difficulties in the wet season due to flooded roads. It is an adequate second choice forest site.

Reserva Indigena 'Mae Maria' is a dense, continuous and extensive forest with only occasional small cultivated areas. Further meetings are required with the local Indian community to obtain access, and some sort of rental, or financial demands in the form of infrastructure improvement, may well be required in order to gain approval.

All the possible forest sites in this area have individual 'dominant' trees which can exceed 40-45 metres, and will probably therefore demand a tower height of 50 metres. The available cleared sites here, as in Rondonia, have occasional remnant trees and meteorological instrumentation will again need to be mounted on a short tower.

6.3. Impact of Site Selection Visits on Future Plans

6.3.1. It is clear that the construction of the new paired sites in Rondonia and Para planned for Mission M2 will involve a work load in considerable excess of that anticipated. It will also make additional financial demands for taller forest towers, for additional short towers for the cleared areas, and quite probably also significant expenditure for improving vehicle access, and perhaps for site rental.

6.3.2. Approval has been sought and gained from ODA for extra funds for the additional tower components, and the Rolling Project Budget given in section 7.2 includes these together with enhanced estimates for the provision of site facilities in the coming financial year. These financial needs are hard to define at this time, however, and could well be underestimated. It is relevant that financial input to the project to improve vehicle access will assist the indigenous Indian communities to sustain their lifestyle in two natural forest reserves which interface with extensive deforestation, and therefore has aid merit in its own right.

6.3.3. The size of the forest towers required at the two new sites, the need in each case for subsidiary cleared site towers, together with the likely need for construction work in improving vehicle access are such that it has been necessary to reappraise the proposed working schedule for Mission M2. This is especially necessary since it is the intention to also maintain data collection at the Manaus site.

6.3.4. It is now not considered feasible or cost-effective to establish the two sites sequentially. The intention is therefore to construct the towers in parallel, with two suitably chosen teams operating simultaneously, one in Para and one in Rondonia, and a third smaller team collecting data in Manaus. The Manaus team will be temporarily supplemented by individuals from the other two teams at approximately 10 day intervals as required.

6.3.5. In order to do this it will be necessary to draw in additional tower construction experts from the Institute of Hydrology, thereby making it possible to form two tower-top teams (comprising 3 persons) for the critical period as the towers approach their maximum height. To use inexperienced staff at this time would be an unnecessary risk. The Rolling Project Budget presented in paragraph 7.2 has been increased to include 0.24 man years at HSO grade during the 1991/92 financial year to allow for this additional specialist input.

7. FINANCIAL OVERVIEW

7.1. Budget Line Revisions

7.1.1. The majority of the known spend on scientific hardware in Budget Lines 1.1.1., 1.1.2., 1.1.3., 1.2.1. and 1.2.2. has already been made or, as in the case of Budget Line 1.2.1., is committed awaiting delivery. A small carry forward into 1991/92 has been made for Budget Lines 1.1.1., 1.1.2. and 1.2.2. of £7K, £7K and £10K respectively, and a further carry forward into 1992/93 for Budget Line 1.1.1. of £7K. These are to allow for site specific equipment whose specification and requisition will be optimally made once the precise locations and formats of the new sites in Para and Rondonia are known. All of the equipment Budget Lines include elements in the 1990/91 financial year, which are for equipment on order and not yet delivered. Some additional carry forward may become essential in the event of late delivery.

7.1.2. The required spend on transport and site facilities continues to escalate. The estimated cost of the towers required in Para and Rondonia (Budget Line 1.3.1) is now £70K: this reflects their increased height, and the consequent need for additional structural strength for reasons of safety. The increased cost of Vehicle Purchase (Budget Line 1.3.2B) follows from the decision to buy and ship Land Rovers. The underspend on Site Facilities (Budget Line 1.3.3.) in 1990/91 largely reflects the failure to find a cost effective solution to intersite and intervehicle communication in Manaus. The projected increased spend on Site Facilities in 1991/92, which is difficult to estimate, reflects the need to provide improved vehicular access to the new forest sites, particularly that in Rondonia, see paragraph 6.1.2.

7.1.3. The overspend on Sundry Scientific Supplies (Budget Line 2.1.) in 1990/91 is offset by the not unrelated underspend in Site Facilities (Budget Line 1.1.3.); and the slight overspend for Counterpart Travel in Brazil (Budget Line 2.3.) by the underspend on Counterpart Travel to UK (Budget Line 2.4.).

7.1.4. The unforeseen heavy importation charges within Brazil described in paragraph 2.3.5. are the primary reason for the overspend on Freight Charges (Budget Line 2.2.) in 1990/91, and for the upward revision in the estimated cost for freighting in future years.

7.1.5. A carry forward of £19.8K has been made in the IH Travel Costs (Budget Line 2.5) from the 1990/91 to the 1991/92 financial years to cover the anticipated heavier costs of multisite activity in Mission M1. This Budget Line and that for Sundry Scientific Supplies (Budget Line 2.1) have both been increased by £5K per year for the remainder of the project. This is under the assumption that ODA accept the need for budgetary provision for Dissemination of Information on the project, see paragraph 5.5.

7.1.6. The increased Institute of Hydrology Staff Costs (Budget Line 2.7) during 1990/91 are a direct consequence of drawing in additional staff support to meet the tight shipping deadlines for Mission M1, not all of which can now be compensated for by reduced post mission activity. The enhanced estimates from 1991/92 onwards are under the assumption that ODA accept the recommendation for additional specialised staff support for tower building in 1991/92, see paragraph 6.3.5; and ongoing support for Dissemination of Information, see paragraph 5.5.

7.2. **ROLLING PROJECT BUDGET** (in £K)

		Year 1 89/90	Year 2 90/91	Year 3 91/92	Year 4 92/93	Year 5 93/94	Year 6 94/95	Totals
	CAPITAL COSTS							
1.1.	Hardware associated with Phase 2							
1.1.1.	Micrometeorological Equipment	0.5	47.6	25.0	23.0	5.0		101.1
1.1.2.	Plant Physiological Equipment		71.8	7.0				78.8
1.1.3	Soil Moisture Equipment		13.5					14.8
1.2.	Hardware associated with Phase 3							
1.2.1.	Climatological Equipment and Receiving Stations		135.4					135.4
1.2.2.	Soil Moisture Equipment		35.0	10.0				45.0
1.3.	Transport and Site Facilities							
1.3.1.	Forest Towers		70.0					70.0
1.3.2.A.	Transport Facilities (Op. and Maint.)		9.0	9.0	9.0	9.0		36.0
B.	Transport Facilities (Purchase)		(88.0)					(88.0)
1.3.3	Site Facilities		6.5	25.0				31.5
1.4.	UK-based Hardware and Facilities							
1.4.1.	Computers		24.0					24.0
	TOTAL CAPITAL:	1.8	412.8	76.0	32.0	14.0		536.6
			(500.8)					(624.6)

		Year 1 89/90	Year 2 90/91	Year 3 91/92	Year 4 92/93	Year 5 93/94	Year 6 94/95	Totals
2.	RECURRENT COSTS (other than vehicle support)							
2.1.	Sundry Scientific Supplies		24.5	27.0	27.0	27.0	27.0	132.5
2.2.	Freight Charges		26.7	25.0	10.0	10.0		71.7
2.3	Contribution to Counterpart Travel Costs		21.1	20.2	38.8	18.4		98.5
2.4.	Counterpart travel to UK	0.2	4.6	5.4	5.4	5.4	23.5	44.5
2.5.	Institute of Hydrology Travel Costs		71.0	83.0	82.5	82.5	38.0	357.0
2.6.	Institute of Hydrology Consultant	0.5	7.0	8.5	8.5	8.4	8.0	40.9
2.7	Institute of Hydrology Staff Costs	34.4	233.1	252.4	252.6	265.5	207.0	1245.0
	TOTAL RECURRENT:	35.1	388.0	421.5	424.8	417.2	303.5	1990.1
TOTAL PER YEAR		36.9	800.8	497.5	456.8	431.2	303.5	2526.7
			(888.8)					(2614.7)
PROPOSAL ESTIMATE OF COSTS (including 10% contingency element)		...955.3.		392.7	426.6	411.4	276.7	2462.0

PROJECTED TOTAL COST OF PROJECT (as at 30 December 1990): £2,568,000

(£2,656,000)