WISE FOREST MANAGEMENT AND CLIMATE CHANGE

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ABSTRACT

Links between atmosphere and the vegetation in pristine and disturbed forests can be classified as indirect linkages, which involve atmospheric constituents as an intermediary, and direct linkage through the exchanges of energy, water and momentum between the vegetation and the air above. Here the extent and nature of such forest-atmosphere linkage is explored with respect to information now available from joint Anglo-Brazilian field studies in Amazonia. The proposition is made that the wise management of tropical forests with minimum contribution to climate change will involve land cover which mimics the atmospheric interaction of existing forest. In particular, it will involve deep rooted, perennial vegetation with a dense but uneven canopy, which is persistently growing in nutrient stable soil, and which is managed with minimum use of fire.

1. Anglo-Brazilian Field Studies research

Much of the research to quantify the linkage between tropical land cover and the atmosphere has carried out jointly over the last decade in Amazonia by Brazilian and British scientists.

The Amazon Region Micrometeorological Experiment (ARME) took place in the early 1980s. Its results have been extensively reported (e.g. Shuttleworth *et al.*, 1984a, 1984b, 1985), and have formed the subject of several reviews (e.g. Shuttleworth, 1988, 1989; Shutteworth *et al.*, 1991). The data have, moreover, now also been widely used in calibration or validation of several modelling studies (e.g. Dickinson and Henderson-Sellers, 1988; Lean and Warrilow, 1989; Nobre *et al.*, 1991; Jacob and Wofsy, 1990; Keller et al., 1991).

In the context of the present paper, the most relevant results from ARME are that:

a) the albedo of tropical forests is typically about 12-13%
b) the loss of incoming rainfall due to re-evaporation of rain intercepted by the forest canopy is typically 10-15%, and provides about 25% of the total evaporation on everage.
c) about 75% of the total evaporation occurs as transpiration, with little evidence of soil water restrictions on forest transpiration in the existing climate of Central Amazonia.
d) 50% of the water falling as rain is re-evaporated in Central Amazonia, and it takes about 90% of the available solar energy to do this.
e) detailed plant physiological measurements of rainforest canopy properties, when synthesized to whole-canopy level and used to

calibrate the surface exchange in models of tropospheric chemistry, suggest that deforestation will result in enhanced tropospheric ozone, and transform Amazonia from a sink to a source of ozone.

f) use of the data in General Circulation Models (GCMs) suggest that clearance of Amazonia may result in regional reductions in precipitation by 30 +/-20%.

The Anglo-Brazilian Climate Observational Study (ABRACOS) built on the research links formed during ARME and began in 1990. In this project there is particular emphasis on providing data and understanding on the atmospheric interaction of cleared pastureland areas, and on possible feedback mechanisms in the atmosphere itself. The data collection includes long-term monitoring of near-surface climate for cleared and adjacent uncleared areas in the States of Para, Rondonia and Amazonas; together with detailed micrometeorological, plant physiological and soil physical studies, these measurements being carried out in intensive field campaigns.

The immediate observational results from ABRACOS coupled with those from ARME given above, provide guidance on wise management of tropical forests with respect to potential climate change.

2 - Wise Forest Management and Surface - related Processes

Carbon Release

Data from ABRACOS (McWilliam *et al*, 1991) support the existing literature, and confirm the substantial loss of carbon associated with tropical deforestation. A recent review by Houghton (1991) which incorporates the most up-to-date estimates of rates of deforestation (Myers, 1991), suggests that the net contribution of carbon so given has increased from (1.0-2.0) x 10^9 tonnes per year in 1980 to (1.5-3.0) x 10^9 tonnes per year in 1989. For comparison the contribution to atmospheric carbon given by fossil fuel burning is currently estimated as around 5.5 x 10^9 tonnes per year.

The release of carbon from the earth's biomass stores is not an irreversible process. A significant proportion of the carbon lost during deforestation could be sequestered during the growth of replacement vegetation cover - providing replacement crops were perennial with substantial biomass. This would be further enhanced if the 'products' of such replacement cropping systems were themselves long-lived carbon stores. Further, Houghton (1991) estimates that if new forests were successfully established through reforestation on an estimated 865 x 10^6 hectares of abandoned degraded lands, lands climatically suitable for forests, as much as 150 x 10^{12} tons of carbon might be withdrawn from the atmosphere over the next 100 years. Mixed crop systems involving both perennial trees with substantial biomass and interspaced cash crops, also have merit since they offer some carbon sequestration along with arguably greater financial viability.

The Exchange Other Of Trace Gases

Other trace gases are released when land covers are changed and also contribute to greenhouse warming. Burning is itself the most substantial mechanism for such release and Table 1 shows the estimated emission of important greenhouse gases given by deforestation. These estimates are based on the approximate emission factors given by Keller <u>et al</u>. (1991), assuming the rate of tropical deforestation given by Myers (1991) and, for the purposes of illustration, assume tropical forests store 125,000 kg of carbon per hectare, as suggested by the ABRACOS measurements (McWilliam, <u>et al</u>.,1992).

Gas	Estimated Fire Emission ($kg\ ha^{-1}\ y^{-1}$)	Estimated Global Release ($kg\ y^{-1}$)
CO_2	32000	444×10^9
CO	3200	44×10^9
CH_4	380	5.3×10^9
N_2O	7	0.1×10^9
NO_x	63	0.9×10^9

Table 1. Estimated emission of trace gases to the atmosphere from the burning of tropical forests.

In addition to these releases generating during the initial burning, it has been suggested by Keller <u>et al</u>. (1991), that post-deforestation agricultural practice which involves repeated seasonal burnings in an extensively (80%) deforested area of Amazonia, can result in significant changes in the chemistry of the troposphere at the local and regional scale. This model, which relies for its calibration on the basic canopy parameters measured by Roberts <u>et al</u>. (1989), is validated against data gathered over virgin Amazonian rainforest (Harriss <u>et al</u>., 1985).

It predicts that dry season concentration in the troposphere over Amazonia would double, and that the forest would become a source rather than a sink of ozone. It further suggest that recurrent burning would also result in enhanced regional concentrations of the greenhouse gases, N_2O and CH_4.

Surface Energy Exchanges

The new data emerging from ABRACOS (Bastable <u>et al</u>., 1992) has confirmed the significant change in the associated with deforestation surface albedo. So far the results suggest that the change, from around 13% to 17% for forest and pastures respectively, is less than had been previously thought. It is not yet clear if this low albedo of Amazonian pastures is a unique feature of the particular study site, and related to the sparse vegetation cover and exposed soils there, which are successively darkened by reburning.

A further result (Bastable <u>et al</u>., 1992) is that there is a substantial difference in the diurnal cycle of long-wave exchange between forest and pastures, which is associated with their very different surface temperatures, this being particulary large in dry portions of the year. This difference in long-wavelength radiation exchange, along with the difference in reflected solar energy can give significantly different diurnal cycles of net radiant energy transfer. Pastures capture less energy as radiation during the day when evaporation occurs, but lose more at night, the net effect being a slight cooling of the near-surface atmosphere for pastureland, and less evaportation.

It is now clear (Wright et al., 1992) that shorter rooted replacement vegetation, and pasture in particular, responds much more quickly to shortage of rain than does deeper rooted forest. Preliminary measurements suggest (Hodnett et al., 1992) that pastures gain their transpired water from within the top two metres of soil, most of it from within the top 1 metre; while Amazonian forests seem capable of accessing soil water to considerable depths, certainly to a depth of 4 metres and quite possibly to depths of 6-8 metres. Access to this substantially greater soil moisture store is clearly important in determining the way radiant energy received at the ground is shared either to evaporate water or to warm the air. The forests are in consequence much more resilient to periods of water shortage, and can sustain substantial transpiration rates for many weeks, possibly for several months.

In addition, the ability of aerodynmically rough and leafy vegetation, such as forests, to re-evaporate water captured by the canopy during rainstorms is well documented (e.g. Shuttleworth, 1989). This predisposition on the part of forest to re-evaporate 'intercepted' rainfall further aids their ability to recycle precipitation back to the atmosphere.

Local Microclimate Differences

The distinctive difference in the aerodynamic transfer efficiency between uneven forest-like canopies and smoother, generally shorter, vegetation types has now been observed and documented through ABRACOS (Wright et al., 1992). It has also been observed to generate substantial differences in near surface microclimates (Bastable et al., 1992). Such differences are easily understood in terms of the different physical transfer mechanisms near the ground: they can lead to noteworthy differences in the temperature, humidity and windspeed measured a few metres above the top of the vegetation. The daily cycle of air temperature, for instance, can be a factor of two different, as can that in specific humidity. Further, windspeeds over cleared areas at night are much reduced. These low nightime winds are often associated with saturated air, and commonly gives rise to fog and dew a phenomenon rarely observed above the original tropical forests. Moisture in the form of dew on plant leaves may be be detrimental to shorter replacement crops since it can facilitate spore germination, and the growth of parasitic fungi and diseases.

3 - Preferred Features in Replacement Vegetation

Table 2 lists the several climate-related linkages described above and the scale at which they are relevant, and also lists those features of replacement vegetation and management practice which would minimize climate change impacts in wise forest management.

In summary, the 'wise management' of tropical forests which seeks, as its primary objective, the minimum contribution to climate change, will involve the use of replacement vegetation which in large which in large measure mimic the existin deeply rooted, perennial vegetation is required, which is persistenly growing, which has a persistenly dense but uneven canopy, and which is manage with the mimimum use of fire.

Climate-related linkage of Management Practice	Scale of Influence	Preferred Feature of Management Practice
1. Indirect linkage through atmospheric constituents, namely		[Re-use already cleared land]
(a) Carbon Dioxide	Global; Regional	Large Biomass; Perenial; Long lived products.
(b) Other trace gases (N_2O, CH_4, O_3, etc.)	Global; Regional	Minimal fire use
(c) Smoke particles	Regional; Local	Minimal fire use
2. Direct linkage through surface exchanges, namely		[Re-use already land]
(a) Solar energy capture	Global; Regional; Local	Uneven Canopy; Optically 'black'
(b) Thermal energy emission		Uneven Canopy
(c) Momentum capture		Uneven Canopy
(d) Re-evaporation of intercepted rain		Dense but Uneven Canopy
(e) Transpiration		Deep-rooted; Dense Canopy
(g) Near-surface local micro-climate	Local	Uneven Canopy; Deep-rooted

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