THE EFFECT OF DEFORESTATION ON THE WATER CYCLE IN THE AMAZON BASIN: AN ATTEMPT TO RESOLVE THE PROBLEM.

J. B. Gat (**) E. Matsui (***) E. Salati (***)

SUMMARY

If widespread deforestation in Amazon results in reduced evaporative water flux, then either a decrease in evaporation is compensated locally by reduced rainfall or else changed moisture balance expresses itself downstream in the yet undisturbed forest. The question of where rain will occur is crucial. It is suggested that the appearance of clouds and the occurrence of rainfall is governed primarily by the interplay of local meteorologic and physical geography parameters with the atmospheric stability structure except for a few well-defined periods when rain is dominated by large scale atmospheric instability. This means that the study of those phenomena (local heat balances, studies on cloud formation mechanism, vertical atmospheric stability, etc.) must be made on the scale of the cloud size, a few tens of kilometers at most.

The fear had been expressed that the evaporation water flux from the Amazon basin would be reduced as the result of a widespread deforestation program (Friedmann, 1977) and that as a consequence the water balance could be upset both locally and worldwide. Emphasis in recent research programs was thus directed towards quantifying the water cycle in the Amazon basin and, in particular, to the assessment of the percentage of the re-evaporated moisture in the precipitation. Classical water balance estimates (Villa Nova, 1976; Marques et al., 1977) indicated that about one half of the precipitation in the basin originates from recycled moisture, which is released within the basin through transpiration of the forest plants and by evaporation from its surface. Data on the (inland) gradient of the Isotopic composition of rainfall (Salati et al., 1979) confirmed the

(**) The Weizmann Institute of Science, Rehovot, Israel.
(***) C.N.E.A., Piracicaba, SP, Brazil.

ACTA AMAZONICA, 15 (1-4): 317 - 310. 1985

307
importance of the recycled moisture in the hydrological cycle of the Amazon basin.

Any change of this re-evaporation flux obviously results in a commensurate change in the amount of precipitable water in the downwind atmosphere. It was implied that there would then be an automatic and equivalent change in rainfall. The scenarios can then be considered:

a) that the system response occurs "on the spot" so that a decrease in evaporation is compensated locally by a reduced rainfall. Nothing much would then be changed in the hydrologic situation of the virgin forest further afield. Indeed the case of the karajá island at the mouth of the Amazonas, of which the half which has no forest is and markedly deficient in rainfall, could be taken as an indication that such a situation might be a stable one. It should be pointed out, however, that it is safer not clear whether the reduced rainfall at Karajá is indeed the result of the deforested state of the island or whether, conversely, the absence of trees is a consequence of a negative water balance which occurs there because of its geographic position near the main sea. This is another version of the question: which came first the hen or the egg?

b) the other possibility to be considered would be that the changed moisture balance expresses itself downwind in the (very) undisturbed forest. This scenario is, of course, fraught with danger as the moisture deficiency can then propagate "island", cutting anastasis into the forest and encroaching progressively into virgin territory.

Obviously the question of where rain will occur, is a very crucial one.

The whole problem has, however, even wider ramifications, very basic meteorological considerations make it appear most unlikely that the consequences of deforestation can be "contained" within the area concerned or indeed be merely controlled by the local water balance. The meteorological role of the immense tropical clouds (cumulo-nimbus towers) is the dissipation of the heat energies which accumulate at these low latitudes (Klein 1963); the latent heat flux is here a qualiant term. Whereas the large scale water transport may not be affected by a change in the updraft flux (i.e. reduction of the frequency of cloud formation) becomes an equivalent reduction in evaporation compensating for any decreases in precipitation; and vice versa, as described above, such accounting cannot be applied to the heat transports; the elimination of even some of the convective cells necessarily reduces the heat flux and perturbs the heat balance both locally and globally. Alternative dissolution mechanisms then evolve to take care in the excess heat; these might, secondarily, even affect the regional water balance.

These are quite general considerations; in the more detailed scale the whole concept of local linkage between evaporation and precipitation amounts must be questioned: the response of the rain pattern to environmental change does not seem to be dictated by water balance considerations alone and is not necessarily proportional to, or even in phase with, the evaporative water flux. We believe that the question of the effect of deforestation on the regional and local precipitation patterns can only be answered when the more fundamental question of the "why, where and when" of rainshowers in the basin has been solved. Unlike most other regions where the qualified precipitation pattern is
dictated by distinct weather systems (cyclones, fronts etc.) or by the topographical features (topography), one rarely finds the development of a large weather pattern such as fronts throughout the Amazonas and there is almost no altitude variation. Indeed only some of the heavy autumn rains during February–May along the Atlantic seashore seem to be correlated with the position of the Intertropical Convergence Zone (Ratilsona, 1960) [these rains are marked by very negative values of both 10° and z (Salati et al., 1971) and some of the precipitation in the southern and central parts of the basin can be attributed to the advection of polar air masses, although the cold fronts proper seem to peter out before even reaching the center of the basin (Ratilsona, 1960)]. These latter rain events are characterized by moderately depleted isotopic values (Matsui, Salati and Gat, this conference). In the majority of cases, however, there is a predominantly westward drift of tropical marine air which appears to be in a rather delicately balanced (neutral) state. Cloud formation and the ensuing rain are then triggered by minor local perturbations such as a hot spot or by turbulence initiated by surface roughness elements, and hindered by any process which would stabilize the air column, for example by cooling as a result of sensible evaporation. The local albedo and the surface structure may well be the key elements which determine the pattern of onset of rain, although the degree of saturation of the surface air which results from local water balance also has to be considered (the distance to the dew point obviously determines the scale of initial lifting which is required). As deforestation affects these variables in addition to the atmospheric moisture load, it will be necessary to take these factors into account in order to define the system's response in time and space.

The content of this presentation is that the appearance of clouds and the occurrence of rainfall is governed to a large extent by the interplay of the local meteorologic and physical–geographic parameters with the atmospheric stability structure, except during a few well defined periods during which rain is dominated by large scale atmospheric instabilities. The study of these phenomena must then be made on the scale of the cloud sizes, e.g. that of a few kilometer at most. The clouds, whose formation is determined by the local conditions are, however, responsible for most of vertical heat and mass transport over the basin (Kienle, 1960). Their frequency of occurrence, rainout efficiency etc. will thus dictate the extent to which energy imbalances reemerge in the system. Regional and global responses to any such imbalances thus also depend, in the final analysis, on the local phenomena, although the exact meteorological or climatic form which such reaction may take will require a synoptic–scale approach to the system.

The research priority of the micro-scale phenomena appears to be clearly indicated. These should include local heat balances, studies on cloud formation mechanism as well as detailed measurements of the local atmospheric (vertical) stability.
água evaporativa, ou a queda na evaporação é compensada totalmente por uma redução na chuva, ou então a mudança no equilíbrio de humidade reflete-se na direção de ventos favoráveis ainda não identificados. A questão crucial é quando ocorrem as chuvas. Supõe-se que o aparecimento de novas e ocorrência de chuvas são principalmente determinados pela interação dos fatores geográficos locais, meteorológicos e eólicos, com a estrutura da estabilidade atmosférica, exceto seja a alguns períodos bem definidos quando a chuva é dominada em larga escala por uma instabilidade atmosférica. Isso sugere que o estudo destes fenômenos (mundo climático local, estudos sobre o mecanismo de formação de novas, estabilidade atmosférica vertical, etc.) deve ser feito de acordo com a extensão da chuva, no mínimo a algumas décadas de Chuvas.

References


(aceito para publicação em 20.11.1984)