

The Essential Role of the Amazon

by Peter Bunyard

For 30 years climatologists have questioned what would happen to rainfall over the Amazon Basin were the forest to go, ripped up for cattle pasture, for soya, for timber or as a result of dramatic changes to the air mass circulation brought about through global warming and the continuing, business-as-usual, emissions of greenhouse gases. Would rainfall decline significantly? Could it even go up over the Andes, as the air mass system, embodied in the Hadley Cell Circulation, passed unheeded across the thousands of kilometres of the Basin?

Most climatological studies of the Amazon Basin, such as those of the UK's Hadley Centre indicate that deforestation would have little effect along the eastern region of the Basin and at worst would bring about a 15 to 20 per cent reduction in rainfall – one millimetre less than the 5.8 millimetres daily average – in the central and western part. Drastic, yes, but not completely catastrophic.

That view has now been challenged. Anastassia Makarieva and Victor Gorshkov at the Theoretical Physics Division of the St Petersburg Nuclear Physics Institute, conclude that the loss of the Amazon rainforests, for whatever underlying cause, would be disastrous in the extreme, threatening much of South America with unprecedented drought, and leading to desertification in the central and western part of the Amazon Basin, with repercussions right up into the Andes and beyond. If they are right, the very existence of the major river-forming system in the upper moorlands, the páramos, would be threatened, with horrendous consequences for the generation of fresh water resources in countries such as Colombia, Peru and Ecuador, let alone in Brazil.

How do they come to that drastic view? The answer lies in their review of hydrological processes and whether they take place over forested regions of the world, or ones, which for whatever reason, have lost their forests. Makarieva and Gorshkov claim that meteorologists, and no less climatologists, have ignored an important atmospheric pumping mechanism which comes into play when water vapour is drawn into the lower atmosphere through evapotranspiration from dense forest, with its relatively high leaf area index. For example, in equatorial regions, such as encompassed by the Amazon Basin, where solar radiation is more than double that throughout the year of the higher latitudes, evapotranspiration from native forest, with its closed canopy and sub-storey vegetation, will consume as much as 75 per cent of the incoming radiation – some 600 calories per gram of water – thereby cooling the surface and powering the process of convection by which towering cumulo-nimbus clouds may form. And they make it very clear that a high leaf area index is vital to the process and that the replacement with pasture or a plantation of soya, in which evapotranspiration is an order of magnitude lower, simply will not do. Indeed, without the natural vegetation the Sun's energy will take the form of sensible heat, which will reduce the potential of rain forming from evapotranspiration. As I have pointed out before, the power of the Sun in terms of energy received over the Amazon is equivalent to some 20 Hiroshima-size 15 kiloton bombs going off every second, day and night, compared to the energy of 15 such bombs being used in evapotranspiration.

Basically, the biotic pump, as proposed by Makarieva and Gorshkov, functions as a result of marked changes in the partial pressure exerted by water vapour at different altitudes in the air column above the rainforest. Just above the canopy, warm temperatures permit the air to hold large quantities of water vapour, and so the partial pressure is high. That partial pressure, plus the higher temperature of air close to the ground act together to create a thermal by which the air expands and rises. As it does so, and gains height, further expansion takes place because of reduced pressure, thereby causing a loss of heat and a simultaneous drop in temperature, just as happens in the expansion chamber of the cooling circuit of a fridge. At the same time, low temperatures high up in the air column cause a sharp reduction in the saturation pressure of water, such that the water vapour condenses and forms droplets of rain. The loss in temperature because of the air mass expanding as it moves upwards is compensated to some extent by the release of latent heat from condensation. Even though the conversion of latent

heat to sensible heat may delay total condensation that in itself does not change that the conversion of water vapour to water brings about a significant drop in partial pressure and, as a consequence, aids the upward movement of water saturated air from below such that it pushes upwards, like a piston driven upwards by the exploding fuel in an internal combustion engine.

The air at the base of the air column is then replaced by air moving in horizontally, which, according to the Russian physicists, derives from the ocean. This process of convection, powered by the partial pressure of water vapour from evapotranspiration, therefore sucks in the Trade Winds, which have accumulated significant quantities of water vapour as they pass over the Tropical Atlantic Ocean between Africa and Brazil.

If, as indeed happens, the air above the tropical ocean is also drawing up water vapour, how then can the forest evapotranspiration pull in air from the ocean? Here, the physicists explain, the seven layers of surface provided by the leaves of the natural forest provide more water vapour per square centimetre than does the ocean and so a differential pressure will exist between the two, acting along the horizontal plane. Add into the equation the capillary action which takes place in the xylem and which draws water into the stomata, from where it evaporates, and also that chemical compounds and maybe bacteria too act as cloud condensation nuclei (CCNs) when released from the stomata, and we have an evaporative force that is finely tuned for generating rain and which simultaneously brings about significant partial pressure differences in both the vertical and horizontal plane, so causing a dynamic disequilibrium and therefore the mass movement of the air.

Wonderful to relate, the natural forest keeps the system going during the dry season and even during drought years, as during a strong El Niño, by increasing leaf coverage and hence the leaf area index by as much as 25 per cent compared with the wet season. Indeed, as Myneni and his colleagues, at Boston University, have shown from satellite images, the forest appears to anticipate the dry season with the growth in leaf area taking place before the 'summer' months have actually taken hold. The increase in leaf area means essentially that the root system of the forest must draw up more water, and it is now known that the tap roots, taking water from the water table, also pass water through lateral roots such that it dampens the area around each tree and keeps soil moisture high. The increase in evapotranspiration and the resulting convection, draws in humid air brought in by the Trade Winds from the tropical Atlantic in the other hemisphere. That extraordinary process whereby the rainforest manages its own climate would seem to reinforce the notion of the biotic pump and the evaporative force as described in physical terms by Makarieva and Gorshkov.

The logic of the evaporative force, as described in Makarieva and Gorshkov's theoretical analysis, leads to the conclusion that a continental region devoid of coastal and inland forests which happens to be located next to a warm tropical ocean will display surface air mass movements that are the reverse of those found were that continent to be forested. Thus, whereas the evaporative force over the canopy of a rainforest is considerably greater than that over the tropical ocean, that is no longer the case when the forest is no more. Now, the evaporative force over the ocean is considerably greater than the biotic pump of a depleted vegetation, and the ocean will draw the air mass towards it, thus drying out the continental soils and vegetation in a downward spiral of degradation.

Simultaneously, without the rainforest recycling rainfall, precipitation will decline exponentially as one passes from the coast inland. The western reaches of the Amazon, as well as the foothills of the Andes, could find themselves receiving considerably less than one per cent of the rainfall they currently experience; they could become as dry as the Negev desert of Israel. Perhaps, the extraordinary drought year of 2005 for the Amazon Basin, which particularly affected the southwestern region, has given us a foretaste of what would happen were the forests to go. During that year, the tropical waters off Brazil and up into the Caribbean were a degree or two warmer than normal, with a corresponding increase in the evaporative force. That increase may have tipped the balance, at least for that year, given the degree of deforestation in the southeastern and southwestern region of the Basin, such as to alter the air mass movement over the Basin and draw it more towards the ocean rather than following its normal trajectory over the Amazon.

Empirical evidence for the Russians' articulation of a biotic pump come from their unique study of the relationship between the precipitation pattern over river basins in which they show

substantial differences according to whether or not the region through which the rivers pass is forested. The Mississippi River Basin is a case in point: where the land is forested from the Atlantic coast inland, stretching some 1,750 kilometres, the precipitation stays steady at some 1,000 millimetres over the course of the year; further inland, where there is no forest, the rainfall declines exponentially to little more than 200 millimetres. Meanwhile, rainfall right across the Amazon Basin remains substantially the same at around 2,400 millimetres per year and even increases at the western extremity of the Basin to as much as 4000 millimetres. The implications of Makarieva and Gorshkov's thesis are enormous; essentially it means that South America cannot do without its rainforests, and that instead of quibbling over how much should be conserved, those countries with substantial areas of the Amazon Basin should be doing everything in their power to ensure that no more is destroyed. Furthermore, it means that we should be focussing less on the amount of carbon that forests contain, and on how much forest destruction is contributing to the overall emissions of greenhouse gases than we should rather be focussing on their fundamental hydrological and therefore climatic role. If Copenhagen is to achieve anything it will need to be a general acceptance that the critical issue we face is the danger to a stable climate which will ensue from further destruction of the planet's ecosystems and in particular its natural forests.

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