Some 80 years ago two contemporary visionaries beyond all others raised awareness of the importance of forests. Viktor Schauberger (1885-1959) described in ways very similar to those elaborated in this important article how forests regulate the world's climates. His warnings about the catastrophic land policies of his generation fell on deaf ears.

Richard St Barbe Baker (1889-1982), on the other hand, a forester and passionate environmental activist, had the charisma and determination to achieve amazing success with his tireless campaigns. His Men of the Trees *movement, founded 1922 in Kenya, was dedicated to planting trees in 108 arid countries. He also did more than anyone to save the Californian redwoods from the 1920s onwards, complaining that he had to restart his campaign every 10 years, as the commercial temptations for felling were so strong.*

St Barbe recognised that Viktor Schauberger's scientific insights were necessary to convince the establishment to change their land policies, so in 1950 he arranged a top English universities lecture tour for Walter Schauberger, Viktor's son. It did not succeed in its purpose. One post-mortem declared that while Walter's presentation was "unassailable", nothing could come of it because "it would mean rewriting all the textbooks in the world!" This important article gives hope that a change in consciousness is at last taking place.

(Alick Bartholomew, Mar. 2010)

The Real Importance of the Amazon Rain Forest

ISIS Report 15/03/10

Rain forests power atmospheric circulation that brings rain to continental land masses from the oceans; a new theory explains why losing forests will cause catastrophic desertification: by
Peter Bunyard *(Science editor of The Ecologist and of Science in Society)*

Would rain still fall on the Amazon without the forest?

For 30 years climatologists have been asking what would happen to rainfall over the Amazon Basin were the forest to disappear, ripped up for cattle pasture, for soya, for timber or as a result of dramatic changes to the air mass circulation brought about by global warming and the continuing, business-as-usual emissions of greenhouse gases. Would rainfall decline significantly? Could it even increase over the Andes, as the air mass passes unimpeded across the thousands of kilometres of the Basin?

Most 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% reduction in rainfall – one mm less than the 5.8mm daily average – in the central and western part [1, 2].

These conclusions are based on climate models parameterized (tweaked) to agree closely with past data such that when they are 'played' back from present conditions they accord well with general climatic conditions of the mid 19th century. And, to be more realistic, climatologists such as Richard Betts at the Hadley Centre have integrated a terrestrial carbon cycle into their models, with rainfall and temperature as critical factors in the maintenance of vegetation cover. They took into account the recycling of rain through evapotranspiration, which over a long stretch – the seven million km^2 Amazon Basin – is the mechanism whereby the rainforest in the centre and further extremities inland is deemed to receive adequate watering.

The Hadley Centre model (HadSM3 coupled to a dynamic global vegetation model –TRIFFID) predicts impacts on surface temperature, on ocean currents and ultimately on the state of the Amazon rainforests as a result of 'business-as-usual' emissions of greenhouse gases, mainly CO_2. Hence, the models predicted that global surface terrestrial temperatures would rise by a good 50% more than indicated in the various IPCC assessment reports, perhaps to as high as

9C°, and that, consequently, El Niño-like changes would take place in the Pacific Ocean. The result would be that the Trade Winds would falter and the rain-bearing atmospheric Hadley Cell Circulation (see later) over the tropical Atlantic would diminish sufficiently to bring about large scale forest dieback over the entire Amazon Basin.

Those who doubt we will reduce greenhouse gas emissions in time to prevent a 4C° or more increase in average global surface temperatures (let alone the 2C° rise considered by James Hansen and others to be the most we can risk) might well say 'why bother to protect the Amazon rainforests if they are likely anyway to die back in their entirety.'

Circulation of the Earth's atmosphere

In general, climatologists and meteorologists believe that air currents in the atmosphere are formed through differences in temperature that bring about heat gradients, with colder, denser air sinking and hotter, lighter air rising. Hence, the explanation of the Hadley Cell circulation between Africa and South America is that cold, dense, dry air sinks over the Sahara region of Africa, forming a high pressure zone (see Box). That same mass of air is then drawn over the tropical Atlantic in the form of trade winds from both hemispheres which converge over the Amazon Basin in what is known as the Intertropical Convergent Zone (ITCZ) (see Fig. 1).

How the earth's atmosphere circulates

The circulation of the earth's atmosphere modulates surface temperatures over land and sea, and determines rainfall patterns:

	INCLUDEPICTURE "http://www.i-sis.org.uk/graphics/importanceOfTheAmazonRainForest.jpg" * MERGEFORMATINET

Figure 1 The Earth's atmosphere circulates to distribute warmth and moisture.

The Earth's atmosphere is set in motion because the tropics are heated up more than the poles. The excess heat over tropical regions is transported towards the poles by the circulation of the atmosphere and by ocean currents.

At the Equator, the hot air with water vapour expands and become less dense, so it rises, creating low pressure. But as the hot air rises, it cools, the water vapour condenses and falls as rain. This creates high rainfall in the Intertropical Convergence Zone in the tropics.

As the air mass cools, it increases in density and falls back towards the surface in the subtropics (30°N and S), creating high pressure. The net circulation is referred as the Hadley Cell, one on either side of the equator.

If the earth did not rotate, there would be a single circulation cell in each hemisphere. Because of fluid motion on a rotating sphere, the single cell is broken up into three circulation cells in each hemisphere, named in order from the Equator: Hadley Cell, Ferrel Cell and Polar Cell.

This creates alternating bands of high and low pressures of approximately 30° latitude. Wind arises as air moves horizontally between regions of different pressures. Very little wind is present at the Equator because air rises vertically as it heats up. Light, variable winds at the equator are known as the Doldrums. Similarly, there is little wind at 30° N and S where the air descends. Air always moves horizontally from an area of high pressure to low pressure.

Meanwhile, the Coriolus Force, which is a consequence of motion on a rotating sphere, deflects the air mass in the mid to upper troposphere, to the right of the direction of motion in the Northern Hemisphere and to the left in the Southern Hemisphere. The lower air mass is more bound by friction to the Earth's surface than the upper air mass, hence the opposed direction of motion of the upper troposphere compared to the lower.

The trade winds pick up masses of water vapour, more than 12 million million (10^{12}) m^3 worth. When that same air mass, passing over the Basin, reaches the Andes in the far west of South America, it is forced upwards because of the topography. It loses its water vapour, all the while releasing its latent heat of condensation, and this helps to heat and push the air mass up still further. The next stage is the movement of the air mass in the direction of North Africa, completing the circulation of the Hadley Cell. The circulation is thus seen as primarily generated through the thermodynamics of the system.

New theory challenges accepted view

However, that view of thermodynamics driving the tropical circulation of the Hadley Cell has now been challenged. Anastassia Makarieva and Victor Gorshkov at the Theoretical Physics Division of the St Petersburg Nuclear Physics Institute, propose that the thermodynamic driver of air mass circulation is far secondary to a much more powerful driver tied to the evaporation and condensation of water vapour [3-6]. They conclude that the loss of the Amazon rainforests, for whatever underlying cause, would be disastrous in the extreme. It would threaten much of South America with unprecedented drought, and lead 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 uncompromising view? The answer lies in their review of the different hydrological processes that take place over forested regions of the world and in regions that have lost their forests.

Makarieva and Gorshkov claim that meteorologists and climatologists have ignored an important atmospheric pumping mechanism that comes into play when water vapour is first drawn into the lower atmosphere through evapotranspiration from dense forest, with its relatively high leaf area index, and then, higher in the lower atmosphere, condenses as a result of declining temperatures. And they make it very clear that a high leaf area index is vital to the process and that replacing the forest 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 not only will reduce the potential of rain forming from evapotranspiration, but will switch the evaporative gradient from the land mass to the ocean. In fact, in equatorial regions, such as the Amazon Basin, where the annual solar radiation is more than double that in the higher latitudes, evapotranspiration from native forest, with its closed canopy and sub-storey vegetation, will consume as much as 75% of the incoming radiation – some 560 calories per gram of water – thereby cooling the surface and powering the process of convection by which towering cumulo-nimbus clouds may form [7]. Meanwhile, the driver of that evapotranspiration is the Sun, which 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, 15 such bombs being used in evapotranspiration.

The biotic pump drives the climate and draws water from the oceans

Basically, the biotic pump, as proposed by Makarieva and Gorshkov, functions as a result of marked changes in the partial pressure (partial because other gases also contribute) 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 force the air column upwards against the partial vacuum caused as the water vapour cools and condenses. That dynamic of evaporation and condensation, forces the air column upwards against ever reducing pressure and, just as happens in the expansion chamber of the cooling circuit of a fridge, the upward motion of the air column causes a loss of heat and a simultaneous drop in temperature, resulting in a sharp reduction in the saturation pressure of water. Virtually all the water vapour in the vertical plane of the air column therefore condenses and forms droplets of rain. The fall in temperature because of the expansion of the air mass is compensated to some extent by the release of latent heat in condensation.

"In the presence of a large vertical temperature gradient", Makarieva and Gorshkov said [7], "the vertical distribution of saturated partial pressure, pH_2O, departs significantly from the static equilibrium; at any height pH_2O is over five times larger than the weight of the water vapour column above this height. For this reason practically all the water vapour ascending in the atmosphere condenses."

The air at the base of the air column is then replaced by air moving in horizontally, coming from the ocean. This process of convection, powered by the partial pressure of water vapour from evapotranspiration, 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. That is a very different picture from the commonly belief that the Trade Winds are driving the air mass circulation system over the Basin, instead of being sucked in.

As the air above the tropical ocean is also drawing up water vapour, how can the forest evapotranspiration pull in air from the ocean? Here, the physicists explain, the multiple layers of surface provided by the leaves of the natural forest provide considerably 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 (water transport tubes of the plants) and which draws water into the stomata (pores of the leaves), 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 simultaneously brings about significant partial pressure differences in both the vertical and horizontal plane, causing a dynamic disequilibrium and therefore the mass movement of the air [7].

It is wonderful to see how 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% compared with the wet season. Indeed, as Myneni and 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 [8]. The increase in leaf area means 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. This dampens the area around each tree and keeps soil moisture high. The increase in evapotranspiration and the resulting convection, draw 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 as described by Makarieva and Gorshkov, and they point out that the rates of evaporation and precipitation in tropical rainforests are twice as high as those of evaporation and precipitation over open oceanic surfaces at similar latitudes.

Nor is such biotic regulation of the water cycle limited to the tropics. The same physics shows that during the late spring and summer months, undisturbed temperate and boreal forests will generate an evaporative force, albeit far weaker than in the tropics, which will create a partial pressure gradient from the ocean to the land. But that biotic pump is switched off in winter [6].

"That physical view," said Makarieva and Gorshkovn [7] "is in direct conflict with the traditional paradigm which considers differential heating to be the major driver of atmospheric circulation. However, this consideration critically fails in the case of the strongest winds observed on Earth, the hurricanes, that, as is well-known, develop along nearly isothermal surfaces.

"But if differential heating is not necessary for producing the strongest winds, perhaps it is not indispensable for producing moderate and weak winds either? The evaporative force concept that relates wind velocities to spatial differences in the intensity of condensation rather than heating provides a unifying explanation for both hurricanes and tornadoes as well as for stationary circulation patterns."

"On a related note," they continue, "according to the traditional paradigm the regions of air ascent should be associated with positive buoyancy. In contrast, observations of atmospheric updrafts indicate a wide range of positive and negative buoyancies. The evaporative force concept resolves the puzzle. Air pressure depends on two independent variables, temperature and number of air molecules in a unit volume. Consequently, there are two independent ways of making local air pressure higher than that in the neighbouring area, so as to initiate air motion: (1) to warm the air locally (this is what the traditional paradigm of horizontal differential heating is about) and (2) to reduce the number of air molecules in the neighbouring area (this is what condensation is doing in the vertical dimension). Thus, if the condensation is intense, it can make even dense cold air rise from the surface by creating a strong weight imbalance in the upper part of the air column."

Dire consequences if forests disappear

The evaporative force hypothesis of Makarieva and Gorshkov [3-6] predicts that a continental region devoid of coastal and inland forests and located next to a warm tropical ocean will display surface air mass movements *in reverse* of those found in the forested continent. 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 gone. On the contrary, the evaporative force over the ocean is now greater than the biotic pump of the 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 to recycle rain, precipitation will decline exponentially as one passes inland from the coast. The western reaches of the Amazon, as well as the foothills of the Andes, could find themselves receiving 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 in the Amazon Basin, which particularly affected the southwestern region, has given us a foretaste of what would happen if the forests were to disappear. 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 oceanic 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 – so 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.

The conventional explanation for air movements invokes thermodynamic processes such that hot air rises and the resulting low pressure draws in cooler, denser air, whether from the ocean or continent. Yet, how can that be an adequate explanation, when the evidence is exactly the reverse? Thus, the air flow is from the warmer tropical Atlantic to the cooler Amazon, made cooler because of the high evapotranspiration and therefore formation of light-reflecting clouds. And whereas the Sahara is warmer, at least during the day, than the same latitude Atlantic, how is it that the prevailing winds are not from the ocean to the land?

"Despite the general meteorological wisdom that warmer air is lighter and hence rises, so it is an area of low surface pressure (which presumes wind flow from the ocean to Sahara and from the

Amazon and Congo to the ocean), in reality the prevailing winds blow in the opposite direction in all the three regions.

"This is perfectly explained by the biotic pump," declared Makarieva and Gorshkov [7], "and not by differential heating. In fact it is the condensation gradient which explains the direction of the winds, whether from the ocean to the continent or vice versa."

Further empirical evidence for the 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 [6]. The Mississippi River Basin is a case in point. Where the land is forested from the Atlantic coast inland, stretching some 1,750km, the precipitation stays steady at some 1,000mm over the course of the year; further inland, where there is no forest, the rainfall declines exponentially to little more than 200mm. Meanwhile, rainfall right across the Amazon Basin remains substantially the same at around 2,400mm per year and even increases at the western extremity of the Basin, for instance in the bio-rich Colombian Amazon, to as much as 4,000mm.

In essence, Makarieva and Gorshkov believe that climate stability, within a limited temperature range, taking glacial and inter-glacial periods into account, has been brought about largely through the evolution of continental forests. In terms of sheer area, the boreal forests of Russia, Canada, and the tropical rainforests of South America and Central Africa, remain critical to the maintenance of a climate which retains some semblance of stability. Preserving those forests is every bit as important as concerns over greenhouse gas emissions and consequent global warming.

"Most importantly," they said [7], "it was necessary for natural forests with their high leaf area index to appear in the course of biological evolution for evaporation from the forest canopy to exceed evaporation from the open water surface. This allowed life to invade the hitherto dry landmasses by sucking moist oceanic air inland as the forests marched forward from the coast. Not surprisingly, modern global circulation models devised without including the physics of the biotic pump fail radically when attempting to account for the water budget of the strongest biotic pump on Earth – the Amazon river basin. The amount of oceanic moisture brought to the Amazon river basin in the models (the modelled atmospheric moisture convergence) proves to be half the actual amount empirically estimated from the value of the Amazon runoff. It is obvious that the traditional accounts of moisture transport in the other great river basins, including Siberian and North American rivers will similarly have to be seriously reconsidered to incorporate the major effects of the forest moisture pumps, the anthropogenic destruction of which is currently threatening to turn the landmasses back into primordial deserts."

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. Forests are not just carbon sinks or havens of biodiversity; they have an essential and irreplaceable hydrological role in the earth's climate.

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HYPERLINK "mailto:pbecologist@gn.apc.org" Peter Bunyard Comment left 16th March 2010 23:11:00

Thanks for your comments so far. Yes, I am familiar with the wonderful work and studies of Schauberger and St Barbe Baker (whom I did meet on several occasions). Meanwhile Makarieva and Gorshkov have thrown down the gauntlet to those - the great majority of climatologists and meteorologists - who have totally overlooked the role of life and in this instance the great forests of the planet in actually managing the mass movements of air which bring rainfall to the deep interior of continents. Hence forests are the generators of evolution in providing the means by which adequate rainfall can maintain the richness of the Amazon to the western reaches of the Basin, some thousands of kilometres from the Atlantic coast of Brazil. We do indeed threaten our very survival by eliminating the vast stretches of rainforest and in my opinion, doing everything in our power to prevent further forest destruction is every bit as important as our concerns with CO2 emissions. By the way, I have written about the teleconnection between the Amazon and the Mid West of the USA and how US crops in the corn belt depend on the water vapour transported in slow standing Rossby waves out of the Amazon. Roni Avissar, then at Duke University and now in Florida, is one of the principal researchers in the field.

HYPERLINK "mailto:ilyan.thomas@virgin.net" Ilyan Comment left 16th March 2010 10:10:57
I saw one article that predicted the loss of the Amazon rainforest would lead to severe drought in middle west North America. Was that omitted because it is too damn scarey?

HYPERLINK "mailto:stukric@hotmail.com" Krichauff Comment left 16th March 2010 11:11:52
Man of the Trees, Richard St. Barbe Baker predicted this about 80 years ago we have had lots of time to mend our ways but blunder on to doom probably.

HYPERLINK "mailto:rorys@homemail.co.za" Rory Short Comment left 16th March 2010 23:11:29
The work of Anastassia Makarieva and Victor Gorshkov makes absolute intuitive sense to me because I take joy in the fact that we live in, and are components of, a bio-sphere not a mechano-sphere. Our thinking n the recent past, and unfortunately still in the present, has been driven by a belief, and perhaps even a desire that somehow we live in a mechano-sphere.

HYPERLINK "mailto:mail@AlickBartholomew.co.uk" Alick Bartholomew Comment left 16th March 2010 23:11:19
This important research corroborates the insights 80 years ago of Viktor Schauberger who demonstrated the close connection between forests, the Earth's water cycle and the production of rain, and who saw the tropical rainforest as the powerhouse for balancing climatic extremes on the planet. He called the forests 'the cradle of water' in the sense that they produce the most balanced and best quality fresh water. The forest canopy receives rain imbued with the Sun's energy and draws up water from deep in the soil, transpiring abundant and high quality water which balances the two energy sources. Schauberger proposed a complex water cycle below ground level, where the water molecules from precipitation are broken down to provide energy for new growth, then to be recycled into new water. He believed that that new virgin water is created by the coming together of molecular hydrogen and free oxygen in the depths of the soil, stimulated by the trees' root systems. Schauberger was an intuitive, and it is good to see some of his insights supported scientifically. Thank you, Peter, for this excellent article!

HYPERLINK "mailto:mlpaul@iinet.net.au" Mary Paul Comment left 16th March 2010 04:04:59
Wonderful article. I would thoroughly agree with the Russian researchers. Having read some of the work of VIktor Schauberger where he describes the hydrological cycle (trees are essential to keep the ground temperature cooler than the rain so as to allow the rain to penetrate) as against the half-hydrological cycle. the latter is seen when the lack of vegetation allows the earth to become so warm that rain does not penetrate, but flows over the top and is rapidly evaporated, and so ground waters are not able to be replenished. Schauberger was an Austrian and did absolutely brilliant work.