evapotranspiration over the monsoon rainforest in Malaysia/Thailand. © *Edward Parker*

Fred Hageneder

The Impact of Forests on Climate

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In August 2006, a remarkable article was published in Hydrology and Earth System Sciences, the journal of the European Geosciences Union. The authors, A.M. Makarieva and V.G. Gorshkov, two scientists from the Petersburg Nuclear Physics Institute in Russia, shed **new light on the impact of the world's forest on climate**. [1]

Here is a summary of their article, with many direct quotes (illustrations and emphases in bold and italics are mine).

First, Makarieva and Gorshkov recapture **the basic geophysical and ecological principles** that allow the landmasses of Earth to remain moistened so that biological life on land can continue:

1. 'Under gravity, land inevitably loses water to the ocean. To keep land moistened, the gravitational water run-off must be continuously compensated by the atmospheric ocean-to-land moisture transport' (otherwise known as *precipitation*, or, more commonly, *rain*).

But clouds rain off and exhaust themselves after some time – or distance, depending on the wind. 'The mean distance to which the *passive* geophysical air fluxes can transport moisture over non-forested areas, does not exceed several hundred kilometers; precipitation decreases exponentially with distance from the ocean.'

2. 'In contrast, precipitation over extensive natural forests does not depend on the distance from the ocean along several thousand kilometers', as can be seen in the Amazon and Yenisey river basins and in Equatorial Africa. ***This cannot be explained by pure geophysics*** and 'points to the existence of an ***active biotic pump*** transporting atmospheric moisture inland from the ocean.'

3. The previously unrecognized link, the force which is able to bring moisture inland over vast distances from the ocean, is the forest. Huge amounts of water vapour rise from the forests and form mist and clouds. Wind from the ocean shifts the clouds further inland where they rain off: 'Due to the high leaf area index, natural forests maintain high transpiration fluxes, which support the ascending air motion over the forest and "suck in" moist air from the ocean, which is the essence of the biotic pump of atmospheric moisture.'

As a result, the gravitational water loss of the land (running down the rivers) 'can be fully compensated by the biotically enhanced precipitation at any distance from the ocean.'

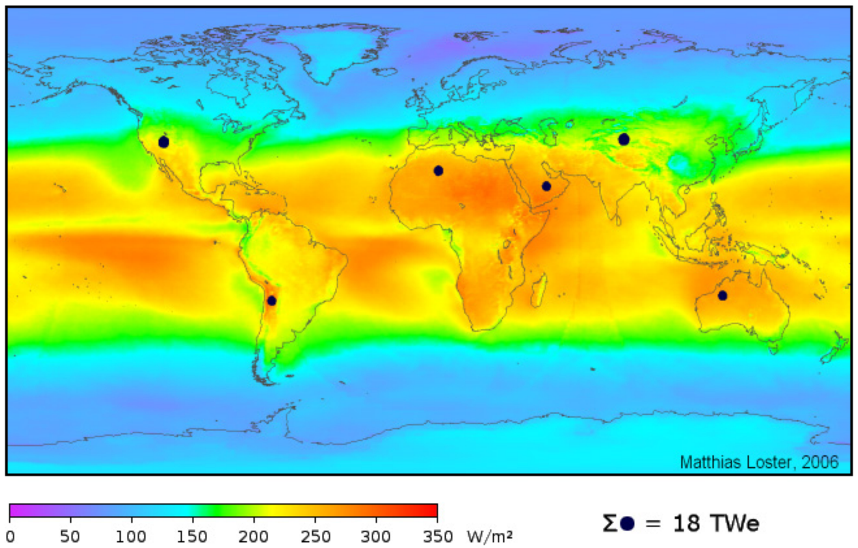
woodlands at the Yenisey river in Siberia. © *http://aroundtheworldwithu.blogspot.co.uk*

The power of leaves

All forest types have a higher 'leaf area index' than other eco systems (e.g. shrublands, grasslands). The highest leaf area index occurs in the tropical rainforest, due to the forest structure with its four layers:

- the emergent layer of very tall trees (45–55m, a few species even 70–80m) which rise above the general canopy;
- the canopy layer (typically 30-45m in height) which forms an evergreen roof over the lower two layers;
- the understory layer which consists of shade-tolerant shrubs, small trees, and large woody vines;
- and the groundcover which soaks up the last penetrating rays of sunlight that have made it that far.

The Earth's exposure to solar energy is highest at the equator, up to over 300 Watts per square metre (see map). Intact tropical rainforest absorbs about three quarters (75%) of the solar energy, equivalent to 560 calories per gram of water absorbed by plants. This means that **the energy turnover of the Amazon Basin** *(*seven million square kilometres*)* **equals the energy of fifteen Hiroshima-type 15-kiloton bombs going off every second, day and night, all year round.** This unimaginable amount of energy is used to pump water from the ground and up through the water transport



solar_land_area © Wikimedia Commons

channels of the plants and trees, where it finally evaporates through the myriads of tiny pores in the leaves. This is called evapotranspiration. Doing this, **the Amazon rainforest creates about twice as much water vapour as the neighbouring Atlantic Ocean!** Because this water vapour rises up in the air, new air masses are 'sucked in' from the ocean. This brings new moist air to the landmass, and hence new rain.

Water that rains onto the Amazon rainforest soon evaporates again through the leaves and forms new clouds. The equatorial winds move these clouds westward, and they bring rain to the interior of the country, further away from the sea. The rain gets 'recycled' five to six times across the 4,000km of the Amazon Basin. Therefore it rains as much in the far west (at the slopes of the Andes) as it does near the ocean in the east. [2]

This is how the Amazon rainforest makes its own rain and its own climate. And the trade winds and ocean currents spread the benevolent effects of this even far beyond the region: the Amazon's rainforest supports the rain in the grain belt of the United States and the Gulf Stream which gives Europe its mild climate.

A similar powerhouse is the Congo, where 'each hectare of rain forest produces almost 190,000 litres of water per year.' [3] The **boreal forest** in the north (Canada, Siberia, Russia) is just as important, although it works in a different climate. But it is, after all, the world's largest forest belt.

Evolution

When life conquered the landmasses of the Earth it was essential to ensure a sufficient water supply at any distance from the ocean. **Early ecological communities had to develop the ability to attract water from a distance.** Life on land required 'an active mechanism … to transport moisture inland from the ocean at a rate dictated by the needs of the ecological community. Such a mechanism originated on land in the course of biological evolution and took the form of forest – a contiguous surface cover consisting of tall plants (trees) **closely interacting with all other organisms** of the ecological community. **Forests are responsible both for the initial accumulation of water on continents in the geological past and for the stable maintenance of the accumulated water stores in the subsequent periods of life's existence on land.'**

Deforestation

Replacement of the natural forest cover by *low leaf index* vegetation (e.g. soy fields or cattle pastures) 'leads to an up to tenfold reduction in mean continental precipitation' – **if the primary forest goes, most of the rain will disappear too**.

'The biotic moisture pump, as well as … efficient soil moisture preservation, **works only in undisturbed natural forests**. … The vegetation cover of grasslands, shrublands, savannas, steppes, prairies, artificially thinned exploited forests, plantations, pastures or arable lands is unable to switch on the biotic moisture pump and maintain soil moisture content in a state optimal for life. Water cycle on such territories is critically dependent on the distance from the ocean; it is determined by random fluctuations and seasonal changes of rainfall brought from the ocean. Such territories are prone to droughts, floods and fires.' And desertification.*

Not even 'secondary aboriginal forests which are in the process of self-recovery from anthropogenic or natural disturbances like fires, cutting or windfall, **are … capable of efficiently running the biotic pump**. In such forests all mechanisms of environmental regulation, including the biotic moisture pump, are under repair and cannot yet function efficiently.

'Only primary aboriginal forests are able to ensure the long-term stability of the biotic moisture pump functioning, **as far as the genetic properties of aboriginal forests are correlated with the geophysical properties of the region they occupy. Artificially planted exotic vegetation with geographically irrelevant genetic programs cannot persist** on an alien territory for a long time; their temporal prosperity is followed by environmental degradation and ecological collapse.'

Native forests are fine-tuned instruments to generate and maintain water supply for their region. For example, we know now that trees can even increase the speed of cloud formation by emanating certain chemicals through evapotranspiration that will act as cloud condensation nuclei (e.g. potassium salts, terpenes, or isoprene). [4]

* Scarcely vegetated ecosystems like the African savannas have been 'rigidly correlated with anthropogenic activities during the last several thousand years. … Savannas represent a successional state of the ecosystem returning to its undisturbed forest state; this transition spontaneously occurs as soon as the artificial disturbances like fire and overgrazing are stopped.' The prolonged existence of savannas is only possible through continuous human interference. 'Therefore, the growing anthropogenic pressure on savannas, which prevents their periodic transitions to forests, gradually turns savannas to deserts. The same is true for steppes and prairies of the temperate zone.'

The crucial coastal belt

'For the biotic moisture pump to work properly, it is also **important that the natural forest cover has an immediate border with the ocean**.' The Mississippi River Basin, for example, is forested from the Atlantic coast inland, and an annual precipitation of about 1,000mm occurs for some 1,750km up the river; but further on up, where there is no forest, it swiftly declines to little more than 200mm. In the Amazon Basin, on the other hand, rainfall remains steady at around 2,400mm a year, and even increases in the far west to as much as 4,000mm. [2]

'If the natural forest cover is eliminated along the oceanic coastline on **a band 600 km [375 miles] wide**, the biotic moisture pump stalls. The remaining inland forests are no longer able to pump atmospheric moisture from the ocean.' Their water surplus will soon run off via the rivers or be blown away via the atmosphere. The fertility of the 'river basin ceases to exist, the forests die back after the soil dries up.' **Much of the store of fresh water on land 'including the water of soil, bogs, mountain glaciers and lakes' will disappear. 'This means that all liquid moisture accumulated on land runs to the ocean in about four years.'**

Total deforestation will in several years turn any river basin to desert.

In **Australia**, the disappearance of the vast forested river basins co-incided with the arrival and spread of early humans (about 50,000-100,000 years ago). 'There is a host of indirect evidence suggesting that humans are responsible for the ancient deforestation of the Australian continent. It is clear how this could have happened.'

'To deforest the continent, it was enough to destroy forests on a narrow band of width along the continent's perimeter. This could be easily done by the first human settlements in the course of their household activities or due to the human-induced fires. This done, the biotic water pump of the inner undisturbed forested part of the continent was cut off from the ocean and stalled … the inland forests perished by themselves even in the absence of intense anthropogenic activities.'

The modern practices of forest exploitation, which are responsible for the unprecedented high rate of global deforestation we witness today, were born in **Western Europe**. But here, the medieval deforestation did not lead to the complete desertification. Why? Because in Europe 'there are no areas separated from the ocean or inner seacoast by more than 600 km'. Rain could always finds its (relatively short) way back inland and keep the landscape green. Today, Europe is the only continent where deforestation is not a large-scale problem (presently, the total forest area in Europe is even increasing). But tragically, the unique geophysical situation of Europe 'worked to **support the illusion that the forest cutting tradition can be safely exported to the other parts of the planet**, despite the accumulating evidence about the disastrous consequences of such practices when applied to vast continental areas.'

However, Europe is paying its price too. The decline of Alpine forests (sacrificed to ski tourism etc.) resulted in a decline of precipitation in higher altitudes and hence has also 'led to the **decline of mountain glaciers**, although the latter phenomenon is almost exclusively considered in the framework of global warming and atmospheric CO2 build-up, while the biotic pump effects are ignored.'

Conclusion

Elimination of the forest cover in the world's largest river basins 'would have the following consequences: at least one order of magnitude's decline of the river run-off, appearance of droughts, floods and fires, partial desertification of the coastal zones and complete desertification of the inner parts of the continents, …associated economic losses would by far exceed the economic benefits of forest cutting, let alone such a scenario would make life for millions of people impossible.'

A possible strategy to restore life-enhancing water conditions on most areas of the Earth's landmasses needs to urgently reconsider the modern forest policies everywhere in the world.

It is necessary to…

- 'immediately stop any attempts to destroy the extant natural forest remnants and, in particular, those bordering with the ocean or inner seas,'
- initiate a world-wide organisation for 'facilitating natural gradual recovery of aboriginal forest ecosystems on territories adjacent to the remaining natural forests. Only extensive continuous natural forests will be able to run a stable water cycle…'

Makarieva and Gorshkov conclude that 'the analyzed body of evidence testifies that the **long-term stability of an intense terrestrial water cycle is unachievable without the recovery of natural, self-sustaining forests on continent-wide areas**.'

Response – How slowly do we learn?

Makarieva and Gorshkov challenge the conventional view of climatologists and meteorologists – and hence they have met a wall of silence and ignorance. The first 'comment' from one of the high temples of global climatology (the Faculty of Earth and Life Sciences, Amsterdam) on this pressing subject took no less than three years to be uttered. The tone is skeptical, but in the very end of the paper the authors surprisingly conclude that…

> 'we do believe with M&G [Makarieva and Gorshkov] that **the role of vegetation – and in particular forest – in generating rainfall is still poorly understood**. Likewise, with changes in terrestrial land cover due to deforestation being on the increase, such questions potentially assume added importance. M&G are to be complimented for their valiant attempt to shed more light on the interaction between forest vegetation and precipitation.' [5]

However, nothing changed after that in climate modeling and calculations which still ignore the full power of the leaves.

Finally, an important step for this knowledge to come to light is an article published in March 2010 by Peter Bunyard, the science editor of *The Ecologist* and of *Science in Society*. In 'The Real Importance of the Amazon Rain Forest' [2] Bunyard states that 'the implications of Makarieva and Gorshkov's thesis are enormous; **essentially it means that South America cannot do without its rainforests**.'

An 'Amazon dieback scenario' had already been predicted by a large-scale computer simulation at Exeter University in 2000, showing a dieback of the Amazon forest in 2050, due to warmer temperatures and water stress. But after the Amazon drought in 2010, scientists began to ask the question what if the dieback might be due 20 years earlier? However, this simulation was performed before M&G published, and hence did not include the *biotic impact of forests on climate*, but only the effects of climate on forests – **seeing forests only as a passive victim and not as an active player remains commonplace in climatology, for the time being.**

The first ray of hope that one day the impact of forests might be considered in mainstream science (and following that in large-scale political environmental decisions) came on 16 January 2012, when *The Guardian* published an article called 'Include trees in climate modeling, say scientists' [6]. It opens with the line…

'Current climate models and projections may be inaccurate because measurements are based on guidelines that do not include the effects of trees on the local climate, according to agroforestry experts…' – note that this comes from the World Agroforestry Centre (ICRAF) and not from climatologists.

‘This in turn may be hindering effective adaptation [of insights and warnings from climate science] by local farming communities, as the true effect of climate change on their crops is not accurately captured.”

> **‘Trees can influence many of the climate factors predicted by modeling, and their effects should be added to climate maps…’**

The article is based on a book published in December 2011 by ICRAF: *How trees and people can co-adapt to climate change.* One of the editors of the book, Meine Van Noordwijk, says that, “following the guidelines of the World Meteorological Organization (WMO), *global weather stations collect climate data on open ground — away from trees.*“ **The WMO standards intentionally “avoid tree canopy effects on the measurements.” – They calculate as if this is a planet without trees. Why?**

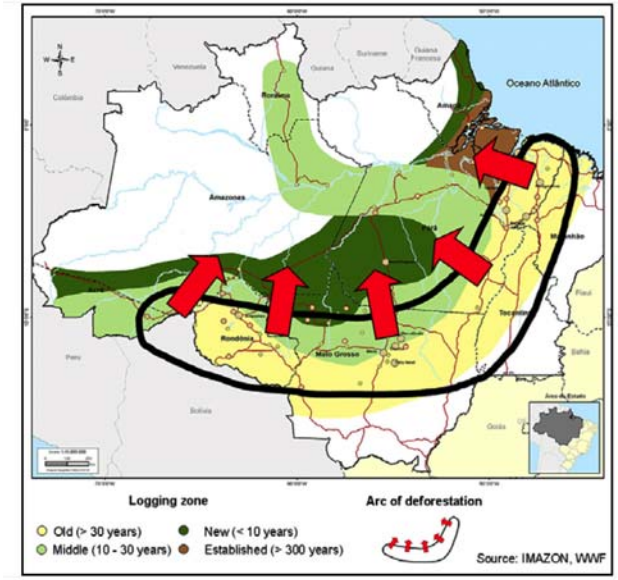
Noordwijk adds: ‘’Unfortunately … climate scientists have not made much effort to quantify [the effects of trees]. By not looking at that, we are missing a large opportunity to understand how we can adapt.”

Comment

As climatologists keep ignoring the global significance of the forests, catastrophic events accumulate that seem to give weight to the warnings presented by M&G:

- With the deforestation in the eastern Amazon (see map) presently coming dangerously close to cut off the ocean-to-land moisture transport, the **first signs of a threatening desertification of South America are starting to manifest**: in 2005 and 2010, two severe ‘once a century’ droughts occurred just five years apart. [7]
- Unprecedented vast forest fires in Siberia and the USA in 2010, 2011 and 2012 point to an increasing landscape dehydration following large-scale destruction of primary indigenous forests. (see www.themeaningoftrees.com/forest-fires-and-their-causes)

Climatologists and meteorologists, after all, are bound to the undoubted theses of thermodynamics; they seem to be old-school physicists devoted to the study of (dead) matter, thinking in purely physical terms: temperature, air pressure, moisture content, atomic weight, etc. are the players, not living things like the vegetation cover. The cognition of an **interplay between biology, chemistry and geology** seems to be too modern and unproven; the study of cybernetics, feedback systems and Earth system science http://en.wikipedia.org/wiki/Earth_system_science only emerged some three decades ago.



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Just how little science knows about trees and forests can be glimpsed, for example, in two articles by Justin Gillis in the *New York Times.* [7] [8] For one, dendrology hardly even knows exactly how trees *die.* Most studies of trees are fixated on how trees grow or how they can be made to grow faster and bigger. But little is known whether – in a drought or other stress situation – trees die of hunger (by closing the leaf pores to avoid water loss and ultimately starving to death for lack of the carbohydrates) or of thirst (due to hydraulic failure after the fine water transport tubes might have received irreparable damage during the drought). And what exactly are the decay processes of an area of rainforest that succumbed to drought? How many years does it take for what amounts of carbon to be released (and effect the climate)? Or would the area burn? Charcoal binds some of the carbon to the soil. Without answers to these questions, how could climate models include any data from the world’s forests? Which, at present, still absorb about one billion tons of carbon per year – a tenth of what humankind produces.

The force of photosynthesis in the Amazon alone uses solar energy equivalent to fifteen atom bombs a second for water evaporation. With this not being reflected in the climate models which tell us about ‘global warming’ and ‘climate change’, then how can we as the public believe these models? Why should we?

A task more pressing than creating ever new statistics is to save what's actually left of the real world: the forests and other ecotopes that are supremely good at doing what they have done for millions of years: Keeping the planet in balance.

'Tree and human stand or fall together.'

Fred Hageneder, 1999

What everyone can do:

- Replace Google with Ecosia as your default search engine. ecosia gives 80 per cent of its earnings to a rainforest project in Brazil. (www.ecosia.org)
- Regularly check in with Rainforest Rescue. Strengthen pressure groups by signing petitions to decision-makers. Donate if you can. (www.rainforest-rescue.org)
- To support tribal people as part of their respective – and threatened – ecosystems, support Survival International. (www.survivalinternational.org)

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