Chapter 11
Role of the Biota in Forming the Environment

Since Vernadsky's time, we have known about the singular role that the planet's living material plays in forming the global biogeochemical cycle due to the part it takes in high-speed chemical reactions. Today there is no need to explain to anybody how life has changed the face of the Earth, and that it is to this the Earth owes its oxygenated atmosphere. The quantitative characteristics of some nutrient cycles, however, including the carbon cycle which forms the basis of organic molecules, the basis of life, became known to scientists relatively recently. That, in turn, allowed us to approach an understanding of many processes taking place in the biosphere.

So, for example, scientists established that stores of inorganic carbon available to the biosphere, unlike in ancient geological epochs, today are materially limited, adding up to about 10^3 gigatons (Gorshkov et al. 2000, p. 117). Primarily this is carbon dioxide gas dissolved in the World Ocean, as well as soil humus, peat bogs, and finally the small admixture contained in the atmosphere—less than 0.04%. However, the great majority of carbon dioxide dissolved in the ocean is located at depths below 200 m and goes barely used by phytoplankton and its emergence from the deeper strata as a result of vertical cycling is relatively low. So, the biota makes extremely economical use of inorganic carbon.

But the life strategy of ancient biotic communities in long-gone epochs looked entirely different, when the atmosphere was much richer in carbon dioxide. The colossal deposits of oil and coal, which have survived to this day and which we utilize so widely, indirectly testify to this. According to the remains of organic communities buried in ancient geological formations, which had not been reprocessed by living organisms, we can assume that, at the first stages of the Biosphere's evolution, waste from life processes emerged from the environment and stored itself in sediments (oil), or that rotting plant remains piled up faster than their bacterial decomposition occurred (coal in the Devonian and Silurian). You could characterize such a type of biotic strategy as high-entropy i.e. accompanied by significant necrosis in the organic community and a high product of mortmass (Krasilov 1992, p. 32).

Therefore, the necessity to more efficiently use the trophic resources of the environment led, over the course of evolution, to a kind of "emissions-free technology"

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on the basis of which modern natural ecosystems function. This enables, first of all, a more complex structure of biotic communities as the diversity of life forms increased, and also the correlation of species within communities, providing the opportunity to repeatedly use the organic material created by producer organisms in the process of synthesis.

Thus arose the multi-tiered system of a more-or-less closed cycle of matter, which included a number of consecutive reprocessing stages for organic production (the food chain), starting with the autotrophic producers and ending with reducer organisms (fungi and bacteria) at the exit. The latter, reprocessing decayed organic matter to its ultimate sub-molecular compounds, makes it accessible to the root system of plants, in this way providing the opportunity to use the nutrient chemical elements necessary for life. That is, it is as though they restore the dead to life.

For the modern biota, however, adapted to an oxidized atmosphere, an oversupply of carbon is just as unacceptable as a deficit—recall the danger of an excessive greenhouse effect. By the way, the main mass of inorganic carbon is concentrated not in the atmosphere or the World Ocean, but in the earth, at a coefficient of 28,570 (lithosphere): 57 (ocean):1 (atmosphere) (Marfenin 2006, p. 80). That is even with the regular release of large quantities of inorganic carbon from the earth into the hydrosphere and atmosphere by way of volcanic activity, degasification of magma and rifts in the ocean floor. Volcanic gasses contain a 15% share of carbon dioxide, 75–80% of water vapor and of all other gasses (CO, CH_4, NH_3, H_2S, etc.) a total share of no more than 10%. However, in the Earth's distant past, there were periods of much greater volcanic activity compared to today, and nonetheless even against a backdrop of major variations, atmospheric concentrations of CO_2 maintained their order of magnitude over the course of hundreds of millions of years (Broecker et al. 1985; Barnola et al. 1991).

The fate of carbon emitted into the atmosphere is already no secret today. In past geological epochs, it was all reliably buried in sedimentary rock—the remains of the fossilized biota in long-gone biosphere (chalk, limestone), as well as varieties of hydrocarbon fuel (oil, coal, peat, shale oil, natural gas, etc.). All of this is linked to the activity of the biosphere, removing superfluous carbon from circulation over many thousands of years. The scale of the stream removed is assessed by experimental means, thanks to the discovery of tiny granules of organic carbon, kerogen, sown in geological deposits. From this, it became clear that carbon was stored at a rate of 0.01 gigatons per year over the past 600 million years (Budyko et al. 1987).

A special place in the regulation of the global carbon cycle belongs to the biota of the World Ocean. 57 times more carbon dioxide gas has dissolved itself in the ocean than is contained in the atmosphere—40,000 gigatons of carbon to 700 (Bolin 1983). And there is a reason why it does not diffuse into the Earth's atmosphere—the carbon-dioxide poor layer of water under the ocean surface.

This layer between 100 and 200 m in depth is called the photic zone, as this is the distance below the surface that rays of light on the visible part of the solar spectrum penetrate, thus establishing conditions for photosynthesis. It is warmer than the deep, practically unheated layers of the ocean. It floats, you might say, above the cold depths, separated by a zone of sharp, bounding changes in temperature and pressure called the *thermocline*. Aside from this, the near-surface layer is well stirred by the wind, which, combined with the chemical properties of water-dissolved carbonates provides for atmospheric CO_2 to be swallowed up quickly enough and its concentrations in air and water balanced according to Henry's Law.

The main particularity of the photic zone, however, is the presence of phytoplankton, which reworks the great mass of waterborne organic material in the process of photosynthesis and serves as food for all ocean consumers. Photosynthesis, as you know, involves the absorption (bonding) of carbon dioxide. The volume of this abortion in the World Ocean is estimated to be at the order of 40 gigatons of carbon per year (Green et al. 1984, vol. 1, Ch. 9.2.1).

In this way, the photic zone plays the role of a unique buffer, swallowing up carbon dioxide gas accumulated in the atmosphere on one hand, and preventing excess CO_2 dissolved in the ocean from entering the atmosphere on the other. This last mechanism received the name of biotic pump, since CO_2 welling up from the sea depths as a result of storms and upwelling[1] enters a process of biotic synthesis at the surface. Afterward, as the organisms living there die off, this bonded carbon again sinks to the ocean floor. There it accumulates in the form of dissolved organic substances or as calcium carbonate ($CaCO_3$) in organisms' limestone skeletons and is buried in dense deposits, then partially released in the process of decomposition.

By the way, as geologist Nikolay Koronovsky writes, "Until entirely recently, this role of biogenic deposit accumulation was still clearly underestimated. Now it is established that of the whole mass of deposits, biogenic material accounts for 50–60% and each year greater than 350 billion tons accumulate in conversion to solid matter. The material dissolved in the water is digested by the aquatic biota that filters ocean water. The sea biota requires only half a year to filter through itself all the water in the World Ocean" (Koronovsky 2003). Thus, the ocean biota carries its weight to maintain the composition of seawater it needs, preserving it practically intact over the course of the whole Phanerozoic Eon, or 600 million years. Analogously, the same mechanism enables the removal of excess atmospheric carbon, absorbing it through a process of organic synthesis and partially burying it on the ocean floor.[2]

If we could transport a modern person in H. G. Wells' time machine back a billion years and give them a chance to look at dry land from a birds-eye view, they would not only fail to see any trace of vegetation, but would not even encounter any landscape as we typically use the word. Instead of rivers flowing along their channels, there would be some kind of limitless delta with countless ducts and rivulets. Instead of a defined shoreline dividing land and sea—a half-flooded space of many

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[1] Upwelling—ascension of ocean water from its deeper strata under the influence of wind forcing warm water from the surface or a number of other causes. The particular importance of this process is linked to the welling up of various nutritional components from the depth, enriching the surface strata and increasing its bio-productivity.

[2] Here we will not touch on the details of nutrient cycles for nitrogen, phosphorus, sulfur, or other so-called minor nutrients, the share of which in the general mass of organic material is relatively small, adding up to no more than 1%.

miles, neither land nor sea. Kirill Eskov wrote, “There are serious grounds to suppose that continental landscapes of the modern look were not there at all” (Eskov 2000). Paleontologist Alexandr Ponomarenko thought (in 1993), “The existence of true bodies of fresh water, whether flowing or still, was very problematic until vascular plants somewhat reduced the speed of erosion and stabilized the coastline.” There is even the opinion that in these distant times, land at a certain distance from the shoreline was deprived of any moisture whatsoever, since all rainfall had to either fall over the ocean or nearby (Gorshkov and Makarieva 2007).

In other words, living organisms not only made landfall, but in some sense created land as we know it, and the decisive contribution in establishing continental landscapes of the modern look was made by higher (vascular) plants. The key moment came with the biota’s soil formation function.

But how could soil appear upon this lifeless rock with its irregular water supply? As Vasily Dokuchaev (1846–1903), one of the founders of soil science, showed in one of his works, soil represents a very complex formation—a natural body of organic material and minerals arising as a result of influence from the biota and physio-chemical factors upon continental rock. One such factor, the process of destroying and eroding mountain rock, was until recent times thought to occur by the actions of sun, wind, falling temperatures, freezing and thawing of water falling into cracks. Only in the past decades have we managed to reveal the enormous role in this process of living organisms, primarily bacteria and fungi, which accelerated erosion 100–300 times.

Landing on eroded rock, they dilute and destroy its surface layer, where, after they die, hollows form, holes and fissures filled with the dry biomass of fallen organisms. Mosses settling on rock surfaces thus prepared draw from them chemical elements necessary for life, and also aid in creating organic acids, sharply accelerating the dilution and hydrolysis of minerals. The biota becomes an active supplier of debris, able, as it accumulates, to hold moisture together with its diluted organic and inorganic compounds, thereafter serving as a fitting substance for plant seeds to grow in. And their growing roots, branching out and penetrating that newly developed layer of soil, assist its structuring and sturdiness, i.e. the formation of our familiar landscape forms.

From the above, it is clear how great a role the biota plays in soil formation, despite the relatively small share of organic material in the soil (about 10%). But the incessant cycle of soil elements takes its properties at once from living and nonliving, or, in Vernadsky’s phrasing, bio-inert substances. Plant roots share the products of their activity with the soil, in part initiating chemical creations, in part creating fodder for fungi and bacteria. The latter, reworking the remains of plants and animals, taking the sustenance necessary for their life activity, aiding the decomposition of organic material into simpler molecular components which again become accessible for use by plant roots.

Another contribution to breaking down organic material is made by invertebrates—larvae, insects, earthworms, centipedes and millipedes, feeding on fallen leaves and passing them through their bowels. It is estimated that, over a period of 100 years, earthworms pass through their digestive tracts practically the entire soil cover of temperate latitudes to a depth of 0.5 m. In the meantime, they grind down and churn up the soil's mineral and organic elements, improving its structure. The paths they make aid in soil aeration and ease the growth of roots (Lapo 1987; Sorokhin and Ushakov 1991).

Thanks to its ability to accumulate organic and mineral substances as well as moisture, soil serves as a reservoir and source of life for the biota. Soil humus accumulates colossal reserves of carbon and biogenic elements. At the same time, the organic material that accumulates here is different from that contained in plant or animal organisms. Most of all, this is humic acid with its 50–60% carbon content. It is this that gives the fertile chernozem its distinctive black color. Finally, due to its porous, highly dispersed structure, soil has a large surface area of formative particles and, therefore, is able to hold a significant portion of rain and melt water, i.e. to serve as a reservoir of moisture.

Ancient land, we remind you, was deprived of these qualities, so returned all fallen rain unimpeded to the World Ocean in unregulated sheet flows. Thus, in making landfall, the biota oceanized this land by creating soil upon it—a kind of ocean filled with alluvium, as well as the current freshwater hydro system—swamps, rivers and lakes.

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Let us now turn our attention to the contribution made by the plant biota in regulating the continental water cycle. As we have already said, soil, due to its crumbly structure, represents an efficient mechanism to hold water. But it holds the water only temporarily. Land, after all, rises above the water at a greater or lesser incline. And so, obeying the law of gravity, soil moisture trickles from the more elevated horizon, gathering in streams and rivers small and great before it finally falls into the ocean. The volume of this yearly flow amounts, according to current data, to about 43,000 km^3 (Marfenin 2006, p. 224).

It is estimated that in 4 years, all of continental water accumulated in lakes, glaciers, and swamps would drain into the ocean were it not refilled from atmospheric rainfall. Much of this rainfall forms itself overland, but roughly one-third, or 35 cm of 100 cm of the rain that comes down on land, owes itself to evaporation of the world ocean. In other words, if ocean moisture did not pour as rain or fall as snow upon the land, then in less than 10 years, dry land would justify its name—it would utterly dehydrate.

Earlier on we mentioned the hypothesis that it is forests that enable rainfall over the interior parts of continents, forming "secondary" clouds due to transpiration above dry land rather than ocean. These clouds move with air masses into continents and provide moisture to forests far from the shoreline, unloading rain and snowfall on them as they go. This, in turn, evaporates as accumulated moisture, causing "tertiary" clouds to arise, and so on.

Of course, what Russians call the "weather kitchen"—the mix of atmospheric fronts, storm development and cyclone formation—is an area of very complex and insufficiently researched phenomena, poorly suited to mathematical formulation and modeling. Nonetheless, in terms of the concept of biotic regulation, Viktor Gorshkov and Anastasia Makarieva undertook an attempt, on the basis of known laws of physics, to more precisely describe the transport of ocean moisture to dry land, linking this process to the functioning of the plant biota, i.e. to prove its universal influence on the processes of the continental water cycle. This primarily relates to the preservation of forest lands, and the authors named this mechanism the *forest biotic pump of atmospheric moisture*. But, in order to more fully deal with the substance of this mechanism, we must linger in more detail on the process of *transpiration*, the evaporation of water from the leaf surface of plants, which holds the key to understanding the nature of this phenomenon.

Transpiration, somewhat analogous to blood circulation in animals, is the incessant movement of water together with the organic and inorganic substances dissolved in it up from the soil through the root system of plants and further along the stem vessels of the xylem (the vascular tissue of plants) to the leaves. The vessels of the xylem are tubes with a narrow shaft, whose diameter varies from 0.01 to 0.2 mm. In order to draw water up a large tree through such tubes, it requires pressure on the order of 4000 kPa.[3] But by mere capillary power, even along the thinnest vessel, water cannot rise higher than three meters, while some trees reach 50 or even 100 m in height, such as the Californian sequoia or Australian eucalyptus.

This phenomenon can be explained by the theory of bonding or cohesion. According to the theory, water rises from the roots as a result of evaporation in the leaves, which deprives cells there of water and raises concentrations of dissolved substances. As water leaves xylem vessels in the column of water, it creates tension going down the stem right to the roots. This is connected to the ability of water molecules to bond with one another (cohesion). This property comes from their polarity, a dipole moment, which causes water molecules under the influence of electrostatic forces to attach to one another (“stick,” you might say) and stay together in hydrogen bonds. Thus arises the propellant force of transpiration, determined by the falling gradient of hydraulic potential, which falls as concentrations of dissolved salts in the xylary fluid rise. As a result, water from sap with higher hydraulic potential streams to leaf cells, enabled by the selective permeability of cell membranes.

The speed at which water travels along vessels in the stem is notably high. Among grasses, water goes about 1 m/h, and among tall trees—up to 8 m/h. Thanks to cohesion, tension in the xylem vessels carries enough force to pull up the entire weight of the water column. Different estimates of tensile strength for this column of sap vary within the margins of 3000–30,000 kPa. Leaves carry a hydraulic pressure on the order of 4000 kPa. So this column of sap is durable enough, in all likelihood, to sustain the tension it creates (Green et al. 1984, vol. 2, Ch. 14.3.3).

At the final stage, water seeks to abandon the plant, since the hydraulic potential of the surrounding moderately moist air is tens of thousands of kilopascals lower than in the plant itself. The water abandons it in gaseous form, which requires additional energy provided by the unseen warmth of gasification. The sun’s rays supply this energy, ultimately serving as the force that moves the transpiration process at every stage—from soil to roots and from roots to stem and leaves.

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[3] 1 Kilopascal (kPa) = 0.01 atmosphere of pressure.

That plants require water to provide for their life activity, including the needs of photosynthesis, is obvious. Less obvious is the intensiveness of the process. After all, the plant itself holds back only 1% of the water it swallows from the Earth, and the other 99% returns to the atmosphere through the plant, in transit, you might say. Meanwhile, the level of transpiration, with sufficient sunlight, soil moisture and surrounding air temperature, can be very high. Thus, for example, grasses such as cotton or sunflowers are able to expend 1–2 L of water in a 24-hour period, and a 100-year oak—more than 600 L.

Over the course of evolution, the majority of plants have developed adaptations to enable the regulation of this process and retain moisture if needed. Some, for example, cast off their leaves during seasonal chills or droughts. Some put away moisture in secretory cells or in the cell walls of different parts of the plant. Some, finally, developed stomata—special pores in the epidermis, located on the leaves and some parts of green stems, through which gas exchange occurs and 90% of water evaporates. Thanks to special interlocking cells, stomata can close in dry weather or at night when photosynthesis stops, thus slowing the process of transpiration. There are other adaptations for reduced transpiration as well, formed under the conditions of dry climate and water shortages, such as a thickened cuticle (a waxy layer covering the epidermis of leaves and stems), opening stomata at night and closing them during the day, etc. (Green et al. 1984, Vol. 2, Ch. 14.3.8).

Nonetheless, under normal circumstances, due to the great surface area of leaves typical most of all in forest cover, water loss from transpiration can be very high, materially increasing evaporation from the reservoir's surface equal in area to the tree canopy's projection over the soil. And if you consider that total leaf surface for the whole vegetative biota exceeds by four times the area of dry land, it becomes clear that complete evaporation of natural forest in possession of a high leaf index (relative value of exposed leaf area to canopy projection over soil) could successfully compete with open ocean surface of the same temperature. So, according to estimates, maximal water evaporation over forest corresponding to aggregate global flow of solar energy absorbed by the Earth's surface, adds up to ~2 M/year, while evaporation from the ocean surface comes in at nearly half as much: ~1.2 M/year (L'vovitch 1979).

It's also worth remembering that transpiration is not the only source of evaporation, since trees have the ability to accumulate a significant amount of rainfall and snow by catching it in their canopies. This moisture contributes a share of forest-developed evaporation that may reach 30%, which is especially relevant for boreal coniferous forests, where the snowy coats and hats caked on pine trees provide evaporation flow even in winter, when transpiration does not. So virgin forest is capable of evaporating moisture practically year-round, and that from the point of view of the authors of the forest pump concept, carries decisive meaning in the formation of the continental water cycle.

This is because passive geophysical streams, carrying moisture from the ocean, extinguish themselves as they move deeper into a continent. They extinguish themselves exponentially. And the further one goes from shoreline, due to the elevated position of continents, the greater the share of rainfall brought from the ocean that

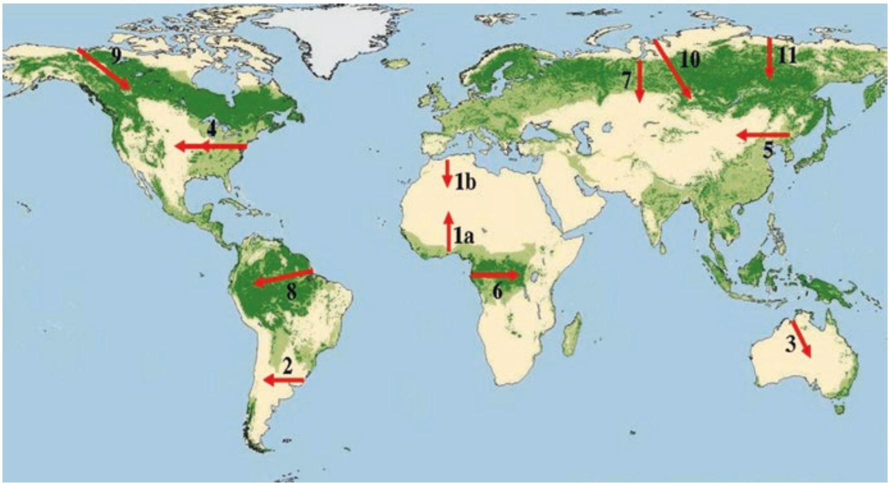

Fig. 11.1 Geophysical regions where research was conducted on the dependence of average yearly rainfall on distance from the ocean. The numbered arrows correspond to the regions: 1a—West Africa, 5° east longitude; 1b—North Africa; 2—South America, 31° south latitude; 3—Northern Australia; 4—North America, 4° North latitude; 5—Northeast China; 6—Africa, Congo Basin; 7—0b Basin; 8—Amazon Basin; 9—Mackenzie Basin; 10—Yenisei Basin; 11—Lena Basin. Source: Biotic Regulation website: http://www.bioticregulation.ru/common/pdf/06e03s-hessd_mg/06e03s-hessd_mg-screen.pdf

returns to it with the river streams. Granted, this rule holds true, most of all, in deforested areas with low steppe vegetation, where for every 400 km one goes inland on steppe, savannah or prairie abutting the shoreline, the flow of moisture and intensity of rainfall decreases by half.

Data analyzed by Gorshkov and Makarieva on the gradient of decreasing rainfall over wide areas of five continents (Fig. 11.1) has shown that passive geophysical transport of moisture is capable of providing normal conditions for grass canopy and scrub vegetation only adjacent to the ocean to a depth of several 100 km (Fig. 11.2c), mainly during the summer period.

But how do you explain the existence of well-watered areas deep within continents, thousands of kilometers from the ocean—in Siberia, Canada, Alaska, Equatorial Africa or the Amazon Basin (Fig. 11.2e–g)? It would be difficult to answer this question, only going off of passive geophysical streams. Here we must draw our attention to the active transport of ocean moisture, the moving source of which is the forest biotic pump. More exactly, those atmospheric physical processes that occur over forests as a result of transpiration or recapture of rain water by tree canopies.

The essence of these processes is as follows. In a stationary, undisturbed atmosphere at any elevation, air pressure is balanced by an atmospheric air column located above this height. And since an increase in elevation reduces the scale of the atmospheric column above it, the pressure balancing it falls correspondingly. Anyone who has ever climbed a mountain knows this well from personal

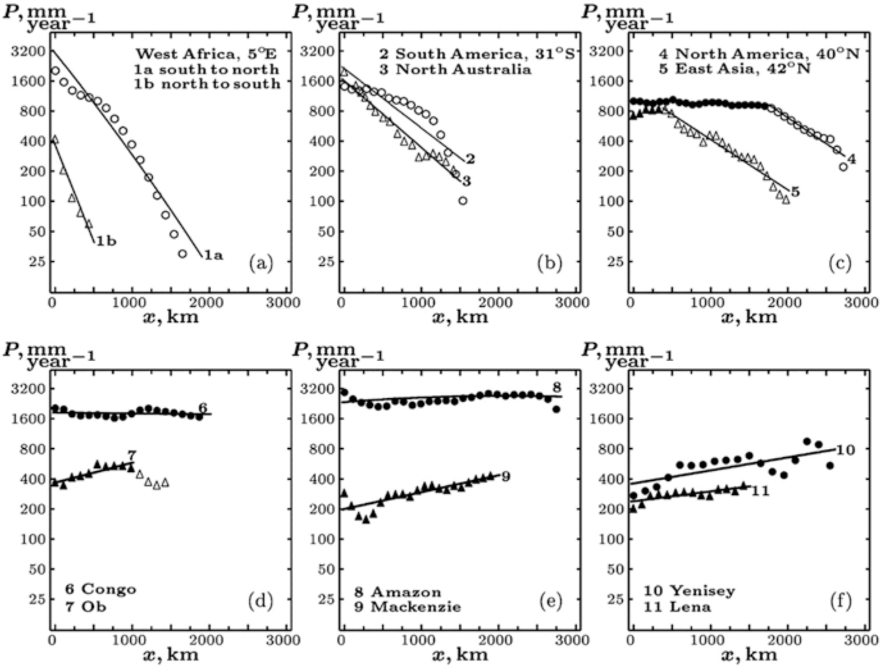

Fig. 11.2 Dependence of the amount of rainfall *P* (mm/year) on distance *X* (km) from the ocean. On deforested ((hollow dots/squares) and forest-covered territory (filled dots/squares). Numbered regions are on the map (Fig. 11.1). Source: Biotic Regulation Website: http://www.bioticregulation.ru/common/pdf/06r08o-eopmp_gm.pdf

experience: It's hard to breathe on a mountaintop because the air is thinner. But while other components of air—nitrogen, oxygen, etc.—are only found in a gaseous state, you couldn't say the same of water vapor, which under typical Earth temperature conditions has two phases, liquid (as raindrops and fog) and gas. Because of this, it behaves somewhat differently, i.e. it is able to transition from one phase to the other.

Fog, as you know, forms with lowered temperatures. This phenomenon is called condensation, and we've all had to deal with it before, observing, for example, the accumulation of dew that settles upon the grass on cool summer nights, or some kind of quickly chilling surface, especially a metallic one. This can be explained by the reduction of kinetic energy in water molecules and the slowing of the evaporation process as the temperature goes down. As air cools, the water vapor contained within reaches the saturation point and begins to condense into dewdrops. In the handsome phrasing of Anastasia Makarieva, "Water molecules 'pack themselves' into drops that occupy a thousand times less volume than water vapor—the gas from which the drops form. And since air pressure at earth's surface is proportional to the overall number of gas molecules in an atmospheric column, atmospheric pressure decreases wherever condensation occurs" (From an interview with the newspaper *Nevskoe Vremya*, August 24, 2014).

In physics, the critical temperature at which condensation begins is called the dew point, depending, in turn, on pressure and relative moisture of the air. Something similar happens to water vapor as it rises in elevation, which, as you know, is accompanied by a drop in air temperature—about 6 °C for every kilometer. Thus, for example, at an elevation of 10 km, where modern airliners fly, the outside temperature is nearly 60 °C lower than at ground level. If, like other components of the atmosphere, water vapor were not a condensing gas, its state of equilibrium would continue at any elevation, independent of temperature, and its pressure would decrease by half for every 9 km it rose.

Over the conditions of quickly lowering temperatures, however, in the upper layers of the atmosphere, water vapor reaches the stage of critical saturation just as quickly—roughly double for every 10 °C—much faster than atmospheric pressure falls at these elevations. And since the concentration of gaseous water vapor cannot be greater than saturation, its relative excess immediately condenses, abandoning the gas phase. This, in turn, is accompanied by a decreased weight of water vapor in the atmospheric column, which is already incapable of balancing its predominant pressure in the warmer near-surface layers of the atmosphere, which leads to the occurrence of upward force.[4] It is this force that carries rising currents of moist air, which, lifting to the upper layers of the atmosphere, also condenses, forming clouds and falling as rain or snow (Gorshkov and Makarieva 2007).

And here, you might say, we come to the focal point of the biotic pump concept. After all, if rising currents formed due to water vapor condensation in the upper atmosphere are constantly fed by surface moisture, that means that moist air from neighboring areas where there is less evaporation should be sucked up in its place. And, if, as we have shown earlier, evaporation over virgin forest areas surpasses evaporation over the ocean surface, then, therefore, forests propel ocean moisture deeper and deeper into a continent, compensating river runoff and providing soil with moisture year round. Granted, this would occur only under conditions where forest areas stretch to the coastline, such as occurs, for example, in the basins of the Congo, Amazon or the northern rivers of Russia and Canada, where taiga forests butt up against swampy tundra with ocean access, or, at least, separated from the shore by a distance closer than the exhaustion point of passive geophysical transport (~600 km).[5]

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[4] This force cannot be compensated by other atmospheric gasses, since, according to Dalton's Law, all of them arrive at equilibrium or are removed from it independent of each other. Therefore, if in some part of the atmosphere a phase change of one of its formative gasses takes place (like water vapor turning to fog), then a rapid fall of atmospheric pressure occurs in that zone. Such as what happens when all the oxygen is pumped out of a vacuum chamber.

[5] There is the particular question of how the great Siberian river basins, thousands of miles wide and covered in forest, can exist by propelling moisture from the frozen Arctic Ocean with its low capacity for evaporation. But the paradox is illusory. It all has to do with the difference in between the intensity of evaporation over the Arctic and the position of the Taiga River Basins in warmer, more southerly latitudes, which ultimately determine the species of horizontal currents of moist air. So the propulsion of ocean moisture is obviously an easier task for the Siberian biota than for tropical forest in the equatorial zone. After all, to provide an analogous transport of moisture from a warm ocean requires significantly higher levels of transpiration.

Thus the destruction of forest cover to a depth of 600 km from the shoreline rips through the biotic pump, and rainfall in the continental interior ceases to compensate river drainage. Moisture in the soil trickles to the ocean, forests dry out and river basins cease to exist. All of these irreversible changes can occur over an extremely short period of time, on the order of 4–5 years—the time required for fresh water, accumulated in mountain glaciers, lakes and swamps, to run out.

In all likelihood, something of the kind took place in Australia 50–100 thousand years ago, when the first humans settled it. We can naturally assume that the new arrivals, as always happens, first took to the shoreline, destroying forests along the way over the whole perimeter of the continent. And when this deforested strip reached the depth at which passive geophysical currents exhaust themselves, the biotic pump was cut off from ocean moisture. Three quarters of native forests then gave way to Australian deserts. By the way, could it be for this reason that most deserts either border on the ocean shore or have access to inland seas? From the position of what has just been said, this detail of geography finds its origin in human history, in human activity, acquiring new territory starting from the seashore.

It might seem that Western Europe, deprived of 9/10 of its natural forests with the exception of northern Scandinavia and the mountain regions of the Alps, Carpathians and Pyrenees but nonetheless free of desertification, would disprove the conclusions drawn above. This, however, is the exception that proves the rule. If Europe has avoided such a fate, it primarily owes this to its unique geographic position—surrounded by internal seas and universal proximity to the shoreline, due to which no territory of this subcontinent is separated from the sea by a distance greater than the point that geophysical transport of moisture is exhausted.

This situation, clearly, gives rise to the illusion that the practice of forest extirpation can be transferred to other regions of the globe with impunity. For these reasons, it will most likely prove, or has already been proven, much more ruinous. By the way, we cannot rule out that the sharp increase in the frequency of catastrophic floods witnessed in Western Europe in recent years might at least in part be linked to the destruction of native forests in mountain regions, which has led to disruption of the natural hydrological regime, the melting of mountain glaciers, etc.

But while we can consider desert practically closed to water (Fig. 11.3a) since the total lack of transpiration there leads not to land sucking up moist air from the ocean but the opposite, dry air being carried out to sea, evaporation may intensify over the ocean's surface in landscape zones of the grassland type, though only in the warm season (Fig. 11.3b, c). During this period, a horizontal current of moist air, commonly known as the summer monsoon (rainy season), arrives from the ocean and gradually wanes over distance. In the colder winter period, evaporation over the grass and scrub becomes less oceanic, and so the remaining moisture is pulled from land to sea, creating the dry winter monsoon. And though vegetation of the steppe type ecosystem provides the support of a certain moisture reserve and evaporation current overland, the lack of forest cover with its high leaf index does not allow this to develop to the level at which moist currents from the ocean would sufficiently compensate river runoff.

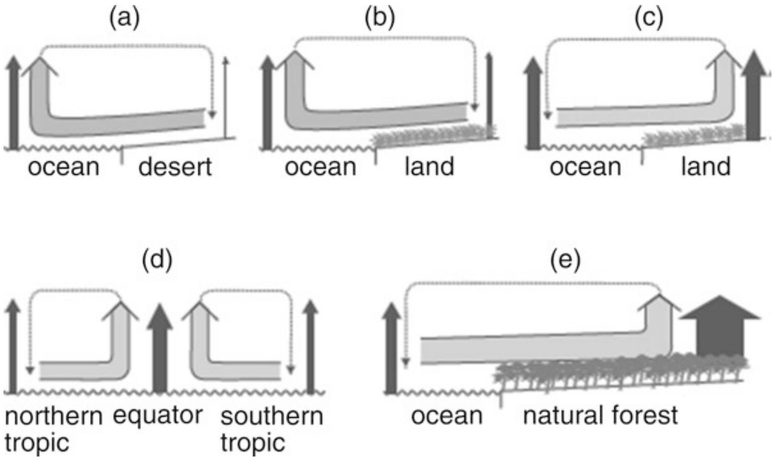

Fig. 11.3 Physical principle of air distribution overland from areas of lowest evaporation to areas of highest evaporation: (**a**) a desert "closed" to water; (**b**) winter monsoon; (**c**) summer monsoon; (**d**) trade winds; (**e**) biotic pump of atmospheric moisture. Thick arrows—horizontal and rising currents of moist air. Thin dotted lines—horizontal and falling currents of dry air. Source: Biotic Regulation Website: http://www.bioticregulation.ru/common/pdf/hess07.pdf

In this way, a fully-functioning biotic pump is the greatest "invention" of the land-borne biota, truly possible only under the conditions of natural primordial forests suited to a given climate zone, whose genetic properties are correlated to the geophysical particulars of the place. Therefore, humanity's primary task, according to Viktor Gorshkov and Anastasia Makarieva, should be recognized as the immediate cessation of the criminal practice of cutting down virgin forest on the territory of river basins, as well as places of access to the shore on oceans and inland seas, with the simultaneous restoration of forest cover on neighboring territories. If this is not the case, we risk not only the loss of the priceless forest wealth we have inherited, but also the conversion of enormous swaths of developed land into barren deserts.

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