

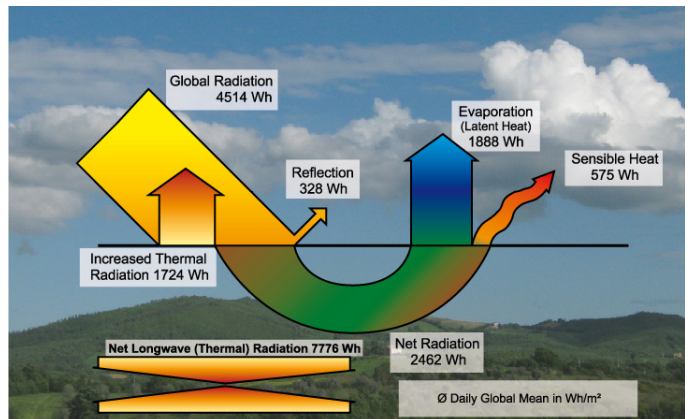
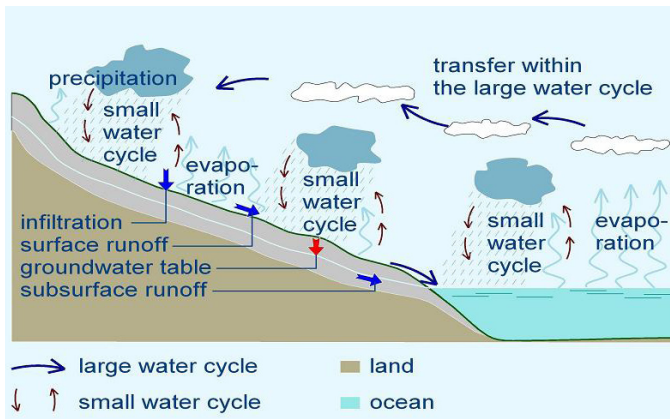
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A New Paradigm in SUSTAINABLE LAND USE

The global change in land use and its impact on the hydrology reduces evaporation and precipitation rates and releases heat. In urban areas, the priority for rainwater management needs to be shifted to evaporative cooling and vegetation.



Page 99: In Egypt deforestation influenced the small water cycle of evaporation and precipitation. This caused an ecological chain reaction and a local climate change already several thousand years ago.



Local precipitation rates are dominated by the small water cycle of evaporated water on land, compared to the large water cycle between the oceans and land (left). The illustration on the right shows the global daily radiation balance as annual mean.

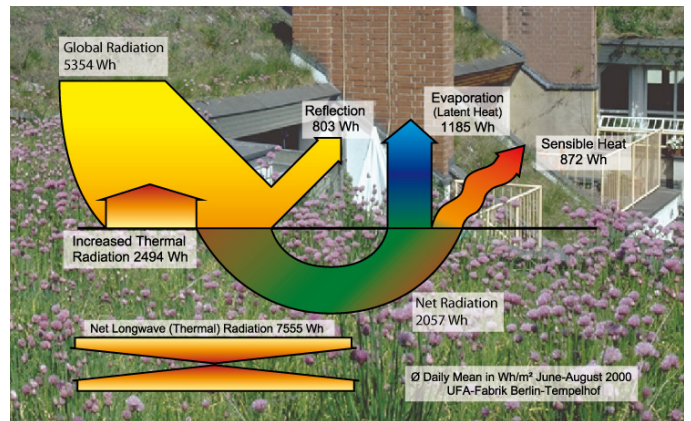
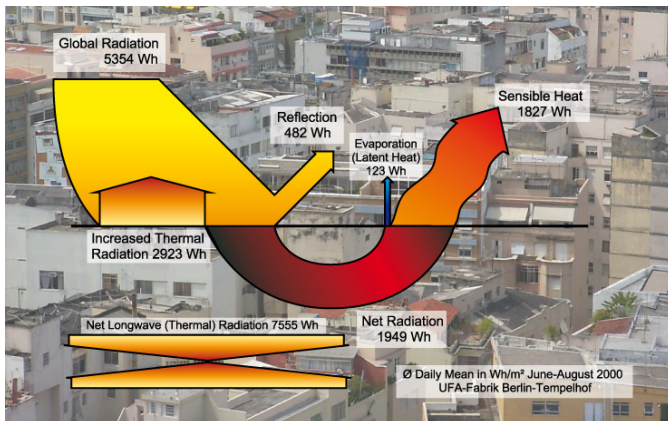
Sustainable land use is essential for future generations yet global development is characterized by daily deforestation rates of 350 square kilometers and a desertification process of 300 square kilometers daily. Both developments are closely linked due to the impact on the water cycle. Moreover, large vegetation structures are lost to urbanization. In Germany, urbanization increases at a rate of 1.2 million square meters per day. If this rate is taken into a global account, mainly agricultural areas of about 150 square kilometers are lost to urbanization daily. The primary reasons are increased settlement requests, like in Germany, and global population growth.

The global change in land use and its impact on the hydrology reduces evaporation and precipitation rates and releases heat. Only water that has evaporated will produce rainfall,

therefore, a reduction in evaporation leads to a further reduction in precipitation. This creates a chain reaction on land. Contrary to public opinion, local precipitation rates are dominated by the small water cycle on land.

Evaporation of water is the largest hydrologic process on earth and also the most important component of energy conversion. Just as rainfall volume depends on the amount of water that has evaporated, so will a reduction in evaporation mean the increased conversion of short-wave global solar radiation to long-wave emissions and sensible heat. All of the components in which global radiation is converted on the earth's surface are illustrated in the right figure on page 100, for a mean energy flux of one square meter per day.

Of this, 7.3 percent of incoming solar radiation is reflected and 38 percent is directly con-



verted to thermal radiation due to the increase of surface temperatures. The total long-wave (thermal) radiation consists of atmospheric counter-radiation [7,776 Wh/ (m²d)] and the thermal radiation of the surface of the earth [7,776 + 1,724 Wh/ (m²d)].

Net radiation can be either converted into sensible heat [575 Wh/ (m²d)] or consumed by evaporation, a conversion into latent heat. With 1,888 Wh/(m²d), the energy conversion by evaporation is the most important component of all, even more than the thermal radiation converted from incoming short-wave radiation. Additionally, evaporation reduces the long-wave thermal radiation due to the decrease in surface temperatures. With consideration of the left figure on page 100, the entire global radiation balance is dominated by evaporation and condensation.

Urbanization dramatically impacts the small water cycle. Additionally, hard materials and surfaces in urban areas absorb and re-radiate solar irradiation and increase that area's heat capacity. Fundamentally, the main driving factor for the urban heat island effect is the lack of vegetation and absence of unpaved soils (left figure on page 101). Impermeable surfaces like roofs and streets also influence urban microclimates through a change in radiation properties. As an example of radiation changes in urban areas, this figure illustrates the radiation balance of a black asphalt roof. Compared to the figure on a global mean square meter (page 100, right), most of the net radiation from the urban setting is converted to sensible heat rather than evaporation. Higher surface temperatures also increase the thermal radiation and change the dew point, which results in a further reduction of precipitation.

An urbanized landscape significantly alters a region's pattern of radiation and hydrology. The radiation balance of a black asphalt roof gives an example for urban radiation changes (left). Extensive green roofs transfer 58 percent of net radiation into evapotranspiration during the summer months (right). Both numbers were measured at the UFA-Fabrik in Berlin-Tempelhof, Germany.

The radiation budget in a desert is quite similar to the radiation budget in the “urban desert” of concrete and asphalt. Compared to a desert, precipitation still takes place. However, instead of closing the water cycle by evaporation, large amounts of water are discharged into sewers. As a result of changes in the urban energy budget, air temperatures inside buildings also rise and lead to discomfort and/or greater energy consumption by climate management. The use of electricity for cooling exacerbates this situation in urban areas by increased heat release outside of the buildings. Instead, water should be used for climate management in evaporation processes (see www.gebaeudekuehlung.de.)

The chain reaction of reduction in evaporation, climate change and drought demands a new water paradigm. Until recently, evaporation has always been defined and understood as a loss. In fact, evaporation is the very source of precipitation. Drought is conventionally expressed as a result of rising global temperatures, but if we take this new perspective then increased aridity is the cause, not the result, of global warming. Our intensive land use patterns are causing the planet to dry out.

Old cultures experienced the same scenario. Once, the whole of North Africa was green. The Egyptians did not found their culture in the desert. Forests were cut and used as building material and energy source. Once deforestation took place, an increase in precipitation intensities and soil erosion, followed by periods of drought, became part of the historical record. Decreased evaporation in the catchment area

caused a climate change. The consequences for crop production led first to artificial irrigation systems; later, whole areas and prosperous cities, like Egypt’s former capital Piramesse, had to be abandoned. About 3000 years ago, the city was evacuated after a massive climate catastrophe caused an ecological chain reaction, known as the ninth of the “Ten Plagues of Egypt”.

The same development occurred several thousand years ago near the cities of Caral (Peru) and Uruk (Sumer, today Irak). The artifacts of the ancient civilizations can be found in the desert. The developments on Easter Island are a later example. The complex causes of the island’s decline can be traced to one major factor: palynology has shown that it has the most dramatic history of deforestation in the archaeological record. A steady growth in population – perhaps up to twenty thousand or more – plus the decline in vegetation, food and the increasing importance of useless activities (platform building, statue carving, and transportation) clearly led to a collapse. Starvation led to raiding and violence.

Today, land use practices and the resulting drought are worse. The most debilitating drought in decades is afflicting Portugal and Spain, while regions like the northeast of Brazil suffer from decreased precipitation and increased temperatures due to deforestation of the Amazon. These developments endanger future crop production.

The new water paradigm includes fundamental changes in land use. Soil fertility, especially the storage capacity for water, is essential for the small water cycle. In urban areas, the priority

for rainwater management needs to be shifted from sewer systems and artificial infiltration systems to evaporative cooling and vegetation.

Natural groundwater recharge and runoff in the eastern part of Germany represents 10 to 20 percent of annual precipitation. About 80 to 90 percent of precipitation is redirected to evaporation. Artificial infiltration systems manage an additional 6 to 10 times the surface of the infiltration area itself. This represents about 40 to 50 times more infiltration at one square meter compared to natural conditions.

However, infiltration can also lead to evaporation provided that vegetation and vegetated structures are constructed in the neighborhood. In such a case, infiltration systems must be supplemented with trees or facade greening systems. A discussion about the overcompensation of groundwater recharge by infiltration systems should not neglect the benefit of preventing rainwater from being discharged into sewers and surface waters. Nonetheless, we must discuss the impacts on the natural water cycle and on groundwater quality in urban areas.

A cheap and reliable measure to improve the microclimate in urban areas and to create more comfortable air temperatures inside and outside of buildings is to green facades and roofs. "Green" in this sense means covered with vegetation, such that solar radiation is converted to evapotranspiration. Currently, the "green building movement" is focused mainly on energy consumption by heating, cooling and ventilation rather than on vegetation and evaporation. Since the energy topic became a critical

concern, the central environmental issues of vegetation, water, climate and soil conservation remain the same.

According to measurements taken at the UFA Fabrik in Berlin, a greened, vegetated roof covered with eight centimeters of soil transfers 58 percent of net incident radiation to evapotranspiration during the summer months (see right figure on page 101). The annual average energy consumption is 81 percent, while the resultant cooling rates are 302 kWh/(m²*a) with a net radiation of 372 kWh/(m²*a). The roof in the right figure on page 101 was monitored parallel in the direct neighborhood to the asphalt roof in the left figure on page 101.

Simulations of global climate changes continue to neglect the fundamental driving forces of the climate: transpiration by vegetation and evaporation by land. With regard to the urban heat island effect and the issues of global warming, sustainable architecture and landscaping need to consider the natural water cycle, including evaporation, condensation and precipitation. Not a single drop of water may leave urban surfaces simply to be funnelled into sewer systems.

The missing global agreements about greenhouse gas emissions of the United Nations Climate Change Conference (COP15) offer a new opportunity to include land use, water cycle and photosynthesis. If we assume this new stance, then a paradigm change for land use and climate is essential. Discussions are welcome on the web portal www.ourclimate.eu. A book on this topic is available for free download on the web portal www.waterparadigm.org.

An international group of scientists met in Kosice, Slovakia shortly before COP15. The main goal was to develop strategies for sustainable land use based on vegetation and water and to publish a protocol announcing the existing gap in the climate discussion. The results are available on the web portal www.ourclimate.eu.

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