Water, Vegetation and Climate Change - Košice Civic Protocol

(addressed to COP15 - Copenhagen)

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***TELE*DOM, KOŠICE, SLOVENSKO**

Contents:

Košice Civic Protocol on Water, Vegetation and Climate Change (and COP15)

The uniqueness of the Earth from the climatic point of view is the result of a combination of favourable conditions, in particular the evolution of life over the course of several long geological periods.

It was above all micro-organisms and later also plants which over billions of years changed the physical and chemical environment of our planet, optimizing and later stabilizing certain parameters, including the climatic ones such as temperature and humidity, and the chemical composition of water, soil and the atmosphere. In this way they created the necessary conditions for the emergence of life as we know it today.

The living world influences the climate mainly by regulating the water cycle and the huge energy flows which are closely linked with it.

Natural ecosystems also develop in the long term towards the stabilization of closed cyclical processes (e.g. the water or carbon cycles), whose central medium is water and which efficiently manage solar energy with minimum material losses.

Transpiring plants, especially forest growth, demonstrate especially efficient water management. They work as a kind of biotic pump, causing humid air to be sucked up out of the ocean and transferred to dry land. Forests in the hot and moderate zones always appear cooler during sunny periods (particularly on infrared satellite photos) in comparison with their unforested surroundings. These and other aspects make for perfect climate-forming systems on the Earth.

For millions of years the self-regulating mechanisms of the biosphere have proven capable of correcting a wide range of unfavourable effects (e.g. fluctuations in solar energy, meteoric impacts, volcanic activity and the constant emergence of carbon from the depths of the Earth), which have continually disrupted the Earth's climatic stability.

Through their activities over thousands of years, human beings have been destroying ecosystems which have the potential to actively correct those unfavourable effects. People themselves began disrupting and changing the closed cycles of nature. The combination of these effects is gradually raising them to such intensity that nature itself is not able to correct them, and in certain cases a state is being reached which is not permanently sustainable.

A prime example of opening the closed cycles of natural ecosystems is the deforestation of land, accompanied by increasingly rapid run-off of rainwater, marked acceleration of soil erosion, reduced content of organic material in the ground, and substantial reduction of its ability to hold water.

Another example of creating imbalance is the collecting of rainwater from the built surfaces of modern towns and villages and its channelling away through sewers into the rivers and the sea. This water is then lacking in that part of the land. It is lacking in the soil, the vegetation, the underground water reserves, and last but not least also in the atmosphere.

Destruction of the hydrological cycle by humans disturbs the sequestration of carbon in the soil and vegetation and by this reduces the water storage capacity of the area. Reduced water content in the ground leads to an increase in oxidation processes and to losses of organic matter. Dry periods and heatwaves reduce photosynthesis and increase the probability of incidence of large forest fires.

Draining of the land requires special attention because of its influence on local climate. The presence or absence of water has considerable impact on the distribution of energy between the two principal heat flows: latent heat of evaporation and sensible heat. If water is not sufficiently present in the land, a large part of the incidental solar energy is changed into sensible heat, and the temperature of the environment sharply rises.

Every year around 54 750 km² of the Earth's surface is urbanized. We calculate that if evaporation from this surface is reduced by 200 mm each year, then in those same areas each year an additional approx. 6.7 million GWh of sensible heat is produced.

If we apply the same reduction in evaporation to the 127 000 km² of the Earth's surface which is deforested every year, then we get a further approx. 17.4 million GWh of sensible heat being produced. This amount of heat alone in itself roughly corresponds to the annual production of electrical energy by the human population of this planet.

Enormous amounts of sensible heat originate from the land surfaces transformed into farmland or urban environments in the past. Fields and pastures and built areas on all continents together make up around 55 million km².

The flow of sensible heat released through draining of the land is locally several orders of magnitude higher than the effect (through amplification of radiation) of greenhouse gases, and greatly outstrips differences in the albedo.

These so-called "hot-plates" originating from the land transformed by humans prevent the condensation of water vapour in the atmosphere, thus causing a reduction in precipitation over these areas. They also produce temperature differences which trigger the development of climatic extremes. These phenomena in drained areas are often mistakenly ascribed to greenhouse effects.

There is a growing number of scientific articles bearing witness to the climatic impacts of extensive damage to vegetation and the natural water cycle by human beings.

It is shocking that the relevant leading institutions in the world have so far paid insufficient attention to the climatic function of the coexistence, formed over geological eons, between vegetation and the water cycle, and the human disruption of this relationship through land management.

If climate change science does not include all relevant parameters into its theories, models and scenarios, the adequacy of the science is threatened. In turn, the policy recommendation will be inadequate or even counterproductive. If water and vegetation are not properly included, a large part of human activity (land management) and its cooling/heating effects will be unexamined.. This may also reduce the motivation of those responsible to undertake unpopular counter-measures.

The principal mitigating and adaptive measure to combat that part of climatic change caused by human draining of the land and/or alteration of its vegetation cover is the renewal of the water cycle (through a consistent programme of rainwater retention) and vegetation in damaged areas.

The importance of renewing and protecting the natural vegetation and water cycle is in no way inferior to any other measures for the recovery of the climate. For this reason we demand that local, regional, national and international communities devote appropriate attention to these factors.

Signed in Košice, dated 26th November 2009

Introduction

Water and vegetation are of primary importance for the global climate. Human activities cause large deforestation, desertification and urbanization rates of hundreds of square kilometers daily. Unsustainable land use causes huge impacts on vegetation, water and the climate. These effects are overlooked in the common climate change debate. A group of Slovak, Czech and German activists, the authors of this civic protocol, has decided to make its voice heard and to draw attention to this problem.

The authors set out from the background of thought developed by the People and Water NGO and the Association of Towns and Villages in Slovakia, the ENKI public benefit corporation (Czech Republic) and the Technical University in Berlin (Germany). Apart from mutual friendship, what links the authors is their interest and several years of work spent in investigating the impacts of human activity on the water cycle, vegetation and changes in energy flows in the land, which all have their effect on the climate. The authors are in regular contact with both scientific and expert communities, and they are aware of the growing amount of research material which, in the shadow of popular theories, draws attention to those aspects of climate change which are also the subject of this protocol.

The text of the protocol itself is not exhaustive. It makes no claim of establishing the ultimate truth. The authors share the awareness that "knowledge is proud that it knows so much; wisdom is humble that it knows no more" (W.Cowper). The attached texts are intended to draw attention to the comprehensive nature of climatic change, paying homage to the considerable perfection of natural systems, but also criticizing human arrogance which does not respect the holistic character of natural processes.

The immediate impulse for compiling this protocol is the approaching summit on climate change in Copenhagen, in particular the tendency in the preparations for this conference indicated by the negotiation text, which, despite protests from some professional organizations, ignores water and vegetation as essential components in the Earth's climatic system. In this sense the attached text is an urgent appeal to remedy this situation, to have water and vegetation placed at the centre of attention of the responsible institutions at the summit and after it.

Our Blue Planet

Planet Earth is unique in many different aspects, its climate being one of them. This is a result of its optimal location in our solar system, its geographical features, its bounteous occurrence of water and the evolution of both the living and non-living natural world found on it. The synergy of all of these and many other circumstances allows for the existence of complex and mutually sustaining ecosystems, and in particular mankind, which is, thanks to his intelligence, the steward of all creation.

The optimal distance of the Earth from the Sun means that our planet does not suffer excessive heat like neighbouring Venus, or an excess of cold like Mars, our neighbour on the opposite side of our orbital path. The proximity and gravitational force of the giant planet Jupiter protects the Earth from frequent impacts of comets and asteroids and the catastrophic consequences such impacts would have on our climatic system.

The relative stability of Earth's orbit, the incline of the planet‘s axis or the speed of its rotation also appear to be optimal from the viewpoint of maintaining a small difference in temperatures. The size of our planet seems be just right from the standpoint of sustaining an atmosphere sufficient for the further balancing of temperatures. The amount of water present on Earth, divided into its latent states, is large enough to fulfil ecological and climatic functions, but not so large that it would flood the continents.

In such a short text, it is difficult to pay sufficient homage to the gift of water. Water makes our planet unique among the planets: it provides it with its characteristic appearance and beauty when seen from space and up close; it is the blood and lymph of functioning nature. But where did the water on Earth come from? Scientists are not in agreement whether a substantial portion of water on Earth is the result of its original composition, whether it originated from meteorites or comets which bombarded the Earth during the early stages of its development, or whether it is a result of biochemical reactions of elemental forms of life.

The last of the mentioned hypotheses credits prokaryotic bacteria, which rank among the first forms and pioneers of life on Earth, as probably causing the biochemical transformation of primitive seas of sulphides into seas of water. We thus arrive at living forms which not only adapted genetically to the existing conditions on our planet but also actively influenced them during the process of evolution.

An example is our atmosphere, which a billion years ago contained practically no oxygen, but thanks to evolutionary changes to the biota, underwent changes and stabilisation of its composition roughly in its contemporary state. Another example is inorganic carbon, which is constantly entering the biosphere from the Earth's crust (particularly through volcanic activity). With the mentioned inputs during the past billion years, the concentration of CO_2 in the atmosphere should be an order of 1000 times higher in comparison with today's state (as it is, for example on Mars). We can thank biotic regulation, however, for the fact that the deviation has shifted maximally within a range of only ten times the average value.[1]

It is impossible to resist the idea that the direction of the biota‘s influence on the environment was not chaotic, but at first headed toward its optimalisation and later toward the stabilisation of certain optimal parameters. Among the most prominent of these mentioned environmental parameters is the average temperature of the Earth, which over the past roughly 4 billion years has changed, in terms of suitability for life, only within a very narrow range of ± 5ºC of the present average.[2] The temperature has also remained stable despite a roughly 30% increase in solar radiation during the geological existence of our planet.

In relation to the mentioned facts, some authors began to compare the complex Earth to a gigantic living organism (the Gaia theory). Without devoting ourselves to the philosophical-religious implications of similar considerations, it is difficult to hide one's surprise and admiration at the discovery of other aspects of the symbiotic functioning of the complexes of living and non-living nature. These, with the help of water as the central medium, are evolving towards the creation of closed cyclical processes, which demonstrate the effective management of energy and a minimal loss of mass, which contributes to their growing stability and ecological sustainability.[3]

Though, the opening of the closed cycles of nature by the activities of mankind is beginning to reach such a degree that the self-regulating mechanisms of nature are no longer sufficient to correct them. Mankind can learn from its own mistakes. It is slowly beginning to recycle some

[1] Gorshkov, V.G., Gorshkov, V.V., Makarieva, A.M., 2000: - *Biotic Regulation of the Environment: Key Issue of Global Change.* Springer-Praxis Series in Environmental Sciences, Springer, London;
[2] ibid
[3] Ripl W. - *Water: the bloodstream of the biosphere.*2003: Philosophical Transactions of the Royal Society London B 358, pp.1921-1934

materials, but has still hardly matured to the stage of recycling those most important components for sustaining life, which are water and vegetation. The larger part of the remaining text is devoted to the current impacts of mankind‘s activities on the climatic system of the Earth by means of water and vegetation as well as how mankind should correct this in order to deserve the epithet of ‘rational being’.

Some Factors in the Earth’s Climatic System

Climatic change is either a long-term significant change of the current trends in the weather for a particular territory or for the Earth as a whole. Changes in the climate result primarily from changes in the energetic balance on Earth. Changes in the energetic balance can have a number of causes which originate within or outside the Earth‘s climatic system.

Among the reasons for changes in the amount of solar energy received by our planet are a number of astronomical influences such as cyclic changes in the shape (eccentricities) of the Earth’s orbital path around the sun, changes in the tilt of the Earth’s axis (axial tilt) and its precession (amplitude). These alternate in 96,000-year, 41,000-year and 22,000-year intervals known as the Milankovitch cycles. They are expressed particularly by the roughly 100,000-year cycles of ice ages, but their intersection also causes warmer and cooler periods within them.

Changes in solar activity are an additional factor potentially influencing the climate on Earth. The best-known are the 11- and 22-year cycle in the number of sunspots manifested in the solar radiation falling perpendicularly on the upper edge of the atmosphere. A smaller number of sunspots can be associated with a decrease in solar activity. The change in the flow of solar energy reaching a surface on the external edge of our atmosphere, that is, the solar constant (1367 W/m^2), which is paradoxically not a constant, is associated with the elliptical shape of the Earth’s orbital path around the Sun and with solar activity. This changes infinitesimally, but, for example, the same statistical periodicity of a number of climate phenomena (temperatures, precipitation, etc.)

such as the periodicity in the occurrence in sunspots, signifies a possible mutual connection.[4] This connection, however, has thus far not been clearly interpreted.

An additional category of factors influencing the climate on Earth is opened by the hypothesis for the extinction of the dinosaurs which says that it was caused by the fall of an asteroid roughly 10 km in diameter some 65.5 million years ago. Dust particles dispersed into the atmosphere by the fall of this and other celestial objects could have dimmed the sun and, for a number of years, limited photosynthesis and causing a long-term decrease in temperatures. The eruption of volcanoes can have a similar effect as the fall of large meteorites. Volcanic eruptions are known which spewed emissions as high as the stratosphere, where they lingered for a long time, and where their effects resonated for a number of years in the form of longer and cooler winters, hailstorms and droughts.

Aside from the total energy balance on Earth, the structure of energy flows also depends on its climatic system into which solar energy is channelled. Factors of both natural or anthropogenic origin influence the structure of energy flows. An example of this first category are orogenic processes. Mountains and mountain ranges significantly influence atmospheric currents, especially those which are orientated north-south, because the influence of the Earth's rotation and the Coriolis effect determine the predominating east-west direction of winds. Mountains and mountain ranges also significantly influence temperatures, the drainage of water from a region, their vegetation, evaporation and precipitation. Possible snow cover changes the reflective power (albedo) of a surface and with it the amount and structure of solar energy in a region‘s system.

Plate tectonics can also be seen as being natural climate factor. It determines, over a very long time scale, the shape and location of the continents and have a similar fundamental influence on the dynamics of climate with regard to the differential warming of the seas and land, or on the climatic impact of warm and cold ocean currents.

Another large group is made up of the influence of changes in the composition of the atmosphere. In the atmosphere a number of gases are found which have these three basic features: radiation activity, spatial arrangement and duration period. By the term radiation activity of gases we mean the absorption of radiation at some important part of the wavelength spectrum. The effect of growing concentrations of such gases on the stabilisation of higher average temperatures in the

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[4] /http://www.global-climate-change.org.uk/3-2-1-3.php/

ground layers of the atmosphere is often labelled as “radiation amplification“. On the other hand, the growth of the concentration of some aerosols can have the opposite effect, that is “radiation damping“. The value of radiation amplification through the influence of anthropogenic emissions in the year 2000 in comparison with the state prior to the Industrial Revolution was estimated to be 2.43 $W.m^{-2}$, and of radiation damping at 0 to 2 $W.m^{-2}$.[5]

Through its activities mankind is influencing the composition of the atmosphere and thus the climate not only through the emission of gases which are commonly called greenhouse gases, but especially through changes in vegetation and the circulation of water and along with this, very closely related flows of energy. We will devote ourselves to these aspects of human activities in the coming sections.

Water as a Climate Factor

Water has a number of exceptional thermoregulatory characteristics. Besides the fact that at temperatures common on Earth, water occurs naturally in all three states, its most important thermoregulation characteristics are that it has the largest specific heat capacity (the ability to receive thermal energy) among commonly occurring substances and the largest consumption or release of large amounts of thermal energy upon a change of state.

We have already mentioned briefly the role of the oceans in the section on the parameters of Earth’s climatic system. The high specific heat capacity of water (c_p = 4 180 J $kg^{-1}K^{-1}$) in the oceans means that temperature fluctuations in the oceans, when compared with land in the course of a day or year, are a great deal smaller (for example, specific heat capacity of soil is $c_p \approx 800$ J $kg^{-1}K^{-1}$). This characteristic of water, in combination with the gigantic amount of it stored in the seas and oceans, represents a great stabiliser of temperatures on Earth.

[5] Lapin M. - Briefly on the theories of the climate system on Earth, particularly in connection with changes in the climate; modification of the professor’s inauguration lecture from 20. 9. 2004, Internet

The greatest portion of the solar energy absorbed by the surface of the Earth is absorbed by oceans in the tropics. The climates in the tropics and subtropics are dominated by a mechanism dictated by the intensive absorption and dissipation of solar energy known as the Hadley circulation, which determines the running trends of winds, cloudiness and precipitation in this zone. The difference in the warming between the tropics and polar regions and the differential warming of the sea and land ranks (along with the Earth's rotation) among the primary reasons for winds contributing to the balancing of temperatures between regions of different geographic latitude.

The differential warming and saltiness of water in the oceans, together with other factors again contributes to the flow of ocean currents, which carry heat energy thousands of kilometres, and especially in the case of the north-south flowing between the Equator and the poles, influences the temperature of large regions. This demonstrates that a possible small change in the structure of ocean currents can have far-reaching effects on the climate over great parts of the Earth.

The fate of solar energy significantly depends on the presence of water in the region on which it falls. The presence or absence of water significantly influences the distribution of energy between two main flows of heat: latent and sensible heat. As the names themselves suggest, sensible heat is accompanied by an increase in the temperature which we feel. Latent heat, in our case the latent heat of water evaporation, is not accompanied by an increase in temperature. It is the amount of energy which water must absorb in order to transform into vapour of the same temperature. The evaporation of water, then, consumes heat, by which the surface of the earth is cooled, and this does not involve a small value. The specific latent heat of evaporating water under normal pressure and a temperature of 25 °C is 2243.7 kJ/kg. This same amount of heat is released later during condensation of water vapour in colder places, mainly during formation of clouds.

Water can change into water vapour and cool the surroundings in a region only if it is present there. If it is not present, a large portion of solar energy is changed into sensible heat and the temperature of the surroundings sharply increases. While in a dried region the majority of incoming radiation changes into sensible heat, in a country sufficiently stocked with water, most radiation goes into latent heat of water evaporation, and only a much smaller portion of solar radiation is changed into sensible heat.[6]

[6] Kravčík M., Pokorný J., Kohutiar J., Kováč M., Tóth E. - Water for the Recovery of the Climate – A New Water Paradigm, Krupa Print, Žilina, 2007,

With evaporation water gains high mobility, thanks to which it is able in relatively large volumes to quickly shift in both horizontal and vertical directions. The surface of a well-watered region is cooled via evaporation in the case of intensive solar radiation. Water vapour, which ascends higher into the atmosphere, condenses under the influence of cold and thereby transfers its thermal energy. The repetition of this process resembles an ingenious air-conditioning device.[7]

Cloudiness limits the entry of solar radiation into the atmosphere and to the surface of the Earth. There is a substantial difference in the amount of solar energy reaching the Earth's surface when the sky is clear and when it is overcast. Clouds reflect a portion of shortwave solar radiation, thus limiting its entry into the atmosphere and the Earth's surface, and thus protecting the Earth from overheating. They also capture, however, part of the longwave (thermal) radiation from the Earth which has a warming effect and which would otherwise escape into space. This greenhouse effect from water vapour greatly predominates over the similar effect of all other so-called greenhouse gases. The atmosphere on Mars contains 95% CO2, and the atmosphere on Earth 0.039%. Despite this fact the greenhouse effect on Earth is six times greater than on Mars. This difference, also when calculating for differences in the density of the atmosphere on both planets, can be explained only by the existence of water vapour and clouds on Earth.[8] Temperature differences on Mars are more dramatic than they are on Earth. Despite the negative image created by mass communications media in connection with the battle against greenhouse gases emissions, the greenhouse effect is vitally important for the stability of climatic interactions on our planet.

Water evaporation is the most important energy transformation on Earth. It functions as the main buffer to the gigantic amount of solar energy that is falling on our planet every moment. Thanks to the evaporation of water, solar radiation arriving to Earth is transformed into latent heat and so moderates the accumulation of sensible heat at the Earth's surface. The draining out of a land has as a consequence the release of an extremely large amount of sensible heat into the atmosphere. A drop in evaporation by one litre per square metre (700 Wh) per day initiates the flow of sensible heat several tens times higher than the effect of greenhouse gases (radiational amplification) from the Industrial Revolution.[9]

[7] Ibid
[8] www.bioticregulation.ru/ques.php?nn=24&lang=en
[9] Pokorný J., Water and the transformation of solar energy on land – closed cycles in ecosystems of land and river basins, Životné prostredie, 2009 (in print)

Water further moderates temperature differences between regions with a different altitude or geographic latitude, between oceans and land, between day and night, between the annual seasons and, in connection with the melting of glaciers, even between ice ages and interglacial periods. The less water there is in a region and in the atmosphere above it, the weaker the effect of balancing out of temperatures, and thus swings in temperature and the weather are more extreme. This is the case in deserts on Earth and other planets (compare, for example, the temperature differences on the Moon, which range from -240ºC to +120ºC).

Vegetation as a Climatic Factor

Through active regulation of waterflows, terrestrial ecosystems can greatly influence the distribution of solar energy mentioned above into two main areas: sensible heat and latent heat. Vegetation reflects some of the incoming solar radiation, transforms (dissipates) some through water evaporation, changes some into sensible heat, a part warms up the soil and, through photosynthesis a relatively small part is stored up in biomass.

Together with the absorption and photosynthetic fixation of carbon dioxide, growing fibres also store water. Growing biomass may have a water content up to 80-90%. As well as for fibre growth, vegetation also needs water for evapotranspiration. Values of evapotranspiration vary according to geographical zone, altitude and other factors. About 3 litres of water per square metre are evaporated in average in conditions of a mild climate (Slovakia) on a sunny day (if there is enough water in the ground), which equals 2.1 kWh (7.5 MJ) of latent heat. Evapotranspiration is a dynamic process primarily dependent on the input of energy and availability of water.

Plants differ greatly in their ability to evaporate/transpire water. In the temperate zone the transpiration of coniferous trees is in general lower than that of deciduous trees. Wetland plants have the highest level of transpiration, some, if they have enough water, being capable of evaporating more than 20 litres of water per square metre in the course of one sunny day.[10] In cultivated land evapotranspiration is, during sunny days, usually limited by a lack of water, which means that the actual levels of transpiration are much lower than they potentially could be.

Transpiring plants, especially trees, are one of the Earth's most wonderful air-conditioning systems. Imagine a large, free-standing tree, its crown with a diameter of 10m. In the course of one day, 450 kWh (4–6 kWh/m^2) of solar energy can fall onto its 80m^2 of crown, some of which is reflected back, some of which goes into heating the soil and some of which is transformed into heat. If the tree is well supplied with water, up to 400 litres of it can evaporate in one day, 280 kWh of solar energy being consumed to convert the water from its liquid state into water vapour. This amount of consumed energy is the difference between the shade of a tree and the shade of a parasol with the same diameter. In the course of a sunny day, such a tree cools with the power of 20 – 30 kW, a power equal to 5 air-conditioning units.

Unlike manmade air-cooling equipment, a tree is "fuelled" only by solar energy, is made of recyclable materials and requires minimal maintenance. The outflow of water vapour is regulated by millions of air pores which react to the temperature and humidity in the environment. What is important is that solar energy stored in water vapour is transferred further and only released when the vapour condenses in cooler places. This way trees help regulate temperatures both in time and space, unlike fridges or air-conditioners, which emit heat into the area around them. In contrast to fridges and air-conditioners, trees also work in absolute silence, absorb noise and dust.

Most people will have experienced the pleasant coolness of a dense forest on a hot summer's day. A temperature inversion (a higher temperature in the crown of the tree than on the ground) during the day helps retain almost 100-percent of the air humidity above the surface of the soil. The balance of humidity and temperatures under the crowns of trees is directly proportionate to the density and height of the vegetation.[11] This is another reason why healthy dense forest is less susceptible to fire. Forest management of water beneath the crowns of trees is so effective that the trees can afford to evaporate large amounts of water from their crowns and so cool the air above

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[10] Kučerová A, Pokorný J, Radoux M, Němcová M, Cadelli D, Dušek J - Evapotranspiration of small-scale constructed wetlands planted with ligneous species, 2001

[11] Makarieva, A.M., Gorshkov V.G., Li B.L., 2006: Conservation of water cycle on land via restoration of natural closed-canopy forests: implications for regional landscape planning. Ecological Research 21, pp 897-906

them. On infrared satellite images, taken on a sunny day, forested land is visibly cooler than unforested land alongside.

In sparser forest and open (for example, grassy) ecosystems, the same temperature inversion does not arise. The night-time temperature inversion above the crowns of the trees and above open, unforested ecosystems often leads to condensation and fog. Part of this gravitates down to the ground and in closed forest ecosystems, unlike in open areas, this part can remain in the form of moisture for the whole day.[12] The water microcycle which in our conditions is manifested by dew drops on grass or on needles is, according to the German hydrologist W. Ripl, the most abundant and widely occurring sign of water circulation in vegetation and the most important stabilizing process on mainland. The cycle dissipates solar energy with great efficiency and without negative side effects, such as dehydration, desertification and soil erosion.[13]

Russian scientists, V. G. Gorshkov and A. M. Makarieva have come up with a new, very interesting interpretation of the relationship between forests and precipitation. Having examined the correlation between levels of annual rainfall in unforested regions in various continents (savannah, steppes, semi-desert) and their distance from the sea, as well as of rainfall in naturally forested areas, they came to the striking conclusion that in unforested parts of continents annual rainfall gets rapidly lower the further away the regions are from the sea, whereas in areas covered by natural forest, not only do levels of rainfall not decrease but in some cases they rise, even over distances of several thousand kilometres.[14]

The above scientists have formulated the so-called 'biotic pump' principle whereby a horizontal flow of moist air arises from a region with lower evaporation and moves into an area of higher evaporation. Thanks to the greater cumulative evaporating surface of leaves, forest ecosystems during the vegetation period evaporate several times more water than open hydrous areas of the same size. Forests thus become a biotic pump providing suction of moist air from the ocean to the mainland.[15]

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[12] op.cit.

[13] Ripl W. - Water: the bloodstream of the biosphere.2003: Philosophical Transactions of the Royal Society London B 358, pp.1921-1934

[14] Makarieva, A.M., Gorshkov, V. G., 2007: Biotic pump of atmospheric moisture as driver of the hydrological cycle on land. Hydrol. Earth Syst. Sci., 11, pp 1013–1033

[15] op. cit.

If evaporation over land decreases in comparison to evaporation above the sea which washes the land, the physical mechanism described above is reversed and moisture is drawn away from the land. Meadows and agricultural land, with their relatively low levels of evaporation, are unable to create the biotic pump effect and their water cycle is critically dependent on their distance from the sea and fluctuations of rain-bearing weather. There is evidence from various corners of the world which supports the above theory, evidence which undermines the long-held assumption that levels of rainfall in a region have nothing to do with the nature and quality of its surface.

Water and the Carbon Cycle

Current climate change deliberations deal almost exclusively with the role of CO_2. Though, promotion of healthy ecosystems and a well functioning water cycle should be a special concern even for those who are convinced about the dominant role of this gas in the Earth's climate system. It is because carbon cycle is closely tied to water and vegetation.

The amount of CO2 in the atmosphere is determined by how much is emitted into the atmosphere through the burning of fossil fuels and cement production, the terrestrial biospheric flow of CO*2*, which includes photosynthesis and plant respiration, the influence of fires and soil management; and finally the flow of CO2 between the ocean and the atmosphere.

To put it simply, we can say that while oceanic biota and well functioning ecosystems on land help store carbon, disturbed ecosystems on land emit it into the atmosphere. The ability of oceans and biota in sea water to sequestrate (absorb and store) CO_2 is not measurably changing. It is however, insufficient to negate the effects of anthropogenic carbon production.

Terrestrial sequestration of CO_2 from the atmosphere is at its highest in the northern temperate zone. About 50% (approx. 1150 Gtons) of carbon supplies in the world's ecosystems are stored in forests, with the remaining 1000 or so Gtons being stored in other ecosystems such as tundra or grassy plains. In the forests of the northern hemisphere, about 84% of carbon is stored in organic soil matter.[16]

The soil sequesters carbon through its vegetation. Bare soil can hardly store carbon although it can release it relatively fast. When soil moisture decreases, the soil becomes more aerated. It leads to an increase in oxidization processes and faster mineralization of the soil's organic matter. If forest land is turned over to agriculture, carbon content in the soil usually falls by 30% or more. This loss of carbon from soil means a fall in its organic content, its fertility and its ability to retain water, one result of which are more frequent local droughts.[17]

The lack of water in soil also increases its potential to overheat, which again contributes to mineralization of organic matter. In land with a lack of water and vegetation, land which overheats, water vapour does not condense and the land suffers from a shortage of dew and steady rainfall from the small water cycle. Rain usually comes as a result of frontal disturbances, with the rainwater running off very quickly because of the land's low water-retaining capacity.[18]

From the preceding text it emerges that the interaction of the carbon cycle with the hydrological cycle plays an important role in the exchange of carbon between land surface and the atmosphere. Annual variations in the exchange reach the levels of fossil fuels burnt by humans. Variations are primarily dependent on levels of rainfall. Droughts in the northern temperate zone have the strongest influence. Droughts and intense heatwaves reduce photosynthesis and increase the probability of destructive forest fires. In the event of disruption of the natural cycles, there is a risk of the vast amounts of carbon stored in organic matter being suddenly released into the atmosphere.[19]

Many experts believe vegetation could compensate for current anthropogenic carbon emissions. According to the Russian scientists, Gorshkov and Makarieva, it would be enough to renew natural forests on about 7% of cultivated land. As in terms of water and other matter balance, artificial ecosystems, e.g. agricultural ones, are largely destabilizing in terms of the carbon balance also.[20]

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[16] Bierkens M.F.P., Dolman A.J., Troch P.A. (editori) - Climate and the Hydrological Cycle, IAHS, 2008

[17] Ripl W., Eiseltová M. - Sustainable land management by restoration of short water cycles and prevention of irreversible matter losses from topsoils, Plant Soil Environ., *55*, 2009 (9): 404–410

[18] ibid

[19] Bierkens et al. - Climate and the Hydrological Cycle

[20] Gorshkov V.G., Gorshkov V.V., Makarieva A.M. - Biotic Regulation of the Environment: Key Issue of Global Change. Springer-Praxis Series in Environmental Sciences, Springer, London, 2000

The Influence of Land Use on Vegetation and Water Circulation

Humans have been shaping the landscape since their first appearance on the planet, the intensity and extent of this shaping process varying over time and reflecting humans' different means of finding food and levels of social development. Major milestones in human evolution and the changing landscape have been shifts such as: the move from the hunter-gatherer way of life to the agricultural and pastoral one (the Neolithic Revolution); the Industrial Revolution, which meant a move from manual to machine-based manufacturing; several waves of urban revolution which were to influence the numbers of town dwellers and their quality of life; and the 20th century green revolution, which again changed the nature of agriculture. Deforestation of huge areas and their conversion to agricultural use or urban development have also had a marked effect on water circulation.

Research into lake sedimentation in northern European lakes during various phases of forestation after the retreat of glaciers about twelve thousand years ago illustrates well the role of vegetation in regulating water circulation and erosion. The 2-3 thousand year period of gradual recolonization of the barren landscape from the first pioneering plants to climax forest is first marked by high transport of surface material to the lakes, material which then gradually diminished to only a tenth of its original amount. When about two hundred years ago, people first started to destroy the vegetation covering these studied river basins in order to develop agriculture and to urbanise, the transport of surface material then increased by between 50 and 100 times compared to the optimal natural state.[21] Humans became an important factor in opening cycles of water and soil material which had hitherto been more or less closed.

What started in some parts of northern Europe only relatively recently had started in other parts of Europe and the world a lot earlier. The outstanding American paleoclimatologist, William F. Ruddiman, draws attention to the fact that human influence on the climate began about eight thousand years ago with the agrarian revolution which followed the last ice age. This influence,

[21] Ripl W., Eiseltová M. - Sustainable land management by restoration of short water cycles and prevention of irreversible matter losses from topsoils, 2009

especially human liquidation of forests, was of a smaller intensity before the Industrial Revolution than today but continued for much a longer period and in total exceeded it.[22]

After the removal of forest, the water management situation is tied in with a whole chain of factors. Deforestation and reduction of the quality of forest vegetation is accompanied by an increase in the speed of rainwater run-off and soil erosion, a reduction in soil's organic material content and with it, its water retentiveness. The more dehydrated and hardened the soil, the harder it is for it to absorb the next fall of rain and the greater the surface run-off. There are several examples similar to that of the Brazilian Tocantins river basin, where, in the period from 1960 to 1995, together with forest removal and development of agriculture, river levels rose by 25 percent despite the fact that rainfall did not increase during that time.[23]

Another factor in the drainage of large expanses of land are the crops grown on them. Certain edible grass seeds were ideally suited to agricultural cultivation and formed the basis of the cereal farming which was to become the most extensive food supply for mankind. In Europe, as well as in many other parts of the world lying in the temperate zone, the cultivation of wheat and barley, which are believed to be the first domesticated cereals, has been dominant since the Neolithic Revolution. These retain the quality of the annual steppe grasses from which they were first bred and so require steppe-like conditions; to grow them well the soil must first be drained. This enormous project has been one of the main causes of land drainage in the modern age.

Artificial irrigation, practised even by ancient civilizations in combination with intensive agriculture, is not a long-term sustainable solution because as we can see from examples, it leads to salination of the soil. As soon as rainwater touches the ground it starts to dissolve the salts which it contains. The concentration of these salts in surface water, not to mention groundwater, increases many times over. This is one of the differences between rain and artificial irrigation. Another lies in the fact that during times of rain there is high air humidity, which reduces evaporation, whereas during processes of artificial irrigation, the opposite is usually true. Salts from evaporated water stay in the ground. The outstanding Australian agriculturist, Peter Andrews, points to another aspect of soil salination which is the suppression of natural vegetation diversity, mainly through the influence of agriculture. Low vegetation, such as various grasses and weeds,

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[22] Ruddiman W. F., Plows, Plagues & Petroleum – How Humans Took Control of Climate, Princeton University Press, 2005, s.88-94

[23] Foley J. A. et al. - Global Consequences of Land Use, SCIENCE, VOL 309, 2005, www.sciencemag.org

are in his opinion the most efficient means of eliminating salt from the soil.[24] The systematic removal of such vegetation is one way of helping to create a salinated semi-desert.

The regulation of rivers is another chapter in the drainage of land. Adjustment of watercourses usually results in a shortening of their overall length, an increase in their gradient and a speeding up of outflow of water. Reinforcement of riverbeds and banks, removal of abandoned meanders, draining of adjacent marshes with river ecosystems, raising of weirs and flood barriers to prevent periodic flooding and other adjustments have reduced the capacity of the land to retain water.

Rapid urbanization accompanying the Industrial Revolution meant mass movements of the fast-growing global population from the country to the towns. Modern towns and cities, but also increasingly, villages too, have their surfaces reinforced with impermeable materials and have drainage systems for rainwater. A huge amount of rainwater is now drained off the paved and roofed surfaces of the "civilized world" via drainage channels running into rivers and the sea. According to estimates, in Europe every year more than 20 billion m^3 of rainwater is channelled off, water which in the past supplied the soil and vegetation, replenished levels of groundwater, strengthened natural springs and with its evaporation, helped humidify the climate and reduce temperatures.

Deforestation, agriculture, urbanization and other anthropogenic transformations of land now affect almost 40 percent of the world's surface.[25] As we shall see, this transformation not only influences the amount of water in the land but also its climate.

The Influence of Land Use on Climate

In the preceding sections we stated that water is one of the key parameters in climate change because of its unique thermoregulatory qualities and the way its circulation is closely tied to the transformation of enormous flows of energy. Vegetation, especially natural forest, is able to manage water in a way which is unique and beneficial to mankind. We have also stated that

[24] P.Andrews – Back from the Brink – How Australia´s landscape can be saved, ABC Books, 2006, s.217-222
[25] J. A. Foley et al. - Global Consequences of Land Use, SCIENCE, VOL 309, 2005, www.sciencemag.org

through their activity, people contribute to the deforesting and draining of land, and thus change the balance of flows of water and energy in land. From these statements it clearly emerges that, at the very least, the use of land has an influence on the regional climate. These regional influences over enormous inhabited and human-impacted areas[26] synergically join up and also have an undoubted influence on the global climate.

Temperatures in a town on a sunny summer's day are often appreciably warmer than in the countryside nearby, while temperatures in ploughed agricultural land are higher than in forests even though the sun may be shining equally on all of these places. The main culprit for raised temperatures in urban areas is the reduced evaporation in towns resulting from a fall in green areas caused by a larger share of built-up areas and reinforced impermeable surfaces. The same goes for tilled soil, where the reduction in topsoil permeability reduces the ability of the land to evaporate water and thus raises the amount of solar energy which changes into sensible heat and longwave radiation.

This is not just a small amount of heat. Every year about 54,750 km² of the Earth's surface is urbanized and if we consider that evaporation on this kind of surface will fall by about 200 mm per year, then about 6,751,040 GWh of sensible heat are generated. If we apply the same fall in evaporation to the 127,000 km² of the earth's surface which are every year deforested, then about 17,374,000 GWh of sensible heat are generated.[27] In fact this amount alone roughly corresponds to the annual production of electricity by the whole of mankind,[28] an amount which would be even higher if we also took into account the decrease in rainfall caused by the reduced evaporation. Huge amounts of sensible heat arise in areas which were turned over to agriculture or urbanized in the past. Fields, pastures and urban zones in all continents cover an area of about 55 million km².

These so-called "hot plates" which arise in human-shaped landscape also have an influence on water circulation and climate. Higher temperatures prevent condensation of water vapour, which can then mean lower rainfall in that region. Temperature differences between hot agraro-urban landscape and wetter and cooler regions (of higher altitude or latitude) cause a higher concentration of clouds and rainfall above the latter of these.

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[26] See e.g. works of Roger Peilke Sr. Research Group, http://climatesci.org/

[27] Schmidt M. - Global climate change: the wrong parameter, RIO 9 - World Climate & Energy Event, 17.-19.marec 2009, Rio de Janeiro, Brazil

[28] Global production of electricity in 2006 was 18 trillion kilowatt hours

Other climatic extremes and their effects which are caused by these hot plates are floods, extended heatwaves and periods of drought, forest fires, falling levels of groundwater, and reduction in soil fertility and biodiversity. Differences in the occurrence of water and vegetation leading to temperature differences provide a more direct and logical explanation for regional climatic extremes than merely the increase in the near homogeneous levels of CO_2 in the atmosphere.

There are a wealth of both old and new examples of climate change brought about by land management. Christopher Columbus wrote about how after deforestation of the Canary Islands, Madeira and the Azores, the gentle afternoon rain that was typical for these islands stopped falling.[29] The same situation occurred after the deforestation of Easter Island, the remotest island on Earth. At present there are several scientific studies drawing attention to lower rainfall in the Amazon as a result of the felling of its rainforest. This is often given as a classic example of the process.[30] Another is Florida, where its huge swamps were drained during the 20th century. The famous American climatologist Roger Pielke has documented the mechanism of the significant drop in rainfall which has now come to Florida during the hot season as well as the new phenomenon of frosts occurring in the drained areas during the cold season.[31]

It is alarming that the relevant global institutions ignore the area of climate change brought about by a change in the state of vegetation and water circulation resulting from anthropogenic land use (with the small exception of plant sequestration of carbon). Equally they almost always speak only about the effect of climate change on the water cycle and not about the reverse process, climate change as effect of changes in the water cycle.

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Encouraging the Climatic Functions of Water and Vegetation

In the previous section we stated that the drainage of a region through deforestation, agriculture and urbanisation all contribute to climatic change. If this is indeed so, then the primary measure for

[29] The biography of Christopher Columbus written by his son, Ferdinand

[30] e.g.. Foley J. A. et al. - Green surprise? How terrestrial ecosystems could affect earth’s climate, The Ecological Society of America, 2003, www.frontiersinecology.org

[31] Pielke R. A. Sr. et al. - A new paradigm for assessing the role of agriculture in the climate system and in climate change, Agricultural and Forest Meteorology 142, 2007

adapting to and assuaging this element of climate change which is caused by the drainage of land by mankind, is the renewal of water and vegetation in affected regions.

History abounds with examples of nature and climate being harmed by mankind. Positive examples are few. The ecological crisis which peaked simultaneously with the Great Depression in the 1930s in the USA is an example from the first group. This was the result of a number of decades of reckless looting of natural resources; for example, the deforestation of the country to one eighth of its original area or the ploughing up of the great prairies and their transformation into cereal monocultures, particularly during the First World War and after. Deforestation brought a change in the hydrological regime, floods, droughts and erosion. The loss of the highest quality soils from fields and pasture lands under the impact of water erosion at this time is estimated at 3 billion tons annually. Millions of acres of recently fertile land were turned into desert and the new phenomenon of gigantic dust storms began to appear.[32]

A positive example is the approach taken under the leadership of President F. D. Roosevelt, who dealt with the mentioned situation by organising the Civilian Conservation Corps (CCC) to help the unemployed and the damaged natural world. The programme, which operated from 1933 to 1942, employed about 3 million young people in jobs which, among other things, included: the planting of forests; the building of fire-prevention reservoirs, ponds and dams; measures for reducing the speed and eroding force of water; the creation of retention spaces for harvesting storm water etc. As an illustration, let’s just mention that the number of trees planted by the CCC is estimated to be 2-3 billion.[33] There is no doubt about the positive impacts of the programme on the lives of people and on nature. The impact of the programme on the climate can be deduced, for example, from the fact that the phenomenon of dust storms ceased.[34]

The part of the Civilian Conservation Corps programme which focused on support for the water-retaining capability of catchment areas is a great inspiration. In order for water and vegetation to fulfil their climatic function, they must first of all be present in sufficient amounts within a region. All of the fresh water on land comes from rain. Therefore it becomes a primary task to implement measures for the massive harvesting of rainwater in the places where it falls. Let drain away to the

[32] Salmond J.A. - The Civilian Conservation Corps, 1933-1942: A New Deal Case Study, Chapter 1, Duke University Press, 1967
[33] www.ccclegacy.org/
[34] http://en.wikipedia.org/wiki/Dust_Bowl

ocean only that water which we are unable to retain. The retention of rainwater is from the viewpoint of humans, ecosystems and climate more suitable than run-off, because in time and space it better preserves water between periods of abundance and shortage. Decreased run-off fulfils an anti-flood and anti-erosion functions also.

Humanity has harvested and retained atmospheric water through millennia and developed a great deal of technology for this purpose: the gathering of water from roofs, on slopes with the help of different types of depressions or terraces, into cisterns, sheets for fog harvesting, etc. While the main purpose in the past was to obtain sufficient resources for drinking water, utility water or irrigation purposes, today a climatic purpose can be added to these. That's why aside from exploitation and infiltration of rainwater the importance of its evaporation is also growing.

Evaporation, which is traditionally considered as a loss, has an immensely important climatic function for cooling a region and balancing temperature differences within it. On a healthy land the larger part of the water returns in the form of dew or rain. What is more, if there is a sufficient amount of evaporation, it "attracts rain" by cooling and by encouraging condensation of other vapours in the air. The absence of evaporation creates in a country a "hot plate" destroying the small water cycle. The recycling of water in the small water cycle is better than relying on the fluctuation of the large water cycle.

The imperative of evaporation in addition to traditional methods of harvesting rainwater opens a new spectrum of technologies which will ideally enable the saturation of soil and vegetation. It is relatively easy to find in a village such opportunities to store rainwater through the support of different ecosystems, by retaining it in wetlands and reservoirs or by saturation into the groundwater. In agriculture it is necessary, for the reasons mentioned above, to apply non-ploughing technologies and to reforest desolated and unused lands.

Rainwater, which at present drains away through sewerage systems from urban areas without being used (and for a great deal of money paid to sewerage companies) into rivers and to the sea, can be provided to lawns, parks, bioclimatic gardens, green roofs, green facades, etc. Obviously, for this purpose it would also be possible, after proper cleaning, to use the rainwater which before served only as utility water and thus relieve the drawing of valuable drinking water. Towns which consume a great deal of water should shoot for zero drainage of rainwater. It is obvious that a new water policy requires innovation in the field of land planning and architecture.

At the local and national level it is necessary to create a system of policies, legal instruments and motivations which encourage the rainwater harvesting, the protection of the small water cycle and last but not least, vegetation. Just as in the field of financial instruments the principle of the "polluter pays" applies, in the integrated management of water and land resources it is necessary to set up the principle of "he who drains – pays". Conversely, the creation of water-retention spaces needs to be rewarded financially or non-financially.

Since the climatic effects of land drainage crosses national borders, it is necessary to apply the mentioned principles both on an international and supranational level. Satellite photography in the infrared (thermal sensitive) spectrum is able to differentiate the hot parts of a country, which in the tropics and temperate zones correspond with desiccated areas or areas devoid of vegetation.[35] The international community can thus easily set priorities for its policy, and possibly monitor each advancement achieved.

The renewal and protection of the natural water cycle for climatic reasons is by no means secondary to the lowering of emissions of greenhouse gases and overtakes it in terms of the immediate urgency to ensure the fundamental needs for mankind. The international community should therefore devote adequate attention to it.

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[35] Pokorný J., Kravčík M., Kohutiar J., Kováč M. - The major role of water in the climate system of the Earth, 2009, www.ourclimate.eu