Water for the Recovery of the Climate - A New Water Paradigm

M. Kravčík, J. Pokorný, J. Kohutiar,
M. Kováč, E. Tóth

Authors:

Ing. Michal Kravčík, CSc., (1956) completed his studies in Waterworks Construction and Water Management at the Slovak Technical University and worked for the Institute of Hydrology and Hydraulics and the Institute of Ecology of the Slovak Academy of Sciences. He is the founder of the People and Water NGO, a holder of the Goldman Environmental Prize and a member of ASHOKA: Innovators for the Public, an international network of innovators who work for public welfare. He is the most prominent representative of the People and Water NGO, which has been awarded the EU-USA Prize for Democracy and Civil Society Development.

RNDr. Jan Pokorný, CSc., (1946) completed his studies at the Natural Sciences Faculty at Charles University in Prague. He is the director general of the beneficial society ENKI, a scientific staffer at the Institute for Systems Biology and Ecology of the Academy of Sciences of the Czech Republic, the co-author of a number of patents, a university lecturer, a member of the international scientific panel of the Natural Resources Commission for the Australian government and a member of the scientific technology panel of the Ramsar Convention on Wetlands for Central and Eastern Europe.

Ing. Juraj Kohutiar (1961), completed his studies in Waterworks Construction and Water Management at the Slovak Technical University, worked at the Institute of Hydrology and Hydraulics of the Slovak Academy of Sciences and at present cooperates as a consultant with the People and Water NGO.

Ing. Martin Kováč (1972)**,** completed his studies in Waterworks Construction and Water Management at the Slovak Technical University, worked in the area of protection of the national cultural heritage, was the co-founder and the first director of the National Trust in Slovakia, is a member of international network ASHOKA. At present he works as specialist for anti-flood prevention at the Association of Cities and Municipalities of Slovakia.

RNDr. Eugen Tóth (1964), completed studies at the Mathematics-Physics Faculty of Comenius University. He works in the field of information systems with a focus on geographic information systems (GIS) and agricultural land. He cooperates with the NGO People and Water as a project manager.

Authors:
Ing. Michal Kravčík, CSc., RNDr. Jan Pokorný, CSc., Ing. Juraj Kohutiar,
Ing. Martin Kováč, RNDr. Eugen Tóth

Consultants:
Prof. Ing. Rudolf Midriak, DrSc.; RNDr. Václav Cílek, CSc.; PhDr. Gabriel Bianchi, CSc.;
Ing. Viktor Nižňanský, PhD.; PhDr. Róbert Kotian; Ing. arch. Radoslav Mokriš;
Prof. RNDr. Michal Hnatič, DrSc.

Preparation of diagrams and graphs: Ing. arch. Ľubica Mokrišová

Photographers: Ing. Michal Kravčík, CSc.; RNDr. Jan Pokorný, CSc.;
RNDr. Eugen Tóth

Title page illustration: Ing. Stanislav Staško

English translation: David McLean and Jonathan Gresty

Printed by: Krupa Print, Žilina

Publication printed with the financial support of: Municipalia a.s. and TORY Consulting a.s.

ISBN:

Year of publication: 2007

This publication originated through partner cooperation between the People and Water NGO, the Association of Towns and Municipalities of Slovakia, the community help society ENKI and the Foundation for the Support of Civic Activities. Its completion would have been much more difficult without the support of colleagues and friends from People and Water.

CONTENTS

1 THE REASON FOR THE FORMULATION AND THE MISSION OF THE NEW WATER PARADIGM

Things should be made as simple as possible, but not any simpler.

Albert Einstein

What is a "paradigm"?

By the expression "paradigm" we understand a set of suppositions, concepts and attitudes of a group of scientists in regards to a particular scientific problem. The term in this spirit is associated particularly with the name of Thomas Kuhn (1922-1996), a professor of the philosophy and history of science. Professor Kuhn dates the beginnings of his theory of scientific revolution to the time when he was preparing his doctoral dissertation. At that time he read Aristotle's *Physics*, which was, until the time of Isaac Newton, the most authoritative work in the field. Kuhn was shocked by Aristotle's dissimilarity to Newton and by his seemingly incorrect, even incomprehensible logic. However, when he was able to adopt a different method of looking at Aristotle and some of his basic concepts, the book suddenly began to make real sense to him.[1]

Thinking in conventional ways

Kuhn observed with surprise that the term "motion," unlike that of Newton's (and his own) understanding, means in Aristotle's physics not only a change in the position of the object being investigated, but also other changes, such as growth, a change in temperature, healing processes and the like.[2] Just as Kuhn needed to free his mind of conventional ideas in order to understand Aristotle, an understanding of the work presented here may also require a certain distancing from some current popular theories and ways of perception. When, for example, this work speaks about water, so long as it is not specified otherwise, it means not only the water in rivers and in lakes which we can see, but also water in all of its states, forms and occurrences. Water vapor and clouds in the atmosphere are more than only poetic reflections of water in the ground and in open reservoirs. Water in living organisms, particularly in plants, is likewise the subject of our attention.

The possibility of challenging a paradigm

Along with his many works of philosophy and various scientific disciplines, Aristotle also wrote the work *Meteorologica*. Unlike today's narrow understanding of this scientific field as being one concerned with atmospheric phenomena, Aristotle covers in reference to this topic a broad spectrum of knowledge and concepts about the Earth. *Meteorologica* is not one of the best works of this brilliant philosopher, but Aristotle's authority from ancient times up to the beginning of the modern age was so great, thanks to his brilliant philosophical work, that hardly anyone dared to challenge him in other

[1] Thomas Kuhn, "What Are Scientific Revolutions?" from *The Probablistic Revolution, Volume I: Ideas in History*, eds. Lorenz Kruger, Lorraine, J. Daston, and Michael Heidelberger (Cambridge, MA: MIT Press, 1987), http://www.units.muohio.edu/technologyandhumanities/kuhn.htm

[2] ibid.

fields of knowledge either. The expansion in exploration and new geographical discoveries in the 16th century gradually showed the obvious fallacy of many concepts and statements included in *Meteorologica*. Aristotle's *Meteorologica* in this case can serve as an example of a paradigm which ceased to remain valid and which needed to be replaced with a new one which would present a better picture of reality.

The mystique of water

The theme of this publication is a paradigm about water, that is, a sum of suppositions, concepts and attitudes of different groups in society (not only scientists) about water. Water is a natural subject for a paradigm, even though it doesn't have to be articulated in scientific formulas. Poets have sung of the mysticism of water; philosophers writing at the time of the birth of philosophy in ancient Greece considered water to be one of the foundations of the world. The ocean was, according to Homer, "the father of all gods."[3] Thales of Miletus considered it to be the elemental matter of the world.[4] According to Empedocles and others, water was one of the fundamental elements of the world, along with earth, fire and air. Water as the basis of life and as a purifying medium has been richly represented in the symbols of the world's religions. In the Bible, the original paradise is described as the Garden of Eden, supplied with water from four rivers (the Euphrates and Tigris among them). A person formally becomes a Christian through baptism with water. Hindus, in their desire for liberation, plunge into the Ganges River, and the promised paradise to believers in the Koran also teems with the water of rivers. In the spiritual perceptions of humanity, harmony with water and with its natural circulation is felt as a gift, a goodness or a blessing, and disharmony with it and the extremes of its circulation are considered as a punishment, an evil or a curse.

The rise and fall of civilizations

Water is first and foremost a basic element of life. Life, according to present theories, originated in water, expanded to land and without water would cease to exist. Water is also an indispensable component in the history of human civilizations. The greatest human civilizations emerged directly around sources of water: the Nile in Egypt, the Euphrates and Tigris in Mesopotamia, the Yellow River in China. Their prosperity depended greatly on their having an abundance of water. Water helped fulfill both the lower and the higher needs of people, provided them with sustenance, protection, energy, transportation, rest, beauty, harmony and inspiration. From history we know of civilizations which successfully developed around fertile land with rich vegetation and an abundance of water. It is possible that many of them, however, brought about their own decline or extinction through the degradation of their sources of water. Today we have become used to seeing archaeologists digging up evidence of ancient, once thriving civilizations in the desert or in the semiarid lands of Northern Africa, the Middle East, Iraq, Iran or in other parts of the world. But it doesn't occur to us that these civilizations possibly died out in a process which is still going on around us today.

[3] Homer, *Iliad*, XIV, 201
[4] Diogenes Laertius: "Thales... designated water as the principle of everything."

The need for a new paradigm

The relationship of civilizations to water has changed over the course of history. In some civilizations water was worshipped. In the 20th century people attempted to confine and subjugate water. Progress in the spirit of the communist slogan: "we command the wind and the rain" was, from the viewpoint of immediate solutions, more effective, but from the viewpoint of sustainability even worse than the worshipping of water. Water cannot be commanded; a more sensitive approach is required. The need for formulating a paradigm is a consequence of the failure of traditional ideas (in this publication, we refer to them as the "old paradigm") to offer lasting, sustainable solutions to some of the burning questions of water resources and water circulation. The paradigm formed slowly in the environment of a civic association concerned with the scientific and practical aspects of these questions. The first reports were published in the early 1990s.[5] Its origin was accompanied by a gradual examination of the knowledge acquired through long years of practice and by the broadening of our knowledge base. Its publication is an expression of the concern and care of a group of citizens interested in public affairs. It is assembled with the objective of reassessing the present unsatisfactory approach to water and the water cycle.

A different angle of view

This work is not founded on new, revolutionary knowledge; its newness arises more from thinking through existing knowledge to its logical consequences. Despite this fact, we are convinced that it is a pioneering work, that it fundamentally changes water-management practice and may be a great inspiration for further research and for the scientific community. Scientific research programs and materials have engaged with climatic changes for many years now around the world, and they have extended over a rather large range. They reduce the whole process of these changes, however, almost exclusively to the question of so-called greenhouse gases. Many scientists themselves, in numerous works, state that the connection of the hydrosphere or changes in the water (hydrological) cycles with climate changes is great but has so far been insufficiently studied.[6] While attention thus far has focused on the impact of climate changes on the water cycle,[7] the altered paradigm recommends concentrating attention on the impact of changes in the water cycle on climate changes. If the alternative view presented in this publication is correct, it opens the possibility of a constructive solution to many of the problems associated with climatic changes. The plan for saturating the small water cycle through the conservation of rainwater on land is, from the point of view of the authors of this publication, a revolutionary solution to the given problems.

---

[5] For example, *The Principles of Water Management Policies and Proposed Measures – An Alternative Proposal, Water for the Third Millennia*, Slovak River Network, Košice, 1993

[6] For example, Prof. RNDr. Milan Lapin, CSc., "A Brief Theory about the Climatic System of the Earth," particularly in connection with changes in the climate; modification of the professor's inauguration speech from 20 September 2004, Internet

[7] For example, European Commission, *Climate Change Impacts on the Water Cycle, Resources and Quality*; Brussels, 25 – 26 September 2006, Conference Proceedings, Scientific and Policy Report, EUR 22422

Content of the chapters

In addition to this introduction and the concluding chapter, which summarizes the message of the publication and the new paradigm, the work is divided into a number of additional chapters. Chapter Two briefly introduces us to the four "environments" of water and to the mechanisms of the large and small water cycles and the balance of energy in them. It briefly mentions the water balance and also points out the great significance of seemingly minute changes to it. Since water and vegetation play a decisive role in the transformation of solar energy falling on the earth's surface and is clearly involved in the water cycle of a country, Chapter Three deals with these important relations—it describes the flow of solar energy between the Sun and the Earth, the distribution of solar energy on land, the ability of the biomass to transform solar radiation into other forms of energy, as well as the importance of evaporation from the ground and from plants for the distribution of heat in ecosystems and the consequences of drainage and removal of vegetation in freeing up heat on land. Chapter Four clarifies the history and impact of the exploitation of land on changes to the runoff rates of water from land and also implies an association with some negative phenomena, not the least of which is soil erosion. Chapter Five addresses changes to the temporal and spatial breakdown of precipitation activities through the influence of human beings and the impacts of these changes not only on local and global climates but particularly on the rise in extreme weather events. We dissect in this chapter the reason for rising ocean levels from an angle and with an emphasis that are different from those which the reader is commonly used to seeing. We also fleetingly touch on the unhappy expectations of world society regarding further development of the mentioned changes and their impacts on the growth of global tension and the destabilization of life on Earth. The essence of this publication is then found in Chapter Six, which, after a brief recapitulation of present attitudes towards questions of water management and their impacts, summarizes the new attitude towards water in the new water paradigm. In addition to proposing a new "culture" in our attitude towards water, it proposes a method of mitigating or redressing the greatest damage caused by current water management practices on land. Chapter Seven opens with a short historical look at some aspects of land and water management in our geographic space. It contains an outline of practical measures for the harvesting of rainwater on land, a description of possible, or proposed processes which will emerge from acceptance of the new water paradigm for public sector institutions as well as for the civil and commercial sectors. Last but not least, this chapter offers a picture of the financial costs and effectiveness of the proposed new processes and measures in comparison with current approaches.

Ideas have consequences

Mistakes that people make with strategic decisions or at the beginning of a great work can have long-term and far-reaching negative consequences. A distorted view on a problem can often lead to counterproductive measures. That's why knowledge of the correct paradigms is important in many fields of public policy. This knowledge is no small matter, and people often reach it using a method of trial and error which can sometimes be very expensive. We are witnesses to the fact that the problems of water and its circulation are solved on all levels: the international, the national, the regional, the local, the communal and the individual. The offered paradigm for water is relevant to each of these levels because it puts them in a continuum and in each, water in all its forms and expressions is a question of prosperity and decline, even of life and death.

The role of the state

As far as the management of water on the state level is concerned, the key processes are creating strategic policy decisions, defining legislative instruments and determining the different authorities and responsibilities of state administration and local government, as well as a system of using financial resources for the protection, creation and utilization of water resources. The state at present supervises and looks after the realization of all the mentioned matters as well as other affairs. If, however, its attention and measures are not aimed at achieving a permanently sustainable water balance on the territory of the state, including water balances on the territory of regions, towns and communities, the state, in the sense of this new paradigm, is acting irresponsibly towards the property and health of its own citizens, even towards the international society of nation states.

The role of local government

Local governments are responsible for the development of their own communities. The care for water on the level of local administration is a key to the happiness of citizens and the health and safety of the environment. Towns and municipalities need to resolve effectively and as soon as possible the protection of their land from flooding, drought and fire, and at the same time secure an abundance of quality water for maintaining development of the community. The development of municipalities is thus dependent on a sufficiency of water and a stable water regime which does not threaten the well-being of the community. The development of municipalities must also be built on the principle of water tolerance, i.e. carrying out on the local level management of water resources which does not contribute to the increased threat of neighboring communities. Recognition of the possible impacts of the local influences of humanity on wider connections, even on global changes in the water cycle, creates a foundation for successful, professionally and effectively manageable solutions on the local level according to the well-known principle of "think globally, act locally!". Sustainable solutions on the local level contribute to stability on the regional, continental and global level. The submitted paradigm offers sufficient inspiration for both global thinking and local action.

Doing business with water

Some business entities are engaged in trading with water and satisfying the economic, social and environmental needs of society. If they use water from natural sources and do not return it to the water cycle, however, they cause a deficiency of water and grave negative changes in this cycle. They often, in the end, do harm both to their customers and themselves. This new paradigm for water therefore opens up space for businesses to strengthen their own interest in the conservation and renewal of water in the water cycle.

Possibilities for individuals

At present, the individual is placed in the position of consumer of water and for the most part is neither aware of his own share of responsibility for the protection of water nor of the possibilities or threats which water (or the lack of it) may bring. And yet each roof and each yard of a family home is a microwatershed on which the annual sum of precipitation represents a surprisingly large volume of water. Water is an asset which the individual citizen can use to improve his own life in a variety of ways. He can also, however, without any profit and for a fee, flush it into rivers and into the sea and thus slowly contribute to the desertification of his own environment and microclimate and, in time, to macroclimatic changes. The new water paradigm makes this choice a conscious one.

The common good

The publication of the paradigm is, in the opinion of its authors, a step towards a responsible approach and greater critical thinking with no intention of offending anyone associated with the "old paradigm" or hurting anyone associated with the changes that could result from the change in paradigm. The new paradigm should be accepted in the spirit that it is offered. The authors provide an independent view on the global scenario of the circulation of water with its effects on a continental, national, regional or town level, so that this knowledge will contribute to the common good. The acceptance of the paradigm, besides other suggested activities, ultimately means the acceptance of a new higher culture in relation to water and thus also a total overhaul of the cultural character of our civilization. In the end result, it's about much more than just water.

2 WATER AND ITS CIRCULATION IN NATURE

Now the sun, moving as it does, sets up processes of change and becoming and decay, and by its agency the finest and sweetest water is every day carried up and is dissolved into vapour and rises to the upper region, where it is condensed again by the cold and so returns to the earth.

Aristotle*, Meteorologica*

Thales of Miletus considered water to be the prime matter of the world. Empedocles and some other ancients, but also later Medieval and Renaissance thinkers, considered it a prime matter of the world along with earth, fire and air. In this chapter we "set the stage" for water, and we sketch out a mechanism for its interaction with the other mentioned "basic elements" during its circulation in nature.

2.1 The four "environments" of water

The environments of water

There are around 1400 million cubic kilometers of water on Earth. When we speak about water in this document, we have in mind water in four "environments": water in the seas and oceans, water on land, water in the atmosphere and water in living organisms *(tab. 1)*. At the same time we have in mind water in all of its states: gaseous, liquid and solid.

Water in the oceans

Water of the "first environment," that is, in the seas and oceans, covers 70.8% of the surface of the Earth and forms the largest part, up to 97.25%, of the volume of all water on Earth. The seas and oceans have a key global thermoregulational function for our planet. Their temperature in the course of a year changes only minimally. If they were not here, however, fluctuations of extreme temperatures (such as occur, for example, on the moon) would afflict our planet, which would then be unable to sustain life on Earth as we know it. And only slightly larger fluctuations of temperature, in comparison with the present, could have fatal consequences on the food security of our planet. Among other functions of the seas and oceans, the supply of precipitation to land will be of especial interest to us in this publication.

Water on land

Our image of water in the "second environment" of land is often distorted and fixed only on water in rivers, or perhaps in natural and artificial reservoirs. Water in its solid state (glaciers, snow), however, forms 2.05% of the volume of all water on Earth and contains up to 70% of the world's reserves of fresh water (*tab. 2*). Alongside this water, visible surface water in rivers forms only 0.0001% and in lakes (inclusive of salt lakes and inland seas) 0.01% of the volume of all water on Earth. Groundwater and soil moisture represent, alongside the oddly placed glaciers, the largest wealth of water on land (0.685%), exceeding the volume of water in all rivers and lakes of the world many times over. Water in the soil is, in terms of amount and usefulness, more important than water in rivers. This undiscovered and misunderstood treasure is, however, overlooked and neglected, and as a result, decimated. This publication is particularly concerned about its improvement with the help of water from the "third environment."

Water in the atmosphere

The volume of water in the atmosphere (in all three states) is approximately ten times greater than the volume of all the water in all rivers. Theoretically, if all the water in the atmosphere were to suddenly fall in the form of precipitation, it would cover the surface of the earth with an imaginary layer of water 25 mm in depth. Just as the seas and oceans hold the key to the *global* thermoregulatory function for our planet, the water in the atmosphere has a key role to play in *local* thermoregulation.

Water in the biota

Water surrounds us. It is, however, not only around us but inside of us, too. Water in living organisms, that is, in the "fourth environment," forms approximately 0.00004% of the volume of all water on Earth, which is in terms of volume the least of the four environments. But what is missing in volume is greatly made up for by the fundamental importance of this water for every individual form of life. The human body, for example, contains more than 60% water and all physiological processes in it take place in an environment made up primarily of water. The content of water in plants differs according to the species and is often much higher than in animal tissues. The volumes of water accumulated in vegetation are not insignificant, equally the volumes of water accumulated in the soil thanks to the existence of vegetation. Vegetation on land has, besides other functions, a hugely important role particularly in the regulation of evaporation from the ground, thus significantly helping maintain the thermal stability on land upon which its own success, even its existence, is greatly dependent. All higher forms of life on Earth are dependent on the existence and prosperity of vegetation.

Tab. 1 **The allocation of stocks of water on Earth**[8]

Reservoir	Volume of water (in millions of km^3)	As a percent of the total
Oceans and seas	1370	97.25
Icebergs and glaciers	29	2.05
Groundwater	9.5	0.68
Lakes	0.125	0.01
Soil moisture	0.065	0.005
Atmosphere	0.013	0.001
Rivers	0.0017	0.0001
Biosphere	0.0006	0.00004
Total global reservoir of water	1408.7053	100

Tab. 2 **Area of continents, oceans, deserts and glaciated territory and the number of inhabitants on the continent**[9]

	Area in km^2	glaciated land in km^2	mean height of continents in m above sea level	Area of desert over 20,000 km^2 in km^2	Number of residents in mil. (year 2000)
Continents as a whole	**149 409 000**	**16 081 030**		**13 771 000**	**6 076**
Europe	10 382 000	115 000	290		729
Asia	44 410 000	89 000	960	3 480 000	3 686
Africa	30 329 000	15	650	8 922 000	796
North and Central America*	24 360 000	2 049 000	715	39 000	835
South America	17 843 000	25 000	580	160 000	
Australia and Oceania	8 910 000	1 015	340	1 170 000	30
Antarctica	13 175 000	13 802 000	2 000		
Oceans	**361 455 000**		**Average depth of the oceans in m**		
Pacific	179 680 000		4 028		
Atlantic	94 243 000		3 542		
Indian	76 170 000		3 710		
Arctic Sea	11 362 000		1 228		
Earth in total	**510 864 000**				

* including Greenland, which despite political and historical associations with Denmark and Europe, geographically belongs to the North American continent. Its glaciated territory totals 1,802,600 km^2

** the glaciated area of the Alps totals 3,600 km^2

[8] Various encyclopedia resources

[9] Source: www.geohive.com and other encyclopedia resources

2.2 Water and thermal energy

The absorption or freeing of heat

Water is exceptional in the fact that at temperatures common on Earth it can occur naturally in all three states: solid, liquid and gaseous. Upon its change of state it consumes, or frees, a certain amount of thermal energy. By the change from solid or liquid forms into water vapor it acquires a high mobility, thanks to which relatively large volumes are able to quickly shift in horizontal and vertical directions. Water has at the same time also the largest measured heat capacity (that is, the ability to absorb thermal energy) of all known substances. Thanks to this ability to bind and to release energy, as well as the ability of transfer, reflect or diffuse energy, water in all its states can cool or heat the planet as needed. It maintains it at such temperatures which make life on Earth possible.

The balancing of temperatures

Water balances the thermal extremes between day and night, between the individual seasons and between individual regions while at the same time tempering extremes in the weather. Water vapor is the most widespread greenhouse gas in the atmosphere.[10] Its concentration in the atmosphere is quite variable, but it typically fluctuates between 1-4% (by comparison, the concentration of CO_2 is 0.0383%). The more water there is in the atmosphere, the stronger its moderating effect on temperatures and the fewer the deviations in the weather. The less water there is in the atmosphere, the weaker its moderating effect on temperatures and the more extreme the deviations in the weather. Where water is lacking in the soil and in the atmosphere, extreme thermal conditions usually predominate. Water and water vapor influence in the most significant way the climate on Earth. Despite this fact, its role in the atmosphere is one of the least researched and rarely discussed questions.[11]

The cooling funtion of rain

Falling solar radiation evaporates water from seas, lakes, rivers, wetlands, soil and plants into the atmosphere. The evaporation of each molecule of water consumes heat and thus cools the Earth's surface. Evaporated water in the atmosphere condenses and forms clouds, fog, water precipitation or ice crystals. Water vapor which rises higher into the atmosphere condenses under the influence of the cold air and thus releases thermal energy. Cooled high in the atmosphere, it returns back to the ground in the form of rain. The repetition of this process represents the acting mechanism for the elimination of surplus thermal energy and resembles an ingenious piece of cooling equipment. It is usually true that roughly half of the Earth's surface is at any given time shadowed by cloud cover. Clouds limit the entry of solar radiation into the atmosphere and onto the surface of the Earth. The limiting of the solar radiation that falls on the surface of the Earth decreases evaporation and thus the further formation of clouds.

[10] See, for example: "The Climatic Effects of Water Vapour," Feature: May 2003, http://physicsweb.org/articles/world/16/5/7/1

[11] See, for example: "Water Vapour Supplies New Climate Clues," August 2002, http://physicsweb.org/articles/news/6/8/7/1#020805

The thermoregulational function of clouds

Clouds play an important role in the regulation of the Earth's energy balance in regards to solar radiation. They reflect part of the shortwave solar radiation, thus limiting its entry into the atmosphere and to the surface of the Earth and thus protecting the Earth from excessive warming. However, they also capture part of the longwave (thermal) radiation from the Earth which would otherwise escape into space; they thus have a warming effect as well. The cooling or warming effect of clouds depends on their type and their altitude. Low-altitude cumulus clouds cool the Earth while thin, high-altitude cirrus clouds have a warming effect.[12] Research on the thermoregulatory effects of clouds and their equilibrium have been shown to be very promising and very interesting with regard to the present problems of humanity.

Evaporation and vegetation

If solar radiation falls on a surface well stocked with water, the majority of the solar energy is consumed in evaporation, the remainder for sensible heat, heating the ground, reflection, or photosynthesis. If the sun's rays falls on a drained area, most of the solar radiation is converted into sensible heat, while in areas that are sufficiently damp year-round most solar energy is consumed for evaporation. Therefore, water surfaces, soil saturated with water and vegetation all play an important role in the circulation of water on land. Functional vegetation fulfills the function of a valve between the ground and the atmosphere. It protects the ground from overheating, and thus drying out, and optimizes the amount of evaporation through the help of transpiration through the many pores (stomata) on the leaves. Vegetation well stocked with water thus has a significant cooling effect and air-conditioning capability. Vegetation—its amount, type and, last but not least, quality—significantly influences surface runoff in watersheds, too. Through deforestation, through agriculture and through urban activities, the amount of water on land has changed. Humanity is thus unwittingly changing the flows of massive amounts of water and energy (for more details see Chapter 3).

Purifying and transport characteristics

Heat (and gravitation) is the motor of the global water cycle, which consists of the large and small water cycles *(Fig. 1)*. Water in the water cycle is the blood and lymph of life, which, under the influence of solar energy and gravitation, flows, circulates and vibrates in all its forms between the seas, the land and the atmosphere. When passing through the atmosphere, it absorbs carbon dioxide and ammonia as well as other gases and impurities. Similarly, it is also enriched by various minerals when flowing across the Earth's surface or during infiltration through the soil and subsoil. Through all of these movements, water drives, cleans and thermoregulates ecosystems, but it also erodes the soil. The amount of mineral substances which water carries away to the seas and oceans each year is estimated at 3.5 billion tons. The displacement of soil and soil nutrients is one of the reasons why the runoff of rainwater from land needs to be slowed and why rivers should carry to the seas only those surpluses of water which do not "fit" into the optimally saturated land and atmosphere.

[12] NASA DAAC Study: *Clouds in the Balance*, 2001, http://nasadaacs.eos.nasa.gov/

2.3. The large water cycle

Evaporation from oceans and precipitation

The large water cycle is the exchange of water between ocean and land. Approximately 550 thousand km^3 of water evaporate each year into the atmosphere. About 86% of the evaporation from the Earth's surface is from the seas and oceans while about 14% is from land. Of the total amount of atmospheric precipitation originating from this evaporation, 74% falls over the seas and oceans and 26% over land. From the above, it follows that the seas and oceans, through evaporation and precipitation, endow land with a certain volume of water which travels by way of atmospheric thermodynamic flows a great distance over the continents, where it then rains down (or falls in the form of snow).

The balance of the large water cycle

Part of the water from precipitation is absorbed into the ground and, if it reaches the groundwater table, is added to groundwater runoff (except for regions without groundwater runoff). Part of the water is used by vegetation and part of it evaporates again. The remainder flows away via surface runoff into the network of rivers and back to the seas and oceans. Thus the large water cycle is completed. Under balanced conditions, the same volume of water flows from the continents into the seas and oceans as fall on the continents from the world's oceans in the form of precipitation. But even relatively small deviations from this state of equilibrium can mean great problems on the continents, particularly if they are longer term deviations and if they affect most river basins. If more water flows from the continents into the oceans than is transferred from ocean to land through precipitation, the land loses water and dries out. This occurs, for example, when humanity systematically lowers the infiltration of rainwater into the soil through its activities (for example deforestation, agricultural activities, urbanization) and channels this water (in the quickest possible way) into rivers and subsequently into the sea. The moisture of the soil decreases, the groundwater table falls, vegetation withers and less evaporation takes place. If the volume of water flowing from continents to the seas and oceans increases and evaporation of water from the seas and oceans remains unchanged, or does not increase adequately (under the influence of increased evaporation due to global warming), then the increased flow of water from the continents (including the increased melting of glaciers) adds to the rise in ocean levels.

Human and other influences

Besides the changes in the global water balance which are caused by phenomena beyond the influence of mankind (solar cycles, changes in position of the Earth in relation to the Sun, volcanic activity...), man unconsciously causes further deviations, thus contributing through his activities to the desertification of the continents. Through conscious activity in the opposite direction, however—namely the deliberate conservation of water on the continents—mankind could stop this ongoing desertification and return the lost water to the continents.

2.4 The small water cycle

Definition and characteristics

The small water cycle is a closed circulation of water in which water evaporated on land falls in the form of precipitation over this same terrestrial environment. Just as a small water cycle exists over land, there is also a small water cycle over the seas and oceans. Mutual interactions take place between the individual small water cycles because these occur in space and time over large areas with different morphologies and surfaces with varying levels of moisture and surface water. The circulation of water in the small water cycle, then, is partially horizontal, but unlike that of the large water cycle, vertical movement is the most characteristic. Evaporation from adjacent areas with different temperatures mutually concur in the creation and development of cloud cover. Perhaps it can also be said that above land water circulates at the same time in many small water cycles which are subsidized with water from the large water cycle.

Evaporation from land and rainfall

The name of the small water cycle is not to its advantage because it gives the impression that the cycle contains only a small amount of water. The opposite is true. Let's look at the information in the previous chapter from a slightly different angle. The average annual precipitation over land is 720 mm and the input from the seas is about 310 mm. From this information it follows that land provides the larger part of its own precipitation (410 mm) from its own land-based evaporation. The precipitation in a region shares in the saturation of soil with rainwater, and through the small water cycle, roughly one-half to two-thirds of rainwater (50 to 65%) goes into the repeated creation of precipitation over land. This is very important information which should fundamentally change our current approach to the management of water in river basins. Mankind cannot transform and drain the land limitlessly without also having an impact on its precipitation and its thermal regime. If we want to have stabile precipitation over the land, it is very important to ensure evaporation from the same land. Evaporation from land is, with a certain simplicity (ignoring accumulation), the difference between precipitation and runoff. If we have a great outflow of water from a territory, this will be to the detriment of evaporation and will cause a subsequent decrease in precipitation. The volume of water in the small water cycle over land will gradually decrease. With a decrease in runoff, on the other hand, we get greater evaporation and thus we actually "sow the rain."

The circulation of water on healthy land

The small water cycle, also the short or closed water cycle, is characteristic for a hydrologically healthy country. In a country saturated with water and water vapor, water circulates in small amounts and for relatively short distances.[13] This occurs thanks to a water-vapor induced moderating of the differences in temperatures between day and night or between localities with different thermal regimes. The majority of water that evaporates condenses again in the given region or its surroundings. Frequent and regular local precipitation retrospectively maintains a higher level of groundwater

[13] Below, the one- to three-kilometer boundary layer of the atmosphere is in this context the most significant. Turbulent flows of moisture, warmth and locomotion run there and over 75% of all water vapor in the atmosphere is found there (Prof. Lapin).

and with it also vegetation and further evaporation, so that the whole cycle can be repeated again and again.

Disintegration of the water cycle

If, however, there is an extensive disruption of vegetation cover (for example, by deforestation, agricultural activities, urbanization), solar energy falls on an area with low evapotranspiration and a great part of it is changed into heat. This leads to a significant divergence of temperatures, and the differences in temperatures between day and night or between localities with other thermal regimes increase. Air currents increase, water vapor is taken further away by the warm air and the majority of evaporated water is lost from a country. Light and frequent precipitation decreases, and there is an increase in intense and less frequent precipitation from the seas. The cycle is opened and the large water cycle, which, unlike the "soft" small water cycle, is characterized by erosion and the washing away of soil nutrients into the sea, begins to predominate. The renewal of the domination of the small water cycle, which is advantageous for humanity, vegetation and the land, depends on the renewal of the functional plant cover of a territory and water surfaces in a country.

2.5 The balance of the water cycle

A balanced equation

The expression "water balance" is understood in hydrology to be a relation which characterizes the circulation of water in a certain system, mainly in a watershed or in its parts. We express it with equations like *(1)*, which show the relationship between elements entering a system (for example, precipitation) and elements leaving a system (for example, evaporation and surface or underground runoff). A third, neglected element exists between the entry and runoff of water and that is the change in the volume of water in a system.

Monitoring of the water balance

Monitoring the water balance of a territory is one of the basic tasks of hydrology and meteorology. Such monitoring consists predominantly of regularly measuring total precipitation and flow rates of water in watercourses through a network of precipitation measuring stations and limnographic stations for selected profiles of watercourses, particularly during their outfall to larger basins, to the waters of neighboring states and to the seas or oceans. In the scope of a meteorological and climatological network, attention is paid, in addition to these parameters of water balance, to the temperatures in a territory, levels of groundwater and the quality of the water.

Mathematical modeling of the climate

Workers from professional institutes subsequently process data obtained from long-term measurement into a long-term series which helps them monitor the current development and trends of the measured quantities. On the basis of different models and results of known data, they create models for the development of these quantities with an eye on the future. Climatology is dedicated to such modeling. A common area for us is perhaps the most well-known modeling of the development of weather by meteorologists, although their models are built on a different principle. A forecasting service is able, with reasonable accuracy, to model weather one, two, three, even ten days in advance. Climatologists, however, model the development of a climate a number of years or even decades in advance.

A condition for the stability of the climate

A necessary, though not sufficient condition for a stable climate in a territory is a stable water cycle (*Fig. 2*). That's why a very important piece of information, which should be the primary purpose for monitoring the water balance, is the difference between the amount of water which enters into a system and the amount of water which exits from a system. This difference, when positive, indicates to us the addition of water to a system (saturation), and when negative, the loss of water from a system (dehydration). Most models of weather or climate don't really provide this information, however, because they do not calculate it or they do not consider it significant.

A non-zero balance

Amongst both the general public and experts the established notion prevails that this difference is, for large units (such as river basins or whole continents) and for long periods of time (a year or more), equal to zero, or around zero. The conviction that the amount of rain the wind brings from the sea is the same amount of water that flows in rivers to the seas is a legacy of the times when hydrologists first discovered the water cycle. They thus explained an old puzzle: how it is possible that the levels of the seas and oceans do not rise when all the rivers of the world constantly flow into them. Today, however, hydrological measurement shows that the levels of the seas and oceans are rising and at the same time the levels of groundwater are falling, and yet it doesn't seem to have occurred to anyone that the balance between the inflowing and outflowing water cannot be zero. The great danger of neglect threatens just when this difference is very small and yet still on the same side of the equation. In such a case it can lead to the drying of a country over whole decades without hydrologists ever noticing the reason for it.

Quantification on the level of micro watersheds

Within the scope of hydrology, meteorology and climatology, the water balance of a state and the water balance of the main watersheds in the framework of the state have so far only been monitored on the level of individual countries. The bigger the system, the easier it is to overlook the dangerous one-sided deviation mentioned in the previous paragraph. If, then, we want to analyse a territory effectively, we need to quantify its water balance even on lower levels – on the regional or local level (community or town) or still lower, in which, depending on the size and character of the investigated territory, the ratio of runoff to precipitation can be mutually differentiated *(Tab. 3)*. As we shall later see, the quantification of the water balance can also be necessary on a personal level in the area of land ownership, for example for the proposal of volumes needed for rainwater harvesting on a plot of land.

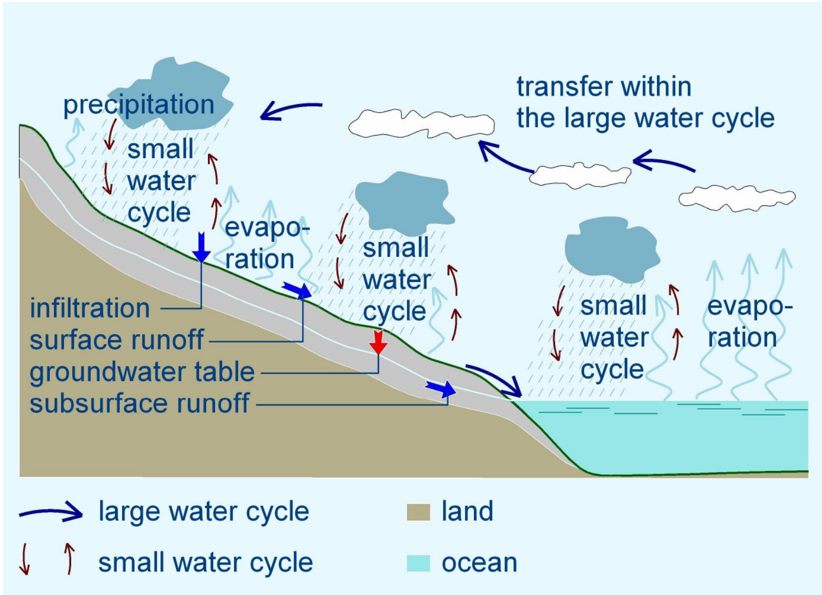


Fig. 1 **The large and small water cycles on land**

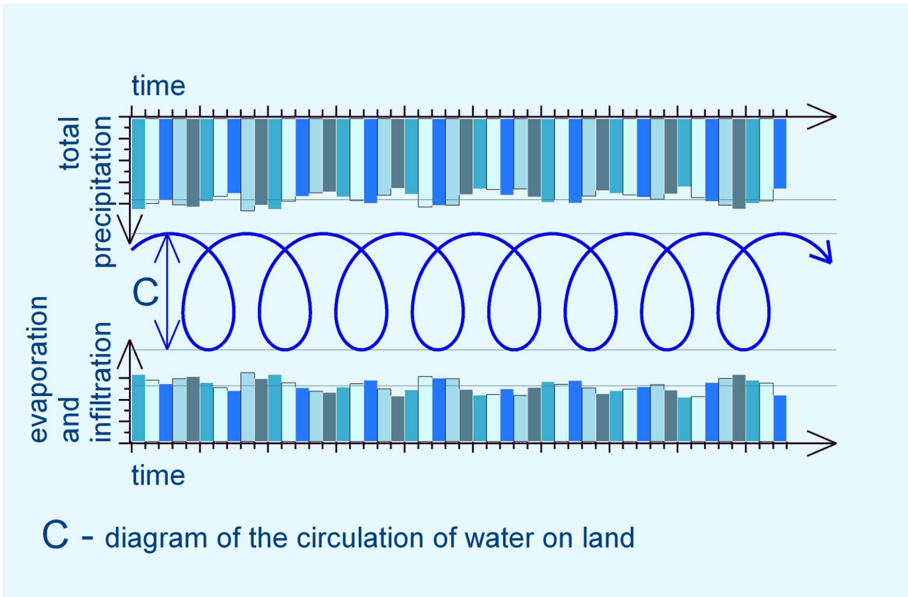


Fig. 2 **Diagram of the long-term stable water cycle on land**

Equation for water balance in a watershed

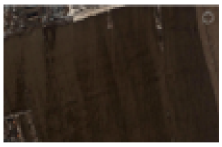
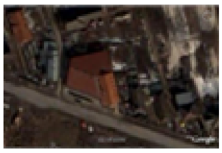
$$\mathbf{R = E + Q + \Delta V} \qquad \mathbf{(1)}$$

[+1 % –1 %] – minute changes Q and ΔV in the annual water balance of a watershed

R – precipitation total over an area (per year), **E** – evaporation from a region (per year), **Q** – surface and subsurface runoff (per year), **ΔV –** change in the amount of water in the system (per year) **+1 %** – relatively small increase in the volume of runoff versus the normal level initiated by the increase of runoff of rainwater from a region for the current calendar year (not observable during the current research); **–1 %** – relatively small decrease of supplied water to the soil profile and subsoil compared to the normal level initiated by the increase of runoff of rainwater from a region for the current calendar year;

A volume of 1% can be used, for the purpose of explaining the problem, as an average value of the decrease in groundwater and the speeding up of surface runoff for a normal calendar year during the 20th century. This value approaches zero if it applies to natural land untouched and unchanged by mankind. This value can be greater than 1 in highly urbanized areas with complete drainage of rainwater into watercourses. If we multiply the amount of water corresponding to this percentage, whatever it may be, by the number of years (for example 100 years; we can consider the 20th century as a reference period) we ascertain that this is a considerable amount of water which the land has lost (particularly in the soil profile). Part of this volume at the same time increased in the oceans (after subtracting the increased evaporation from the ocean levels) and along with water from melting glaciers, contributed to the rise in their levels.

Tab. 3 Examples of water balance depending on the size of the studied territory[14]

Water balance of the investigated territory	Amount (mm/ year)	Volume of water circulating	Share of drainage from the total	
Oceans and seas (area 361,455,000 km^2)				
– evaporation of water from the oceans	1 180	425 000 km^3		
– precipitation over the oceans	1 070			
– inflow	110	40 000 km^3		
Continent – example: Europe (10,382,000 km^2)				
– amount of precipitation	750	7 790 km^3		
– infiltration and evaporation	480	4 980 km^3		
– outflow	270	2 810 km^3	36 %	
Nation – example: Slovakia (49,035 km^2)				
– average amount of precipitation at present	762			
– infiltration and evaporation	500	37 km^3		
– outflow	262		34 %	
River basin – example: Torysa river basin, Slovakia (area 1,349 km^2)				
– average amount of precipitation at present i	681	3 km^3		
– infiltration and evaporation	454			
– outflow	227		33 %	
Urban area – example: area within city limits of Prešov (19.5 km^2)				
– average amount of precipitation at present	628	0,012 km^3,		
– infiltration and evaporation	173	t. j. 12 mil. m^3		
– outflow	455		72 %	
Plot of land – example: field measuring 0.8 km^2				
– average amount of precipitation at present	630			
– infiltration and evaporation	397	504 000 m^3		
– outflow	233		37 %	
Object – example: residential home with an asphalt driveway (1,217 m^2)				
– average amount of precipitation at present	630	766 m^3		
– infiltration and evaporation	151			
– outflow	479		76 %	

[14] Source of initial data: Slovak Hydrometeorology Institute, Bratislava, Slovakia; *Large Atlas of the World*, Kartografie Praha, Prague, 2000; O. Majerčáková, P. Šťastný: "The Hydrological Cycle". *Environment*, Edition 35, number 3, pg. 123, Insititute of Land Ecology, 2001; Study "Integrated Protection of Water in Prešov", People and Water, 2007

3 THE ROLE OF PLANTS IN THE CIRCULATION OF WATER AND IN THE TRANSFORMATION OF SOLAR ENERGY

May I each day take a wandering walk along banks beside water. May my soul rest on the branches of trees I planted myself. May I refresh myself in the shadow of my own fig tree.

Inscription on an Egyptian tombstone, cca 1400 years before Christ

All praise be yours, my Lord, through all that you have made, And first my lord Brother Sun, Who brings the day and the light you give to us through him…

All praise be yours, my Lord , through Brothers Wind and Air, and fair and stormy, all the weather's moods, by which you cherish all that you have made.

All praise be yours, my Lord, through Sister Water, So useful, humble, precious and pure…

All praise be yours, my Lord, through Sister Earth our mother, who feeds us in her sovereignty and bears various fruits and coloured flowers and herbs…

St. Francis of Assisi, Song of Creation

This chapter begins by dealing with "fire," the imaginary opposite of water, specifically with the distribution of solar energy on land. It draws attention to the significant role of water and with it the power of vegetation for tempering the burning effects of the sun. It demonstrates the fact that the roles of water and vegetation have in the concept of the greenhouse effect and global climate change been thus far greatly neglected. It focuses also on the possibility of alleviating the effect of climate change by improving management of water and vegetation.

3.1 The flow and distribution of solar energy on land

The philosopher Heraclitus of Epheseus, living at the turn of the sixth and fifth centuries before Christ, according to some ancient fragments considered fire as the prime matter of the world. A little later, Anaxagoras conjectured that the Sun was a giant flaming ball of metal, larger than the Peloponnese. For this he suffered condemnation and banishment from Athens. If we were to figuratively

Ideas about the sun

identify fire with the Sun in the first case and if we were to take into consideration the psychological difficulties of the contemporaries of Anaxagora with the physical nature and the size of the Sun, these two philosophers would probably be two of the ancient authors who came nearest to today's knowledge that the Sun contains 98% of all mass in our solar system. Some 1.3 million Earths could be placed within the Sun.

Energy from solar radiation

The sun is the primary source of energy for Earth. For approximately five billion years now, it has illuminated daytime on our planet, doing so thanks to the nuclear fusion in its interior, which transforms light hydrogen into helium. The Sun annually sends about 180,000 teraWatts (TW) of energy to Earth in the form of electromagnetic radiation. Only for the purpose of comparison: the amount of energy which the whole of humanity uses for driving its economy is approximately 14 TW annually. About 1.4 kW of energy falls on each square meter of the outer surface of Earth's atmosphere (the solar constant). Solar energy keeps the atmosphere in a gaseous state, warms our planet to a temperature favorable for life, keeps the circulation of water in motion and provides energy for photosynthesis and other life processes. The energy concealed in fossil fuels also has its origin in solar energy in the transformation by photosynthesis of plants in the long distant past.

Solar radiation in the atmosphere

Of the total amount of solar energy which reaches the Earth, about 30% on average is reflected back into space in the form of shortwave radiation, 47% radiates as longwave (thermal) radiation and 23% is consumed in the circulation of water for evaporation. Upon passing through the atmosphere, solar radiation is partially absorbed by gases and water vapor as well as being absorbed and reflected by powdery particles and aerosols. The energy of the radiation in the ultraviolet zone decreases, while the share of longwave (thermal) radiation increases. The solar radiation that falls on the Earth's surface consists of two components: direct and diffuse radiation. Direct radiation forms parallel rays which arrive directly from the Sun (they form shadows), or are refracted upon passing through the atmosphere. Diffuse radiation originates with the dissipation in atmospheric gases, clouds, powdery particles, aerosols and other impurities. Both of these components are present in daily sunlight, but their proportion frequently and very markedly changes.

Solar radiation reaching the Earth's surface

The amount of solar radiation which reaches the surface of the earth varies considerably in time and space. Solar radiation reaches the surface of the earth in daily and seasonal pulses.[15] The maximum value of the radiation which arrives per square meter per year can reach 3000 kWh. In the temperate zones of our geographic surroundings, the annual input of solar radiation reaches a value of about 1100 kWh/m^2. The amount of solar energy which falls on the Earth's surface is determined by the weather at any given time. The difference in the amount of solar energy reaching the Earth's surface on days of clear and on days of overcast skies is formidable (see *Fig. 3a, b*).

[15] The values of solar radiation in different places on Earth can be found on the webpages of NASA (http://eosweb.larc.nasa.gov/sse)

The distribution of solar energy depends also on the character of the terrestrial surface. Incoming solar radiation is partially reflected (albedo expresses the ratio of reflected radiation out of total radiation). The amount of reflected radiation depends on its wavelength, on the angle of its fall and on the character of the surface. Vegetation reflects 5-15% of shortwave solar radiation; a dry surface reflects up to 35% of the radiation falling on it while freshly fallen snow reflects up to 90% of solar radiation.

Albedo

The fate of incoming solar energy depends significantly on the presence of water in an ecosystem, which strongly influences the distribution of energy between the two primary flows of heat: sensible and latent heat. As the name itself suggests, sensible heat is accompanied by an increase in the temperature of substances or bodies which we can feel. Latent heat is not accompanied by any increase in temperature. Latent heat, in our case the latent heat of vaporization of water, is the amount of energy which water must receive in order to turn into vapor of the same temperature. Let us refresh our school knowledge of physics: evaporation from the free surface of a liquid takes place at every temperature, the intensity of this evaporation increasing with the temperature of the liquid, with the size of its free surface and with the removal of the vapor formed above the liquid. At boiling point, liquid evaporates not only on the surface, but also from the interior as well. The specific latent heat (that is, the latent heat per unit of mass) of water under normal pressure and at a temperature of 25 °C is 2243.7 kJ/kg. This indicates the amount of solar energy which is consumed to evaporate each liter of water without increasing the temperature (This same amount of heat is released later during condensaton of the water vapor in a colder place.).

Sensible and latent heat

Of course, water can change into water vapor only if it is present on land. If it is not present, a great part of the solar energy is changed into sensible heat and the temperature of the environment sharply increases. Whereas in a parched country up to 60% of solar radiation changes into sensible heat, in a country saturated with water up to 80% of pure radiation can be bound to the latent heat of the vaporization of water and only a very small portion of solar radiation is changed into sensible heat *(Fig. 4).*

Water on land and heat

3.2 Flora, water and the distribution of heat

At the conclusion of the previous chapter we stated that the fundamental difference between drained land and land saturated with water rests on the way solar energy is dissipated, namely in its transformation into other forms of energy. From this fact it follows that terrestrial ecosystems can through active regulation of water

Water and the dissipation of energy

currents significantly influence the distribution of solar energy into two main components: sensible and latent heat. The primary importance of vegetation on land for the climate is in its influence on the transformation of solar radiation.[16]

The distribution of energy in flora

The distribution of solar energy reaching vegetation is represented in *Fig. 5.* Solar radiation reaching the Earth's surface is partly reflected; unreflected radiation is called net radiation. This radiation is partially tranformed (dissipates) through the evaporation of water, is partially changed into sensible heat, partially conducted away as heat to the soil and is partially accumulated in the biomass via photosynthesis. The amount of energy accumulated in biomass is relatively low, with the net production of 1 kg of biomass per square meter representing about 0.45% of the annual input of total solar energy per square meter. The amount of biomass produced in the course of one year (annual primary production) varies greatly between different places on Earth according to the amount of the sun's rays arriving, the stocks of water and the accessibility of nutrients. Generally, the more solar energy there is, the higher the potential production. With the increase in input of solar energy, water becomes the main limiting factor in primary production.

Evaporation and transpiration of plants

The majority of living plants contain a great deal of water in their tissues, with growing biomass containing up to 80-90% water. At the same time, water is also bound to growing tissues through the intake and photosynthetic fixation of carbon dioxide (CO_2). For a 10g daily growth of dry matter per m^2, roughly 14g of CO_2, 1g of nutrients and 80-90g of water are fixed to cell structures and plant tissues. Besides water for the building of tissues, we should also mention in connection with vegetation the consumption of water for evapotranspiration. Evaporation includes the vaporization of water from the soil or from the surfaces of plants. Transpiration is the release of water by plants in the form of water vapor. Plants constantly regulate the amount of water vapor released by the opening and closing of a large number of pores, or stomata, under the surface of their leaves. Together with providing shade, plants, given the right levels of incoming energy, are able to cool and protect the soil, but particularly to optimalize amounts of water which would otherwise very quickly evaporate from the soil and atmosphere. It can be said that the ground "sweats" through plants, with realistic values for evapotranspiration per square meter in the conditions of the temperate climate zone reaching values of 3 litres per day, which represents a latent heat of 2.1 kWh (7.5 MJ). In the mentioned case roughly 3.09 kg of water per m^2 passes through the flora *(Fig. 6).*

The different abilities for transpiration

Evapotranspiration is a dynamic process which depends primarily on the input of energy and the accessibility of water, a process which increases with the growth of inflowing energy (solar radiation, the supply of dry air, wind). It has a high range of values from zero up to a maximum value (potential evapotranspiration) at which up to 80% of the incoming solar energy is used in the evapotranspiration process. Plants differ greatly in their ability to

[16] Hutjes, R. W. A., Kabat, A., Running, S. W., Shuttleworth, W. J. et al. 1998. "Biospheric Aspects of the Hydrological Cycle." *Journal of Hydrology*, 212 – 213: 1 – 21

evaporate/transpire water. In the temperate zone, the transpiration of evergreens is in general lower than the transpiration of deciduous trees. Wetlands vegetation has the highest capacity for transpiration. On a sunny day in the temperate zone with sufficient water available, natural flora achieves transpiration values of several mm (several litres per square meter per day), values above 5 mm being considered high. Some plants, so long as they have sufficient water available, are able to evaporate in the course of a sunny day more than 20 litres of water per square meter.[17] On developed land, evapotranspiration on sunny days is mostly limited by a shortage of water, so that the values of actual transpiration are markedly lower than those of potential transpiration. From this it is obvious that insufficient water also limits the primary production and circulation of carbon.

The tree as an air-conditioning unit

Transpiring plants, especially trees, are thus the perfect air-conditioning system of the Earth. Let's imagine a large, independently standing tree with a crown of about 10 meters in diameter. On the crown of this tree, which has a surface area of 80 m^2, there falls each day about 450 kWh of solar energy (4-6 kWh/m^2). Part of the solar energy is reflected, part is absorbed by the soil and part is converted into heat. If such a tree is well stocked with water, it evaporates (transpires) some 400 litres of water each day. For the transformation of water from a liquid state into water vapor, 280 kWh is consumed. This amount of energy thus represents the difference between the shadow of a tree and the shadow of a parasol with the same diameter. In the course of a sunny day, then, such a tree cools with a power equal to 20-30 kW, power comparable to that of more than 10 air-conditioning units. The tree is at the same time “fuelled" only by solar energy, is made of recyclable materials, requires a minimal amount of maintenance and emits water vapor that is regulated by millions of stomata which respond to the heat and humidity of the surroundings. The main thing is that the solar energy bound up in water vapor is carried away and is released upon its condensation in cool locations. It thus balances temperature in time and space, unlike a refrigerator or air-conditioner, which release heat into its nearby surroundings. A tree, unlike a refrigerator or air-conditioner, is also completely noiseless, absorbs noise and dust and binds CO_2.

Evaporation more effective than albedo

The cooling effect of plants caused by transpiration is apparent in *figures 7, 8 and 9.* The pictures in the infrared spectrum show that the leaves of the plants are, thanks to transpiration, visibly cooler than the surrounding soil *(Fig. 7)*. The cooling effect of vegetation is also evident from the infrared photographs of the square and park in Třeboň *(Fig. 8)*. The temperature of the roofs and facades of homes exceeds 30°C, whereas the temperature of the trees in the park is around 17°C. Vegetation actively cools through the evaporation of water. Vegetation, particularly forests, has a darker color and thus a lower reflectance (albedo) than most other surfaces (clay, sand, etc.). This difference in reflectance is sometimes

[17] Kučerová, A., Pokorný, J., Radoux, M., Němcová, M., Cadelli, D., Dušek, J. (2001). "Evapotranspiration of small-scale constructed wetlands planted with ligneous species." In: Vymazal, J. (ed.): *Transformations of Nutrients in Natural and Constructed Wetlands*, Backhuys Publishers, Leiden, The Netherlands, s. 413 – 427

interpreted as meaning that forests warm the Earth's surface. *From figure 8*, it is obvious that plants, independently of reflectance, cool through transpiration. *Figure 8* again shows that the effect of reflectance is much lower in comparison with the effects of transpiration.

The influence of water on land temperature

A useful tool for judging the state of vegetation and its function during the distribution of solar energy over large areas is to take satellite photographs. *Figure 9* shows photographs of the Mostecka (northern Czech Republic) and Třeboňsko (southern Czech Republic) regions.[18] Mostecko has been greatly affected by strip mining, vast areas of land there having been drained of water. Conversely, in Třeboňsko more than 10% of the land is covered by ponds, and other wetlands have also been preserved here. Temperatures are represented by colors: The highest temperatures are shown in red, orange and yellow, whereas the lower temperatures are colored in green. The highest temperatures are in places without vegetation, particularly in the strip mines and dump areas in Mostecko. The thermal amplitudes are evidently higher in Mostecko, in comparison with Třeboňsko, where the temperature differences are balanced out thanks to its higher humidity.

3.3 The impact of drainage and the removal of vegetation on the release of heat

Changes in the flows of colossal amounts of energy

Large-scale draining and removing of vegetation is connected with the release of a colossal amount of heat and with the formation of so-called "hot plates" on land. Sensible heat released from just 10 km^2 of drained land (a small town) for a sunny day is comparable with the installation power of all the power plants in the Slovak Republic (6,000 MW). A fall in evaporation by 1 mm per day over the total area of the Slovak Republic (49,000 km^2) leads to release of sensible heat of around 35,000 GWh for one sunny day. This is an amount of heat larger than the annual power production of all the power plants in the Slovak Republic. The effect of human activities on the land is still not fully appreciated. Drainage of developed land is accompanied by a drop in functional vegetation. Under the influence of the negative impact of drainage and the loss of permanently functional vegetation on the rainfall regime and on the distribution of temperatures,[19] we have gradually become victims of degradation and desertification of vast areas of once fertile land.

Neglecting of water in models

In recent years the problem of global warming has become a major topic of discussion. The direct reason for climate change is at present considered to be mankind's production of greenhouse gases (CO_2, CH_4, N_2O, hydrofluorocarbons). Ever more sophisticated models show the

[18] From the Landsat Thematic Mapper and Enhanced Thematic Mapper+ satellite
[19] Ripl W., "Management of Water Cycle and Energy Flow for Ecosystem Control – The Energy-Transport-Reaction (ETR) Model," *Ecological Modelling 78*, 1995, pgs. 61 – 76; Ripl W., "Water: the Bloodstream of the Biosphere". Philos Trans R Soc Lond B Biol Sci. 358(1440), 2003, pgs. 1921 – 34

impact of the growth of concentrations of greenhouse gases. In view of the fact that the circulation of water is very dynamic and complex, water as an important greenhouse gas has been greatly neglected in these models, however. Water is considered to be a stable component of the atmosphere. Reasons for changes in the water regime of a country are difficult to show unequivocally, because they involve a complex of innumerable mutually connected processes.

Drainage worse than greenhouse gases

One measure of the impact of increased concentrations of greenhouse gases is the so-called radiation effect, which expresses a change in the balance between radiation entering into the system of the Earth's atmosphere and radiation flowing out of this system. According to the International Panel for Climate Change, global industrialization (the effects of human activity) has caused, in comparison with the pre-industrial period, warming with radiation effects equal to $1.6 Wm^2$. This means that on average about $1.6 Wm^2$ more energy falls per square meter of the Earth's surface than in about 1750.[20] In comparison with this value, the impact of a country’s water management on its climatic conditions is (at least on local level) appreciably larger.

Vegetation for tempering climatic changes

The development of our climate in the future is perhaps difficult to envision, even though scientists are constantly discussing these questions. It has become even more difficult to forecast the long-term trends in the weather in recent times; we meet with extreme precipitation, extreme temperatures, and prolonged periods of drought. One condition for the alleviating of climatic change is the renewal of those basic ecological functions which are closely connected with the return of water and vegetation to the land. The functions we particularly have in mind are the soft dissipation of solar energy through the circulation of water, the absorption of carbon dioxide and the keeping of nutrients and substances on land. The return of vegetation and water to land can only have a positive effect. With sensible management of water and vegetation we can curb climatic change on the local level; if we can act in the same way across larger areas, perhaps we can expect a tempering of global climate change.

[20] IPCC, 2007

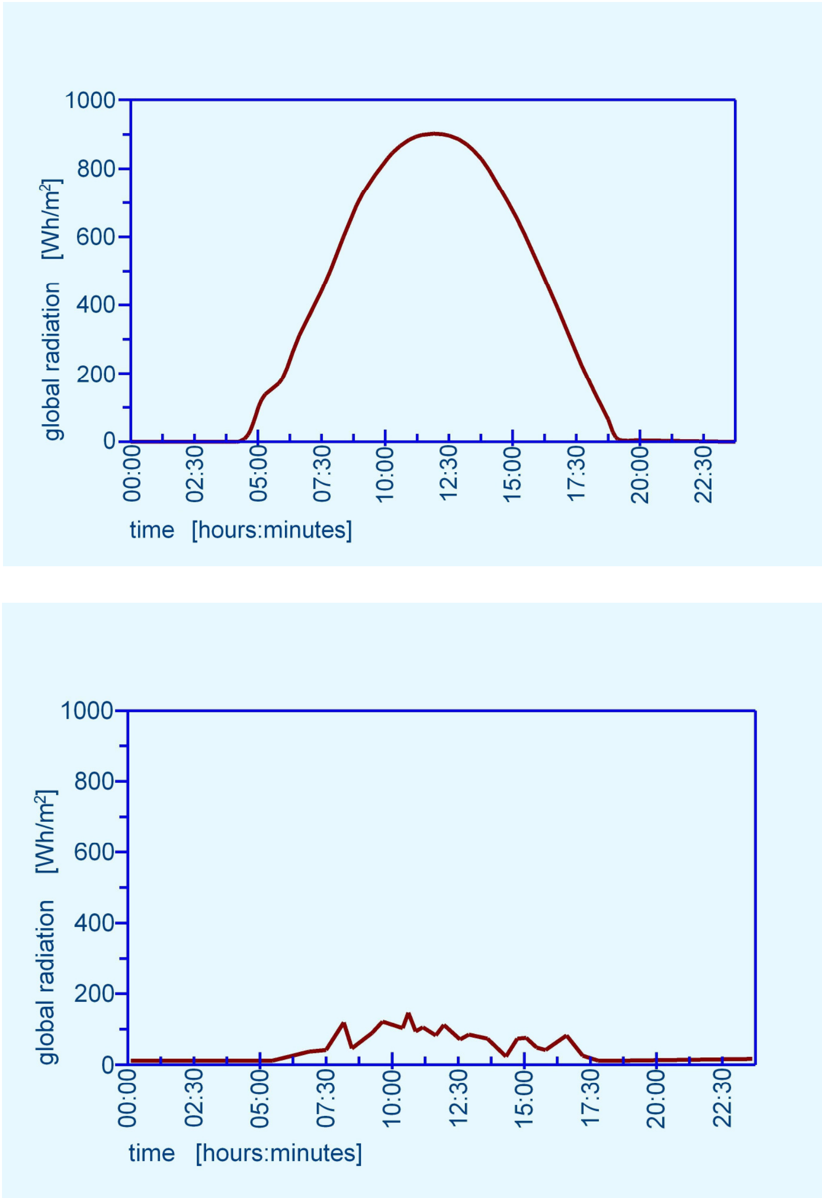


Fig. 3a, b **Values of solar radiation on a clear day and on a cloudy day**
(recorded on 18 July 2006 and 3 August 2006, in Třeboň, Czech Republic)

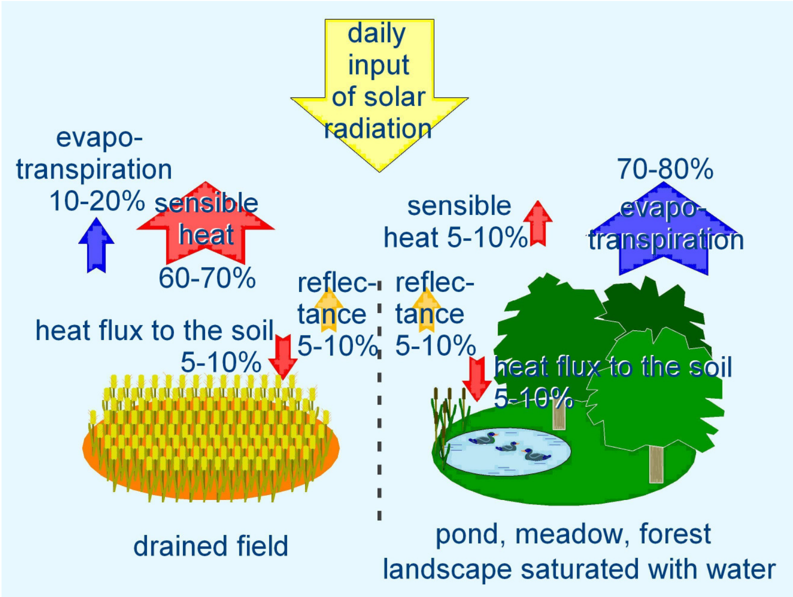


Fig. 4 **The distribution of solar energy on drained land and on a landscape saturated with water**

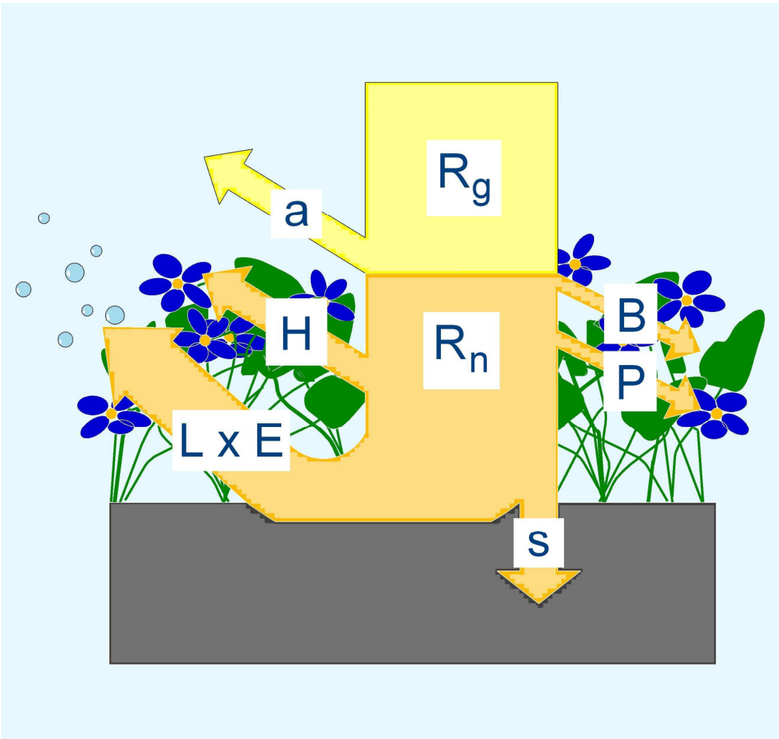


Fig. 5 **The distribution of solar energy on vegetation**
Rg – global radiation, Rn – net radiation, a – albedo (reflected radiation), H – sensible heat, L × E – latent heat x evapotranspiration (evaporation from soil and vegetation), s – flow of heat to the soil, B – accumulation of heat in the biomass, P – consumption of energy for photosynthesis

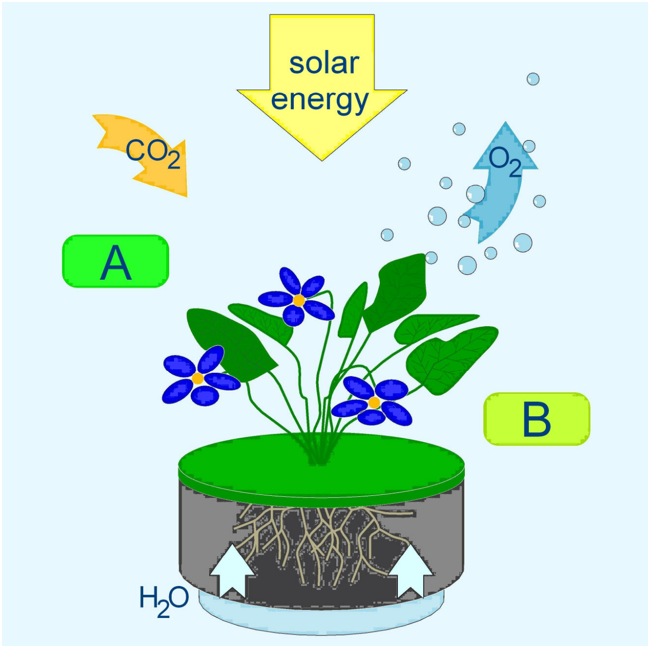


Fig. 6 **An example of the daily energy balance of CO2 and H2O fluxes per 1 *m2* of vegetation stand:** A: For the creation of 10g of dry matter, 48Wh (170kJ) are consumed for the fixing of 14g CO_2 (0.32 mol). B: Evapotranspiration (3 l) requires 2.1 kWh (7.5 MJ).

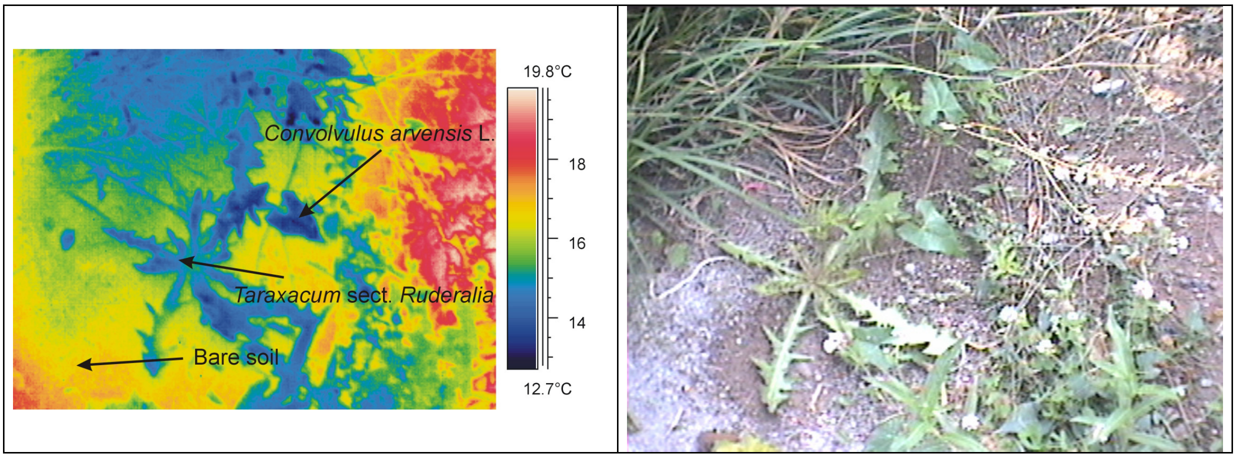


Fig. 7 **Photographs of thin vegetation in the infrared spectrum and in the visible spectrum**. The bare surface of the ground is visibly warmer than the surface of the leaves cooled by transpiration. (Třeboň, Czech Republic, 12 July 2002, 10:00 hrs).

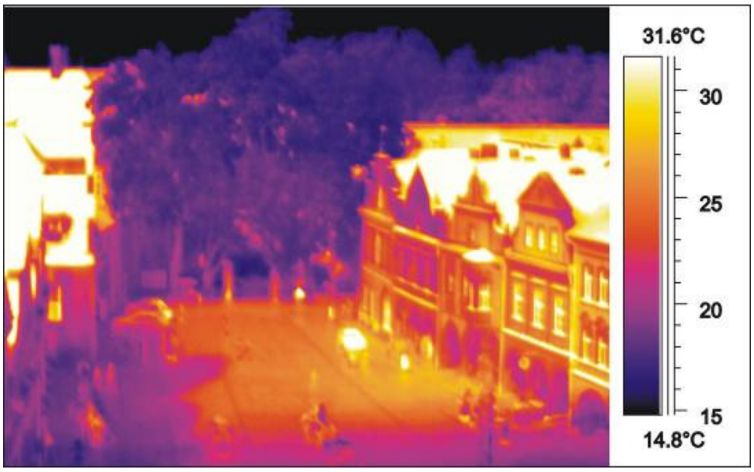


Fig. 8 **Photograph of the square and adjacent park in Třeboň, Czech Republic, taken with a thermal camera**
The differences in temperatures between the vegetation, facades and roofs of the houses is visible.

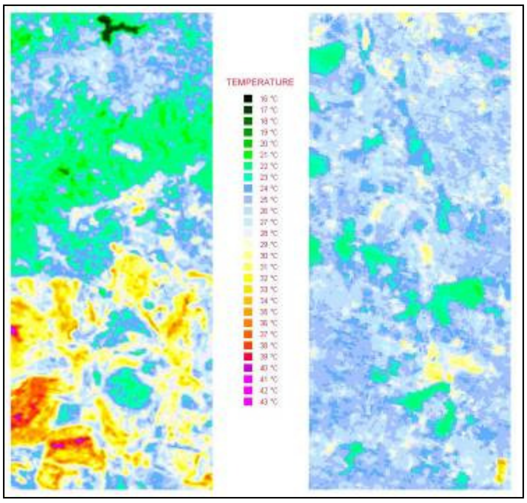


Fig. 9 **Comparison of the distribution of sensible heat in two different types of land (Mostecko and Třeboňsko)**
The pond-covered Třeboňsko with wetlands shows a lower regional temperature difference (right) than the drier land of Mostecka (a strip coal mining area), which has insufficient vegetation (left).

4 THE IMPACT OF THE EXPLOITATION OF LAND ON THE CIRCULATION OF WATER

The Slavonic countries stretch from the Mediterranean Sea through to the Northern Seas... The Slavs build most of their own castles...on meadows rich in water and bushes...they reside in the most fertile lands, rich in different means of subsistence. They till the soil very intensively to provide themselves with enough food... Famines caused by long-term drought don't exist in [their] lands. On the contrary. Famine can break out when it rains too much... If it rains only a little, they do not have poor results, because these lands are damp...

Ibrahim Ibn Jacqub at-Turtushi, *About the Western Slavs,* middle of the 10th century [21]

During the whole of its history, humanity has reshaped natural land into civilized land. The land thus obtains a cultural memory of individual civilizations, nations and generations. This memory is expressed distinctively in the attitude of people towards water. No civilization has ever trivialized the significance nor the need for water. Few, however, have known how to adequately assess the consequences of their own behaviour and create a method for reshaping the land in order to conserve water in the environment and ensure its long-term abundance. From the perspective of shaping a land through human activity and attitude towards water, we will now consider forested land, agricultural and urban lands, as well as the bodies of water in them.

4.1 Forests

Deforestation in prehistory

Deforestation is not a new phenomenon in human history and has probably been going on since the time mankind started using fire. As people began to live by hunting, fire could serve as an aid for scaring up animals or for obtaining new living space or hunting grounds. With the development of pasturage and agriculture, deforestation served as a way of obtaining new land for these activities. With the development of the settled way of life, and even more, after the replacement of the stone axe by the bronze one, wood became a material with multipurpose uses: for building, for the production of working tools, weapons or boats and last but not least, as an accessible fuel for burning, whether for heating, cooking or for metalwork.

Deforestation in antiquity

The negative consequences of deforestation in the form of erosion and flooding affected the oldest known civilizations, which consumed a great deal of wood. The oldest works of classical literature, such as the *Epic of Gilgamesh* and the Bible, as well as ancient authors such as Herodotus, Plato, Pliny, Strabo and others, all reflect these processes. Today it is difficult to believe that

[21] Cited from the book: *Slovakia through the Eyes of Foreigners, Sources of History of Slovakia and Slovaks II*. Literary Information Center, Bratislava, 1999, pg. 242

great areas of the Middle East were, in the 3rd century before Christ, covered by thick cedar forests. They were, however, so devastated that Emperor Hadrian at the beginning of the 2nd century had to issue an order forbidding their felling. Wood from them was used largely in massive building projects and for construction of Phoenician boats. Prior to the development of agriculture, oak, beech, cedar and pine all grew in the Mediterranean region. Now, though, only the cultivated olive, which ranks among the most drought-resistant trees because its roots can reach up to 10 metres deep, remains. Some contemporary authors ultimately consider deforestation, with its consequent degradation of the environment and loss of productivity of the land, as the reason for the fall of the Roman Empire. A similar situation to the one in the Mediterranean and Middle East also arose in Afghanistan and in Central Asia. Civilization in the Indus Valley collapsed after deforestation around the year 1400 BC.[22]

Deforestation as the expansion of civilization

Europe to the north of the Roman Empire was almost entirely covered with thick forest, a fact that aroused astonishment and fear in the Romans. The impenetrably thick forests were in their eyes home to dangerous wild animals, inscrutable barbarians and goblins and were full of swamps and other unknown dangers. To the Romans' imagination, the forests became the exact opposite of civilized life in the town or the peaceful peasant life in the fertile flood plains of rivers. The expansion of civilization, therefore, became identified with deforestation. This idea, supported by economic arguments, persisted even after the fall of the Western Roman Empire and was present during the formation of Europe during the Middle Ages.[23]

The abundance of forests from the time of the old Slavs

According to preserved scraps of information, the old Slavs, prior to the acceptance of Christianity, envisaged the world as a gigantic tree. On top of this tree lived Perun, the god of thunder and lightning, as well as weather. In many Slavic lands Perun was the highest of the gods and his worship was geographically the most widespread. We can only speculate whether the saturation of the small water cycle, accompanied by frequent local showers thanks to the gigantic retention of water of the forested land, was the result of the fact that Perun was placed on the highest point in the Slavonic pagan pantheon. In any case, Perun's opposite and most serious antagonist was, according to Slavonic mythology, the god Veles, who resided in the underground regions around the roots of the world tree and was associated with water, earth and dampness. From observation of the rising mist from the forests, the image obviously emerged from our ancestors that Perun and Veles stole one another's water (and the sun). At the time of the arrival of Christian missionaries Saints Cyril and Method to the territory of Great Moravia in 9th Century, forest covered about three-quarters of the territory of today's Central Europe.

Deforestation in the modern age

Deforestation, which was in Europe most intensive in the first half of the last millennium and in the USA from the 17th to the 20th centuries,

[22] J. Pokorný, *The Development of the Land Under the Influence of Humans*, 2003
[23] Felipe Fernandez-Armesto, *Civilizations – Culture, Ambition and the Transformation of Nature*, Simon & Schuster, ISBN 0-7432-0248-1, 2002

reached its peak in many developed countries in the 20th century. The overall global rate of deforestation of continents is at present, according to data from the FAO, more than 120,000 km^2 per year. The total extent of deforestation of the continents is significantly higher than the natural growth of new and native forests (with the exception of Europe and the USA, where this trend has been stopped). A lowering in the quality of forest vegetation is, for many reasons, also occurring. Old-growth/primeval forests, which likewise face deforestation and the primacy of economic interests, have a special role in the world's ecosystem. Deforestation of land and the lowering of the quality of forest vegetation is accompanied by an increase in the speed of the runoff of rainwater and water from melting snow in the given areas, as well as the rapid erosion of soil. The microclimatic conditions of areas are also changing.[24] These phenomena, which have led to the decline or extinction of numerous great civilizations in the past, are as a consequence of the expanding technical possibilities of humanity today present throughout the entire world.

Plato, in his unfinished work *Critias*, wrote about a war between the residents of Atlantis and Athens-led inhabitants of the continent which had supposedly taken place 9000 years prior to Plato's discussion. Alongside the idealized description of fabled Atlantis there is in the work such a rudely and realistically captured process of water erosion following the devastation of the forests around Athens that one can't help getting the impression that Plato wrote about something he was seeing with his own eyes:

"…The land was the best in the world… in those days the country was fair as now and yielded far more abundant produce… Many great deluges have taken place during the 9000 years...and during all this time and through so many changes, there has never been any considerable accumulation of the soil coming down from the mountains, as in other places, but the earth has fallen away all round and sunk out of sight. What happened is like a body growing thin to the bone as a consequence of an illness. All the richer and softer parts of the soil have fallen away, and there remains the mere skeleton of the land. But in the primitive state of the country, its mountains were high hills covered with soil, and the plains, as were full of rich earth. There was abundance of wood in the mountains. Of this the last traces still remain. Although some of the mountains now only afford sustenance to bees, not so very long ago there were still to be seen roofs of timber cut from trees growing there, which were of a size sufficient to cover the largest houses; and there were many other high trees, cultivated by man and bearing abundance of food for cattle. Moreover, the land reaped the benefit of the annual rainfall, not as now losing the water which flows off the bare earth into the sea, but, having an abundant supply in all places, and receiving it into herself and treasuring it up in the close clay soil, it let off into the hollows the streams which it absorbed from the heights, providing everywhere abundant fountains and rivers, of which there may still be observed sacred memorials in places where fountains once existed; and this proves the truth of what I am saying…"

[24] See, for example, Eneas Salati, Carlos A. Nobre, Possible climatic impacts of tropical deforestation, Climatic Change, Volume 19, Numbers 1 – 2 / September, 1991

4.2 Agricultural land

Neolithic revolution

One of the most important revolutions in human history was the change from the hunter-gatherer way of life to a life of agriculture and pasturage. The impetus for this changeover was clearly a global warming of the climate after the end of the Ice Age. We can observe that, approximately 10,000 years ago in the Middle East (the region of the so-called "Fertile Crescent", that is, the lands from the mouth of the Euphrates through the valley of the Jordan up to the mouth of the Nile), China and sooner or later in other parts of the world, a more or less spontaneous move towards the cultivation of agricultural crops and the rearing of domestic animals took place. Alluvial agriculture in the valleys of great rivers gradually put a seal on the first great centers of civiliation, which were usually distinguished by a high level of organization, a network of irrigation and drainage canals, large-scale agricultural production maximizing the utilization of the soil and cultivation of a small number of crops which were not natural to the given land, i.e. crops which without the help of humans would not thrive.[25] This Neolithic revolution, which from the viewpoint of the whole of human existence took place not so very long ago, gradually created through the ensuring of a food base the conditions for a whole range of civilizational changes such as greater population density, the establishing of larger population centers, a division of labor, trade, the development of knowledge and so on.

Cultivation of cereal grains

Some edible seeds of grasses proved to be exceptionally suitable for agricultural cultivation. Besides advantages such as rapid growth and simple cultivation, they above all provided valuable sources of energy and could be stored easily. They became the basis for cultivation of grains which were to become the most widespread crop for human nutrition. In Europe, but also in many other parts of the world in the temperate climate zone, the cultivation of wheat and barley, which we can assume were the first such domesticated crops, has dominated since the times of the Neolithic revolution. These have retained the traits of the annual steppe grasses from which they were cultivated and therefore require steppe-like conditions to grow. The soil for their cultivation therefore has to be drained of water.

Climate change

For their cultivation of grains, people drained agricultural land and over huge areas created a cultured steppe. With the change in the character of the land, the climate also changed,[26] and where land had been drained of water, it became necessary to irrigate it again. Today we don’t know the reasons for the drying of the climate over great regions and which occurred many times over in the first half of the Holocene period. We cannot even exactly determine whether and possibly what share ancient civilizations had in them.[27] We don't know whether the draining of

[25] Felipe Fernandez-Armesto, *Civilizations – Culture, Ambition and the Transformation of Nature*, pg.174

[26] Virginia H. Dale, "The Relationship Between Land-Use Change and Climate Change," Ecological Applications, 1996, pgs. 753 – 769

[27] J.A. Dearing, "Climate-Human-Environment Interactions: Resolving Our Past," Cim. Past, 187 – 203, 2006

land was the primary reason for the extinction of some of these civilizations. We should, however, keep this possibility in mind, because despite all the differences, we are probably arriving at a similar process of the dehydrating of land, a process which has results that we cannot know.[28]

Fate of the Sumerians

The intensive cultivation of barley and wheat expanded from the Fertile Crescent to a wider world. Possibly the final act of their cultivation was written by the "discoverers of agriculture," i.e. the Sumerians, who lived in southern Mesopotamia from the 4th to the early 2nd millennia before Christ. The exceptionally successful nation of the Sumerians intensively cultivated, over great areas of land, monocultures of the mentioned crops along with other produce. Using a system of canals, they brought water from the Euphrates and Tigris rivers, and using a system of drainage canals, carried it away. The soil, despoiled of natural vegetation and subjected to an annual cycle of irrigation and drainage, became salty and stopped producing yields. The power of the Sumerians waned, their numbers decreased, the country became a desert and they were overcome by enemies and ultimately assimilated. Other great civilizations founded on alluvial agriculture underwent a similar fate to that of the Sumerians of Mesopotamia. In many of them we can witness over a period of two to four thousand years a further decrease in levels of rainfall and subsequently the civilization's extinction or transformation.

Further revolutions in agriculture

The Middle Ages contributed to the development of agriculture, for example by introducing the yoke, which allowed for deeper plowing and a change from dual crop rotation to triple crop rotation. Another revolutionary change brought in a new age of agriculture: a boom in natural and artificial fertilizers, pesticides, specially bred plants which achieve much higher yields, as well as a growth of mechanization which allowed for the tilling of much larger areas than in the past. The Green revolution in the middle of the 20th century spread the technology used in the West across almost the entire world and helped feed the rapidly growing number of people on the Earth. The Red revolution in socialist countries collectivized the small fields of small peasant farmers, plowed over boundaries and united plots of land into units of scores, even hundreds of hectares. Gigantic fields with no natural barriers, field zones or protected bands of vegetation limiting surface runoff from the land, were presented as great leaps forward *(Fig. 10)*. With the goal of maximizing the hectare yields of cultivated monocultures or disposable tracts, extensive drainage using gravitation systems or pumping stations was carried out. Additional irrigation of these fields is no substitute for the need to conserve rainwater on the land, although it partially contributes to the return of the water drained from the land.

Erosion, degradation and the carrying away of soil

Thus, alongside the changes in microclimatic conditions *(Fig. 11)* on such agricultural land, the speed of the surface runoff of rainwater also increased, as did the water-caused erosion associated with the destruction and displacement of soil *(Tab. 4)*, which led to the

[28] See, for example, Deepak K. Ray et al., "Influence of Land Use on the Regional Climate of Southwest Australia," 13th Symposium on Global Change and Climate Variations and 16th Conference on Hydrology, 2002 (http://ams.confex.com/ams/pdfpapers/29880.pdf)

degradation of the quality and even the devastation of the land and the emergence of desolate ground. Of the mentioned processes, the most serious phenomenon is the displacement (loss) of soil. It seems, however, that the displacement of soil in our country is among the least monitored of phenomena and that pedologists lag behind in research just as hydrologists lag behind in the monitoring of the decrease in water on the land. And thus, there is no one to cause any commotion. While the creation of soil is tallied up in the hundredth or even thousandths of millimetres annually, erosion runs rampant at a rate many times greater.

Soil erosion in Slovakia

In Slovakia the real loss of soil through water erosion runs on average in the forested vegetation of the middle to upper mountain regions at about 0.01-0.03 mm/year, in permanent grasslands at around 0.06 mm/year, in cereal fields at 1.8 mm/year, on bare ground above the tree line at 3.4 mm/year and in root crop fields up to 3.6 mm/year.[29] This means that in many regions of Slovakia we lose precious agricultural soil which has been formed over centuries or even millennia. In view of the fact that soil is so slowly created, it can be considered as a non-renewable resource. It can thus be said that we are living off our very foundations.

Potential loss of soil

The urgency of measures needed to combat water-caused erosion become still more urgent with the view of potential (possible) water-caused erosion of the soil. This involves erosion which would occur naturally on the surface of the soil if it were not protected by vegetation even without anti-erosion measures. The average intensity of such possible erosion represents in Slovakia 2.3 mm each year (23 m^3 of soil per hectare per year). Water erosion of moderately, strongly and extremely threatened agricultural soil in Slovakia represents 55.6% of all agricultural land in the national land fund. Moderately, strongly or very strongly to catastrophically threatened forested land comprises up to 97.1% of all forested land in the fund (*Tab. 5*).[30] From the comparison of data about real and potential water-caused erosion in forests, it becomes imperative to maintain forestation to the extent that conditions allow. A further conclusion should be the need for urgent forestation, particularly of desolate lands, which would allow for the fulfilling of the anti-erosion and hydric functions of the forest on them.

[29] Rudolf MIDRIAK, "From Threats of Erosion to the Desolation of the Soil in Slovakia," Third Soil Science Days in the SR, VÚPOP Bratislava, 2004, p. 193 – 200
[30] ibid.

Tab. 4 Actual water-caused erosion of agricultural soil[31]

Level of erosion	**Linkeš, et al. (1997)** (thous. ha)	**Environment Ministry SR (2002)** (% PPF)
Low erosion	1 198	47
Moderate erosion	514	22
High erosion	49	2
Extremely high erosion	24	1
Total	1 785 thous. ha (73.1 % PPF)	72% PPF

Tab. 5 Erosion threatening soil according to the type of land in Slovakia under the influence of surface runoff of water (potential water erosion)[32]

Threat of erosion (degree)	**Intensity of potential erosion (bearing away) of soil**	**Agricultural land**		**Forested land**		**Total**	
	(mm per year)	(thous. ha)	(%)	(thous. ha)	(%)	(thous. ha)	(%)
1. minute	up to 0.05	107	3.4	3	0.0	110	2.2
2. weak	0.06 – 0.50	1 296	41.7	117	6.6	1 413	28.9
3. moderate	0.51 – 1.50	823	26.5	333	18.7	1 156	23.6
4. strong	1.51 – 5.00	783	25.2	1 075	60.3	1 858	38.0
5. very strong	5.01 – 15.00	100	3.2	255	14.4	355	7.3
6. catastrophic	over 15.00	1	0.0	1	0.0	2	0.0
Average / total	2.30	3 110	63.5	1 784	36.5	4 894	100.0

"More things have changed in the memories of the oldest living people in our country today than in the previous one thousand years. In our time, in the past 75 years, it is businesses that purport to improve our lives which are responsible for these changes. They are draining the soil and in so doing, damaging its chemical solutions. The fact that fens, old branches of rivers, swamps and high places on uplands are all being drained of water is contibuting to a change in our climate, with a greater contrast between severe winters and summers with fewer clouds and isolated periods of drought and flooding. The fact that these improvements allow the peasants to plough up any pasturage and drained bottomland, means that layers of topsoil are being uncovered and washed away, with no new topsoil being created in its place."

Vladimír Úlehla,[33] 1947

[31] Rudolf MIDRIAK, "From Threats of Erosion to the Desolation of the Soil in Slovakia."
[32] ibid.
[33] Cited from the publication Míchal I. *Ecological Stability*. Veronica, Brno, 1994, s. 200

4.3 Bodies of water

Hydraulic civilizations

As was mentioned in the previous chapter, the greatest human civilizations which led humanity out of the Stone Age into antiquity originated along the Nile, the Euphrates and Tigris, the Indus, the Yellow Rivers and others. These civilizations are sometimes called "hydraulic civilizations,"[34] because their alluvial agriculture depended on watercourses and extensive networks of canals, which besides the function of transportation, had the particular task of bringing and taking away water during regular annual floods. Surface water was a key for irrigation, coming once each year and taking the place of missing rainwater.

Initially other conditions here

These civilizations were thus, from a climatic-agricultural point of view, completely different from that of our ancestors after their arrival in Central Europe, where, thanks to a high degree of forestation, rain fell frequently. The ability of the land to retain water was furthermore so high, that according to testimony of the Spanish trader Ibrahim Ibn Jacqub at-Turtushi from the middle of the 10th century, even in those cases, *"if it rains only a little, they do not have poor results, because these lands are damp."* For a view of the countryside in our area, we can, to a certain extent, form an image from period landscape paintings hanging in galleries. Landscapes from the 19th century show a wealth of surface water in unregulated rivers gushing out into wide riverbeds, their lush plant life suggesting a living communication with the groundwater. If Romanticism was to come back into fashion today, it would struggle to find similar scenery to depict.

Pressure for the altering of watercourses

In the time of expansion of agricultural development, settlements and industrial sites moved nearer to watercourses, a fact which led to a fear of flooding. Along with this came the need for agriculture to expand cultivated areas. During the development of transportation it was necessary to crisscross flows of water. The need to use water currents more intensively for transportation purposes also arose, hence the need to start making alterations and regulations of rivers *(Fig. 12)*. The alteration of water flows usually entailed shortening their total length (many naturally blindly meander), reinforcing the banks and the bottoms of watercourses and raising levees alongside them. Many adjacent fens and swamps which were connected with river ecosystems were also drained. Many bottomlands which had once served for the meandering of watercourses or for the spillage of water outside of riverbeds during increased periods of rainfall were built over, and the original body of water was now given a precisely determined place and cross-section profile. We should add to this that often the problem of flood protection has been misunderstood, the mere raising of banks or protective levees and the deepening or enlarging of the watercourse's cross-section profile for better drainage of flood waves in a given community not always being the solutions they seem. This is because the performing of such alterations without judging the context of the entire river basin and territory only raises the risk of floods in communities and towns which are located further downstream.

[34] According to the book by Karl A. Wittfogela *Oriental Despotism* (1957).

The primary negative effect of the mentioned modifications was the acceleration of the runoff of water from the land and the lowering of the land's ability to retain water. The mentioned "civilizational" alterations of watercourses contributed to a gradual decrease in the amount of water in the water cycle and disproportionately decreased the relative head start our country had in comparison with others, which were not blessed with such favourable climatic conditions and an abundance of water. In the end, large waterworks like dams, which in the recent past were built for the utilization of water energy, the transformation of flood waves or the creation of reserves of drinking water, are according to research paradoxically less effective from the viewpoint of conserving water on land than a large number of smaller reservoirs with the same total volume.[35]

Acceleration of runoff of water from land

4.4 Towns

As we have already mentioned, one of the most important revolutions in human history was the Neolithic agricultural revolution. In both significance and time this is followed by the urban revolution. The emergence of towns and city states is one of the milestones in the transition from prehistoric to historic times for humanity. We know of towns like the biblical Jericho (and some others) whose existence goes right back to prehistoric times. However, cities with all the attributes that differentiate them from mere settlements, not only in their number of citizens but also in the organization of life (for example, keeping written records about its administration), date, according to current knowledge, from the times of the Sumerians in the period from 3100 to 2900 BC in lower Mesopotamia. Almost at the same time, towns began to emerge in Egypt and in the valley of the River Indus. Many authors give the need for a high level of organization arising from the challenge of implementing alluvial agriculture as one of the reasons for the emergence of cities in the so-called "cradles of civilization." The detailed reasons for the emergence of ancient cities, their attributes and the cause of their extinction are not subjects for this publication to address, however.

The urban revolution

Cities enormously speeded up the development of civilization—both for good and for bad. At this time let us briefly focus our attention on an exceptional achievement which emerged during the first urban revolution and which was destined later to make a return: the sewerage system. The ancient towns of Harappa, Mohenjo-daro and Rakhigarhi in the Indus valley (present day Pakistan) are the first known cities in the world to build a city sewerage system, and they did so 2600 years before Christ. The sewerage system was covered, walled, bordered the streets and was connected to private homes and public buildings, and last but not least, to baths and flushing toilets. The overwhelming majority of countries in the world had to wait until the second urban revolution, practically until our own times, for their own systems.

The achievement of sewerage

[35] Brad Lancaster, *Rainwater Harvesting for Drylands, Vol. I.*, Rainsource Press, Tucson, Arizona, ISBN 0-9772464-0-X, 2006

History sometimes repeats itself, but according to Heraclitus we can never step into the same river twice. The second urban revolution is associated with an industrial revolution. The start of the industrial revolution, the end of slavery and serfdom as well as the development of a market environment, allowed the free movement of people and enabled a more dynamic movement of the workforce. This period of growth and economic prosperity was also the beginning of new global growth in the world population, which since the year 1800 has grown six-fold to today's population of more than 6 billion people. It was also a period of migration from villages to towns, of an increase in the share of people living in cities versus villages, as well as a shift in the mentality and values of people from the village to the city—sometimes for good and sometimes for bad. This process, which lasted a long time in Western Europe and in North America, is especially visible in the second half of the 19th century. In Slovakia, the process of urbanization with all its attendant attributes began about 100 years later and occurred more intensively, de facto within the life of one generation. The percentage of urban dwellers between 1960 and 1990 in Slovakia increased from 30% to 56% (where it approximately remains today), but did not reach the same levels as in Western Europe.

The second urban revolution

The details of the second, or even the third urban revolution, associated with urban decentralization and with the emergence of post-industrial society, are not the subject of this publication, but we want to again focus on sewerage. Our modern cities, and increasingly our villages, too, unlike the cities of the old Sumerians, have their own sewerage systems *(Fig. 13)*. Furthermore, unlike the old cities from the Indus valley, other cities of antiquity, the Middle Ages and the larger part of modern times, our modern cities and more and more villages, are paved and their surfaces are reinforced with impermeable materials.[36] The development of technology allowed for the invention of ingenious and powerful building machines and mechanisms which were able to shape the surface of the land for the construction of buildings, roads and other requirements of modern life more quickly than at any time in the past. The mass use of cement and asphalt began to predominate in the building of cities and the transformation of rural environments into urban ones *(Fig. 14, 15)*. The shortage of space and the need for comfort caused rainfall over cities or urban spaces to be perceived as a kind of burden. So, rainwater began to be perceived more as wastewater, which is carried away by public sewerage, in most cases along with sewage water.

Impermeable surfaces and the sluicing away of water

So now nearly all rainwater from the cities of Europe is carried to rivers and eventually to the seas from paved and roofed areas by rainwater sewers. According to estimates, more than 20 billion m^3 of rainwater are sluiced away each year from the European continent. Over the past 50 years, then, more than 1000 billion m^3—that is, 1000 km^3—of rainwater, which in the past saturated the ecosystem and soil, filled out the stocks of groundwater,

Giant volumes of water sluiced away

[36] Sid Perkins, "Paved Paradise? Impervious Surfaces Affect a Region's Hydrology, Ecosystems – Even its Climate," *Science News*, week of Sept. 4, 2004; Vol. 166, No. 10 , p. 152

replenished springs and through its evaporation, moistened the climate, has been sluiced away from the European continent. Last but not least, the rapid runoff from paved urban environments with sewerage systems contributes to the higher occurrences of flooding threatening populations downstream. The most serious fact, however, is that, for a long time, we have been draining the environment in which we live. We are causing a long-term drop in groundwater supplies beneath our paved and roofed surfaces; we are causing a growth in temperatures in city structures, a fall in atmospheric humidity, a start of civilizational diseases typical for urban environments and a worsening of the quality of our environment as a whole.

The dissipation of water in towns

Added to the multiple effects of cities, it is also necessary to consider the drawing of water from the ground for the purposes of drinking and other functions, all of which have a great cumulative effect. This drawing of water goes on without ensuring the adequate return of water gained from territory back into the land. The water instead runs out into the sea after use. Cities which profligately and expensively let millions of cubic metres of rainwater flow into their sewerage systems will later face worsening shortages of drinking and utility water, shortages which in many cases will become chronic. Insufficient drinking water is thus not only a problem of poor but also of prosperous cities. Obviously, cities in developing countries have their own particularities. The poorer parts of cities in many developing countries are permanently dependent on wood for uses such as fuel and thus the forests in their surroundings are systematically cut down.

Change of climatic conditions

Drainage and deforestation lead to the fact that towns, while growing, change the microclimatic conditions of the original territory. They are becoming urban hot islands over which a hot climatic umbrella is growing (*Fig. 16*). These "islands" are slowly but surely changing the flow of clouds and the movement of winds over their territory and in their surroundings. Particularly in the summer, they push precipitation to the cooler mountain regions, which consequently increases the risk of extreme torrential rains in the mountain regions and floods which threaten mountain valleys as well as populations in the lowlands downstream on rivers. And here we have a much more direct and logical cause for climate changes and the rising extremes of weather than the impact of a 30 percent growth in the fractional content of CO_2 in the air over the past 150 years.

Water management is unsustainable

More than half of the Earth’s inhabitants live today in cities, a share of the population which will continue to grow significantly. Cities have become a kind of new-age factory of economic prosperity which slowly and gradually absorb their surroundings.[37] Thus mankind, through developing land for agriculture and other human activities, has now "claimed for itself" more than 40% of the area of all continents. It's necessary to emphasize that a solution for the problems mentioned in this text exists and that population growth in itself is not in conflict with permanently sustainable development. Instead, what is in conflict with permanently sustainable development is the present method of managing water on land.

[37] Urban Sprawl in Europe - The Ignored Challenge, ISBN 92-9167-887-2, EEA Report No. 10/2006

Fig. 10 **Agricultural land beneath the Tatra Mountains**
Giant fields that originated during communist era with the collectivizing of tracts of land. Due to the absence of barriers, rapid surface runoff causes water erosion of the soil.

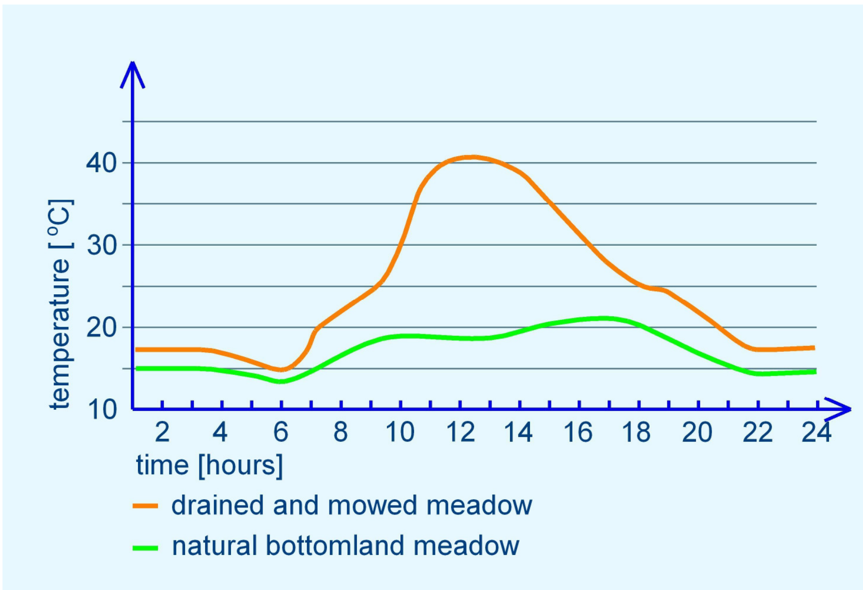


Fig. 11 **The daily course of temperatures on the surface of soil on a drained and mowed meadow and on a natural bottomland meadow**

Fig. 12 **Alteration of the Latorica River in the 1960s**
This was a component of the program of drainage of the eastern Slovakia lowlands.[38]

Fig. 13 **The sluicing away rainwater**
The original aim of owners was to achieve "dryness and warmth". The fulfilling of this goal is beginning to get out of control.

[38] *Slovakia – Encyclopaedia*, Published by Veda, 1972

Fig. 14 **Gigantic areas covered with impermeable materials**
On sunny days they become "hot islands" which transform most solar energy into sensible heat.

Fig. 15 **An asphalt road and a perfectly paved canal in a city environment**
Some solutions don't allow even the smallest amount of water to infiltrate the soil.

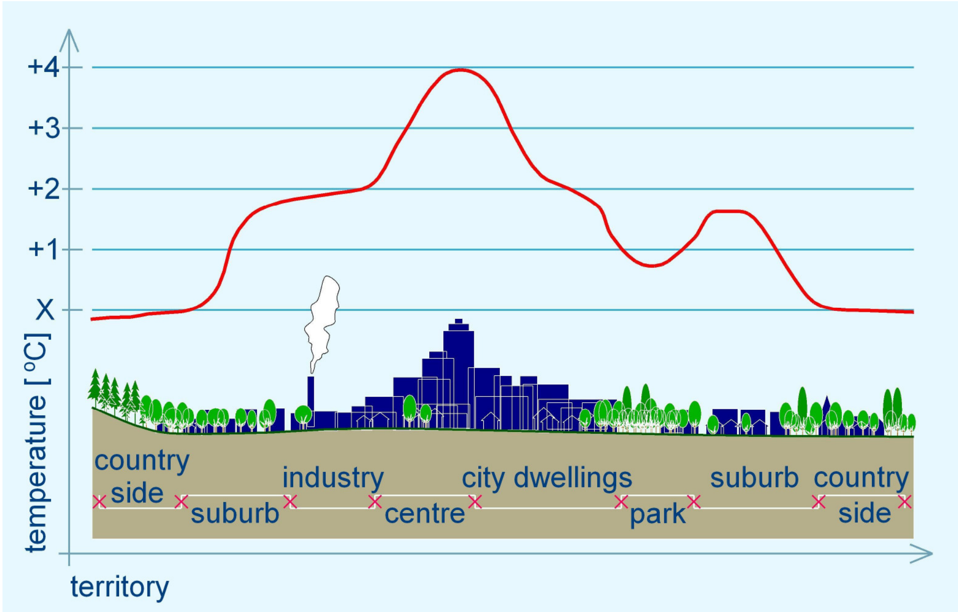


Fig. 16 **The hot climatic umbrella of an urban space**
Temperature depends on the relation between a built up area and area covered by vegetation.

5 THE CONSEQUENCES OF A DECREASE IN THE WATER OF THE SMALL WATER CYCLE

There is nothing in the world more soft and weak than water, and yet for attacking things that are firm and strong there is nothing that can take precedence over it. Everyone in the world knows that the soft overcomes the hard and the weak the strong,but no one is able to carry it out in practice…

Lao-tzu, The Tao-te Ching, LXXVIII

The acceleration of the runoff of rainwater from a territory, the decrease in the infiltration of water into the soil and a shortage of vegetation all cause a warming to the surface of the land and a gradual change in the microclimatic conditions of the territory involved. This section is dedicated to the mechanism through which growing temperature differences cause extreme weather events even on areas of land (almost) untouched by human activity. Along with the melting of glaciers caused by global warming, the acceleration of the runoff of water from an area and the draining of land also contribute to the rising levels of the world's oceans. At the end of the chapter, we take note of the growth of global tension resulting from the deficiency of water in the small water cycle and the inability of popular theories to provide satisfactory explanations and solutions.

5.1 The impact of the decrease in the water of the small water cycle on the growth of climate extremes

The damaging transformation of land

In the previous sections we spoke about how the transforming of a natural landscape into a developed one speeds up the runoff of rainwater from a territory. The intensity of the sluicing of rainwater away from the continents varies from place to place and is dependent on population density, the area and structure of the relevant agricultural and urban land, but above all on the sensitivity of its management. It's possible to say that alterations to the land always cause damage when the decrease in water needed for vegetation, evaporation and infiltration to the transformed territory is not taken into consideration. This decrease in water from the small water cycle is directly associated with the rise in extreme weather and with climate changes.

The spiral of the drying out of land

One particularity of the decrease in water is that however small it is, it is expressed almost immediately in the saturation of the topsoil with water, because it runs from the top parts of the soil profile, or the level of groundwater, down to the impermeable subsoil. Lowering the saturation of topsoil with water lowers the ability of the land to evaporate water and increases the share of solar energy which is immediately changed into sensible heat. The more drained (and at the same time also hardened) the soil, the more difficult it is for it to absorb new rainwater upon further precipitation, while built up areas automatically carry away rainwater from a territory as fast as possible. Drained soil warms up and creates thermal islands, which slightly shift precipitation activity away from their own area. Each further turn in the water cycle affected by these factors slightly decreases the volume of water in the water cycle over the relevant territory *(Fig. 17)*. With long-term observation, however, we can see a permanent and systematic decrease in the water balance of the observed territory (in the course of a century, this represents several percent). Such an incremental, but systematic reshaping of the Earth's surface has a global character. A synergetic effect emerges and microprocesses grow into macroprocesses which lead to a clearly discernible, vast and continuous deepening of regional, continental and global climatic changes.

Natural regions also affected

Original natural regions, or cooler and damper regions and territories, today represent a more stable part of the environment of the continents. Despite this fact, even they cannot avoid changes in precipitation totals and extreme displays of weather. How is this possible? Warmer air over hot and dry urban and agricultural expanses (as with completely dry territories such as semideserts and deserts) pushes precipitation activities into cooler environments formed by woods and bodies of water, or to places of higher altitude *(Fig. 18)*. The interaction of so-called dried "hot plates" (agricultural-urban land) with cooler and damper (for example, mountain) regions causes an unprecedented concentration of cloud cover over the latter regions.[39] Water from the clouds thus falls in great measure on the cooler (mountain) regions *(Fig. 19)*, where it initiates tragic flood waves. Floods then affect the lower agricultural-urban regions despite the fact that in these regions it only rains a little.

The interaction of warm land and cool land

During the 20th century, total precipitation increased in the mountain regions of Slovakia, while in the lowland regions, it fell (*Fig. 20*). Furthermore, the time period when the majority of rain falls has become shorter and the periods of low precipitation totals have lengthened[40] (*Fig. 22, 23*). This effect of the interaction of warmer and cooler territories also functions on a smaller scale, for example, in the interaction of a city and its surroundings, as well as on a larger—even continental—scale: the level of annual rainfall in northern Europe in the 20th century, according to observations, increased by 10-40% while in the Mediterranean region it fell by 20%.[41] The occurrence of extreme heat waves and intensive showers increased over most of the landmass, and it is very likely that this trend will continue.

[39] See, for example, Roger A. Pielke Sr., "Influence of the Spatial Distribution of Vegetation and Soils on the Prediction of Cumulus Convective Rainfall," American Geophysical Union, Reviews of Geophysics, 39, 2 / May 2001, s. 151–177

[40] For analysis of these trends in Slovakia, see: *M. Kravčík, Water for the Third Millennium: Let us Not Harm Water, and It Will not Harm Us*. Košice, People and Water, NGO. ISBN 80-968031-3-1, 2000

[41] "Climate Change 2007: The Physical Science Basis – Summary for Policymakers," 10th Session of Working Group I of the IPCC, Paris, February 2007

Growth of extreme weather

The growth of extreme weather is the most destructive manifestation of the climate changes currently taking place and sharply contrasts with the long-balanced original climate conditions in the region. Breakdowns in weather are expressed through sudden changes in weather and often through the violent character of these changes. Extreme storms, torrential rains and cyclones are occurring more often, temporal and spatial differences in rainfall are changing, [42] and periods of unbearable heat and severe drought are getting longer. Regions which are the most drained are also the most affected by extreme weather events. Examples of flooding in the Danube *(Fig. 21)* but also the Morava, Tisa and Prut rivers confirm this fact. Paradoxically, the incidence of more destructive and more frequent flooding is preventing people from realizing that their country is undergoing a process of desertification. This is a great mistake. Some of the ancient stories of humanity, such as the Sumerian-Akkadian *Epic of Gilgamesh* or the Old Testament of the Bible, come from those countries of the Fertile Crescent which underwent desertification, and reflect the theme of a deluged world. This reflection must have had its basis in real experience.

Dry soil helps runoff

It is also paradoxical that soil partially saturated with water is capable of better absorbing more water than dried out soil. If precipitation falls on compacted and dried out soil, infiltration to deeper layers occurs only after a period of ten minutes or more. In the first minutes, however, the soil behaves like an impermeable surface. During extreme rains, there is a rapid runoff and concentration of rainwater to river beds. This same rainfall, which would be easily absorbed in land healthily saturated with water, in a drained land changes streams and creeks into fast-flowing rivers, causing extreme flow rates and flood situations. This means that a surface with no ability to evaporate water creates not only favorable conditions for the origin of extreme weather, but also exacerbates the effects of such weather.

The transformation of land into desert

Long-term drought initiates a spiral of desertification, namely the transformation of land into semidesert or desert. Within the context of this publication, deserts and semideserts can be understood as fully dried-out parts of a continent with minimal or no circulation whatsoever of water in the small water cycle. Even conventional natural landscape with vegetation and sufficient water can turn into semidesert or desert through the destruction, by human activity, of the small water cycle over the territory (this can, for example, come about through the burden of too much urban development, too much intensive farming or the excessive raising of cattle and consequent overgrazing).[43] This fate possibly afflicted even the coastal regions of hundreds of towns in northern Africa, which was once the granary of the Roman Empire. This gradual process of transforming once natural landscape with vegetation and sufficient water resources into completely

[42] P. Faško, J. Pecho, K. Mikulová, P. Šťastný, "Instances of high daily, monthly and seasonal amounts of atmospheric precipitaion in East Slovakia at the end of the 20th century and the beginning of the 21st century in the context of historical data." Collected contributions from the international conference Protection from Flooding. Podbanské, 2006, pgs. 153 –158

[43] Richard van Noorden , More plants make more rain, Satellite observations suggest vegetation encourages rainfall in Africa; www.nature.com, September 25, 2006

arid land can also be called the conversion of a land into semidesert or, in extreme cases, desert.

Consequences of extreme manifestations of weather

The consequences of extreme manifestations of weather are frequent forest fires, floods, degradation and erosion of soil, landslides and various ecological and other catastrophes *(Fig. 24 and 25*), threatening the life and health of people and causing vast economic damage. With the recurrence of these manifestations of weather comes a gradual and permanent lowering of the competitiveness of the land, which is evident in practical terms by, for example, the fact that insurance companies refuse to insure property in such affected localities and the banking sector limits loans and guarantees for projects on these territories. Floods, drought, tornadoes and other extreme weather events are a syndrome of land which has been exploited and inhabited by human beings with today's approach to surface water and rainwater.

5.2 The impact of the decrease in the water of the small water cycle on rising ocean levels

Speed of rising ocean levels

In the past, when the water cycle was still unknown, people posited the question of how it was possible that the levels of the seas and oceans did not rise when all the rivers in the world constantly flowed into them. Today, when the water cycle is known and hydrological measurements show that the levels of the seas and oceans are rising, it's as if it hasn't occurred to anyone that the reason for this phenomenon might also be in the rivers that flow into them *(Fig. 26).* The rising levels of the oceans are attributed to the melting of icebergs because of global warming. Individual information sources diverge regarding the degree of the rise of ocean levels during the 20th century, but the majority suggest an amount of 10 centimetres or more, meaning an average of about 1 millimetre per year. At the start of the 20th century, the speed of rising levels was in all probability less than 1 mm per year; at the end of the 20th century, however, it was significantly more than 1 mm per year. At present, the rate at which the seas are rising is up to 2.4 mm per year.[44]

Water stored in icebergs and glaciers

The process of monitoring icebergs and glaciers is a logical one given the fact they contain so much water, water contained in permanent ice and snow making up about 1.7% of the world's stocks of water and nearly 70% of the world's stocks of fresh water. The extent of glaciation throughout history has logically corresponded with temperatures on Earth, this fact also being responsible for fluctuations in ocean levels. The level of the world's ocean at the peak of the last Ice Age, 20,000 years ago, was about 125 meters lower than it is today. Most ice today can be found in Antarctica, accounting for nearly 90% of the world's ice that is stored on land in icebergs. The ice in Greenland accounts for about 10%. The

[44] Source: NASA, http://sealevel.jpl.nasa.gov/gallery/presentations/public-presentation/03-GP-science-apps.ppt#19

melting of all glaciers found in Antarctica and Greenland would, according to calculations, cause the world's oceans to rise by 60-80 meters, while the melting of icebergs on all other lands would contribute only about half a meter to such a rise. The melting of ice of non-terrestrial origin (for instance in the Arctic Ocean) which floats on the ocean, on the contrary, does not increase sea levels. The Archimedian principle applies here: just as in the case of a free-floating ice cube in a cup full of liquid.

Balance of icebergs

For the stability of glaciers the same thing is important as for the stability of hydrological ratios within a country: a stable water balance. In the case of glaciers this involves a balance between accumulation, particularly through the impact of falling snow, and reduction, particularly through the influence of melting and sublimation. Unfortunately, a more complex glacial balance is studied in (smaller) glaciers away from the more inaccessible territories of Greenland and Antarctica. The majority of these actually record larger or smaller decreases in volume. As for Greenland and Antarctica, the images the public have of them are formed especially under the influence of popular and emotional scenes promoted in the media showing icesheets breaking off and shattering in areas around the oceans. Such footage is usually made from the edges of ice-shelves which are most easily accessible to the media and to expeditionary parties. Often, though, the reason for ice-shelves breaking off is interpreted incorrectly. The breaking off of icesheets from the edges of continental glaciers directly extending into the oceans and seas and the cracking of non-terrestrial icebergs are often mechanical in origin, e.g. with constant fluctuations in (rising) sea levels caused by tidal ebb and flow contributing to this process.

Terrestrial glaciers

Research conducted on glaciers in Antarctica and Greenland, however, show that inland the thickness of the ice is, in fact, permanently growing, because in the environment of permafrost snow piles up and never melts. Data about the balance of glaciers in Antarctica and in Greenland are not unambiguous. In recent times, however, Greenland looks to show a decrease in total balance of ice.[45] It is logical that the present trend of warming continents will lead to a rapid decrease, for example, in glaciers in the Alps, which are surrounded by the "hot plates" of Europe’s industrial regions. Glacier water in this case becomes a component of runoff and ends up in the seas, thus contributing (partially) to their rising levels.

Drainage of land and the rise of ocean levels

A further logical explanation of the rising levels of the oceans, besides the increase of runoff from glaciers, is the increase in the runoff of water from land of non-glacial origin and its subsequent storing in the oceans. While the runoff from melting icebergs is almost unanimously accepted as an explanation for rising ocean levels, any explanation that points to a decrease in the amount of water on land is met with great prejudice and intellectual opposition. And yet a small, hardly noticeable increase of roughly 1% in the annual

[45] See, for example, "Greenland's Ice Melt Grew by 250 Percent, Satellites Show," *National Geographic*, September 20, 2006, http://news.nationalgeographic.com/news/2006/09/060920-greenland-ice.html

runoff to the oceans (in comparison the equilibrium balance) through rivers would, to the detriment of groundwater, soil moistness and the growth of vegetation, represent a volume of water that over 100 years would increase the volume of the oceans by about 36,146 km³ of water (ignoring the increased evaporation from ocean levels as a result of rising temperatures, thermal expansion of water, etc.), an increase which would account for a rise in their levels of about 10 cm.

Missing water on land

Levels may have increased by even more centimeters during the cultural history of humanity thanks to the water which numerous civilizations lost from their own territory: water from the European climax forest logged over the past thousand years or water which in the time of the Roman Empire irrigated cities and fields in a coastal strip of Northern Africa. If someone denies that this water is in the oceans, then he should be able to say where else it actually is. One thing is certain: in the overwhelming majority of cases the amount of water on land "civilized" by humanity is not the same as it once was. At the moment we don't know what share of water involved in the rise in ocean levels is of glacial and non-glacial origin. It is thus a responsibility of the scientific community to start dealing more seriously with the question of land water of non-glacial origin and its effect on rising sea levels. It is, after all, water missing from land and not from icebergs which we feel the absence of more.

5.3 The impact of the decrease in the water of the small water cycle on the rise in global tension

Slovakia as illustrative of the problems

During the 20th century the annual average air temperature in Slovakia rose by about 1.1 °C (even more in winter). Meanwhile, the average annual sum of precipitation fell by 5.6% (in the southern plains the fall was more than 10%; in the mountainous north there was a rise of 3% during the century). Also, a significant decline in relative air humidity was recorded (up to 5%). Characteristics of potential and actual evaporation, soil moistness, global radiation and the radiation balance all confirm that south Slovakia is gradually drying out (potential evapotranspiration grows and soil moistness falls).[46] Spatial concentration in the fall of precipitation is accompanied by a concentration in the time division of this precipitation, i.e. periods of "drought" are lengthening and the timeframe in which the majority of precipitation falls is getting shorter. Flood waves arise, extending into the warmed lowland regions where it almost never rains. Little Slovakia, even though it in no way ranks among the most problematic countries in the world in terms of the problems outlined here and the subsequent damage they cause, can be seen as an example illustrating the typical hydrological problems of the modern world.

[46] "Fourth National Report of the SR on climate change and the Report on achieving progress for fulfilling of the Kyoto Protocol." Slovak Republic, Ministry of the Environment of the SR, Slovak Hydrometeorological Institute, Bratislava, 2005

The United Nations' predictions for the climate and circulation of the world's water in the 21st century are at best worrying and at worst catastrophic: "Global warming may already be with us, but the much greater warming forecast for the 21st century will produce vast changes in evaporation and precipitation, allied to a more unpredictable hydrological cycle. Higher air temperatures will increase evaporation from the world's oceans, intensifying the water cycle. They will also mean faster evaporation of water from land, so that less rainfall reaches rivers. These changes will be accompanied by new rainfall patterns and more extreme weather events, including floods and droughts."[47] This climate shift in which the influence of the large water cycle starts to dominate the small water cycle is just one of the UN's gallery of horrors. Along with predictions that dry regions of the world will in the future be even drier and wet regions still wetter, their list of threats ends with the statement that in the unpredictable world of the future, one thing which is predictable is a growth in the number of countries with water shortages.

The prognosis of further worsening of the climate

Direct personal consumption of water for drinking and hygiene is relatively small and can be counted in dozens of litres per person per day. The amount of water needed for turning out the daily ration of food per person, however, can be measured in thousands of litres and is increasing. The consumption of water in industry in the 20th century also had a tendency to grow. The availability of 1700 m^3 water per person annually is defined as the basic level for satisfying the combined needs of people, agriculture, industry and the environment. In view of this, we can consider a volume between 1700 and 1000 m^3 of water available per person annually as a state of stress and a volume of under 1000 m^3 as an insufficient amount of water. Countries with less than 500 m^3 of water per person annually are considered to be countries with a catastrophic shortage of water. Such countries are, for example, Somalia or the territory of Palestine, which have access to only about 320 m^3 per person annually. At present an estimated 700 million people in 43 countries around the world live in a state of water stress. These are particularly centered in the Middle East and in Sub-Saharan Africa.

Consumption and the need for water

With the current tendency of cities to grow, a growth in both personal and industrial consumption of water can be anticipated. At the same time a growth in the need for water for the production of food in the poorest developing countries can also be anticipated. Those countries with high population growth and low financial capital, already using more than 80% of their water on agriculture, will be severely affected by the increase in extreme weather. We can expect a loss of livelihood for millions of small farmers and a growth in their dependence on food from developed countries. The need for water sources is growing because the number of such sources, their volume and their quality, are all getting lower. In the face of the growing demands of people, agriculture and industry, it is usually the environment which pays, and if no change occurs, the environment will continue to pay the biggest price. According to a UN report, the number of people living in a state of water stress will have probably increased by the year 2025 to more than 3 billion, with 14 countries

Prognosis of future water needs

[47] *Human Development Report 2006*. Published for the United Nations Development Programme (UNDP) – Beyond scarcity: Power, poverty and the global water crisis

having moved from the category of "water-stressed" to the category of "water-insufficient".[48]

Absence of solutions

Some indications of the coming shortage of water are already visible today. Reports are coming from different corners of the world about catastrophic droughts, desertification or salination of the soil over vast areas, about regions with a rapid decline in groundwater levels or rivers and lakes drying up or the expansion of deserts. Increases in average or seasonal temperatures can have serious consequences on the physical and psychological health of people and bring about problems with adaptation. The scenario of adaptation is, in fact, almost the only one which international organizations have so far been able to offer the world's public. This scenario, however, merely documents a sense of resignation and admission of powerlessness in dealing with the problem. The shift of a huge number of people, populations and industry to cooler regions is also practically impossible because it would be accompanied by the irreplaceable loss of the cultural and natural heritage of the abandoned population centers and lands.

War or water?

In this atmosphere of stress, a growing number of authors are repeating the words of the previous Secretary General of the U.N., Boutros Boutros-Ghali, that the wars of the 21st century will be wars over water. Water has already begun being used as a de facto weapon of political pressure between states, last but not least on the territory of what used to be Mesopotamia. The Turkish GAP project (a development project for southeast Anatolia) is counting on the construction of 21 dams and 19 hydroelectric plants on the Euphrates and Tigris rivers. This massive exploitation of their waters and the waters from their tributaries for intensive agriculture over gigantic areas should increase the number and volume of harvests each year, the agricultural products of which will be largely sold as exports. But Syria and Iraq, lying further downstream, both seriously fear the possibility of being blackmailed and threatened with lower amounts (as has already happened) and lower quality (higher salinity) of water. And the situation is not helped by the statements of some Turkish representatives who say that just as it wouldn't occur to them to make claims on crude oil whose sources are in Iraq, so Iraq can make no claims on water which originates in Turkey.

Pessimistic views

Pessimists on the question of wars over water recall the account from the year 2450 before Christ about just such a war between two Sumerian city states, Lagash and Umma, in the lower Mesopotamian valley. Optimists point to the fact that even though water, as almost everything in the world, has often been the subject of internal battles and armed conflicts, except for the case mentioned, there are no other known interstate armed conflicts in history in which supplies of water would be considered a strategic and not "merely" a tactical goal. It's good to be an optimist, even though it is often cynically argued that an optimist is merely a badly informed pessimist, but in the case of potential supplies of water in the 21st century both groups are inclined to agree that the prospects are gloomy, with more dangers on the horizon than promised solutions.

[48] ibid.

***Tab.6* Possible indicators of the reasons and the consequences of a decrease in the water of the small water cycle**

– trend in fall of minimal flow rates in watercourses – trend in growth of extreme flow rates (flood waves) in watercourses
– trend in long-term decrease of precipitation in a drained area, – space and time changes in distribution of precipitation in an area – trend in growth of extreme precipitation and storm activities
– trend in long-term rise in ocean levels – trend in long-term decline in groundwater levels
– trend in fall of soil moistness – trend in fall in volume of groundwater reserves – expanding of drained territories, semideserts and deserts
– growth in the number of populations with worsening access to drinking and utility water – fall in the biodiversity of a territory – rise in ecosystem imbalances
– overheated territory and expanding areas of "hot urban and agricultural plates" – trend in growth in temperature differences between hot plates and preserved natural areas with vegetation cover – trend in expanding of built-up areas, impermeable surfaces, surface coverings of buildings and other built-up spaces
– shortening the length of watercourses (by alteration of flows, cutting off tributaries) – trend in fall in the percentage of bodies of water (lakes, ponds and other water surfaces within villages or outside of villages) and wetland areas (marshlands) from the total area of a country – trend in growth of drained areas (by buildings and hard surfaces) –trend in fall of forested areas
– growth in the number of insurance events and the volume of paid-out insurance for natural disasters and for damages caused by extreme weather and their results

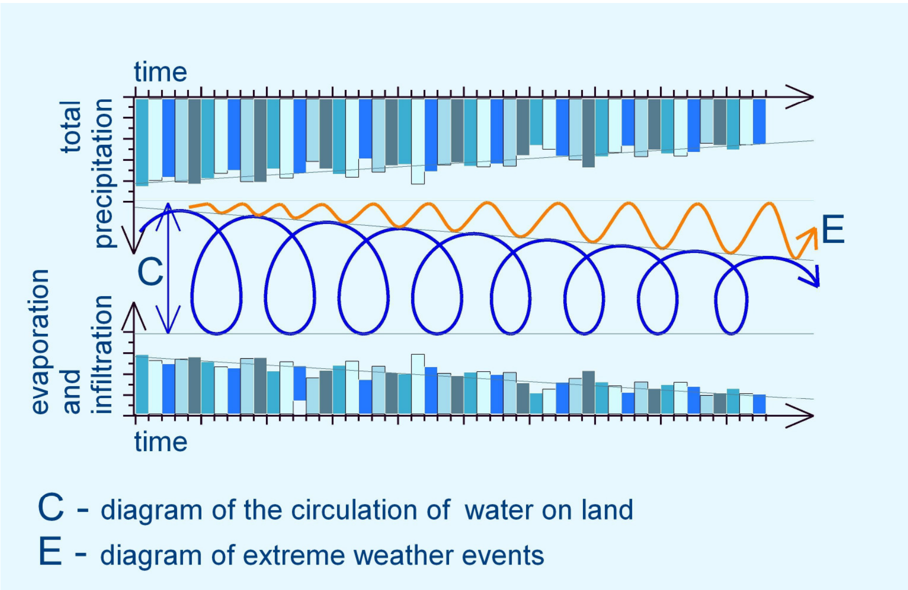


***Fig. 17* The growth of extreme weather with the decrease of water in the small water cycle**

With a decrease of water in the system, temperature differences arise which cause different types of extreme weather.

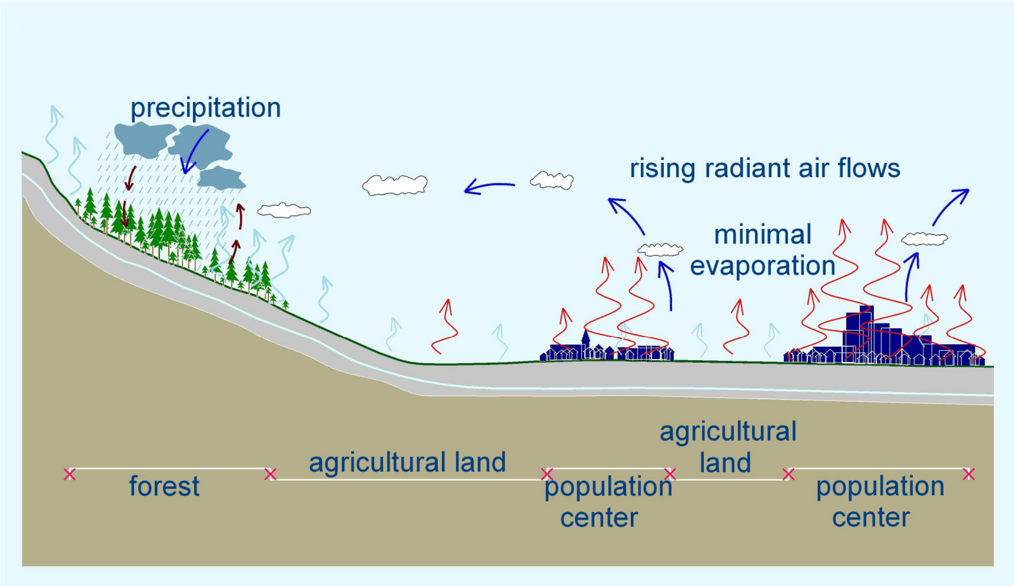


Fig. 18 **The impact of the transformation of land on the destruction of small water cycles**
Rising radiant flows push clouds to cooler environments.

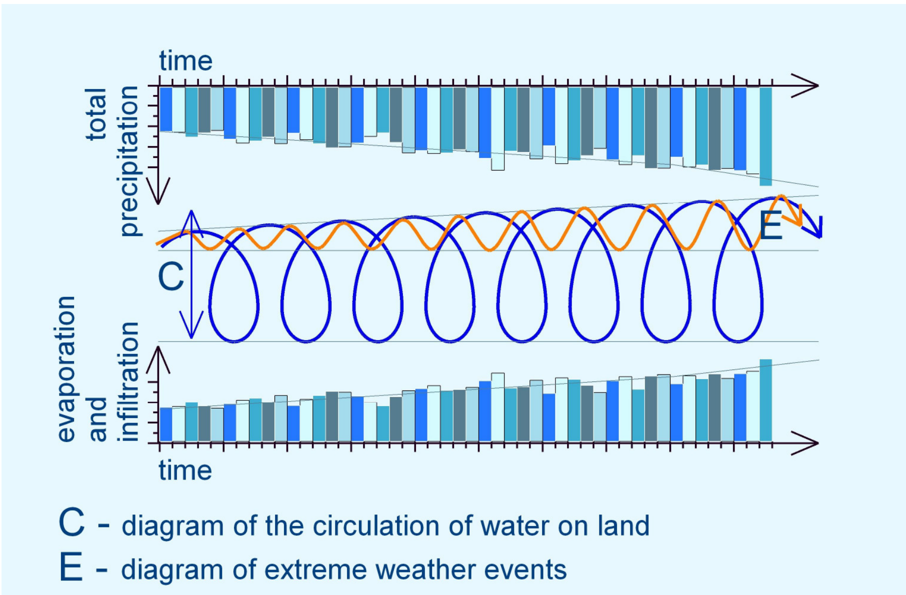


Fig. 19 **The growth of weather extremes in damper and cooler environments – the concentration of precipitation forcing it from dryer lands**

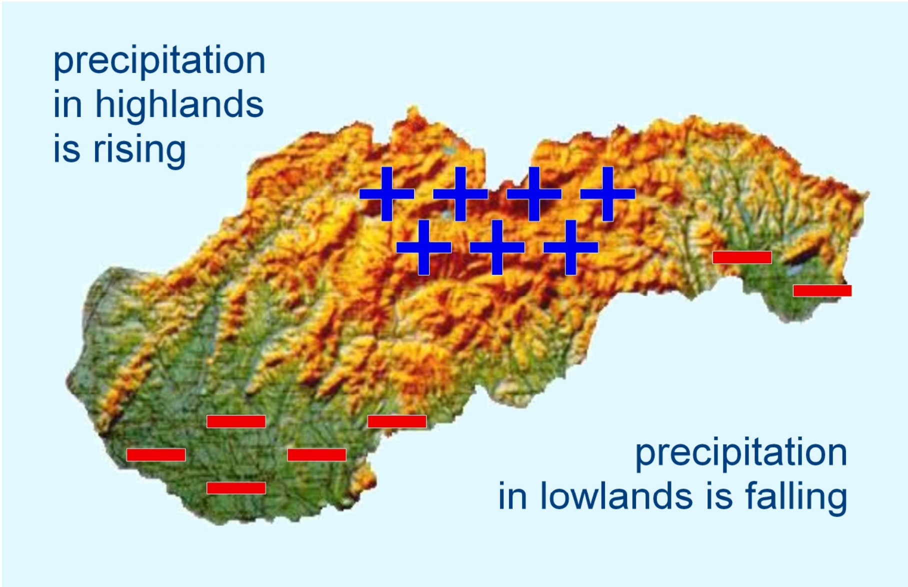


Fig. 20 **The growth of precipitation in mountainous northern regions and the decrease of precipitation in southern lowlands – Slovakia used as an example**

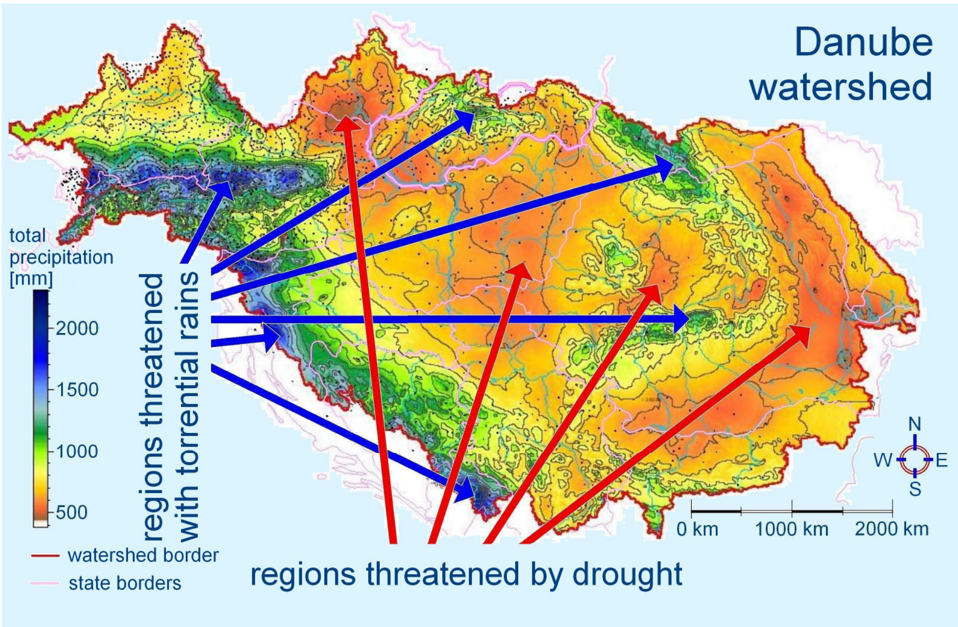


Fig. 21 **The rise in precipitation in mountainous regions and the decrease of precipitation lowlands – Danube watershed**

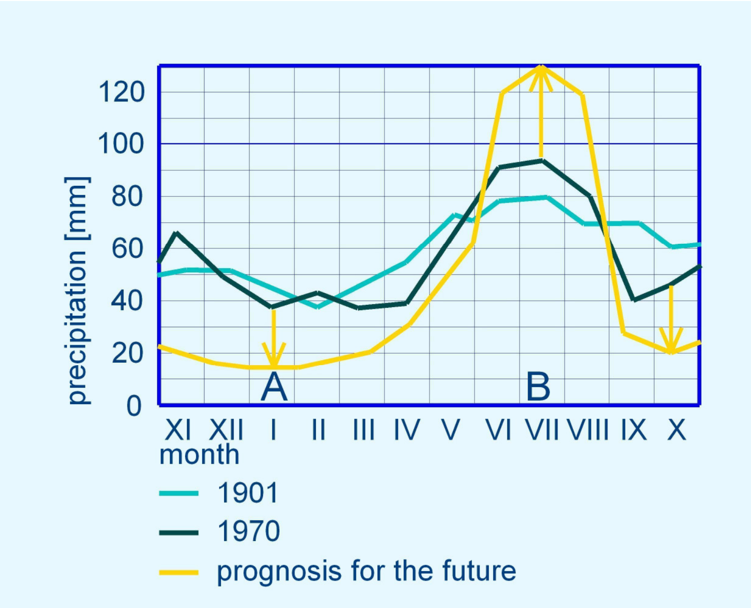


Fig. 22 **Precipitation trends in Slovakia**
Periods of "drought" are lengthening (A) and the time period in which most precipitation falls is getting shorter (B).

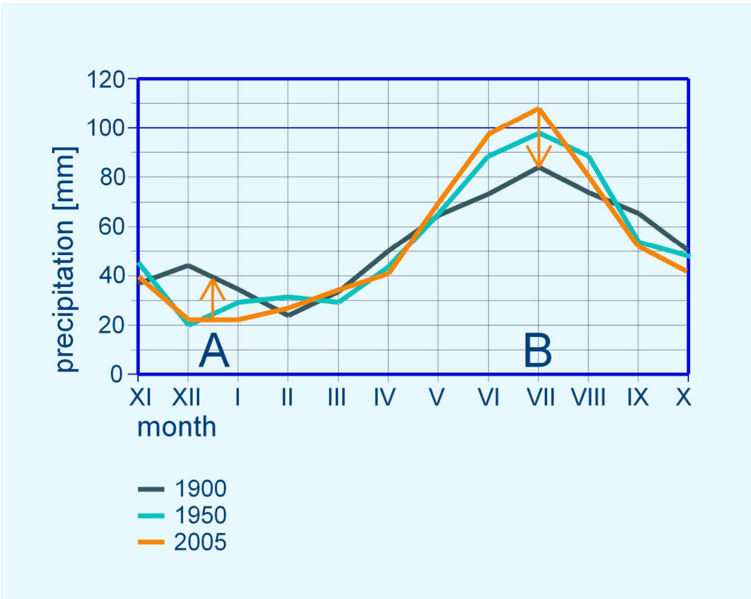


Fig. 23 **Average annual precipitation totals in Prešov**
Resembles the average trend throughout Slovakia.

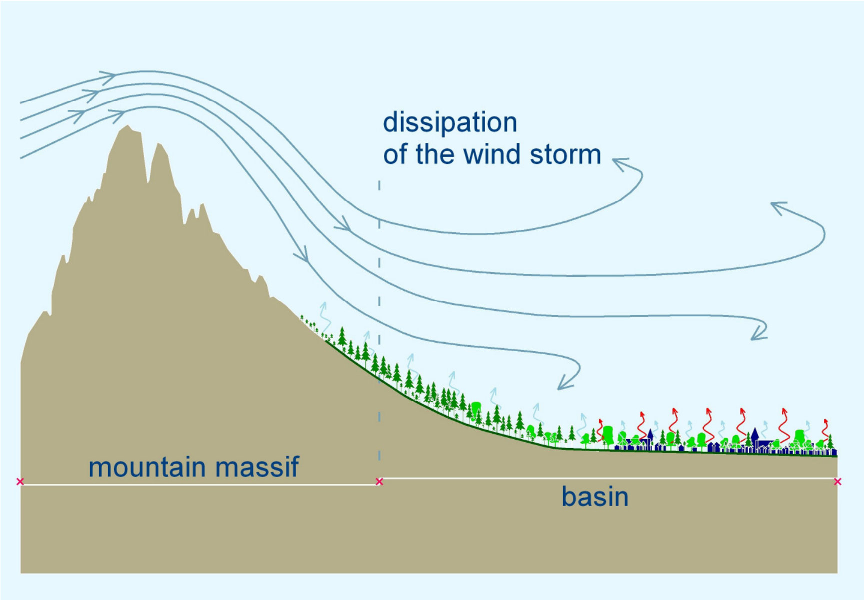


Fig. 24 **The incursion of cold air to the High Tatras regions (the Tatra bora) - the assumed state around the year 1800**
The conditions of the land under the mountains allowed for the gentle dissipation of the currents.

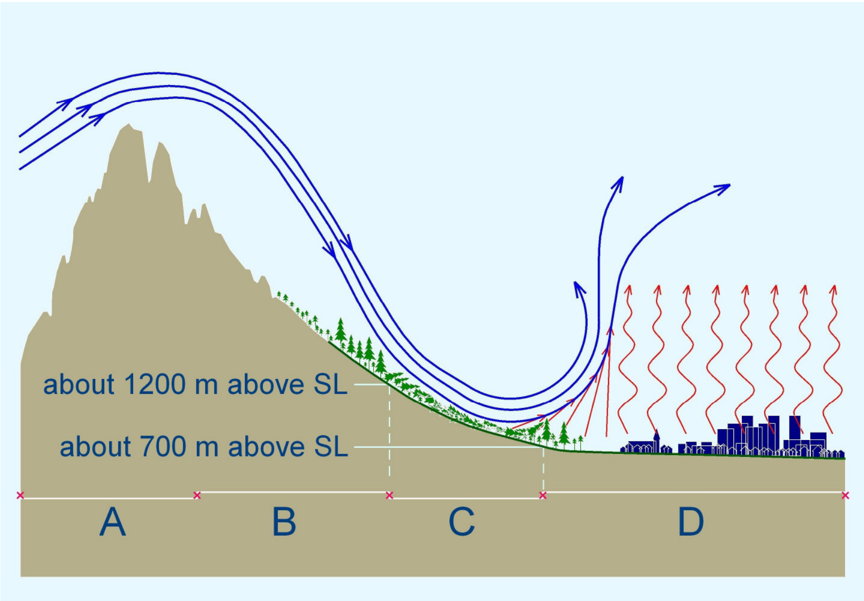


Fig. 25 **Wind storm in the High Tatra mountains, Slovakia, November 19, 2004**
Radiant flows of warmed currents from agricultural-urban areas (zone D) accelerated air currents with the rapidly falling cold front through the ridge of the High Tatra mountains: v(A) 150 – 200 km/h, v(B) < 100 km/h; v(C) 200 – 250 km/h, v(D) < 150 km/h.

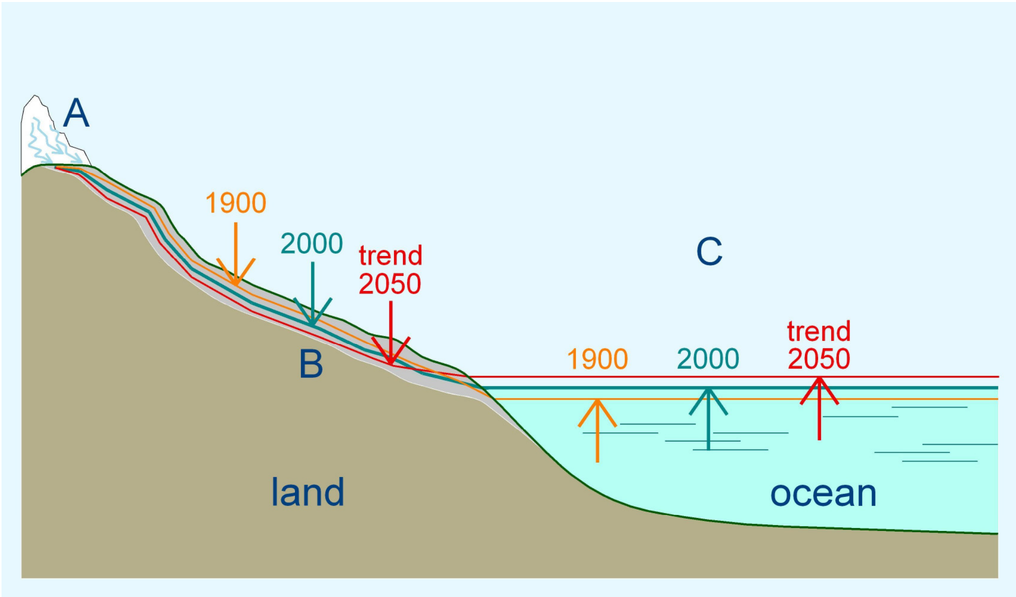


Fig. 26 **The impact of glaciers melting (A) and the decline in the reserves of water on the continents (B) on rising ocean levels (C)**

6 THE OLD AND THE NEW WATER PARADIGM

Hath the rain a father? or who hath begotten the drops of dew?

The Bible, Job 38:28

For in the wilderness shall waters break out, and streams in the desert, and the parched ground shall become a pool,and the thirsty land springs of water...

The Bible, Isaiah 35:6-7

Philosophers, historians and thinkers diverge in many things in regard to the modern age in Europe, but concur in the fact that it has been characterized by a strong emphasis on rational thinking and scientific knowledge. The reality of the problems associated with the lack of what until recently seemed to be a ubiquitous, commonplace substance—water—has challenged this rather self-important and arrogant modern age approach. From a careful critique of the old perception of the water question, we will present in this chapter a new attitude to water which respects its value and function in the environment much more.

6.1 The old water paradigm

Faith in science and progress

Above all, the modern age is characterized by the conviction that human understanding can solve all our problems and that science and technology inevitably lead to continuous progress and to an ever happier and better world. Two world wars and many other wars in the 20th century, as well as the Holocaust, the atomic bomb, the emergence of totalitarian regimes, the share of science in the development of destructive weapons, industrial ecological catastrophes and many other factors have, however, undermined this faith in science and in inevitable progress to the point that many thinkers even consider the years 1965-1975 as the beginning of a skeptical, post-modern period in which some people believe that evolution can also go backwards, or move in cycles or spirals.

Humanity changes the course of nature

We can clearly see a reflection of the originally Biblical and, in the 20th century, a strongly secularized mind of the type: "man, lord of all creatures, is changing the course of nature" in the management of water. Hardly anyone in countries possessing sufficient water supplies ever considered the possibility of a future shortage of water. Occasional voices calling for responsibility in the management of water were often lost in the optimism founded on the seeming omnipotence of scientific and technological solutions. Engineering solutions were able to carry water over great distances when necessary.

Great waterworks, which aside from the usual functions of waterworks, also had energy-generating functions and served as anti-flood protection, were built for the accumulation of water. Water in the land and the soil was seen more of a handicap, so wetlands were drained, river flows straightened and meanders and dead-end tributaries removed in order to gain more agricultural land. Watercourses were channeled so that water could be sluiced away as fast as possible. Boundaries were plowed and hydromorphic land elements were removed in order to obtain the largest contiguous areas, which seemed at the time, to be a synonym for modern mass-production. The drainage of land was aimed at expanding areas, increasing profits from certain xerophilous cereals and achieving self-sufficiency in the production of bread. If necessary, there was plenty of surface water available for irrigation.

The seeming victory over nature

Rainwater in cities suffered the same fate as water in the countryside. Standing water or mud in cities were considered as signs of a lower culture. Therefore, as many open areas as possible were covered in concrete, and rainwater that fell on them and on roofs was carried away by sewers to the nearest stream. All water for residents was generously supplied as drinking water, without any consideration of the fact that only a small part of it would actually be used for consumption. Water was utilized once only and after purification, sent to the seas. The supplying of water from ducts and the sewage systems of cities and villages were certainly and rightfully given credit for their successful part in the suppressing of many infectious diseases, hence the strategic goal to expand these facilities to as many of the population as possible. This way of perceiving and handling water enjoyed great successes and for developing countries became a model of order and civilization to achieve, expanding particularly in countries with a relatively abundant supply of water.

The first great failures

The "old paradigm" is more tradition and actual practice than a unified, articulated theory. Despite this fact, as a background of thought it really exists and is reflected in textbooks and in practice. It once promised peace, safety and prosperity. With the passage of time, however, we can now say that this promise has not been fulfilled. If we were to search for a textbook example of the failure of engineering approaches to the management of water in the modern age, we would probably find the most drastic example in the former Soviet Union. The Communist regime in that country fancied itself, in a certain sense, to be the perfect embodiment of "rationalism" of the modern age, and the catastrophe of the inland Aral Sea, even though not all aspects of it are typical, can be considered an epitome of the arrogant handling of water in the second half of the 20th century. Some 3500 years of inhabited fertile land between the water-rich Amu Darya and Syr Darya rivers ended in ecological catastrophe after just 30 years of profligate plundering of water for irrigation: the partial drying out of the sea and the rivers, the destruction of their ecosystems, the rapid lowering of biodiversity (fish no longer live in the Aral Sea) and the total desertification of the region culminating in winds now spreading salt and pesticides from the bare seafloor all across the region. For the most part, the dried up Aral Sea has stopped moderating the differences of temperatures between winter and summer. With the growth of temperature differences, the speed of the winds has increased, as has the intensity of local dust storms.

The degradation of the environment has gone hand in hand with the economic decline of the area and a long list of related health problems amongst approximately 3 million inhabitants in the immediate area and 35 million inhabitants in the broader regions around the sea.

The cracks warning of the fall of a construction

But the insensitive handling with water is not only a problem of Central Asia. Here in Europe we know it more as human activity in the areas of forest and water management and agricultural and urban zones, activity which derives from the philosophy of getting rid of water from watersheds as quickly as possible. We've already mentioned some of its consequences in this publication. Lowering the ability of watersheds to retain water has the effect of emptying the small water cycle in nature, causing a decline in soil moisture and a fall in groundwater levels, as well as a warming of the whole local area. In mountains and foothill regions, fields without natural barriers to prevent the runoff of rainwater are an ideal setting for soil erosion and the occurrence of local flooding. Other negative results are the rapid aggradation of reservoirs, the lowering of groundwater reserves, a fall in the minimal flow rates in rainwater deficit periods and the growing trend in the culmination of flood flow rates. Water managers no longer even try to disguise the fact that if the extreme claims on the state budget the measures they have suggested were actually provided, the situation would not improve, or would only improve only a little. More and more our cities are being converted into dried-up "hot islands" where people suffer allergies to dust and pollen and where, in the summer heat, elderly people die of heart attacks. Cities, whose locations were once selected with an eye on their rich sources of water, now go to extreme lengths to transport and purify water from great distances and at the same time as sluicing away all the rainwater that falls on their own heads.

The growth of weather extremes

Meteorological observations demonstrate that 11 of the past 12 years (1995-2006) are among the 12 warmest years on record in terms of the average temperature of the Earth's surface. Global warming, according to the main current of contemporary science, will not stop, however, even centuries after the elimination of its apparent causes, these being emissions of CO_2 and other greenhouse gases from human activity, gases which cause an increase in the effects of solar radiation in the atmosphere. And associated with increasing temperatures of the atmosphere and the oceans is a proportionate increase in the content of water vapor in the atmosphere (for each degree Celsius of this increase, the air can theoretically absorb about 7% more water vapor). This causes numerous long-lasting climatic changes of regional and continental significance. The occurrence of extreme heat waves and intensive showers increased over most of the landmass, and it is very likely that this trend will continue.[49] Serious dry spells (droughts) have affected vast regions of Europe, Asia, Canada, western and southern Africa and eastern Australia. The number of heavy floods (100-200 year floods) also increased significantly during the second half of the 20th century.[50]

[49] "Climate Change 2007: The Physical Science Basis – Summary for Policymakers." 10th Session of Working Group I of the IPCC, Paris, February 2007

[50] CRS Report for Congress, *Climate Change: Science and Policy Implications.* Order Code RL33849,

Global warming as the chief enemy

The scientific knowledge on which the modern age once relied nowadays spreads more fear of the future than hope for solutions. Contemporary science blames global warming for most of the above mentioned, and many other, negative trends. The growing extremes of climate are, in its eyes, a subset, if not a direct synonym, of global warming, which will likely intensify in this century. And yet the period between the 9th and 13th century, which was markedly warmer than the 20th century, appears to have been the best in Europe from today's climatic-historical point of view. Vineyards were cultivated on a commercial basis 300 to 500 kilometers north of the limits of their cultivation in the 20th century, and the Vikings settled Greenland. This was above all, however, a period of unprecedented climatic stability, only occasionally disrupted by extreme weather events. This climatic "golden age" allowed for a great economic boom, the building of cathedrals as well as further expansion of agriculture with accompanying deforestation. On the other hand, the cooling period we long for today brought Europe, in the time of its Little Ice Age (with certain departures, from the 14th to the mid-19th century), high instability in the weather accompanied by poor harvests, poverty, famine and other misfortunes.[51] The growth in climatic extremes are thus not identical with global warming, nor is the stabilization of the climate necessarily dependent on its cooling.

Trends in scientific research

It is astounding, then, that while scientific publications and conferences emphasize the impacts of global warming on the circulation of water in nature, almost all of them are totally silent on the influence the water cycle has on climatic changes. The fascination with CO_2 is so great, though, that it even dominates the relatively small number of scientific articles which are concerned with the relationship between vegetation and the climate. The mechanism by which heat in water vapor is given off in the upper part of the troposphere is, like the effects of clouds on the thermal balance of the Earth, under-researched.[52] What excites the interest of scientists is the albedo, i.e. the proportion of reflected solar radiation in relation to the total falling on Earth. Here vegetation falls into disfavor, because it absorbs more (reflects less) solar radiation than soil cleared of vegetation.[53] It's logical that, given the current state of knowledge, many scientists are missing among those who argue for the watering and forestation of continents, even though they rarely speak openly about this. They don't, however, have another formula for rescuing the planet, aside from the already mentioned prospect of lowering the levels of CO_2 in the atmosphere (by lowering its production in industry, not its absorption by vegetation). No wonder that in this desperate situation scientists and politicians are orienting their efforts more towards methods of adapting to the "inevitable" negative changes than towards averting them.

January 25, 2007

[51] Brian Fagan, The Little Ice Age - How Climate Made History, 1300-1850, Academia, Prague, 2007
[52] Wigley, T. M. L., V. Ramaswamy, J. R. Christy, J. R. Lanzante, C. A. Mears, B. D. Santer, C. K. Folland, Temperature Trends in the Lower Atmosphere – Understanding and Reconciling Differences, Executive Summary, A Report by the Climate Change Science Program and the Subcommittee on Global Change Research, 2006
[53] See, for example, "Trees to Offset the Carbon Footprint?" Lawrence Livermore National Laboratory, April 10, 2007, http://www.llnl.gov/PAO/news/news_releases/2007/NR-07-04-03.html

Not only in the modern age, but probably throughout all of history, people in regions abundant in water have felt as if its abundance would never come to an end. Even just a few decades ago, a shortage of water in a country like Slovakia was as hard to imagine as a sudden change in the climate. In the 20th century, however, humanity reached a degree of development that allowed it, knowingly or unknowingly, to change the water cycle to an unprecedented extent, and these changes, caused by human activities (along with many other factors) have clearly occurred and are still occurring. The old paradigm, which considered water as an eternally renewable resource, has failed, the truth being that water is only a renewable resource as long as the water cycle is functional. A new paradigm is therefore needed which will carefully protect the fragile equilibrium of this water cycle.

The need for a new paradigm

6.2 The new water paradigm

That which we have introduced in the previous chapter is not meant to be an absolute denial of everything that the old water paradigm propagated and achieved. The truth is otherwise. We know that in the history of ideas, systems that have attempted to negate everything that preceded them have turned out badly. We also know that even such a great scientist as Sir Isaac Newton once modestly stated: "If I have seen further it is only by standing on the shoulders of giants." The old water paradigm achieved exceptional effectiveness in solving immediate and particular problems of water. If it was necessary, it managed to retain water, transport it great distances, use it, purify it and carry it away. The old water paradigm is still successfully fulfilling these tasks today and would undoubtedly continue to do so even more successfully in the future. Just as Christians in the first centuries used stones from pagan temples to build their own temples, so will the emerging new water paradigm utilize many of the old achievements. The new water paradigm, however, must utilize them in a new spirit.

Merits of the old paradigm

The new water paradigm must learn from the mistakes of the old paradigm. In our opinion, among the biggest mistakes of the old paradigm is that water was perceived as an isolated entity, water's interaction in the framework of the whole ecosystem being neglected, particularly water hidden from view (water in soil, in the atmosphere, in plants). The paradigm also neglected the synergic effect of introducing even minor measures to regulate the state and circulation of water in a country. Readers who did not begin reading this publication at this chapter but who have also read the previous chapters, know what kind of measures and what impacts we have in mind. The old paradigm considers water as a fixed given renewable resource which is subordinate to deviations in the global climate, or is even its "toy," but which itself has no noticeable influence on the global climate. The circulation of water, according to the old water paradigm, was rarely influenced by human activities and if it were, then only marginally and indirectly, via the influence of other parameters which supposedly had a larger impact on the global climate

Learning from mistakes

than water. The blindness of the old paradigm to climatic impacts of water management measures is furthermore crowned by its ignorance and denial of the importance of the small water cycle. Given the current level (lack) of knowledge, we can hardly wonder that water managers and all other people who come into contact with water issues, are neglecting the importance of the water balance on all levels, manage it badly and are especially destructive in their treatment of the small water cycle.

Only a permanent balance is sustainable

In the new water paradigm, the water balance at all levels—on the territory of individual communities, within cities, in forests, on agricultural land—is the central theme. The new water paradigm warns that unlike the issue of global warming, the issue of the drying of the continents, or substantial parts of them, is receiving very little public or scientific attention. The drying and subsequent warming of the continents causes an acceleration of natural processes following a certain specific pattern and interdependance.[54] The drying is caused by urbanization with its rapid sluicing away of rainwater to the seas and oceans, by agricultural activities and by the deforestation of ever larger areas of the Earth's surface. This drying creates "hot plates" with a complete chain reaction: the warming of continents, the destabilization of the water cycle and an increase in extreme weather. This is causing extensive damage to both economies and civilization. That's why calculating, systematic monitoring, guarding and maintaining equilibrium in water balances is becoming imperative even on the city level. Thus far in its history, however, mankind has not even considered this condition for sustainable economic and civilizational growth.

Replenishing the deficit in the balance

The new paradigm, though, not only calculates the balance of water but also offers a solution for making up the deficit. We can return the lost water back to the continents by keeping rainwater on a massive scale in the places where it falls, particularly in those areas where the influence of human activity is causing a drying out. Just as the impact of human activities (as their unplanned secondary effect) can lead to a breakdown in the small water cycle, so concerted human activity can contribute to its renewal over land as well as to securing long-term stability in the water balance of a territory with sufficient water resources. If the current method of managing rainwater and surface water on land is turned around and the conservation of rainwater and surface water on land is ensured by a system of all-embracing measures for increasing the water-holding ability of an entire watershed (which are often identical with anti-erosion measures); and if only the surplus surface water is sluiced away from an area, then with each turn of the cycle there will be recovery of the small water cycle, the reserves of groundwater will gradually improve, the volume of precipitation will increase, and extreme weather events will decrease.

The principle of water cycle saturation

Mankind has used different means of rainwater harvesting and water-conservation over the millennia in order to obtain sufficient water resources. Our knowledge of their broader impact on the stabilizing of

[54] See, for example, "A new paradigm for assessing the role of agriculture in the climate system and in climate change," Roger A. Pielke Sr., Jimmy O. Adegoke, Thomas N. Chase, Curtis H. Marshall, Toshihisa Matsui, Dev Niyogi, Agricultural and Forest Meteorology 142 (2007), 234 – 254

the water cycle and climate is often primarily intuitive—it was never described from the scientific standpoint. Traditional systems for obtaining water in the 20th century were founded on the building of reservoirs in which water was collected and which served to balance the water regime of rivers. This water was subsequently used to supply the population and to serve the needs of industry and the production of energy and food. In our case, however, the goal is to collect rainwater and, wherever possible, return it to the small water cycle. The primary principle is to allow infiltration of water into the soil, its saturation and the creation of groundwater reserves as well as surface water reserves, and thereby foster the growth of vegetation, which works as a climatization valve between the soil and the atmosphere. The capacity of soil (and subsoil) is usually much higher than the volume of the largest artificial reservoirs in a country. The process of saturation of the small water cycle should be repeated so long as the hydrological regime of watersheds are out of balance. However, such measures need to be carried out on a massive scale. Leaving untreated great "hot plates" lowers the effectiveness of measures taken in their nearby surroundings and sometimes even directly threatens them. The measures that need to be taken are simple, effective and cheap but need to be implemented in the territory of each community and town. Wherever possible, all the communities in the world should get involved in this program of rainwater harvesting and conservation on the continents.

Water against water

Rainwater harvesting and the conservation of water on land has a number of aspects which on first view can appear to be paradoxical. People fearing floods can mistakenly expect that a dry country can better absorb a great amount of water than a country which is already significantly saturated with water. Experiments and experience show otherwise, however. Water flows over sun-burned land as if over impermeable plastic foil while water infiltrates into healthy soil, held firm by vegetation, as if into a sponge. What's more, moderate temperature differences on the surface of land covered with healthy vegetation do not induce the torrential type of precipitation which occurs in an overheated, dehydrated landscape. One paradox, then, is that water itself is the best protection against water.

A growing cake

Another apparent paradox is that, despite what many people might think, the method of conserving rainwater in one area does not deprive neighboring lands downstream of precious water. The difference is similar to that between a static command economy and a developing free economy. The first always divides the same small cake, and a larger piece for one means a smaller piece for the other. The second, however, divides a cake which is always growing for the benefit of all. The conservation of rainwater on land actually helps neighboring lands. The runoff of rainwater from a country is not stopped completely but is merely slowed down. In place of the sudden rain-dictated, often extremely small or extremely large flow rates, particularly from surface runoff, a much more balanced runoff, fed from groundwater, can now be passed on to one’s neighbors. Moderate rain from the small water cycle rooted in a water-saturated country moistens the cities, fields and forests of neighboring lands and thus opens up the opportunity for these places to manage water in the same way. The method of retaining rainwater on land creates cascades of watersheds (or their parts) rich in water instead of dry cascades of watersheds.

The new water paradigm means developing, utilizing and supporting overland rainwater harvesting and conserving rainwater in watersheds so that ecosystems can "produce" enough good quality water for humanity, food and nature, can purify polluted water, can reduce the risk of natural disasters like floods, droughts and fires, can stabilize the climate and strengthen biodiversity and can become a component of economically sustainable development programs. What the new water paradigm offers is promotion and support for such a culture of land use which will permanently renew water in the water cycle through saturation of the soil with rainwater. The new water paradigm means a return to a natural responsibility for the state of water in one's region, but can also bring a new dimension of solidarity and tolerance between people and communities in watersheds.

A new culture of responsibility for water

The new water paradigm brings with it a lot of exceptionally good news. The new economy of water promises that it will be able to balance the debt that arose in the past, lower the unwanted effects of this debt manifesting themselves in ever more extreme weather, stabilize the management of water and guarantee its sufficiency.[55] The continents, with harvested rainwater, will stabilize thermally and climatically and the extremes in the weather—particularly floods and drought—will be mitigated *(Fig. 27)*. Increasing the water-holding capacity of the land and harvesting precipitation in the places where it falls are themselves effective anti-flood measures. Natural disasters will obviously always occur, but excluding external factors, the level of economic and civilization damage caused by the weather will be greatly reduced. These statements also apply to the possibile revival of semideserts and deserts through rainwater (*Fig. 28, 29, 30*). With these areas we can assume an exceptionally long and difficult process, because the evaporated water, given the thermal differences, will be carried away to other regions. Nevertheless, particularly in those cases where the change was unwittingly caused by man, deliberate, carefully planned human activity can perhaps return them to their previous state. The slow and gradual revival of semideserts and deserts through rainwater, particularly in places where just a relatively short time ago civilizations blossomed, should not therefore be impossible.

The promises of a new paradigm

This thinking represents both an exciting challenge and a program of activity at the same time. Just as our ancestors attempted in their battle with nature to stake out a piece of uncultivated land and civilize it, so must we attempt to recover from the ocean the water we all have lost in the struggle, so that the efforts of our ancestors to civilize our planet were not merely in vain. We can begin with relatively small volumes of water, like collecting rainwater for the dried-out lawn in our front yards. From there we should go on to the much larger task of finding a way to regain the water which once existed on the territory of cities and which, since the times of the industrial revolution, has been running out into the oceans. The largest, and in a country like Slovakia the maximally taxing, requirement would be to recover all the water which existed in the ecosystem at the time of the climax forest that covered the

Exciting challenges

[55] See, for example, Oldřich Syrovátka, Miloslav Šír and Miroslav Tesař. "A change in the approach to land – a condition for sustainable development" (2002). Available at www.changenet.sk/ludiaavoda/sprava.stm?x=66907

land a thousand years ago. On other territories, the challenge would have to go even further; for example, we would like to return water and renew the water cycle in the Mediterranean or on the once fertile lands of the Fertile Crescent.

A parallel with financial management

It's good to be aware of the objective fact that water itself represents a financial value and adds to a country's wealth. Let's imagine, then, that a society of people living in a watershed or one of its parts, is employed in a relatively independent branch of a large company which includes all of humanity. The company deals in the appreciation of fresh water, which, in this case, we can imagine as synonymous with money. Water in living organisms will have the most value. The more water there is in living organisms, the more life, biodiversity and food there will be and the better will be the protection of all other water environments. We can compare this water in living organisms to a treasure we do not want to give up under any circumstances. Water in the soil is a deposit in a high-interest account. If there is money in the bank, the profit from it will pleasantly grow thanks to the interest rate. If, however, we fall into debt in soil moisture and we don't want to lose our treasure of water stored in living organisms, the downward spiral of taking new loans from other surrounding water to pay the interest may suddenly threaten to destroy us. The draining of the land is like living on debts. Water falling from the large water cycle is like a state subsidy. It comes for free but not regularly, often to wrong recipients and in the wrong amounts. It sometimes brings more harm than good. To rely on it is risky because today it is here but tomorrow it may not be. It is only the rainfall in the small water cycle which springs from the activities of the company, or sometimes from the activities of its other branches; often, too, it is the previous generation of company employees who, through their hard work, deserve credit for much of the profit we have today. Water in rivers is, if you like, a gift which the community higher in the watershed hands down to the communities lower on the river. The society which acts as the bearer of such a gift should not try to plunder it, but should pass it down in a fit and cared-for state.

The growth of extremes is worse than warming

The new water paradigm promises more to reduce extreme weather than to stop global warming altogether, even though the evaporation of water into the atmosphere would cool the local climate. There are two reason for this. Despite the great space the media offers to popular theories about the alleged causes of global warming, these causes have not been sufficiently researched with respect to present or past climate changes, nor with respect to the influence of humanity and other influences. The second reason is that we perceive the increasingly extreme weather and climate in territories with insufficient water as a much greater threat to humanity than global warming. The fact that some mechanisms in the balance of energy flows are not explained yet means we cannot prescribe a formula for global cooling. However, it in no way changes our assertion that a saturated water cycle is a planet’s cooling mechanism. Rainwater kept in ecosystems cools the surface of the Earth through evaporation; vegetation greatly helps moderate temperatures and optimize evaporation; clouds create shadows which stabilize the temperature of the Earth's surface.

Obviously, the new water paradigm is not omnipotent. It will not be able to prevent those great and sudden changes in the water cycle and in climates whose origins are outside the activities of humanity. These include the cycles of solar activity, swings in the Earth's axis, the fall of meteorites, the eruptions of volcanoes and the like, though the effects of some of these can in some ways be mitigated. The domain of the new water paradigm are changes in the effects of human activities, and this field is far wider than was understood in the old water paradigm. All other things should be perceived through the prism of the classic stoicism of Epictetus: "Some things are within our power and some things are beyond it...if we desire those things which are not in our power, we will surely be disappointed."[56]

Changes which are not in our power

Tab.13 **A comparison of starting points and approaches according to the old and the new water paradigm**

Old water paradigm	**New water paradigm**
The water on land does not influence global warming, which is caused by the growth in the volume of greenhouse gases produced by human activity.	An important factor in global warming may be the change in the water cycle caused by the drying and subsequent warming of continents through human activity.
The subject of research is the impact of global warming on the water cycle.	The subject of research is the impact of changes in the water cycle on global warming.
Urbanization, industrialisation and economic exploitation of a country has minimal impact on the water cycle.	Urbanization, industrialisation and economic exploitation of a country (over about 40% of the area of the continents) has a fundamental impact on the influence of the water cycle.
The impact of humanity on the water cycle is negligible and changes in the cycle cannot be reversed by human activity.	The impact of humanity on the water cycle is at present considerable and its changes can go in both directions.
Adverse climatic trends will increase, mitigation can perhaps be expected within a horizon of centuries.	If the new approach to water is applied, a possible recovery of the climate can be expected within decades.
Interest in the large water cycle, which seems difficult to influence, is dominant while the significance of the small water cycle is trivialized.	Interest in the small water cycle dominates.
The reason for extreme weather effects is global warming .	The reason for extreme weather effects are changes in the water cycle.
Global warming and extreme weather effects are inextricably linked.	Global warming can exist without extremes of weather, extremes of weather can exist without global warming.
Global warming is the main climatic problem for humanity.	Extremes of weather are the main climatic problem for humanity.
Vegetation is not ideal from the viewpoint of global warming because it has a low albedo (reflectivity); water vapor again increases the greenhouse effect.	Water and vegetation alleviate unwanted temperature differences; cloudiness moderates the intensity of solar radiation falling on the Earth's surface.
Speaks about the atmosphere as a greenhouse covering of the Earth.	Speaks about the atmosphere as a protective covering for the Earth.

[56] Epictetus, *The Handbook*. Svoboda, 1972, pgs. 27 – 28

Rising ocean levels are a result of melting icebergs.	Rising ocean levels are a result of melting glaciers on land, but also of a decrease in soil moistures, levels of groundwater and the state of other waters on landmasses.
Rainwater is an inconvenience and needs to be quickly removed.	Rainwater is an asset that needs to be retained in soil/plants.[57]
The main source and reserve of water is surface water.	The main source and reserve of water is groundwater.
There is an impersonal attitude by owners and users of land (citizens, companies and offices) towards rainwater in a territory.	A change in the anonymous approach to rainwater on an individual's land and the creation of a spirit of shared responsibility for water resources.
Water is used only once for one purpose and then is sluiced away.	Water can be used for more purposes, then purified and recycled.[58]
Water supplied to communities primarily through a system of mains with "potable" quality water.	Water supplied through a system divided into potable and utility water.
Mutual isolation of public policies in relation to water.	Policies in relation to water are based on a thorough perception of water in the scope of a functioning water cycle in a country.
A sectoral approach to managing water resources on land.	Integrated management of water resources in a territory.

In the year 2000 Axel Kleidon, Klaus Fraedrich and Martin Heimann presented the results of mathematical modeling of global climate on our planet from the two extremes of conditions: 1.) The simulation of a "Desert World," in which, applying the current distribution of oceans and continents, values corresponding to the parameters of the desert surface were placed on all unglaciated landmasses; and 2.) The simulation of a "Green planet," in which land surfaces were covered with vegetation.[59] Even though we are aware that each such model is a simplification of reality, the results of the modeling are still very interesting.

Precipitation over land of the "Green Planet" was twice that of over the "Desert World." On the "Green Planet," where evapotranspiration was up to three times higher and the content of water vapor in the atmosphere a third higher, there was paradoxically about a quarter less surface runoff than in the "Desert World." The average annual surface temperature over the entire "Green Planet" (including the oceans) was about 0.3 °C lower than in the "Desert World and the surface temperature on land 1.2 °C lower. Above the land of the "Green Planet" there was about 8% more cloud cover. It's interesting that the greater cloud cover on the "Green Planet" caused slightly less evaporation from the oceans and slightly less precipitation over them. The greater cloud cover on the "Green Planet" caused only approximately 5% more absorption of solar radiation, which is surprisingly small in view of the more than 20% difference in the albedo of both worlds. The most important changes occurred in large expanses of the arid regions of Africa, South Asia and Australia, where, in the "Green Planet" simulation, a forest climate was created.

[57] "A Paradigm Shift for Water Management." Rocky Mountain Institute, www.rmi.org
[58] ibid.
[59] A. Kleidon, K. Fraedrich and M. Heimann. "A Green Planet Versus a Desert World: Estimating the Maximum Effect of Vegetationon the Land Surface Climate," *Climatic Change* 44, Kluwer Academic Publishers, pgs. 471 – 493, 2000

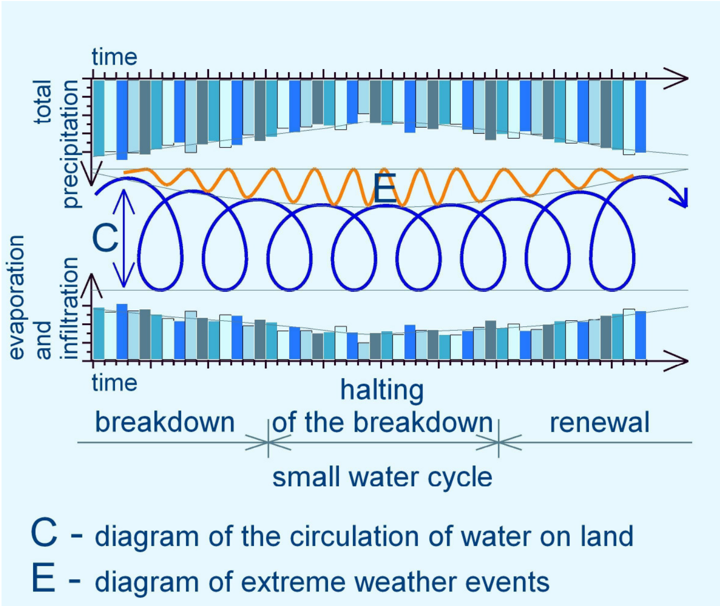


Fig. 27 **The course of destruction of the small water cycle over land until it is halted and then renewed to its original state**

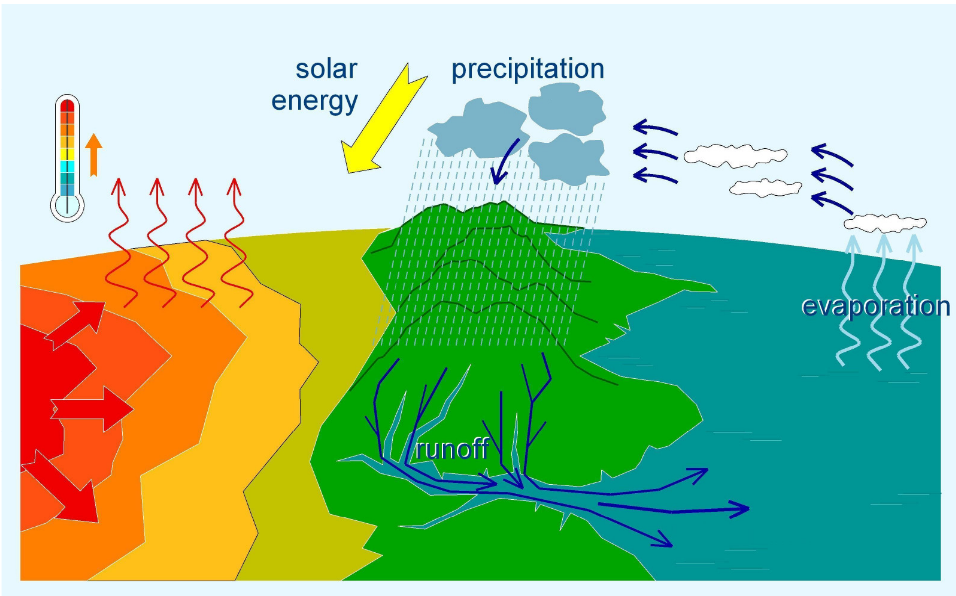


Fig. 28 Diagram of the expansion of deserts or semideserts with the breakdown of the small water cycle

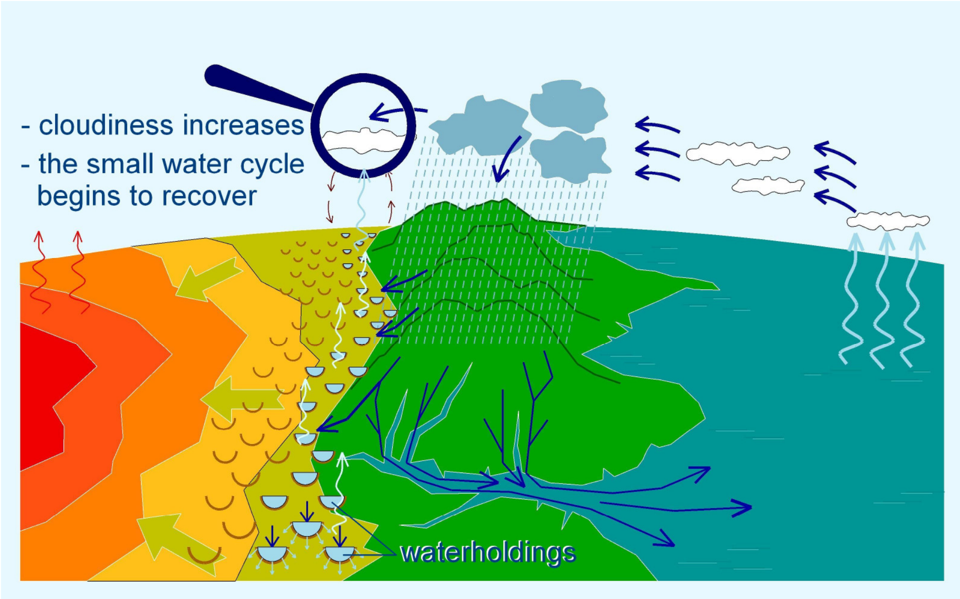


Fig. 29 Waterholding measures on the edge of critical areas
Their role is to harvest and hold water from the small water cycle from adjacent lands, or water from the large water cycle (even in deserts it rains occasionally). The period in which the water cycle is renewed depends on circumstances (the hydrological and pedological conditions, success of the growth of protective vegetation, etc.).

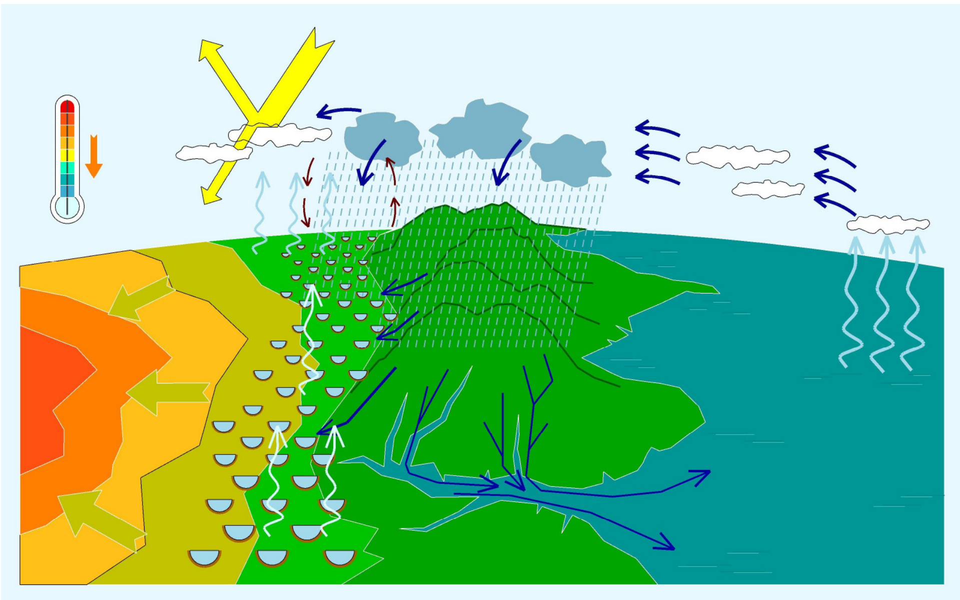


Fig. 30 **Decreasing areas of desert**
The climate recovers in an area with a renewed small water cycle and it can possibly be used as a forefront for further expansion of the hydrological recovery of land.

7 INSTITUTIONAL SUPPORT FOR THE USE OF RAINWATER

"To all the aristocracy and towns, I hereby issue an order to build ponds industriously, first to provide an abundance of fish to feed the people, and secondly to secure the better use of the land - to gather marsh and morass water, so that it might be evaporated by the sun and by warm winds and as a water vapor to fully benefit the surrounding vegetation. Furthermore, a pond is to retain a large amount of water in times of lasting rains or melting snow, and in doing so, shall avert the sudden flooding of downstream lands."

Charles IV, Czech king and Holy Roman emporer, 1356

The Wallachian colonization of Slovakia was accompanied by brutal deforestation. Despite this fact, one can learn learn from their water conservation measures, which effectively compensated for the negative consequences of their activities on the runoff of water from the land. Part of this chapter is devoted to a relatively simple solution for harvesting rainwater on land, through which the new water paradigm promises to return the lost equilibrium to the water cycle in nature and to temper the negative weather phenomena which trouble mankind today. The application of the new water paradigm in practice (its implementation) cannot be done, however, without the appropriate legislative, organizational and financial measures on local, national and international levels. In this part, we will show ways of reforming our relationship towards water in favour of policies reflecting a whole new culture in our civilization’s attitude towards this precious resource.

7.1 The conservation of rainwater in our history

Harvesting and conservation of water in the distant past

The conservation of rainwater on land is not a new idea. Human beings have collected and held atmospheric water throughout the millennia. India has a 4000-year-old tradition of harvesting rainwater for domestic consumption and agricultural use, while in China the tradition is even older (6000 years). The cisterns for the harvesting of rainwater mentioned in the Bible were spread throughout the entire Mediterranean. In semi-arid regions, such cisterns existed in every village and their demolition by enemies made the territory uninhabitable. The Phoenicians and Carthaginians practiced the harvesting of rainwater from the roofs of homes 500 years before Christ, while the Venetians were long dependent on such technology for obtaining water, as were a number of other nations, too.[60]

[60] Brad Lancaster, "Rainwater Harvesting for Drylands," pg. 7

Diverse methods

People used diverse methods for conserving water and these differed depending on the surroundings, the need for water and the available possibilities. The drier the surroundings, the more sophisticated the methods people had to develop (for example, the technology for harvesting water on sloped microbasins used by the residents of the Negev Desert or by the Native Americans in what is today the southwest part of the United States). In lands rich in water, where it was necessary to protect the soil on slopes from water erosion, the creation of terraces developed. This method is known particularly in connection with the paddy fields of China, but has also been used, to a greater or lesser extent, in various other parts of the world, including Slovakia. Terracing is among the most interesting methods of retaining water because it utilizes the infiltration of water into the soil and the free exchange of water between the soil and the atmosphere through vegetation.

Development of agriculture in Slovakia

As we have already mentioned, the central part of Europe did not suffer droughts in the past thanks to the presence of climax forest. The principal shift from natural land to cultured land in the region took place around the 13th century through the development of agriculture, in which most of the population was employed. Changes in the organization of land ownership, particularly in the distribution of specific land, hitherto uncultivated, to individual users, had a decisive impact on agriculture. The basic production units were smallholdings whose acreage sufficed for sustaining the family of the producers. For early medieval tracts (farmsteads and demesnes), the struggle for self-sufficiency was typical. With an increase in the population, however, the land was divided between more families (whether owners or users) and tiny tracts of land originated. Land around individual settlements, separated from neighbors by firm or vegetational lanes, created village territories divided into several parts: into fields for sowing winter and spring wheat, into fallow lands which were an accessory to pasture land, into meadows, into pasturage and into forest tracts. Each such independent unit fulfilled a proportional component of water management, from which it followed that if each user of the land retained water individually on his own territory, then the whole area was equally saturated with water.

Wallachian colonization

An increase in economic growth occurred during the 14th century after the settling and permanent settlement of the territory. We encounter the first Wallachian colonists, then predominantly Ruthenian-Ukrainian (partially also Polish) settlers, a few of Balkan-Romanian origin who penetrated into the Uh river region and afterwards the Zemplín, Šariš and Spiš regions. They gradually merged to form permanent settlements and found villages. To a great extent, this involved territory 300 to 600 meters above sea level which previously had been only sparsely settled or was not settled at all. Wallachian settlements on Slovak territory, which typically were based on farmsteads located on mountain ridges (also in the middle of forests around springs and so expanding deforested areas), extended across great parts of the present-day territory of the state. They were built up in the White Carpathians and Javorník mountains in the Slovakia-Moravia borderlands while the large forests of Central Slovakia, as well as the upper Nitra and upper Tekov valley, were also significantly reduced by their activities. In the 14th century, Wallachian breeding (pasturing) of livestock became increasingly common and meant economic exploitation of highlands which were unsuitable for agricultural cultivation. And here we can observe a gradual and systematic building up of untilled boundaries (separating fields) preventing the spontaneous erosion of soil. This measure was a rational compensation for the destructive deforestation of the territory (predominately by uprooting and burning). We can still see today in the Spiš region, for example, largely bare peaks altered by these water conservation barriers.

The need for conservation and antierosion measures

In remote, particularly submontane regions of this territory, there can still be seen traditional terraced land where characteristic narrow belts of land divided by untilled boundaries lie in horizontal lines along sloped terrain, which, thanks to its inaccessibility, was not affected by communist collectivization. Regardless of their long-term neglected state, these are minute patchwork territories of ecological stability, which despite long-term deforestation, demonstrate considerable vitality. We also find similar territory in the surrounding countries of Central Europe. Remarkably well preserved is the character of the cultivated land in Transylvania (today's Central Romania), for example, where a giant mosaic of tiny fields resembles the structure of the gently differentiated and mutually complementary cells of healthy tissue. Despite the fact that the majority of local watercourses are not regulated, this "backward" part of Romania has not been affected even when the rest of the country has had to battle with destructive flooding *(Fig. 31).*

Functionality of old measures

Partitioning of agricutural land, which for centuries created a living and working environment for our ancestors, reflected not only on land ownership relations but also on a particularly mature and viable structure that allowed for different forms of land husbandry. The ability of the land to retain and evaporate water was in the past significantly higher despite the fact that partitioning of land was not developed for this particular purpose. The intensive economic activities of humanity in such a system did not interfere with the natural water cycle on land because it was compensated by measures which preserved the ability of the land to retain water. This system of cell arrangement, dating back to the "dark" Middle Ages, has, however, changed over the last few decades into a vast monoculture, the dictate of "scientific" theories and "the invisible hand of the market" variously combining to bring about this change. The land has become monotonous and less structured, today’s gigantic drained areas around human settlements, monocultural agriculture on vast and undivided fields, decimated forests and regulated watercoursess all having lost the ability to retain water in a country.

Ignoring the experience of ancestors

7.2 The principles, methods and advantages of conserving rainwater on land

If humanity realizes that the impact it has had on the land has accelerated the runoff of rainwater, surface water and subsurface water and thus damaged the small water cycle in all the ways mentioned in this publication, it should be prepared to take measures for the renewal and recovery of this cycle. The essence of a practical solution to the problems of climate change and water shortages caused by human activity is the renewability of the small water cycle by human activity through a full implementation of comprehensive measures in individual communities and towns. These involve measures which will limit the accelerated runoff of water, increase the water-conservation capability of watersheds and improve the water balance in the region. These measures are often identical to anti-erosion measures. Rainwater harvesting in the places where rain falls, before its drops become part of an uncontrollable current, are excellent means of flood prevention. These are simple measures in the field, similar to certain land planning and land modeling processes.

Technological and biotechnical measures

These measures have a technological, biotechnical and technological-preventative character. Technological measures include absorption ditches through contouring (lengthways shallow drainage ditches), the use of sloped depressions as absorption and reservoir areas, the building of depressions, absorption pits, waterholdings and limans, improvement of surfaces and the conservation and infiltration of rainwater, small dams or wells for watercourses, streams in gulches or ravines, the building and maintaining of dry reservoirs, polders, keeping and using the meanders of watercourses and blind tributaries, objects for linear protected dams for the discharging of water into flood plains, the building of small weirs for water reservoirs and ponds, the damming of streams and anti-erosion measures in forests and the like (*Fig. 32, 33, 34, 35, 36*). Biotechnological measures are similar but barriers to surface runoffs are associated with the use of vegetation—borders, grassy belts, belts of shrubbery and trees, unused grassy and forested areas and the like.

Technological-preventive measures

Examples of technological-preventive and economic measures could be the application of favorable procedures for protecting the soil (for example, contour plowing), ensuring the replenishment of water sluiced away from a territory, the limiting of non-vegetation hard surfaces in built-up areas, replacing impermeable surfaces with permeable ones, constructing protective barrages further from the centers of water flows, forbidding the clear-cutting of forests, the protection of forests from damaging insects (for example, bark beetles), optimal structure and quality of forests, land-planning or a new division of agricultural ground, the applying of integrated management and a more sensitive use of the land with the view towards conservation and anti-erosion measures and the like.

With the conservation of water on land a number of principles need to be kept in mind. The first of these is the principle of *solidarity* (the principle of water tolerance), which means that along with the design and implementation of measures which have an impact on the runoff conditions from a territory, it is necessary to take into account the whole watershed area. Measures implemented in one territory cannot worsen the situation downstream or upstream in the watershed region. The principle of *partnership* means that an analysis of the situation in the area of runoff levels from a territory (community, town, region, watershed and the like) and important decisions related to proposed measures for increasing the water-conservation ability of a catchment area and decreasing the process of erosion, only take place after discussions and mutual agreement of all deciding partners in the basin—administrators of water flows, agriculturalists, forest rangers, representatives of communities and town, landowners and experts. Anti-erosion projects and technological measures for increasing the water conservation capability of a water catchment area should be prepared and carried out in a partnership. The principle of *subsidiarity* as defined in the Middle Ages and applied in the EU, in this case means that with practical administration and protection of water resources in a territory and in a watershed, that what can be done better by a lower level of public administration should be left to be handled on this level. This principle points to the need for effective decentralization of activities which can be better, faster and more cheaply handled by local or regional self-government.

Tolerance, partnership, subsidiarity

Alongside the previous principles, which are bound up with human activities, we can also mention the principle of *autoregulation of natural processes*, which means that the effect of an initial and one-time investment into the implementation of measures aimed at improving the water balance in an area should gradually each year show an improved quality of the natural environment and should raise the effectiveness of other local measures implemented in the territory. The principle of *a sustainable solution* is bound together with this principle. Carrying out these mentioned measures helps eliminate some of the reasons for unwanted climate changes caused by human activities. Thus, better living conditions and a better environment for future generations will be created, the natural potential of the territory will remain the same and the protective and autoregulating functions of ecosystems will be preserved.

Renewing the autoregulation of natural processes

7.3 The civil sector

Alexis de Tocqueville, in his work *Democracy in America* from the first half of the 19th century, wrote that while in France the government was at the forefront of great new projects and in England the aristocracy, in the United States it was civic associations that performed this function.[61] In a democratic society the most important "institution" is the citizen. He has a far more important function, but also greater responsibility, than a citizen in a non-democratic society. And just as we believe more in a great number of humble drops of rain than in their concentration in rivers, the will and the conviction of common citizens has, in the application of the new water paradigm, greater meaning than the decrees of

The citizen – the most important and institutions

[61] Alexis de Tocqueville. *Democracy in America, II*, Chapter V

government (although the government, like the river, also has its function). Similarly, as in all other cases, in the case of the conservation of water on land, the tasks and authorities should be divided in agreement with the principle of subsidiarity; that is, institutions on a higher level should handle a given item only when it cannot be more effectively resolved on a lower level. The need to conserve water in a country is worldwide, and therefore institutions on all levels, including national and international, should be involved. This all depends, however, on the initiative of citizens and their ability to determine which activities they can manage themselves (those where intervention from above would be counterproductive) and which they would need help from higher levels with. The individual citizen, or a citizen in association with others, has an "open space" in which to do more than just his duty.

Possible involvement of citizens

Citizens who embrace the thinking of the new water paradigm will advocate the protection of water in their own living space and actively demand from public administration the preparation and realization of measures aimed at the renewal of the water cycle in an area. Citizens of cities and communities will see the water in their own surroundings as the thermoregulator of climatic conditions and rainwater as the main "provider" of sufficient water resources in the region. They will support the need for building catchment areas, depressions and evaporation surfaces for the renewal of the country and land-planning purposes. They will request a separated supply of drinking and of utility water and will encourage repeated use of water.

Opportunities for non-profit organizations

Non-profit organizations which embrace the thinking of the new water paradigm will inform the public about the need for a new approach to water and call for access to information about the application of the new approach in practice. They can initiate different local projects aimed at improving public and civic interest in water resources in the region (projects, for instance, aimed at cleaning a river and its surroundings, foresting unused plots of land, projects with slogans such as: “Let's not pay for the sluicing away of rainwater, let's conserve water in an area“, projects aimed at cleaner groundwater, better use of utility water for different purposes, and the protection of drinking water). Some of them can focus on encouraging leadership and on building the capacity of civic and community involvement in the given problem. In addition, they can create a new space for the development of business philanthropy and donations towards implementation of the new approach to water, both for developed, as well as for developing countries.

Property owners

Owners and co-owners of flats, buildings and property within the residential areas of municipalities and towns should create water societies in the interest of coordinating and ensuring the retention of rainwater on built-up land. In rural areas outside of towns and municipalities, particularly in agricultural and forested areas, water cooperatives aimed at retaining water in an area could be established through the active participation of the owners and users of these lands. Local councils could then become responsible for coordinating such measures effectively. Meanwhile, independent owners of neighboring buildings and property in the territories of individual towns and municipalities can, among themselves, establish water societies and cooperatives, if such a form of cooperation makes it easier to to carry out technical and biotechnical measures aimed at increasing the water-conservation capability of catchment areas and decreasing the process of erosion in the given territory. Cooperation is also required for the maintenance of such established systems. Anti-erosion and water-conservation measures serve for the long-term protection and improvement of their own property.

Independent media

Independent media could focus on the hitherto neglected importance of water in discussions about climate changes. If the media were to embrace the principles of the new water paradigm, they could become "watchdogs" guarding against the indifferent and exploitative treatment of water on land, treatment which, in various ways, is damaging the interests of the majority of the population.

7.4 The economic sector

Innovation and a noble impulse

Thanks to its economic and management dimension, the new water paradigm represents a fundamental innovation in current economic practice and is thus becoming a basis for new economic thinking and knowledge. At the same time it provides a noble and socially useful impulse for the economic sector as well as an asset for private and state water management, agriculture and forestry companies. Since from the viewpoint of the new water paradigm land managers are important, it will be in their interest to ensure sufficient water resources, minimize extreme weather and increase the economic usefulness of the land. They are important socio-economic partners in preparation of integrated management plans for watersheds as well as in their implementation. Usually they promote only "sector" policies, but in the new water paradigm, they will take on an umbrella role in the integration of management of water resources on land.

Integrated management and coordination centers

It is necessary to accelerate the preparation for integrated management of surface water and rainwater on land and its implementation through involvement of the coordination centers in close cooperation with local government. Water companies could focus on building a dual system for the supply of drinking and utility water in an area and decentralized systems for purifying sewage water with the use of different recirculation systems. The water removed from a territory could, after multiple uses, be purified and returned to the ecosystem.

A meaningful increase in employment

Adopting the new paradigm will create space for employers to carry out jobs which are relatively simple and undemanding but unprecedented in scale. These will be both in the public and their own interest in terms of protection of property (soil, buildings, moveable objects). Employing workers for the preparation, implementation and maintenance of anti-erosion and water conservation measures means valuable employment opportunities both in the affluent and the developing world. This can then serve as an impulse for economic and social growth and the elimination of poverty in economically weak regions and in regions with insufficient sources of water.

Land planning

A new challenge will arise for landscape engineers, architects, urbanists, construction engineers and planners, because a new era of zoning and landscape planning for populations and whole regions will dawn. The need will arise for a thorough local reappraisal of drainage relations and the design of anti-erosion and water conservation measures on the land. Opportunities will arise for rating agencies to make independent evaluations of an area's water balance and to determine its value and competitiveness from the viewpoint of water resources. With knowledge of the new paradigm, scientific communities could devote their attention to a detailed mapping of the mechanism of the water cycle as well as to predictions of climate change patterns.

Developers

In building greenfield sites and residential buildings, in restoring and renewing original historic and urban structures, and in rebuilding old and building from scratch new industrial parks, shopping and amusement centers, developers should include in the urban and architectural strategies of such projects the two key principles: "Retain water on these plots of land!" and "Allow it to evaporate and infiltrate into the soil!“ Retaining rainwater and creating greenery should be two of the main ways of making the environments of building centers and parks more attractive.

Construction companies

Construction, garden and design companies can use the impulse of the new water paradigm to implement local flood prevention measures, to renew the water regime in an area and to apply new approaches and technologies which create good conditions for conserving, absorbing and evaporating rainwater in combination with vegetation. Supply companies can focus on widening their assortment of machinery, materials, technologies and services, all of which will be needed to carry out these measures in the field, as well as to ensure their subsequent maintenance.

Banks and insurance companies

The new paradigm creates the need for rapid financing of prepared projects and the implementation of conservation and anti-erosion measures in a territory. The banking sector can help through a system of loans to the public as well as to the private sector. In recent years insurance companies have registered a sharp growth in insurance events, so they could focus on supporting the creation of authorized centers which will allow anyone to gain the knowledge needed for assessing the state of the water cycle over their own territory and property, as well as for preparing and taking necessary measures in the field. They can add to their range of services complex new products with suitable motivational schemes for their clients.

7.5 Public sector institutions

Current approach versus EU policy

The relationship of society to water up till now can be understood as a combination of mutually isolated policies and of various personal attitudes and approaches (the obtaining and discharging of water, the production and supply of drinking water, purifying waste water, water for agriculture, water for manufacture and industry, surface water and bodies of water, protection from floods, water for firefighting, household drinking water, water for my garden, rainwater from my roof, etc.). The sectoral, departmental and professional approach has hitherto been characterized by interior and mutual isolation (expert, professional and supplier-purchaser) and by the strictly limited authority of separate bodies of public administration. Each office deals with water from one specific point of view. The EU general directive on water (Directive 2000/60/EC) attempts to go beyond such an approach, however, and points out the need for one which is more integrated.

The paradigm as a framework for an integrated approach

Through the acceptance of the new water paradigm, the protection, perception and use of water becomes genuinely integrated and holistic in the context of recognizing the significance of the water cycle and the conditions of the given catchment area. Understanding the basic circulation of water in nature is relatively simple and can be precisely described and quantified. The adaptation of this knowledge for political decisions, however, requires a fundamentally qualitative and systematic transformation of traditionally isolated local water management policies into ones which are fully integrated. For administrators of water basins, an opportunity arises to reevaluate the management of administered bodies of water and the infrastructure in the region. In the sense of the new water paradigm, they can emphasize flood prevention (anti-erosion measures and measures for increasing the water retentiveness of all microcatchments in the administered territory), and thus create, in cooperation with local government, an institutional starting point for the integrated management of watersheds.

Opportunities for educational institutions

Educational institutions should include knowledge of the new water paradigm in the curriculum both at schools and at centers of adult learning and also connect such education with the needs of people already working in these fields. This includes support for education of local government representatives and support for international exchange programs. The study of water in the context of the new water paradigm could also become a subject of study at universities and faculties. Such a subject would have scientific, research and above all study programs typical for other university subjects.

Opportunities for towns and municipalities

Towns and municipalities are key partners in the practical introduction of the new approach to water and the implementation of the necessary technologies, biotechnologies and economic measures in a region. They can be highly effective in pushing through the relevant measures on their territories at the same time as respecting the principles of partnership, solidarity and subsidiarity. Above all, towns and municipalities must endure the results of floods and climate changes which decrease their competitiveness. They should therefore focus on promoting an intersectoral and integrated approach towards renewal of the water cycle on their own territories as a starting point for the economic development of their locality. In practice, this means carrying out studies and projects aimed at: increasing the water conservation capability of the territory (within the community or outside of it); lowering water-caused soil erosion; creating and fulfilling motivational economic programs for residents and landowners in the region (regional administration can, for example, provide special tax relief and one-off subsidies for every 1 m^3 water conservation space created or for an anti-erosion alteration to lands on community land); or for judging the impacts of investment activities on the runoff levels in an area. Neighboring settlements, associations of towns and municipalities, as well as whole regions, can create and coordinate a common system of flood prevention and encourage the creation of their own consulting, informational and competency centers for towns and municipalities and for owners of land and buildings. This cooperation could take the form of "self-administered basins" organized within the borders of hydrological watersheds.

Opportunities for government policy

The essence of the measures which need to be passed on the national level is the implementation of structural reforms for water management and economic policies (including agricultural and forestry policies) which influence the runoff conditions on a territory. The new water policy should focus on the overall protection of the territory with a focus on improving the water balance through the passing of measures aimed at increasing the water retentiveness of a watershed and decreasing processes of erosion. The state should create the conditions and a framework for the systematic integration of hitherto isolated sectoral policies relating to water and the associated harmonization of subsidy policies. A complex approach to water requires passing a new generation of laws, including acceptance of a law on the protection and renewal of the small water cycle in land, which would lead, in addition to other things, to an assessment of the influences of investment activities on the water balance of a territory. New financial, supportive and motivational instruments for the implementation of the new approach to water can then arise. The state budget can provide support for the application of anti-erosion and water conservation measures, support for the preparation and implementation of community projects, as well as support for research activities and the monitoring of newly proposed and implemented measures in a region.

Opportunities for international institutions

If a community of states (the European Union) and global institutions (for example, the United Nations) embrace the new water paradigm, they could assert their authority and declare their support for a new approach to the protection and conservation of rainwater on land. In some cases, these institutions have the powers of international law in their hands, powers which, if needed, could be used, of course, in appropriate measure and in respect to the principle of subsidiarity. Just as the UN was able to mobilize itself into supporting research into the relationship between climate changes and greenhouse gases (IPCC) and into specific steps in the implementation of the conclusions of this study (for example, the Kyoto Protocol), it should act similarly with respect to the role of water and the need to renew the small water cycles over the continents. The updating of developmental aid from countries or communities of states to developing countries could gain this new dimension. In the interest of monitoring processes, it would be necessary to add to the list of indicators of sustainable development in *Agenda 21* monitoring of the renewal of the small water cycle over land (over continents, regions, settlements) and implementation of comprehensive systematic measures for increasing the water retentiveness and comprehensive anti-erosion measures. The renewal of the small water cycle and the integrated management of water resources in catchment areas could become a new pillar of agricultural, forestry and water management practice, of a policy of solidarity and of the policy for rural development (giving opportunities for a more meaningful reform of the Common Agricultural Policy of the EU). The currently running campaign of the European Commission, *Your Impact on Climate Changes* through four activities—slow down, switch off, walk and recycle—could be expanded to include a fifth activity—conserve rainwater on land.

> *"The day is not far away when it will be considered wrong for an engineer inexpert in biology, and especially in ecology, to go into the countryside with a sliderule and the intention of altering it…The natural landscape has been so violated by these alterations, left so shabby and superficially civilized,, that soon everyone will feel the need to return to our countryside its true meaning and value. But how to do it? A simple return to its original state is not possible. We cannot efface the population from the surface of the Earth, nor can we decrease its economic progress, standard of living and involvement in global production processes. We cannot annul any of what has distinguished our age from the period one hundred years ago. On the contrary, we have to lift everything to a higher level. That is why we cannot keep the countryside in a stage of economic primitivism. Nothing remains but to alter the current state of the country, but to alter it more intelligently, more naturally, more professionally. And this is a task so noble that all missions of the nineteenth century pale before it."*
>
> Vladimír Úlehla, 1947[62]

7.6 Financial costs and the assessment of scenarios

Undemanding financially and timewise

The economic and systematic assessment of the advantages of the new water paradigm can be divided into three areas—these are balance calculations, economic calculations and the assessment of social and environmental costs and benefits of individual scenarios. Balance calculations allow for the monitoring of the water balance of a territory and the analysis of weather patterns (temperature patterns, precipitation totals, the progress of water runoff from a territory, changes in the groundwater levels, changing levels of soil dampness, the frequency and incidence of extreme weather events). Economic calculations of the separate projected patterns include adaptation costs, damage caused by extreme weather events and a fall in

Aspects of assessing advantages

[62] Cited from the publication of Míchal I. *Ecological Stability*, pg. 217, Veronica, Brno, 1994

the economic performance of an area. The assessment of social and environmental aspects also includes various assets which cannot be easily expressed financially.

The IPCC scenario

The two primary scenarios from the viewpoint of the new water paradigm are derived from the most widely assumed reasons for climate change. The scenario emerging from the decisive role of the growth of CO_2 concentrations in the atmosphere,[63] which is the widely preferred theory both scientifically and politically, assumes that adapting and improving technology in order to lower emissions of CO_2 is a necessary step in responding to climate change. This scenario indicates that by the end of the 21st century, the following are to be expected: an increase in global temperatures on the surface of the Earth of 5 to 6 °C; a rise in sea levels of 50–100 cm; a growth in extreme weather events; economic damage costing up to1–5% of the annual gross domestic product of every country, with a possible acceleration of up to 20% in the most unfavorable circumstances.[64] Thus far, not all the financial costs of adaptation are known; their gradual rise is expected, however.

Scenarios with the use of water

The scenario emerging from the decisive role of water in the recovery of the climate through the renewal of the small water cycle takes a more active approach, and in the case of worldwide implementation of the new water paradigm's measures, promises a fundamental, across-the-board decrease in extreme weather events on land, a more uniform spreading of precipitation over the continents, effective protection from flood and drought, the stabilizing of the climate in rural and urban environments, enough water for the growth of the world population, as well as a decrease in economic damage caused by extreme weather events. With regard to the increase in the global temperature of the Earth and the rise in sea levels, it promises a moderating of their rise to that extent to which they come from human activities in transformation of the surface of the land. In the understanding of the new water paradigm, this is a significant part of what humanity is really able to influence.

The new water paradigm represents, both in terms of time and money, a manageable investment in relation to the stabilization of the climate and the provision of sufficient water. For implementation of the necessary measures in a country, investment costs worth roughly 0.1% of a country's annual GDP should suffice for a program lasting 10-15 years. These costs are equivalent to the costs needed for the preparation and implementation of comprehensive flood prevention measures (anti-erosion and water conservation measures) in a region. The average costs for the renewal of the small water cycle (increasing water conservation capabilities of watersheds and decreasing erosion processes) in a unit of land depend on its character, morphology and the need for intervention. There are diverse technological and biotechnical measures which do not require massive investments and investment construction. On the contrary, they are undemanding and utilize local materials and the local labour force. The maintaining of measures implemented in a territory would be handled by landowners. This would cost, however, only a relatively small amount and would create a useful level of primary and

[63] http://www.ipcc.ch/
[64] http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/

subsequently secondary employment on a global level. The average costs for implementation of the new water paradigm for each square kilometer of land therefore represents 0.1% of the annual GDP of a country multiplied by the number of years needed for implementation and then divided by the area of the region (in km^2). This approach is less expensive than any other solutions which have already been tried or proposed.

Fig. 31 **Terraced slopes in Romania's Transylvania region**
Territories altered by this ancient method showed an admirable resistance to flooding.

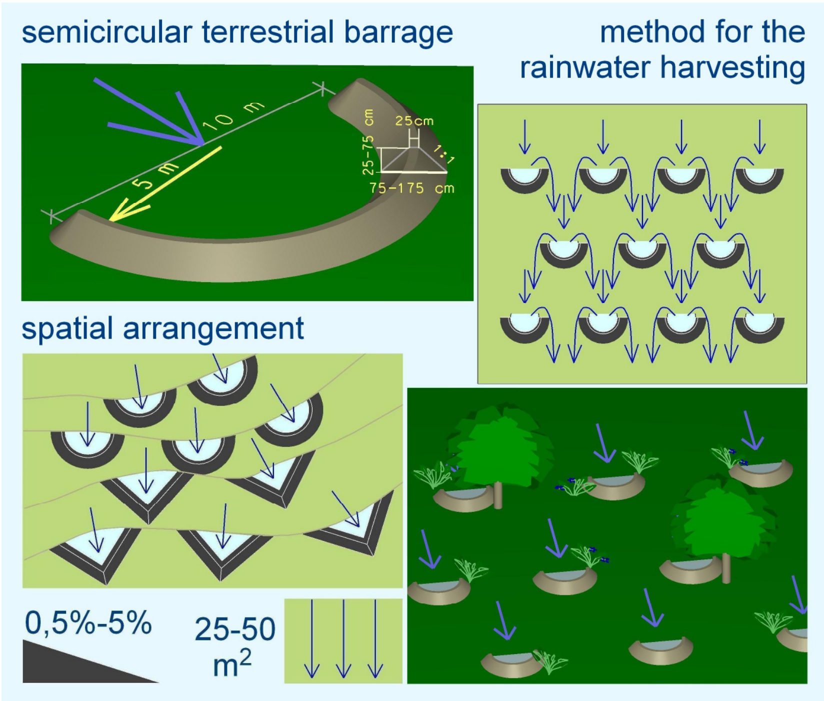


Fig. 32 **An example of cascade ground tanks for rainwater harvesting on slopes**

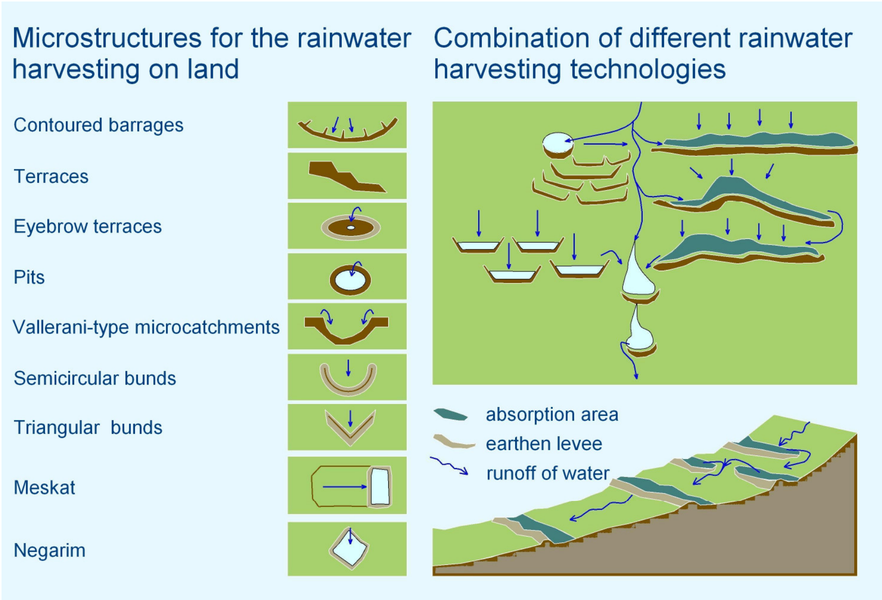


Fig. 33 **A diagram of technological measures for the protection of land against erosion and for rainwater harvesting and conservation on land**

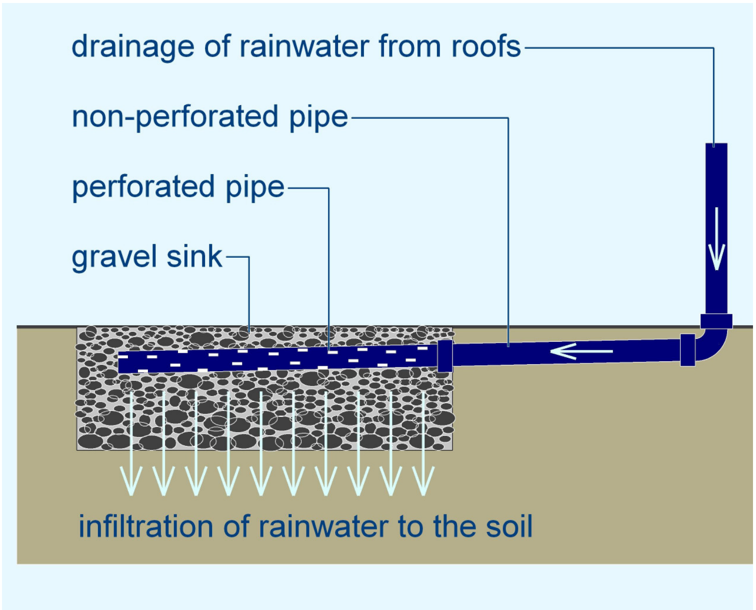


Fig. 34 **Detail of a pipe for taking rainwater to a gravel spall drain**[65]
Utilized for the infiltration of rainwater from the roofs of houses to the soil and subsoil.

[65] City of Tucson – Water Harvesting Guidance Manual, Ordinance Number 10210, October 2005, page 16

Fig. 35 **A Water Forest in the High Tatras – building water conservation measures on territory destroyed by a natural disaster**
An example of the renewal of vegetation and hydrological stabilization of a territory through the conservation of water on land.

Fig. 36 **The KVP housing estate in Košice – protection of buildings under a slope with the help of earthen bunds along contour lines**

8 CLOSING SUMMARY

Disruption of the balance of the water cycle

The circulation of water in nature takes place through the large and small water cycles. Humanity, through its activities and systematic transformation of natural land into cultured land, accelerates the runoff of rainwater from land. Limiting evaporation and the infiltration of water into the soil decreases the supply of water to the small water cycle. The equilibrium of the water balance in the small water cycle is thus disturbed and it gradually starts to break down over land.

Climatic change, the growth of weather extremes

If there is insufficient water in the soil, on its surface and in plants, immense flows of solar energy cannot be transformed into the latent heat of water evaporation but are instead changed into sensible heat. The surface of the ground soon overheats, and as a result, a breakdown in the supply of water from the large water cycle arises over the affected land. Local processes over huge areas inhabited and exploited by human beings are changed into global processes and with processes that occur without the assistance of human beings; together they create the phenomenon known as *global climate change*. The part of global climate change caused by human activities then is largely based on the drainage of water from the land, the consequent rise in temperature differences triggering off mechanisms which cause a rise in climatic extremes. The disruption of the small water cycle is accompanied by growing extremes in the weather, a gradual drop in groundwater reserves, more frequent flooding, longer periods of drought and an increase in the water shortage in the region.

Opportunity for renewal of the water cycle

The part of climatic change which is the result of human activities (draining of a region), can be reversed through systematic human activity (the watering of a region). The watering of land can be achieved through saturation of the small water cycle over land by ensuring comprehensive conservation of rainwater and enabling its infiltration and evaporation. This can help achieve the renewal of the small water cycle over a region and fundamentally change the trend of changing climatic conditions: it can—to reverse the trend of regional warming—temper extreme weather events and ensure a growth in water reserves in the territory.

Relatively undemanding financially and timewise

The renewal of the small water cycle over an area, however, depends not only on the extent to which the area has been damaged but also on a number of other factors. In the case of Slovakia, we can expect visible results relatively soon (10 to 20 years) after implementation of these measures. The financial costs of these specific measures are moderate sums which can be allocated from state, public and private budgets. Support for the implementation of far-reaching measures should be linked pro rata to each 1 m^3 of reservoir volume built in the ground or to anti-erosion measures carried out. The implementation of water conservation measures should, until the renewal of the small water cycle and the maximalization of a stable water balance in a region, replace previous investment measures, which only served to accelerate the runoff of water from a region.

Every drop matters

The conservation of rainwater on land "in situ" and the conducting away only of the natural surplus of water in a region is "condicio sine qua non"—a condition essential for ensuring environmental security, global stability and the sustenance of economic growth. Fulfilling these conditions should be of interest to each individual and each community. This is the first time in the history of human civilization when the impact of mankind's activities on the water cycle and the decrease of amount of water in it will have to be evaluated. The statement of the Srí Lankan king, Parakramabahu the Great—"Not even a single raindrop should be allowed to flow into the sea without it first having been used for the benefit of the people..." —is the best summing up of the new water paradigm, a statement which, in the coming decades, should become a slogan for mankind calling for the preservation of civilization.

TEXT FOR THE BACK COVER:

Not even a single raindrop should be allowed to flow into the sea without it first having been used for the benefit of the people...

King Parakramabahu the Great of Sri Lanka (1153 – 1186)

In his groundbreaking book, *An Inquiry into the Nature and Causes of the Wealth of Nations*, Adam Smith introduced the example of smiths who, even with the greatest of effort, could not make more than one pin per day. The division of labour increased production of pins twenty-fold and simple machines many thousand-fold, so that what was once a luxury item soon became available to even the poorest of families. This book is concerned primarily with the importance and origin of the wealth of water on land. Its ambition is to change the current practice of draining water from large areas of land, a process caused by deforestation, agricultural activities and the sluicing of rainwater out of cities. The draining of land means decreasing evaporation, the transforming of solar radiation into sensible heat and a change in the great flows of energy in the area. This has an impact on the circulation of water on land and a rise in extreme weather events. The authors of this publication see a solution to these problems in relatively simple rainwater harvesting and water conservation measures, the kind that people in different parts of the world applied for hundreds or even thousands of years. They served for the acquiring of new sources of water and are often identical to flood prevention and anti-erosion measures. With widespread use, they can multiply the amount of water which can be used by people, nature and manufacturing; at the same time, they can temper micro- and macroclimatic problems caused by the drainage of land and thus contribute to the recovery of the climate. The panel of authors, who all come from an environment of non-governmental organizations, offer this book to anyone involved with water and its management as well as to public sector institutions and private investors, and more or less every single citizen of our planet.