Recommendation of Slovakia for recovery of the damaged landscape of Greece in selected areas of Attica region

Ministry of Agriculture and Rural Development of Slovakia

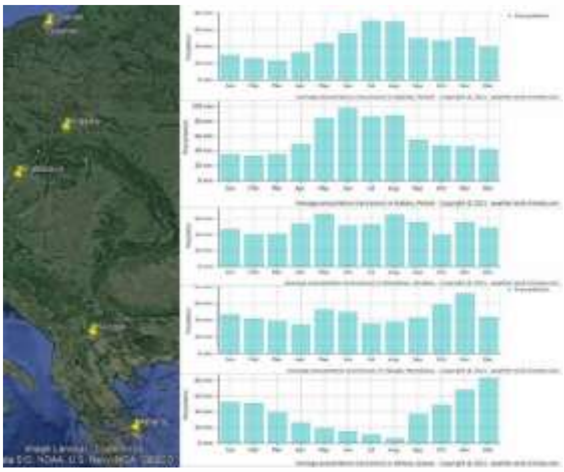
Martin Kovac, State Secretary of MAaRD and expert team:

Michal Kravčík, Ing. CSc, Danka Kravčíková, DiS., Ing. Miroslav Hríb, Ing. PhD., Dusan Travniček, Ing. Pavol Šuty,

Water resources across the European continent are declining and are insufficient for the long-term needs of EU countries, threatening the water, food, social and climate security of our common European dome. Land management has been changing the structure of the landscape for a long time, damaging the hydric function of ecosystems. Historically, the most extensive landscape changes and loss of hydric function have spread northwards from the Mediterranean. This is characterised by the diagonal distribution of monthly rainfall across Europe from the Mediterranean to the Baltic Sea.

While the most pronounced summer rainfall is in northern Europe, the most pronounced and intense rainfall in southern Greece is in the Mediterranean region. We commonly refer to this as characterising the maritime climate here. That is true, but not the whole truth. If we look at the formation of clouds over the Cypriot peninsula in the summer, it can be understood that the drier the island is, the more it overheats and the more it practically stops raining in the summer.

This trend can also be observed in the area of Greece, where the periods without rain in the summer are getting longer. From autumn onwards, this trend is reversed. Moist frontal systems accumulate over the sea, which are “sucked“ inland by the lower temperatures of the land and this brings extreme rainfall. In autumn, Bowen's ratio between latent and sensible heat changes. All summer long, the dry land with high sensible heat production causes high air mass pressures over land that prevent moist ocean currents from reaching the land.

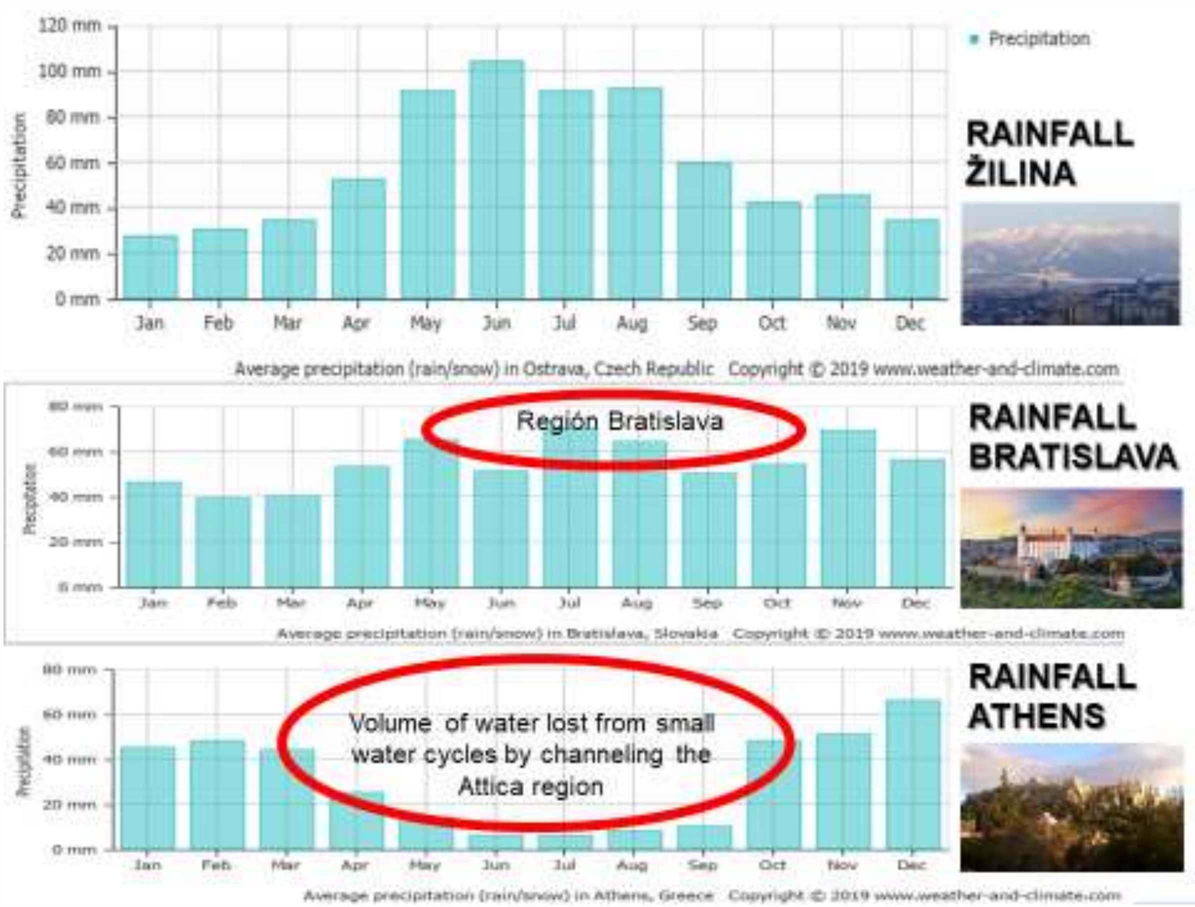


That is why it rains less in the summer on the mainland, and this trend has been deepening over the long term as the damaged land becomes more and more parched year after year. The irrigation index of the land is very low and this also brings the risk of fires. In autumn, when the sea is warm, slowly cooling down, the dry land cools down dramatically and this causes the suction of wet jet masses from the sea onto the land. This brings with it extremely intense rainfall on land. The year 2021 was just a typical year when, after a prolonged drought, fires were set and then came torrential rains causing unprecedented damage in the Attica region.

Drought, fire and flood risks are a phenomenon of all southern European countries. This condition has been caused by a historical underestimation of the interaction between the water that falls on the landscape in the form of rain and the water that is in the landscape. The need to keep water in the ground was not appreciated, and so for centuries all the economically exploited areas around the Mediterranean and in the Middle East, as far as India, were drained. By letting rainwater run off the land for centuries, small water cycles were gradually emptied. The emptying of small water cycles has long been caused by exploitation of forest, agricultural and urbanised landscapes.

The most intense emptying of small water cycles is caused by the sealing of the earth's surface and the channelling of rainwater from the earth's surface into streams, rivers and subsequently the sea. If we look at the pattern of monthly rainfall in Athens, we see that it rains the least when temperatures are highest in the area. This is so because in arid lands there is an intense production of sensible heat which causes high air pressures over land, and this restricts the moist marine currents from entering the atmosphere over land. The drying up of damaged landscapes brings with it the new phenomenon of prolonged periods without precipitation.

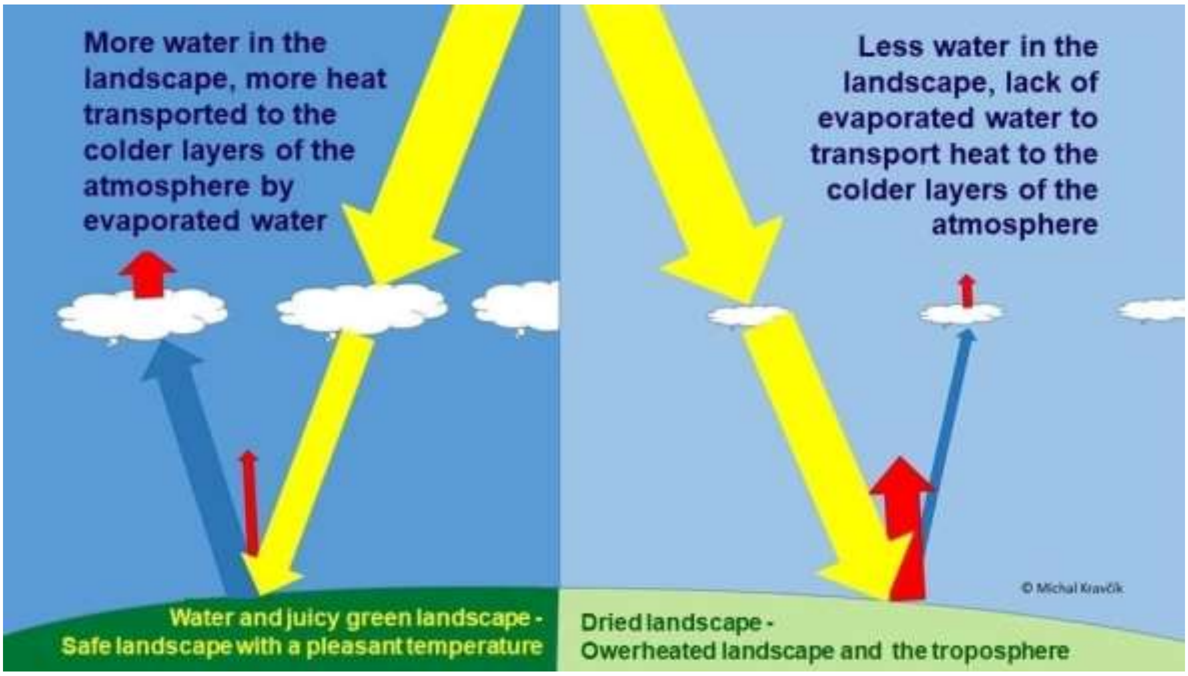
In principle, the more arid the land becomes, the more it overheats and the longer the rain-free periods become. Expert estimates suggest that probably up to 40 billion m^3 have been lost from the small water cycles in the Greek territory. This water from small water cycles is now stored in the oceans. Therefore, the loss of water from small water cycles in all countries of the world is contributing to rising ocean levels. Slovakia is also contributing. With the industrialisation of the country, about 15 billion m^3 of water has been lost over the last 60 years, and globally more than 700 billion m^3 per year is being lost from the continents, raising ocean levels by about 2.1 mm per year.



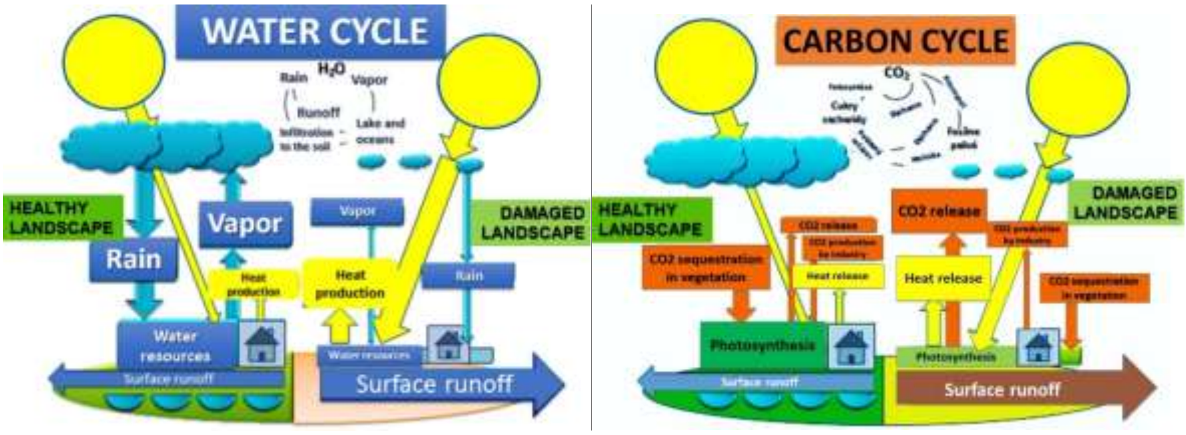
This water, which before damaging the land recycled in small water cycles, stabilised the country's temperature regime, provided enough water for people, food, nature and climate, reduced the risks of wildfires, flowed into the sea and there contributed to rising ocean levels. Thus, historically, Greece was one of the most prosperous and fertile countries, with rich fauna, flora and a stable climate. Based on the historically documented messages of the philosopher Plato, the drying up of Greece was already taking place in ancient times at the turn of the epoch. Plato reminded the political leaders of Ancient Greece of this many times in his reflections and messages.

Looking at the diagram of the small water cycle one can see that if rainwater is allowed to soak into the ecosystem, here, after saturation of the soil, part of the water percolates underground (about 1/3) and replenishes the groundwater reserves, and about two thirds of the volume of water evaporates through the vegetation into the atmosphere. This forms the basis of new rain. This evaporated water also transports latent heat to the upper cold layers of the atmosphere, where, after condensation of water vapour, it transfers this heat to the cold layers of the atmosphere and warms them up, in accordance with the law of energy conservation. This means that it is a unique land conditioning system that stops working when rainwater has a limited capacity to seep into the soil.

As small water cycles empty, sensible heat production increases (Bowen ratio increases) and this overheats the troposphere because there is no heat carrier to transport it to the cooler layers of the atmosphere. The heat carrier is evaporated water. Therefore, we need more water in the ground to evaporate and transport heat from the troposphere to the upper layers of the atmosphere, which are cooler. By historically reducing the water supply in the ground, we have reduced the real evaporation and therefore more heat is being concentrated, particularly in regions that are arid. These changes in the hydrological cycle bring with them other adverse phenomena, such as the temporal and spatial change in the distribution of precipitation.



The carbon cycle is also interactively linked to the water cycle, which stores carbon in vegetation and soil through photosynthesis. The more water in the ground, the more intense photosynthesis and thus the more water there is in the ground, the more fertile the soil, and of course the more organic carbon accumulates in the soil, with a positive impact on soil and water conservation, biodiversity and slowing down the processes of weather change. The trend of declining photosynthesis brings about degradation processes of soil mineralisation, loss of biological matter in the soil and carbon is bound with oxygen, which increases the concentration of CO2 in the atmosphere, as shown schematically in the figure.



That is why the United Nations General Assembly, through resolution 73/284, declared 2021-2030 as the *United Nations Decade on Ecosystem Restoration*. This resolution, also signed by Greece, calls for support and increased efforts to prevent, halt and reverse the degradation of ecosystems, as well as to raise awareness of the importance of water and soil restoration. The restoration of water and soil in the earth is therefore a major priority for economic growth in all regions of the world, with the necessary need for global security.

To support the implementation of the *UN Decade on Ecosystem Restoration*, a working group was established to develop best practices, led under the auspices of the Food and Agriculture Organization of the United Nations (FAO). On 29 October 2020, the FAO again issued a call for increased efforts to restore and revitalise landscapes and forests.

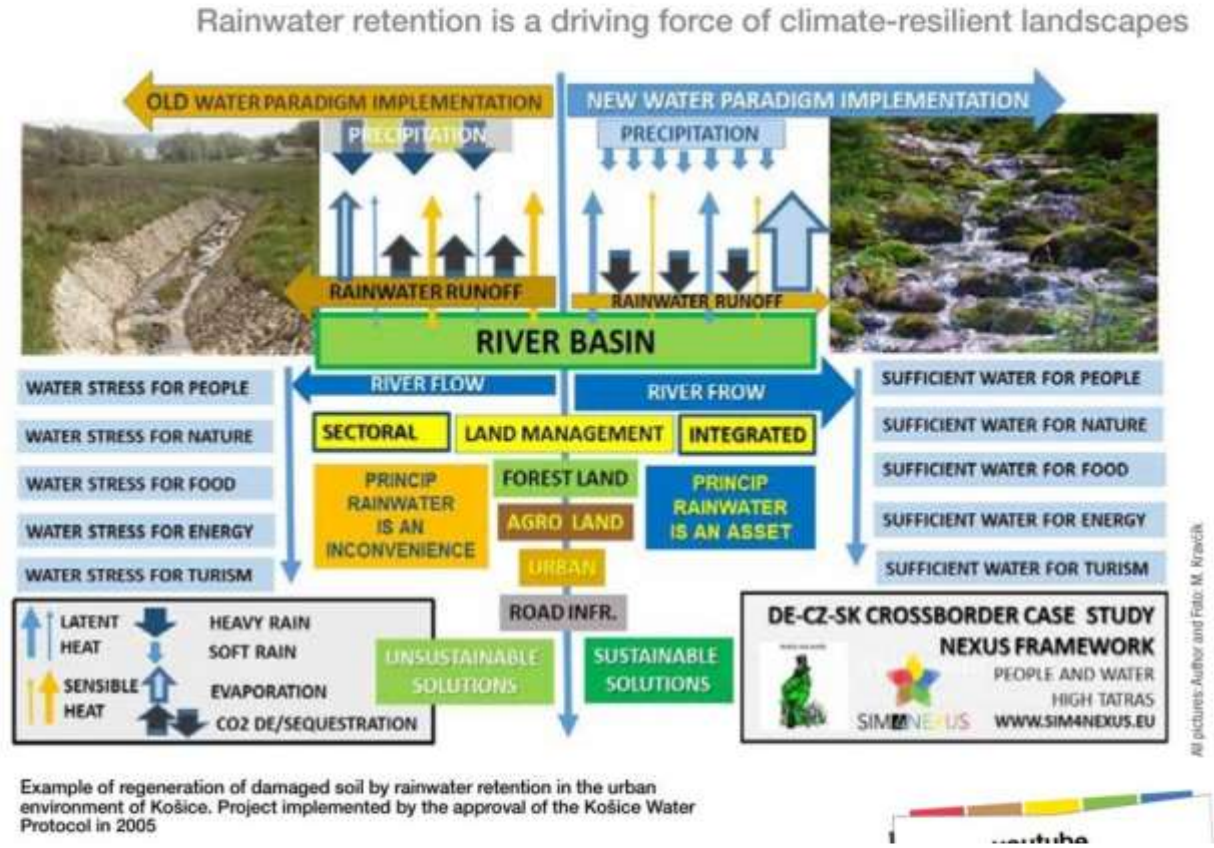
Comprehensive integrated solutions are the way to bring about systemic changes in the use, conservation and restoration of natural resources. Water, land and energy are the basic elements on which the community, the region, the state and the international community stand. With an abundance of these resources, humanity in different parts of the world has managed to survive even in the worst of times. The deterioration of natural resources: the loss of soil fertility, extreme weather events and the deterioration of environmental security, are risks that are both a challenge to tackle and a threat to our ability to cope. For this reason, we also recommend promoting integrated natural resource regeneration in Greece, which can systematically restore what Greece has lost in the past.

The water (W) - energy (E) - food (F) nexus has attracted a great deal of international attention. The concept first emerged at the World Economic Forum (2011), which issued a call to address the challenges of economic growth in the context of water, energy and food. The World Economic Forum (WEF) published a report entitled "Water-Security: The Water-Food-Energy-Climate Nexus", which highlights that an integrated approach to water, energy and food increases resource security, efficiency, poverty reduction and better resource management in all sectors of the economy. To achieve sustainability of the Water-Energy-Food Nexus (WEF), natural, social as well as economically oriented scientists need to combine their efforts in problem solving and approaches for integrated policies and this is a major challenge for Greece as well.

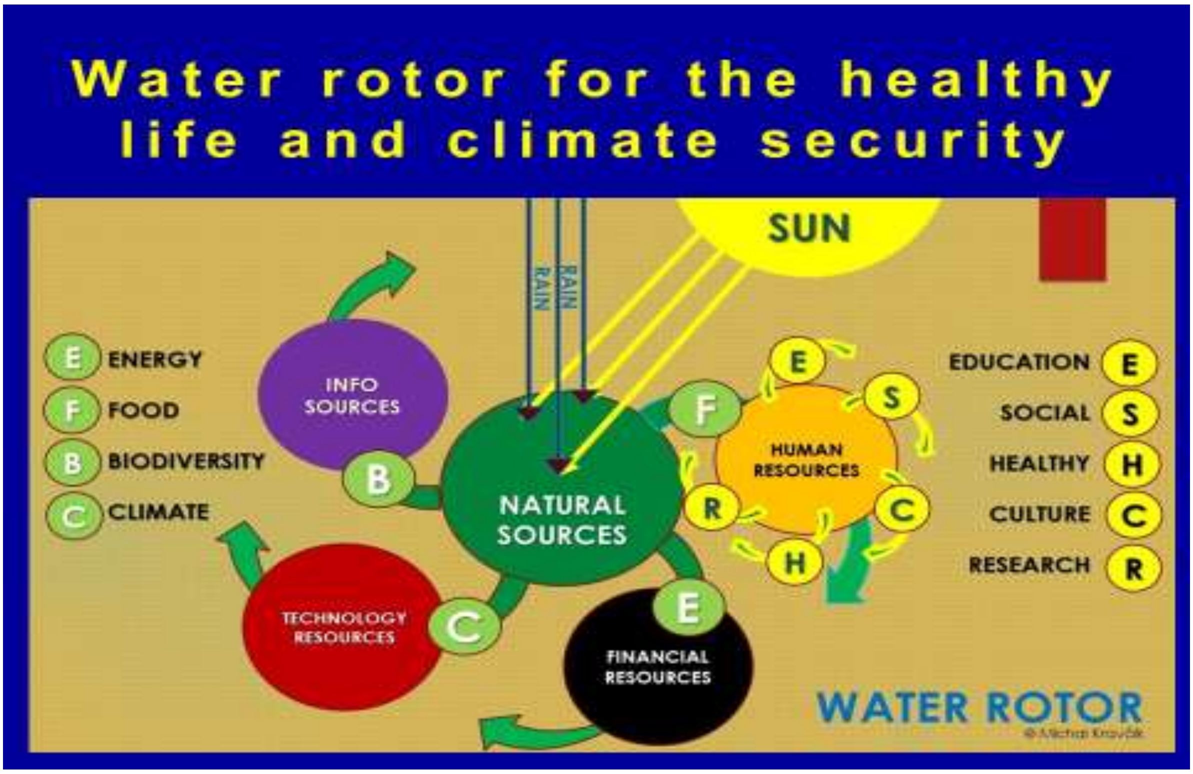
This calls for the need to elaborate the concept of ecosystem-based water restoration in the arid landscape structures of Greece in order to promote thermoregulation of the landscape, intensive photosynthesis, and thus carbon sequestration in biomass and soil for improving its fertility.

This approach was first elaborated in the EU research project SIM4NEXUS (www.sim4nexus.eu) on a German-Czech-Slovak case study.

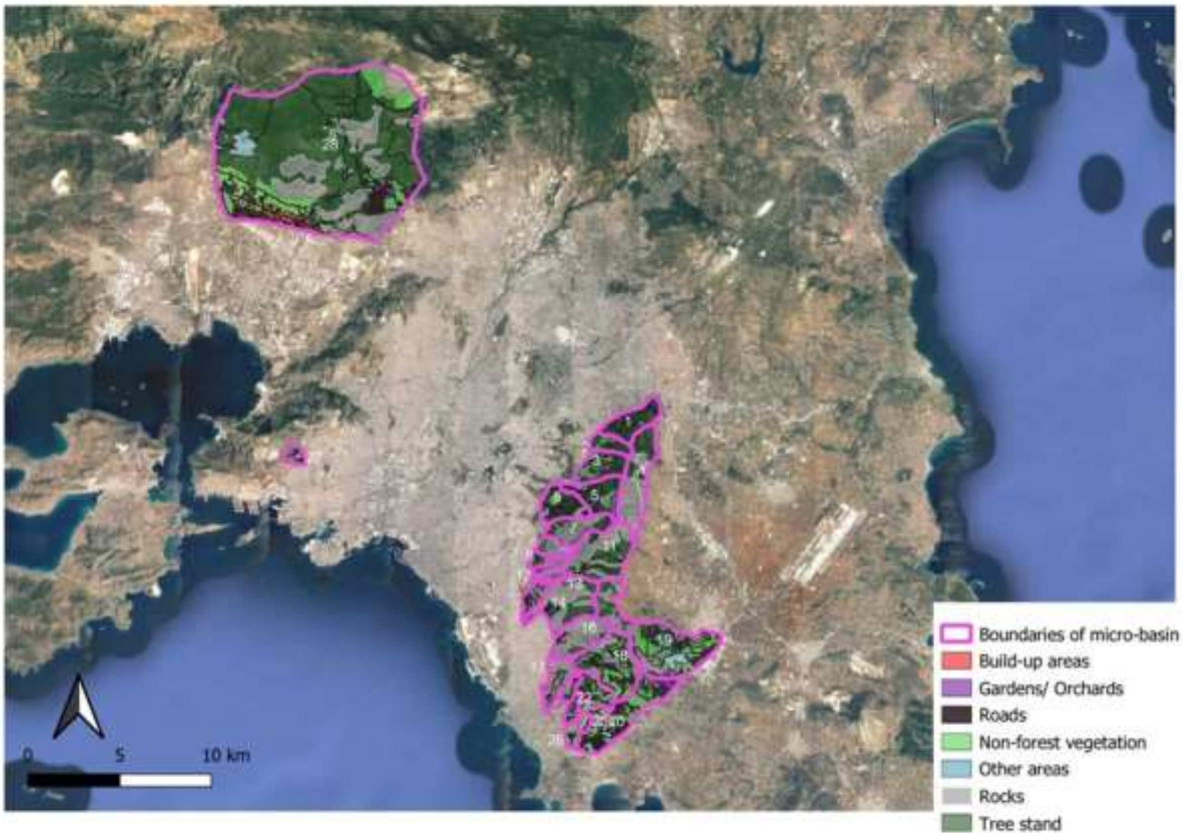
The idea behind the approach is that water sufficiency in the landscape can be ensured by using rainwater runoff from the land where it falls or in its vicinity. Ecosystem-based rainwater retention in forested and urbanised landscapes not only enhances the water reserves in the landscape in an eco-systemic manner, but also increases soil moisture and the intensity of photosynthesis. Plant roots are capable of extracting as much water from the soil water reserves as the vegetation needs for its growth. From the current state of water stress that operates in the old water paradigm (www.waterparadigm.org), the transition to the new water paradigm ensures water abundance for humans, nature, food and climate, as shown in the model diagram.



The Integrated Implementation Model of the New Water Paradigm shows that appropriate stormwater management in the landscape can sustainably restore natural resource regeneration that enhances economic growth, human resource development and prosperity with the imperative need to maintain climate security. Restoration of natural resources activates human resources, this generates financial resources, technological resources and of course the dissemination of information on how and approaches to restore natural resources in the landscape we have damaged (see Water Rotor diagram).



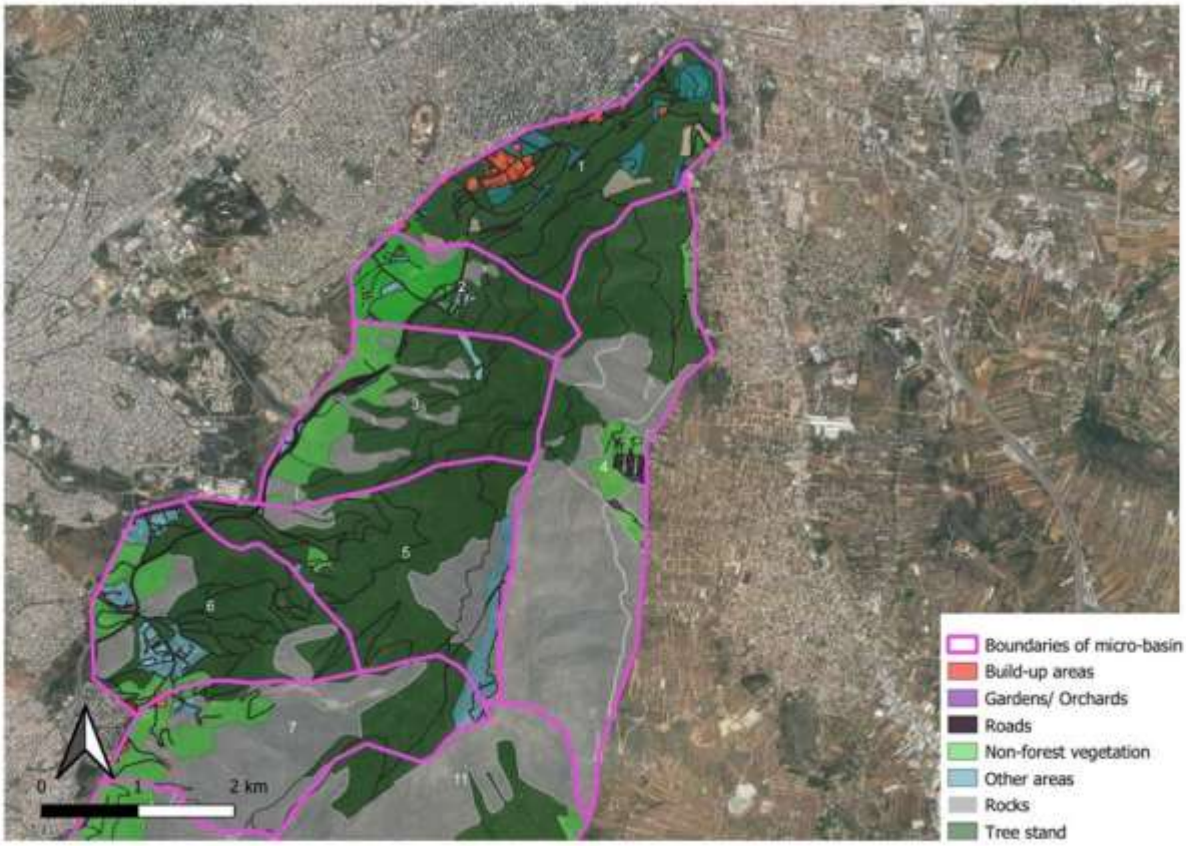
Based on the assumptions defined above, we have diagnosed the potential for the possibility of using non-beneficial stormwater runoff to restore natural resources in damaged ecosystems. We selected damaged parts of the Attica region and analysed the potential of stormwater runoff from the damaged part of the landscape and defined the benefits from the implementation of the New Water Paradigm. Three sites are defined on the map.



The first site we called Holy Monastery of Kaisariani for the whole territory. This site is numbered 1-26 with an area of 9,557 hectares starting at the east of Athens. In this site we identified 26 runoff areas in which we made calculations of the volume of stormwater runoff and what benefits will be created if we create conditions for cyclical retention of stormwater in the damaged landscape.

We have done the same at the small site No. 27 Keratsini's rock climbing sector (west of Athens) on an area of 89.7 hectares and northwest of Athens at site No. 28 (St. Cyprian Monastery) on an area of 8,521 hectares. The reason for selecting these sites was to take into account the characteristics of the landscape structure and the state of deterioration.

At each site we analysed the landscape structure, the state of damage and calculated the balance of the volume of non-beneficial runoff per extreme rainfall event of 100 mm by the CN curve method. For the volume of stormwater runoff from this extreme rainfall event, we propose water conservation measures to keep all the stormwater from such an extreme rainfall event in the damaged landscape structures. Based on the methodology from the SIM4NEXUS case study (www.sim4nexus.eu), we calculated the ecosystem benefits of retaining rainwater directly in runoff areas (water resources gained, increased evaporation, reduction of sensible heat, reduction of mean annual temperature at the site, carbon storage in soil and vegetation, and Co^2 consumed for photosynthesis).



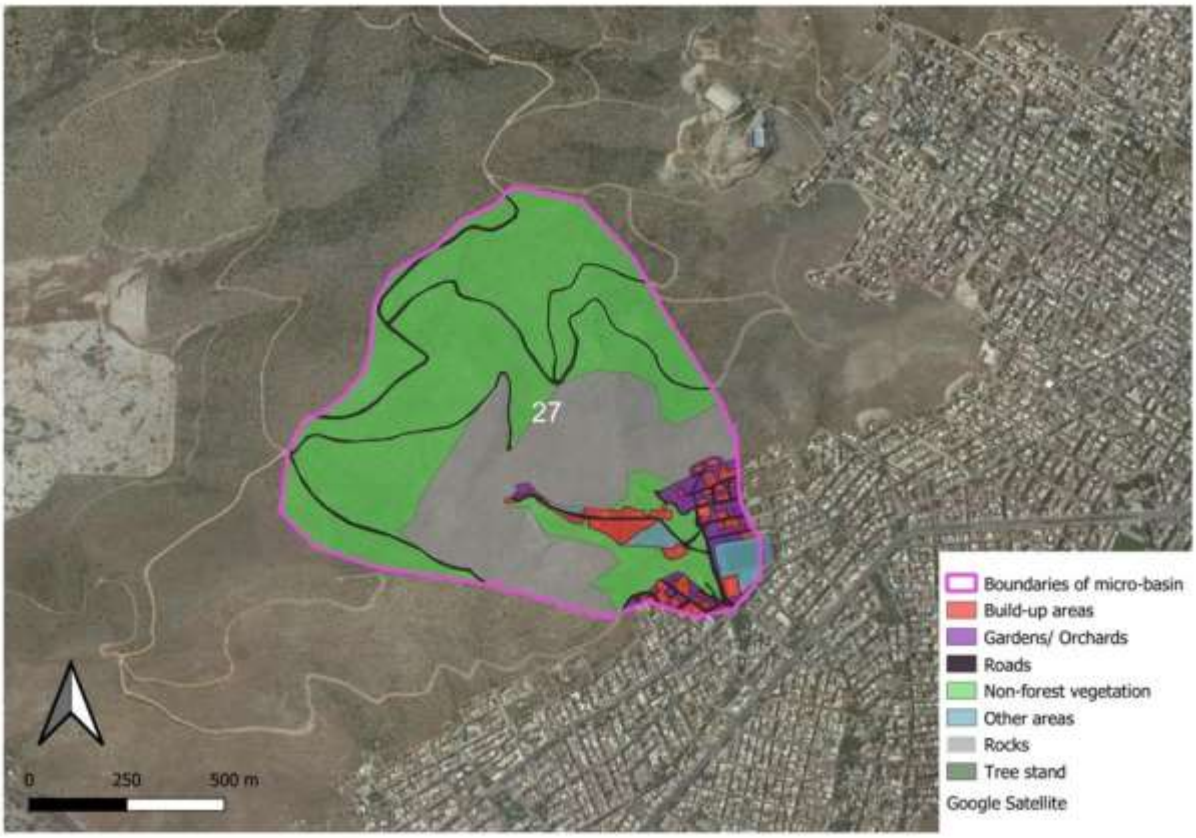
The results are summarised in the tables in each catchment area 1-26 and we have also prepared a summary table of benefits for the Holy Monastery of Kaisariani site. Note that the benefit calculations are calculated for one year. However, the recommended water retention measures will act in a cyclical manner, that is, there will be a cumulative effect from the long-term effect of cyclical rainwater retention not only in the growth of water resources but also with the long-term trend of mitigation of temperature fluctuations and also with the gradual recovery of native vegetation species on the sites. The positive effect will already be visible with one's own eyes within 5 years. The site is very rugged and we have therefore divided the area into natural catchment areas to allow the restoration of the site on a section-by-section basis. In each catchment area the necessary amount of water retention measures has also been calculated. For example, it is recommended that 218,013 m^3 of water retention measures be carried out in site No. 1.

Catchment N. 1	Build-up areas	Gardens	Roads	Non-forest vegetation	Other Areas	Rocks	Tree stand	SUM
Area (m2)	227 123	0,00	231 127	124 134	419 776	198 690	2 628 883	3 829 733
Runoff volume (m3)	18 222	0	16 787	7 036	34 787	13 477	127 703	218 013
Obtained water source (l/s)	0,19	0,00	0,18	0,07	0,37	0,14	1,35	2,30
Increased evaporation (m3)	12148	0,00	11191	4691	23192	8985	85135	145342
Sensible heat reduction (GWh)	9	0	8	3	16	6	60	102
Temperature reduction (0C)	-0,35	0,00	-0,32	-0,25	-0,36	-0,30	-0,21	-0,25
Carbon sequestration (t)	16	0	15	6	31	12	114	194
CO2 for photosynthesis	58	0	54	23	111	43	409	698

If the entire area is implemented according to the proposals in this study with a total volume of 5.5 million m^3 of water retention measures for cyclical stormwater retention, the area will develop water resources with a yield of more than 60 second/litres, a reduction of sensible heat of 2,617 GWh will be reduced, resulting in a reduction of 0.26 degrees in the average annual temperatures. Please note that this is a reduction in average annual temperature. Summer temperatures at the site will be reduced by more than 3 degrees. However, additional calculations need to be done for this, which is already beyond the scope of this study. More than 5,000 tonnes of organic carbon will be deposited in this part of the landscape annually, which in the long term will have significant benefits for the formation of the soil, which apparently was there in the past and has been washed out to sea by gradual erosion.

Catchment N. 1-26	Build-up areas	Gardens	Roads	Non-forest vegetation	Other Areas	Rocks	Tree stand	SUM
Area (m2)	1 477 455	3 194 824	2 607 541	24 574 924	5 164 086	32 970 308	25 579 160	95 568 298
Runoff volume (m3)	118 534	202 005	189 389	1 392 962	427 955	2 236 382	1 242 558	5 509 028
Obtained water source (l/s)	1,25	2,14	2,00	14,72	4,52	23,64	13,13	61,41
Increased evaporation (m3)	79022	0,00	126259	928641	285303	1490922	828372	3738520
Sensible heat reduction (GWh)	55	0	88	650	200	1044	580	2617
Temperature reduction (0C)	-0,35	0,00	-0,32	-0,25	-0,36	-0,30	-0,21	-0,26
Carbon sequestration (t)	105	0	168	1238	380	1988	1104	5033
CO2 for photosynthesis	379	0	606	4457	1369	7156	3976	17945

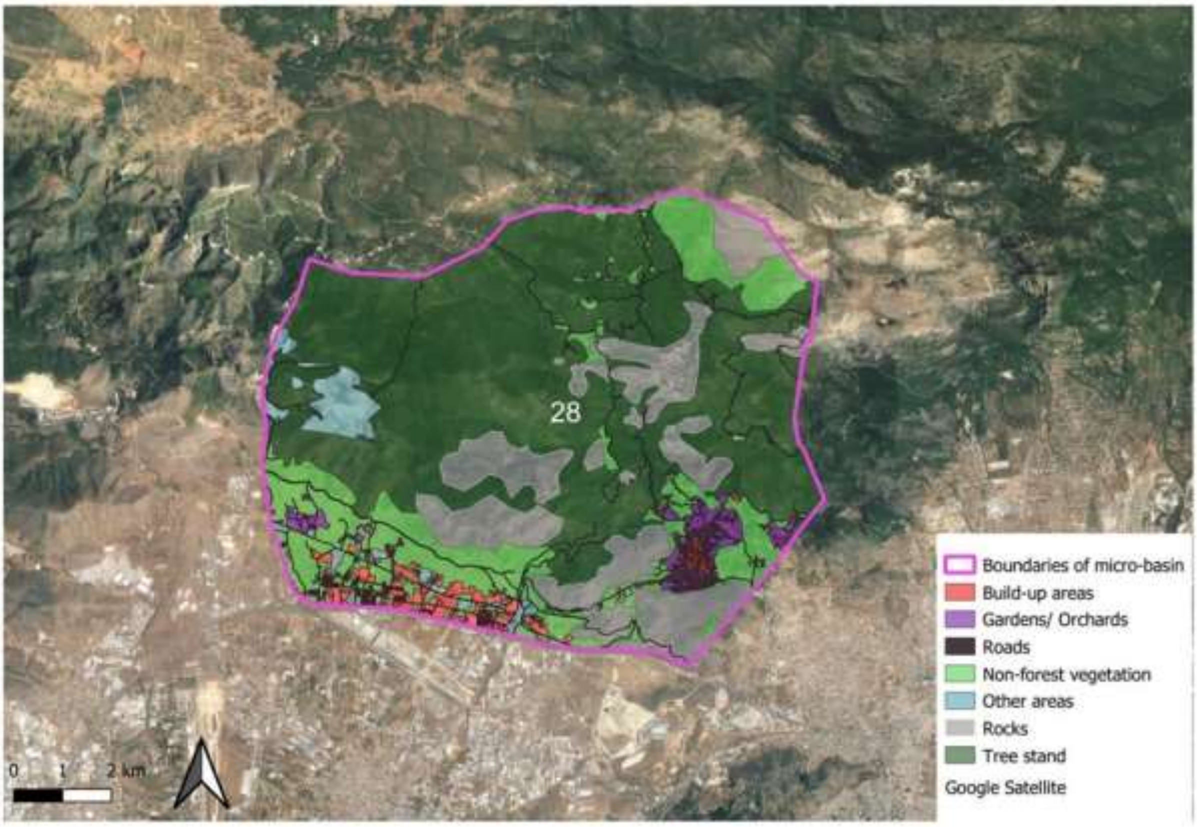
The tiny site No. 27 on the western side of Athens of less than 90 hectares was chosen in order to start the recovery processes also in the vicinity of the Schisto Perama Environmental Park, so that in the future the interactions of the recovery of ecosystem services between the protected area and the completely damaged area can also be monitored.



After the recovery of this site through the creation of surface water retention measures, it will also be possible to monitor the interaction between the protected area and the restored area. The benefits are defined in the table below.

Catchment N. 27	Build-up areas	Gardens	Roads	Non-forest vegetation	Other Areas	Rocks	Tree stand	SUM
Area (m2)	32 274	27 170	30 310	527 759	18 756	260 402	0	896 671
Runoff volume (m3)	2 589	1 718	2 201	29 915	1 554	17 663	0	51 333
Obtained water source (l/s)	0,03	0,02	0,02	0,32	0,02	0,19	0,00	0,59
Increased evaporation (m3)	1726	0,00	1468	19943	1036	11775	0	35949
Sensible heat reduction (GWh)	1	0	1	14	1	8	0	25
Temperature reduction (0C)	-0,35	0,00	-0,32	-0,25	-0,36	-0,30	0,00	-0,26
Carbon sequestration (t)	2	0	2	27	1	16	0	48
CO2 for photosynthesis	8	0	7	96	5	57	0	173

In the north-west of Athens, an opportunity emerges to restore ecosystem services in the damaged landscape by building water retention measures for the cyclic retention of rainwater of approximately 4.5 million m^3 over an area of 8,521 hectares. This site is also recommended because there is frequent flood damage beneath this area in the densely populated part of the site that needs to be addressed. The estimated investment for flood protection through the reinforcement of the water infrastructure (storm water catchment) in the built-up area under the revitalised site amounts to approximately € 200 million. The investment in the revitalisation of the damaged landscape is estimated not to exceed € 150 million.



However, this investment brings additional benefits such as increased yield of water sources in the revitalised area by 50 second/litres, a reduction in the average annual temperature by 0.25 degrees with a summer heat decrease by more than 3 degrees. The impact of this solution on the consumption of CO^2 from the atmosphere is also beneficial. Around 23 thousand tonnes per year.

Catchment N. 28	Build-up areas	Gardens	Roads	Non-forest vegetation	Other Areas	Rocks	Tree stand	SUM
Area (m2)	2 311 931	2 163 749	1 209 427	15 386 033	2 919 479	14 743 043	46 478 584	85 212 246
Runoff volume (m3)	185 482	136 811	87 842	872 115	241 941	1 000 023	2 257 789	4 459 711
Obtained water source (l/s)	1,96	1,45	0,93	9,22	2,56	10,57	23,86	50,55
Increased evaporation (m3)	123655	91208	58561	581410	161294	666682	1505193	3188003
Sensible heat reduction (GWh)	87	64	41	407	113	467	1054	2232
Temperature reduction (0C)	-0,35	-0,28	-0,32	-0,25	-0,36	-0,30	-0,21	-0,25

Carbon sequestration (t)	247	182	117	1163	323	1333	3010	5946
CO2 for photosynthesis	890	657	422	4186	1161	4800	10837	22954

In addition to the benefits for addressing water, food, environmental and climate security, the implementation of this project is also beneficial for strengthening ecosystem services and social security. Hundreds of employment opportunities will be generated in the micro-region during the program implementation, which will develop the foundations for strengthening integrated landscape security with strengthening local economic, social, environmental and climate security in regions adjacent to Greece. At the same time, the recovery of the damaged landscape in Greece can be an inspiration for the countries of the Mediterranean, the Middle East as well as Africa, which suffer from water scarcity and the resulting migratory waves.