Revised set of indicators

A structured network for integration of climate knowledge into policy and territorial planning

DELIVERABLE INFORMATION	
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1. Introduction

The purpose of the document “Proposed set of indicators”, as the title indicates, was to propose a set of indicators which will be tested in different pilot areas of 3 Thematic centers (TC):

- TC1 - Forestry and Agriculture (pilot studies in Austria and Romania);
- TC2 - Drought, Water and Coasts (pilot studies in Italy and Greece);
- TC3 - Urban Adaptation and Health (pilot study in Hungary).

The calculation of indicators is executed side by side using the observed meteorological data and data time series generated on the basis of climate projections. Based on reports received from project partners proposed set of indicators is revised. In this document, an overview of the pilot studies and indices that have been proven to be suitable for climate change monitoring is given. Calculation methodology of the indices is presented in the Appendix.

2. Forestry & Agriculture

2.1 Adapted forest management at LTER Zöbelboden

The Federal Environmental Agency runs a long-term ecosystem research site in the “Kalkalpen” national park with a total area of 500 ha (LTER Zöbelboden, N 47°50'30", E 14°26'30"). The forest types of LTER Zöbelboden are representing major forest types of the Northern Limestone Alps in Austria, in particular mixed spruce-fir-beech forests. Karst areas such as the limestone mountains are a source of half of the drinking water in Austria. The core of Pilot study 1 was the development of model based scenarios of climate change effects on water runoff amount and quality that is influenced by forest management. The scenario results were discussed with local authorities, forest managers, and policy makers and optimal adaptation strategies for forest management were defined.

Having in mind the sensitivity of forest ecosystems to changes in the climate, impacts will be more or less severe. In the observed area increasing temperature is anticipated in the future and particularly in summer. With regard to precipitation, trends are uncertain but increase in precipitation may only occur in winter and not during summer, resulting with several consequences. During summer, drought effects may become more severe and may occur more frequently. Dependent on the degree of winter temperature increase, either more precipitation will immediately turn into more runoff or snow will accumulate turning into runoff when temperature rises in the spring. Forests retain precipitation via interception and evapotranspiration thereby reducing the risk of surface flow and soil erosion. Furthermore, potential water pollutants are stored in the soil so that the loss to the groundwater is reduced. These retention and filter capacities are strongly influenced by the soil type and forest stand characteristics. As an example, monodominant spruce forests have a lower retention capacity for nitrate than mixed conifer-deciduous forest on the same soil. Forest stand characteristics together with site characteristics are therefore ideal sensitivity indicators for climate change impacts (QFI). A forest subsidy for water-related management is used as an adaptation indicator (FWW). All tested indicators are given in Table 1.

Table 1 Tested indicators in pilot study 1

Index	Definition
R50mm	Precipitation days with RR ≥ 50 mm
RCPTOT	Total precipitation in wet days
SWE	Snow Water Equivalent
SPI12	Standardized Precipitation Index 12 months
CDD	Consecutive Dry Days
QFI	Forest Water Index
FWW	Forest Water Funding

Observed and modelled daily values of temperature (maximum, mean and minimum), accumulated precipitation, global radiation, wind speed, relative humidity and air pressure are used for calculation of indices. Observed data are collected from 3 meteorological stations and cover the period from 1996 to 2013. Modelled data cover the period from 2000 to 2100. In this case, multimodel and multiple scenario approach is applied. Data on 10 km resolution are obtained with dynamical downscaling of two global climate models, ECHAM5/MPI-OM and HadCM3 with regional climate model COSMO-CLM. Further downscaling to the research site is done using weather generator ClimGen. Three scenarios from IPCC-AR4 report: A1B, B1 and A2 are applied for climate simulations. Data are downscaled to either a forest plot or the entire catchment.

2.2 Climate change adaptation measures in Romanian agriculture

The assessment of efficiency of crop water use under current and future climate conditions is considered for different cropping systems (winter wheat, maize, sunflower, potato). Two sites in Romania are considered: Caracal in Olt county located in the south part of the Oltenia region and Covasna in Covasna county located in the south-eastern part of the Transilvania region. Both pilot areas are located in area vulnerable to extreme drought conditions, water scarcity and/or floods which can affect agriculture considerably.

From the observed data, daily, monthly and multiannual values of meteorological (air temperature – min, max, medium, rainfall, solar radiation) and agrometeorological parameters (soil moisture, heat waves, phenological and yield data from winter wheat and maize crops) are applied. In addition, satellite-derived products: Normalized Difference Water Index (NDWI), Leaf area Index (LAI), Fraction of Absorbed Photosynthetic Solar Radiation (fAPAR) are used for determining the effects of the extreme moisture condition on agriculture. Data cover the period 1961-2013, with the exception of NDWI, 1961-2010.

Modeled data are obtained from:

- RegCMs/SRES A1B climate predictions at a very fine resolution (10 km) over 2021-2050 (obtained in FP7 project ENSEMBLES)
- ensemble mean from CMIP5 experiments (RCP 4.5 and RCP 8.5 scenarios for 2021-2050 period vs. 1971-2000)
- CERES-Wheat and CERES-Maize models.

Applied modelled data include:

- climate parameters: air temperature (minimum and maximum), rainfall, monthly values of solar radiation;
- crop phenology and management crop data
- the genetic coefficients that characterize vernalization, photoperiod response, duration of grain filling and phyllocron.

All modeled data are downscaling to the station point. There are 2 stations, one for each pilot area, Caracal and Tg. Secuiesc meteo stations.

Table 2 Tested indicators in pilot study 2.

Index	Definition
SPI3	Standardized Precipitation Index 3 months
SM	Soil Moisture
HS	Heat Stress
AI	Aridity Index
fAPAR	Fraction of Absorbed Photosynthetically Active Radiation Index
NDVI	Normalized Difference Vegetation Index
NDDI	Normalized Difference Drought Index
NDWI	Normalized Difference Water Index

Indices given in Table 2 are currently in use in the agrometeorological operational activities (agrometeorological bulletins – diagnoses/ forecasts) and for research purposes in Romania.

PDSI and **SPEI** indices still need to be tested.

3. Drought, Water & Coasts

3.1 Climate change adaptation in the new water regime in Puglia region, Italy

Economic and social vulnerability to extreme climate events such as droughts and the already observable trend towards reduced water yields is investigated in selected watersheds and coastal areas in Puglia region, Italy.

Based on bias-corrected outputs from COSMO-CLM regional climate model simulations forced by CMCC-CM at 8 km for RCP4.5 and RCP8.5 scenarios, extreme event indicators for coastal areas are investigated using maps and aggregated data to report the spatial distribution of meteorological and agricultural drought indices. In addition, building on water balance evaluations, streamflow-based indices are selected and applied to derive a set of indicators for hydrological droughts enabling the study of changes in the frequency, duration and magnitude of low-flow extremes (Table 3). Simulation data cover the period from 1970 to 2070.The DESYCO decision support system for coastal climate change impact assessment is used to undertake an integrated assessment of multiple climate change impacts represented by indicators in relation to vulnerable coastal systems. The system uses a regional risk assessment methodology that ranks the natural and human targets and areas potentially at risk from climate change, identifies hotspots and priority areas for intervention, and defines adaptation strategies using site-specific physical, ecological and socioeconomic data.

Table 3 Tested indicators in pilot study 3

Index	Definition
ATR	Annual Temperature Range
MAT	Mean Annual Temperature
APA	Annual Precipitation Amount
GDD	Growing Degree Days
R5mm	Precipitation days with RR ≥ 5 mm
CWD	Consecutive Wet Days
PET-HA	Hargreaves Potential Evapotranspiration

3.2 Effects of climate change on the wetland ecosystems of Attica region, Greece

Wetlands, as regulators of water regimes, can play a role in climate change mitigation in South Eastern Europe. However, since droughts and changes in water regimes are expected to have a significant impact on wetlands, the aim of this pilot study is to support territorial planning and policy making related to wetland ecosystems. The pilot study is being carried out in the Attica region of Greece, with a focus on 13 wetlands, including lakes, coastal marshes and lagoons, and streams.

In order to assess wetland vulnerability indicators that combine climate change impacts, expressed in terms of drought exposure, with wetland sensitivity, expressed by function (water storage, food web support, nutrient removal, the trapping of sediments and toxins, flood attenuation and shoreline stabilization), values (protection against floods and erosion, improvement of water quality, and recreational, cultural, educational, scientific, biological and economic activities) and anthropogenic threats are applied. Threats are calculated as changes to a wetland area and to land cover in its vicinity, monitored over a period of 30 years through remote sensing data. In parallel, adaptive capacity is assessed through a questionnaire, focus group meetings and interviews with key stakeholders. The wetland vulnerability indicator is assessed as a function of exposure to drought, wetland sensitivity (wetland values and functions coupled with anthropogenic threats) and the capacity of key stakeholders to respond and formulate adaptation measures.

Modeled data obtained from regional climate model EBU-POM/ECHAM5 for SRES A1B and A2 scenarios are applied for assessment of climate change. The spatial resolution of the model outputs for temperature and precipitation is 25 km and they cover the period 1961-2100. All model data are bias corrected using observational data from eight meteorological stations in the Attica region.

Table 4 Tested indicators in pilot study 4

Index	Definition
SPI12	Standardized Precipitation Index 12 months
DVI	Drought Vulnerability Index
WS	Wetland Sensitivity
WAD	Wetland Adaptive Capacity
WV	Wetland Vulnerability

3.3 Water resources and the use of hydroelectricity, Italy

In the long term, the uncontrolled development of hydropower plants may cause sustainability problems, as the systematic exploitation of water resources may reduce the ability of aquatic ecosystems to provide services to the population.

The two basins in alpine region are very suitable for water resources investigation, in particular: Brenta River basin and Noce River basin. The area of Brenta basin is 1133 km^2 with altitude from 200 to 3035 m a.s.l. and the area of Noce basin is 1367 km^2 from 200 to 3760 m a.s.l. with two glacier sites and five artificial lakes.

In this pilot study observed and modelled data for daily precipitation, daily maximum and minimum temperature and daily river discharge are used. Modelled daily river discharge data are obtained by GeoTransf hydrological model. The GeoTransf model has been developed by a research group at the University of Trento.

Observed meteorological data from 44 precipitation and temperature stations and 70 precipitation only stations cover the period 1971–2010 while river discharge data from 9 hydrometer stations cover 1981–2010 period.

Modelled data for meteorological data are obtained from COSMO-CLM/CMCC–CM for RCP8.5 and RCP4.5 scenarios and on 8 km resolution for the period 1971 – 2070. For river flow data GeoTransf of about 3 km^2 area for each computational sub-catchment is applied.

Tested indicators in this pilot area are given in Table 5. Indicators are created specifically for stakeholder needs.

Table 5 Tested indicators in pilot study 5

Index	Definition
SYC	Storage Yield Curve
NVPWR	Natural Variation of Potential Water Resources
TAPWRA	Trend of Annual Potential Water Resources Availability
SMEF	Sustainability of Minimum Environmental Flow
WBI	Water Balance Index
WVV	Withdrawal Volumes Variation
THV	Theoretical Hydropower Variation
TATH	Trend of Annual Theoretical Hydropower

4. Urban Adaptation & Health

4.1 Vulnerability assessment in Budapest and Veszprém

Southern Europe and South Eastern Europe are the most vulnerable regions in Europe to the impacts of climate change. At the same time, the rate of urbanization in these regions is among the highest in Europe. Various studies have shown that the urban environment serves as a multiplier of the impacts of climate change on a number of economic sectors and ecosystems, including public health. Increasingly frequent heat waves are resulting in higher mortality rates. Experience acquired by municipal authorities around the globe in addressing this problem needs to be shared with medium-sized and large municipalities in Southern and South Eastern Europe.

The two areas in Hungary are chosen for urban adaptation and health investigation: Municipality of Veszprem and Municipality of 13th District of Budapest. Veszprém is a medium-sized city (126.90 km^2) situated in the western part of Hungary, about 110 km from Budapest and 15 km north of Lake Balaton, in a hilly area. The 13th district of Budapest is one of the most intensively developing areas in the Hungarian capital, located on the north Pest side alongside the river Danube. Despite the small size of area (13.44 km^2), the population of the district is relatively high, and intensively growing. The district is a densely built residential, business and commercial area, with a constantly increasing volume of traffic.

Observed data of daily mean temperature cover the period from 1970 till present (baseline period 1970-2000). Statistical data related to health condition of population and parameters characterizing their living conditions (both physical as buildings and socio economic situation) for the period 1998-2004 are used as well.

Change of daily mean temperature and daily mean precipitation (averaged for 30 year period), linear trend coefficients of monthly mean temperature and linear trend coefficients of seasonal mean precipitation were calculated in every grid point by ALADIN-Climate (10km resolution) and REMO models (25 km resolution). Models were run by the Hungarian Meteorological Service covering the Carpathian Basin with 10-25 km resolution for the periods 2021–2050 and 2071–2100, with reference to 1961–1990, and for A1B SRES scenario.

Beside indices based on meteorological parameters there are number of others. The indices given in Tab. 5 are related to exposure data. The list is not including indices related to sensitivity and adaptive capacity, in particular those related to socio-economy which are very important and suggested to use. The complex exposure indices as **UTCI**, **PhET** and **HCI** might be very useful but might be problematic to calculate due to the lack of data. For each case beside exposure indices the most relevant sensitivity and adaptive tool related indices are to be identified and used.

Table 6 Tested indicators in pilot study 6

Index	Definition
HW	Heat Waves
CTD	Consecutive Tropical Days
CTN	Consecutive Tropical Nights
WSDI	Warm Spell Duration Index
UTCI	Universal Thermal Climate Index
PhET	Physiologically Equivalent Temperature
HCI	Human Comfort Index

- **Sensitivity** related indicators related to socio-economic conditions, living conditions, education etc.:
  - the ageing index represents the ratio of the elderly (65-x) and children population (0-14 years old);
  - socio-economic status index, based on the combination of some selected factors reflecting the settlement-level social situation (settlement level indicators include unemployment rate, low educational level, income conditions, number of passenger cars, rate of large families, rate of incomplete families, population density);
  - living environment/conditions: density of housing (person per room), proportion of dwellings lacking basic amenities, rate of one parent families, rate of one person households, rate of lonely pensioner households, rate of green areas per person, large families (parents with three or more children, in proportion of families);
  - education level: settlement level educational situation, rate of population with basic education, rate of population with secondary education, rate of population with high education;
  - economic conditions: proportion of population of productive age, gross income serving basis for income tax, number of passenger cars per 100 inhabitants.

- **Adaptive capacity**, as ability to adjust to heat excess, characterized by the physical parameters and conditions of the buildings, awareness and knowledge, communication, measures and healthcare related indicators:

- adaptive capacity complex index determined by factors as per capita income, inequalities, availability of healthcare services, access to information.
- building features - material, insulation, shade etc.;
- adaptive tools - e.g. outer shade, special menu etc.;
- rules, measures - e.g. heat wave plan, alerts;
- awareness/knowledge;
- mass communication/information available;
- per capita income;
- health care services.

- **Vulnerability** (function of exposure, sensitivity and adaptive capacity) indicators:
  - excess mortality - number of cases or % (causes of death, mapping the territorial distribution of mortality by settlements by age groups and by sex);
  - excess number of emergency calls, or number of cases or %.

APPENDIX

A

AI – Aridity Index: a numerical indicator of the degree of dryness of the climate at a given location

Let P be accumulated precipitation and PET potential evapotranspiration in the chosen period. Then aridity index for the period is given by:

$$AI = P/PET$$

APA - Annual Precipitation Amount: total precipitation in a year

Let RRij be the daily precipitation amount on a day i in year j. Then:

$$APA = \text{sum}\ (RR_{ij})$$

ATR - Annual Temperature Range: difference between annual absolute maximum and annual absolute minimum temperature

Let TXi be the daily maximum and TNi minimum temperature at day i of the year. Then the annual temperature range is:

$$ATR = \max\ (TX_i) - \min\ (TN_i)$$

C

CDD – Consecutive Dry Days: maximum length of dry spell

Count the largest number of consecutive days in chosen period where RR < 1 mm.

CTD - Consecutive Tropical Days: maximum number of consecutive tropical days

Count the largest number of consecutive days in chosen period where TX > 30°C

CTN - Consecutive Tropical Nights: maximum number of consecutive tropical nights

Count the largest number of consecutive days in chosen period where TN > 20°C

CWD - Consecutive Wet Days: maximum length of wet spell

Count the largest number of consecutive days in chosen period where RR ≥ 1 mm.

D

DVI - Drought Vulnerability Index

Drought Vulnerability Index is an index for the assessment of vulnerability to drought and water scarcity and fixing relative risk zones. It is resulted from the combination of all features of drought (duration, intensity, frequency) as they have analysed and calculated in relation to SPI12 index. Method of calculation of DVI has been by the River Management Plan of Attika Water District. DVI receives values from 1 (Low vulnerability) to 4 (High vulnerability).

More details you can find in Drought and Water shortage Management Plan of Attica Water Basin District, Ministry of Environment, Energy and Climate Change (2013).

F

fAPAR - Fraction of Absorbed Photosynthetically Active Radiation: satellite derived product.

fAPAR presents solar radiation reaching the canopy in the 0.4 - 0.7 μm wavelength region. It is considered a good indicator for detecting and assessing the impact of drought on plant coatings.

FWW - Forest Water Funding

Financial compensation of additional expenses due to adaptive forest management measures according to water protection.

G

GDD – Growing Degree Days: the number of temperature degrees above a threshold base temperature (10°C) in a chosen period.

$$T_b = 10°C$$

$$GDD_i = TG_i - T_b \quad \text{if } T_b < TG_i$$

$$GDD_i = 0 \qquad\qquad \text{if } T_b \geq TG_i$$

$$GDD = \sum_{i=1,I} GDD_i$$

H

HCI - Human Comfort Index

For more details take a look at e.g.:

http://repositories.lib.utexas.edu/bitstream/handle/2152/13980/1-boduch_fincherstandards_of_human_comfort.pdf?sequence=2

HS - Heat stress: maximum temperature reaches 32°C.

HW - Heat Waves

Number of days in intervals of at least 6 days with TX 5°C higher than long term mean calculated for each calendar day using running 5 day window.

M

MAT - Mean Annual Temperature: mean temperature for the year

Let TGij be the mean temperature at day i of year j. Then mean values in period j are given by:

$$TG_j = \sum_{i=1,I} TG_{ij} / I$$

N

NDDI - Normalized Difference Drought Index: satellite derived product.

The NDDI index can offer an appropriate measure of dryness of a particular area (sensitive indicator of drought), because it combines information on both vegetation and water. It is defined as:

$$NDDI = \{NDVI - NDWI\} / \{NDVI + NDWI\}$$

NDVI - normalized difference vegetation index (see below)

NDWI - normalized difference water index (see below).

NDVI - Normalized Difference Vegetation Index: satellite derived product.

The NDVI index can be used to provide information for agriculture and vegetation health situation. This information is useful in determining water stress levels in vegetation and estimation of crop yield as well as for drought assessment. It is defined as:

$$NDVI = \{NIR - VIS\} / \{NIR + VIS\}$$

NIR - measured radiation in near-infrared band;

VIS - measured radiation in visible (chlorophyll absorption) band.

NDWI - Normalized Difference Water Index: satellite derived product.

The NDWI is a good indicator of water content of leaves and it is used for detecting and monitoring the humidity of the vegetation cover. It is known that the vegetation is affected by water stress during dry periods, which influence plant development and can cause damage to crops in agricultural areas. It is defined as:

$$NDWI = \{NIR - SWIR\} / \{NIR + SWIR\}$$

NIR - measured radiation in near-infrared band;

SWIR - short wave infrared band.

NVPWR - Natural Variation of Potential Water Resources

Potential water resources are understood here as the stream flow in a given section, in the absence of withdrawal. The indicator describing the variation is expressed as the ratio between the volume (or average flow) flowing annually in the section of the watercourse for the future period examined, as compared to the period of reference.

$$NVPVR = V^F / V^R$$

VR - the volume flowing on average in a year/season in the period of reference (R) in the given section of the watercourse;

VF - the volume flowing on average in a year/season in the future period (F) in the given section of the watercourse.

P

PET-Ha – Hargreaves potential evapotranspiration

PET based on Hargreaves method (Hargreaves et al. 1994):

$$PET\text{-}Ha = 0.0023 \cdot RA \cdot (TG + 17.8) \cdot TD^{0.5}$$

TD – mean daily temperature range (TX-TN)

RA – extraterrestrial radiation, radiation on top of atmosphere, calculated as function of latitude and day of the year

PhET - Physiologically Equivalent Temperature

Certain air temperature related to fixed standard indoor conditions at which the heat balance of the human body is maintained with core and skin temperature equal to those under the conditions being assessed. It is developed on the base of body-atmosphere energy balance and may be calculated by the RayMan model which has been developed for applied climate studies (based on the Munich Energy-balance Model for Individuals, MEMI).

For more details take a look at e.g.:
http://www.met.wau.nl/metlukweb/Practical/module11.pdf

Q

QFI - Forest Water Index

Forest stand and soil indicator which describes the functionality of forest ecosystems for water protection.

R

R5mm: precipitation days with RR ≥ 5 mm

Count the number of days in chosen period where RRij ≥ 5 mm

R50mm: precipitation days with RR ≥ 50 mm

Count the number of days in chosen period where RRij ≥ 50 mm

PRCPTOT: total precipitation in wet days

Let RRwj be the daily precipitation amount on a wet day (RR ≥ 1 mm) in chosen period j. Then:

$$PRCPTOT_j = sum\ (RR_{wj})$$

S

SM - Soil Moisture: field measurements

It allows analysing the in-soil water reserve over various profiles/depths and at crop-specific calendar dates. In addition, it identifies areas potentially affected by pedological drought phenomenon dynamics (intensity, duration and spatial distribution).

SMEF - Sustainability of Minimum Environmental Vital Flow

The minimum environmental flow sustainability indicator aims to evaluate variations in the minimum flow regime, in terms of duration, by comparing the permanence of flows higher than the minimum environmental flow (MEF) in the riverbed, now and in the future. The flow corresponding with the MEF is taken as a reference, as it represents the minimum flow necessary to guarantee the natural ecological integrity of the watercourse, identified by provincial regulations, and which must therefore also be respected when granting licences for withdrawal. The indicator thus compares the percentage exceedance, now and in the future, of the minimum environmental flow, by the flows present in the riverbed, starting from the flow duration curves simulated for the natural hydrological scenarios.

$$SMEF = F_{DMV}^{F} / F_{DMV}^{R}$$

F_{DMV}^{F} – the percentage exceedance of the MEF flow in the future scenario considered;

F_{DMV}^{R} – the percentage exceedance of the MEF flow in the reference period.

SPI3 - Standardized Precipitation Index

Computation of the SPI involves fitting a Gamma probability density function to a given frequency distribution of precipitation totals for a station. The alpha and beta parameters of the Gamma probability density function are estimated for each station, for time scale of 3 months and for each month of the year based on the referent period 1961-1990. The distribution is defined by its probability density function:

$$g(P) = (1/\beta^{\alpha}\,\Gamma(\alpha))\;\; P^{(\alpha -1)}\, \exp(-P/\beta) \;\text{ for }\; P > 0$$

α, β - the shape and scale parameters respectively, P - the precipitation amount and

Γ(α) - the gamma function.

α and β can be estimate from climatology using maximum likelihood method:

$$\alpha = 1 / (4A)\ \{1+ \sqrt{}\ (1+4A / 3)\}\;\; ; \;\; A = \ln (P_{mean}) - \textstyle\sum_i \ln(P_i) / n$$

$$\beta = P_{mean} / \alpha$$

Pmean – mean precipitation amount,

Pi – precipitation amount for time scale 3 months and for each month of the year in climatological period (1961-1990), and

n - number of observations.

The resulting parameters are then used to find the cumulative probability of an observed precipitation event for the given month and time scale for the station in question. Since g(P) is undefined for P=0 and a precipitation distribution may contain zeros, the cumulative probability becomes:

$$H(P) = q + (1\text{-}q)G(P)$$

q - the probability of a zero, and

G(P) - the cumulative density function of Gamma distribution.

If m is the number of zeros in a precipitation time series, then q can be estimated by:

$$q = m/n$$

Then SPI can be obtained by:

$$SPI = - \{t - (c_0 + c_1t + c_2t^2) / (1 + d_1t + d_2t^2 + d_3t^3)\} \quad \text{for } 0 < H(P) \leq 0.5$$

$$SPI = +\{t - (c_0 + c_1 t + c_2 t^2) / (1 + d_1 t + d_2 t^2 + d_3 t^3)\} \quad \text{for } 0.5 < H(P) < 1$$

$$t = \sqrt{\ln [1 / (H(P)^2)]} \quad \text{for } 0 < H(P) \leq 0.5$$

$$t = \sqrt{\ln [1 / (1 - H(P))^2]} \quad \text{for } 0.5 < H(P) < 1$$

c_0 =2.515517 d_1 =1.432788

c_1 =0.802853 d_2 =0.189269

c_2 =0.010328 d_3 =0.001308

Classification by SPI values

SPI	*Category*
> 2.0	Extremely wet
1.5 – 2.0	Severely wet
1.0 – 1.5	Moderately
-1.0 –	Near normal
-1.5 - -	Moderately dry
-2.0 - -	Severely dry
< -2.0	Extremely dry

Definition and method of calculation can be found in e.g. McKee (1993) and Loukas (2004).

SPI12 - Standardized Precipitation Index

Calculation is the same as for SPI3, only precipitation amount is for time scale of 12 months.

SWE - Snow Water Equivalent

It is a measurement of the amount of water contained in snow pack. It can be considered as the depth of water that would theoretically result if the whole snow pack instantaneously melts. Snow Water Equivalent (SWE) is the product of snow depth and snow density:

$$SWE\ (kg/m^2) = \text{snow depth (m)} \times \text{snow density } (kg/m^3)$$

SYCr - Storage Yield Curve

Area under the storage yield curve represents the storage capacity needed to provide a given basin yield or, alternatively, the firm basin yield produced from a given level of water storage. In other words, this curve makes it possible to associate the volume of water exploited (yield) with the reservoir volume necessary to guarantee a given demand for water utilisation (storage). The SYCr indicator expresses precisely the percentage variation in average annual yield, calculated for the different future scenarios as compared to period of reference, for each of the hydropower reservoirs considered:

$$SYCr = \{Y_F - Y_R\} / Y_R$$

Y_R - the average annual yield for the period of reference for the reservoir considered;

Y_F - the average annual yield for the future period for the reservoir considered;

T

TATH - Trend of Annual Theoretical Hydropower

THAT is an indicator making it possible to evaluate changes in the five-year theoretical power trend, calculated starting from the maximum potential withdrawal capacity. The average annual power that could theoretically be produced was calculated for each five-year period within the thirty-year period analysed. Value assigned to the TATH indicator corresponds with the slope of the straight line, interpolated linearly by the average annual power that could theoretically be produced in a year obtained for each five-year period.

TAPWRA - Trend of Annual Potential Water Resources Availability

This indicator makes it possible to evaluate changes in the volume of water flowing in the riverbed on a five-yearly basis within thirty-year periods. The TAPWRA evaluate the trend for average annual volumes. For each five-year period within the specific thirty-year period analysed the specific average annual volume is calculated, understood as the ratio between the volume flowing in the given section and the surface area of the contributing basin. The value assigned to the TAPWRA indicator corresponds with the slope of the straight line, interpolated linearly by the specific average annual volume figures obtained for each five-year period.

THV - Theoretical Hydropower Variation

Once the maximum potential withdrawal capacity of all existing hydroelectric concessions is known, it is possible to establish the theoretical power available to the plant using the known formula:

$$P_{max} = \eta\ g\ Q\ H_g$$

in which yield η is considered to be unitar; g is the gravitational acceleration [9.81 m/s^2], the gross head H_g is that characterising the individual plant; flow Q is calculated starting from the maximum potential withdrawal capacity simulated by the model for the period of reference and future periods. For all withdrawals for hydropower purposes, the THV index is therefore expressed as the ratio between the average annual/seasonal theoretical power that can be produced in future periods as compared to the period of reference:

$$THV = \Sigma_T P_{max}^F / \Sigma_T P_{max}^R$$

P_{max}^R - the sum of average power that can theoretically be produced in a year/season in the future period considered for all the hydropower plants present within each sub-basin;

P_{max}^F - the sum of average power that can theoretically be produced in a year/season in the period of reference for all the hydropower plants present within each sub-basin.

U

UTCI - Universal Thermal Climate Index

The UTCI index represents air temperature of the reference condition with the same physiological response as the actual condition. The assessment scale of UTCI bases on the intensity of objective physiological reactions to environmental heat stress in wide range of weather and climates.

For more details take a look at e.g.: http://www.academia.edu/3034811/Principles_of_the_new_Universal_Thermal_Climate_Index_UTCI_and_its_application_to_bioclimatic_research_in_European_scale

W

WAD - Wetland Adaptive Capacity

Wetland adaptive capacity is a function of infrastructure and operational capacity and of social awareness in regard to wetlands and climate change.

It based on: Gitay, H., Finlayson, C.M. & Davidson, N.C. 2011. A Framework for assessing the vulnerability of wetlands to climate change. Ramsar Technical Report No. 5/CBD Technical Series No. 57. Ramsar Convention Secretariat, Gland, Switzerland & Secretariat of the Convention on Biological Diversity, Montreal, Canada. ISBN 92-9225-361-1 (print); 92-9225-362-X (web).

WBI - Water Balance Index

The water balance index simply verifies whether a flow exceeding the MEF established by the regulations in force is flowing through the watercourse. If this is the case, the whole basin concerned by the watercourse is considered to be balanced; otherwise the basin can still be defined as balanced, in the event that the deficit is not due to withdrawal upstream of the basin. To establish this it is necessary to compare flows simulated with active anthropogenic utilisation (anthropogenic scenarios) with reconstructed flows involving their deactivation (natural scenarios). In this way a basin is defined as balanced if the flows lower than the Minimum Environmental Flow (MEF) simulated in the anthropogenic scenario coincide with natural flows, namely:

$$Q_N = Q_A \text{ for } Q_A < MEF$$

Q_A - the flow modelled in the presence of anthropogenic withdrawal (anthropogenic scenario A);

Q_N - the flow modelled in the absence of anthropogenic withdrawal (natural scenario N).

On the basis of this distinction, the water balance index (WBI) is defined in a different way, depending on whether the basin is balanced or not; in the first case it is calculated in such a way that it expresses the volume percentage of water flowing in the riverbed at the closing section of the basin for flows higher than the MEF, whereas in the second case it establishes the imbalance volume percentage.

In the case of a basin which has an equilibrium in terms of hydrological water balance, the WBI index is thus calculated to be positive in the following way:

$$WBI = \{V_{A,TOT} - V_{N,MEF}\} / \{V_{A,TOT}\} \quad \geq 0$$

$V_{A,TOT}$ - the total volume of water flowing in the riverbed in the anthropogenic scenario;

$V_{N,MEF}$ - the volume flowing in the riverbed in the natural scenario for flows lower than the MEF.

If instead there is an imbalance in terms of the hydrological water balance the WBI index is calculated with a negative result, according to the following formula:

$$WBI = \{V_{A,MEF} - V_{N,MEF}\} / \{V_{A,TOT}\} \quad < 0$$

$V_{A,TOT}$ - the total volume of water flowing in the riverbed in the anthropogenic scenario;

$V_{A,MEF}$ - the volume flowing in the riverbed in the anthropogenic scenario for flows lower than the MEF.

$V_{N,MEF}$ - the volume flowing in the riverbed in the natural scenario for flows lower than the MEF.

The WBI is therefore very useful for evaluating the impact of withdrawal on the ecological state of the watercourse: negative values highlight a potential scenario of over-exploitation of resources, while positive or zero values instead show that anthropogenic withdrawal does not diminish water resources to the extent that the watercourse regime falls below the MEF limits established by the regulations.

WS - Wetland Sensitivity

Wetland sensitivity is a composed indicator. It is expressed as a function of four single indicators:

(a) changes due to agriculture (WCA) - it is expressed as "high", "moderate" or "low, based on the amount of land (wetland and buffer zone of 500 m) taken by agricultural land;

(b) changes due to urbanization (WCU) - it is expressed as "high", "moderate" or "low, based on the amount of land (wetland and buffer zone of 500 m) taken by urban and other artificial land development (industrial and urban uses, transport infrastructures, urban “green” areas and sport and leisure facilities);

(c) wetland values for human beings (WV) - it expresses the mean value of the degrees of expressions of nine wetland values i.e. protection against floods, protection against erosion, improving of water quality and quantity, biological, scientific, education, recreational, cultural and improving of microclimate. The degrees of expressions of values are "3: high expression of the value", "2: moderate expression of the value", "1: low expression of the value" or "0: none expression of the value". The means from 0 to 1 are classified as “wetland with low value for human beings”, from 1,1 to 1,9 are classified as “wetland with medium value for human beings” and from 2 to 3 are classified as “wetland with high values for human beings”;

(d) protection status of wetland sites (WP) - it is expressed as "high” in case that no designation applies for conservation purposes, and therefore the wetland is highly sensitive to degradation. It is expressed as “moderate” in case of designation for historical or other purposes (i.e hunting reserve). Finally it is expressed as “low” in case the wetland lay inside designated areas for nature conservation purposes and consequently the wetland is protected from further degradation.

WS is expressed as "high", "moderate", "low" with the following formula:

$$WS = 0{,}30*WCU + 0{,}30*WCA + 0{,}20*WP + 0{,}20*WV$$

Higher weight has been given to threats from agriculture and urbanization, since these two factors constitute the major pressures on Attica wetlands.

It based on: Gitay, H., Finlayson, C.M. & Davidson, N.C. 2011. A Framework for assessing the vulnerability of wetlands to climate change. Ramsar Technical Report No. 5/CBD Technical Series No. 57. Ramsar Convention Secretariat, Gland, Switzerland & Secretariat of the Convention on Biological Diversity, Montreal, Canada. ISBN 92-9225-361-1 (print); 92-9225-362-X (web).

WSDI - Warm Spell Duration Index: count of days in a span of at least six days where TX > 90th percentile. Choose the maximum spell duration in a chosen period.

Let TXij be the daily maximum temperature on day i in period j and let TXin90 be the calendar day 90th percentile of daily maximum temperature calculated for a five-day window centred on each calendar day in the base period n (1961-1990). Count the number of days where, in intervals of at least six consecutive days TXij > TXin90.

WV - Wetland Vulnerability

Wetland Vulnerability is a composed indicator. It is a function of exposure to drought (DVI, look above), of the wetland sensitivity (WS) to further degradation and of the adaptive capacity (WAD) of the involved users in regard to climate adaptation. It is based on the qualitative relationship between the exposure to drought and sensitivity, resulting in the so called Impact, and adaptive capacity. According to an assessment matrix, usually used for qualitative approach, a wetland can range from being "extreme high vulnerable" when the Impact (synergy of drought and sensitivity) is high and the adaptive capacity is low, up to being "not vulnerable" when impact is low and adaptive capacity is high.

It based on: Gitay, H., Finlayson, C.M. & Davidson, N.C. 2011. A Framework for assessing the vulnerability of wetlands to climate change. Ramsar Technical Report No. 5/CBD Technical Series No. 57. Ramsar Convention Secretariat, Gland, Switzerland & Secretariat of the Convention on Biological Diversity, Montreal, Canada. ISBN 92-9225-361-1 (print); 92-9225-362-X (web).

WVV - Withdrawal Volumes Variation

It is expressed as the ratio between the maximum volumes that could potentially be withdrawn in future periods as compared to the period of reference. The modelling scenarios are the anthropogenic scenarios in which all the withdrawals, including large hydropower plants (LHPs), are considered to be active:

$$WVV = \Sigma_T V_{DER}^F / \Sigma_T V_{DER}^R$$

V_{DER}^R - the maximum overall volume that can be withdrawn by concessions present in the sub-basin considered (excluding LHPs) in a year/season, for the period of reference;

V_{DER}^F - the maximum overall volume that can be withdrawn by concessions present in the sub-basin considered (excluding LHPs) in a year/season, for the future period.