CLISWELN

Climate Services for the Water-Energy-Land-Food Nexus

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Joint Call for Transnational Collaborative Research

Topic A – Researching and Advancing Climate Service Development by Advanced Co-development with users

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1	2018-09-20	First draft
2	2018-10-21	Improve the deliverable after returned from project's manager review
3	2018-11-05	Incorporated project manager's observations
4	2018-11-07	Final version

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Executive summary

This deliverable contains a description of the Tărlung River Basin, the Romanian case study. Namely, it contains data regarding the hydrological model of the river basin (developed using Soil and Water Assessment Tool - SWAT), data regarding land use structure and forest management, as well as scenarios for their further development. This information is presented alongside data on urban development, water consumption, and energy consumption, which are useful for achieving a dynamic approach to interactions and interdependencies between the elements of the "Water – Energy – Land – Food Nexus" (WELFN) in the context of climate change.

Contents

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) estimates that, for the 21st century—and especially at its end—an increase in global air temperature of up to 4.8°C and high variation in rainfall dynamics (IPCC, 2014). Moreover, climate change would considerably increase the risk of floods in European regions, particularly in the northern portion of the continent (Alfieri et al., 2015). Also, other events such as droughts are expected to occur in southern Europe as a result of decreasing precipitation in this area (Kovats et al., 2014). Beside, the previsions include the intensification of extreme events (floods and droughts), especially due to the frequency and intensity of changes in the global human population, as well as socio-economic and technologic developments. The projections presented in the 5thAR (IPCC, 2014) include four climate change scenarios, named Representative Concentration Pathways (RCPs), were differentiated according to radiative forcing changes. Another differentiation criterion is the degree of global socio-economic and technological development, as summarised into five Shared Socioeconomic Pathways (SSPs) (Riahi et al., 2017). All of the expected changes also imply land use modifications that could affect water resources (especially quality and quantity); thus, any attempt to quantify these modifications is essential for ensuring human wellbeing.

In recent years, many studies have attempted to quantify climate variability, particularly in the context of hydrological processes (Wang et al., 2008; Galavi and Shui, 2012; Bonumá et al., 2014; Duan et al., 2017). The influence of various land use practices and forest structures on hydrological processes were also analysed (Huntington et al., 2009; Ekness and Randhir, 2015; Durlo et al., 2016). The present research aims to raise awareness regarding natural resource availability and on the importance of taking measures towards sustainable management.

For the assessment of climate change, many studies have used Representative Concentrations Pathways, especially RCP4.5 (which implies a medium degree of land use, energy, and greenhouses gases (GHG) emissions changing as a result of adopted mitigation actions) and RCP8.5 (a non-intervention scenario with a high degree rate of globalisation, increased greenhouse gases emissions, and weather parameter changes) scenarios elaborated by the IPCC in 2014 (IPCC, 2014; Riahi et al., 2017). In order to better capture the local variation of the studied area, these scenarios were further brought to regional scale. Using data from EURO-CORDEX, regional scenarios were developed (Jacob et al., 2014; Mascaro et al., 2018) with higher resolution, which, alongside local terrain models, resulted in the improved accuracy of research results (Giorgi et al., 2008; Scinocca et al., 2016).

Considering these trends in the context of Romanian case study, it is necessary to establish measures for the sustainable management of water resources from river basins, especially for mountain river basins, in order to adapt hydrological processes to foreseeable climate change, especially for droughts (Pintilie, 2013). In accounting for these considerations, the purpose of the present study is to create a hydrologic model for the Tărlung river basin upstream of the Săcele Reservoir.

The Săcele Reservoir is the primary water supply (90%) for one of the most dynamic urban areas of Romania, Brasov City. Additional groundwater drillings were operationalised as to cope with the demand for water in all sectors. Both water sources have their individual strengths and limitations, and both are very important for a stable water supply for the city due to the increase of extreme events in recent years (i.e. June and April 2018, when water provided by the Săcele Reservoir became unusable for two weeks due to extreme rain that led to large surface runoff- https://www.apabrasov.ro/ro/pagini/comunicat.html - Communication made by “Compania Apa Brașov”).

In order to meet the challenges of climate change and local development dynamics, local authorities require tools to support them in developing sustainable water resource management strategies.

2. Materials andmethod

2.1 Study area

Located in the central region of Romania, the Tărlung River—with a basin area of 485 km^2 - flows from the Ciucaș Mountains into the Negru River, with the tributaries of the Ramura Mică (Babarunca), Dracu, and Doftana being upstream of the Săcele Reservoir (Figure 1). The hydrographic network of the entire catchment drains an area with altitudes between 502 m and 1887 m, with an average altitude of 957.5 m.

A 45 m height dam designed to form the Săcele Reservoir was built in the early 1970s. The Reservoir catchment has an area of 184 km^2, with an average altitude of 1163.44m (H_{min} = 724m; H_{max} = 1899m). The water provided from this Reservoir represents the main source of drinking and industrial water for Brașov Municipality and the surrounding area (approximately 400,000 inhabitants).

Figure 1. Study area

Săcele Dam is an earth-fill dam, whose bottom is built up of rocky and stony rocks with clay soil shores, with an accumulation lake of 148 hectares in area. The dam has a height of 45 m and a canopy length of 709 m, and has the purpose of supplying water to Brașov, Săcele, and nearby communities.

2.2 SWAT model

The Soil and Water Assessment Tool (SWAT) is a basin-scale model that operates at a daily time step, and was developed to assess the impact of different land management practices on water resources, sediment, and nutrients in an ungauged watershed with different soils types, land uses, and management conditions over long time periods (Arnold et al., 2012). The SWAT model was developed following the modelling activities conducted over a period of 30 years by the USDA Agricultural Research Service (Gassman et al., 2007), starting from CREAMS (Chemicals, Runoff and Erosion from Agricultural Management Systems), GLEAMS, and EPIC (Erosion-Productivity Impact Calculator) (Neitsch et al., 2009).

It is a physical model that uses inputs which are relatively readily available, though this has often been used for large basin areas or even the continental level; thus, it must be carefully calibrated. Steps that must to be taken to run the model are presented in Figure 2 (adapted from Dlamini et al., 2017).

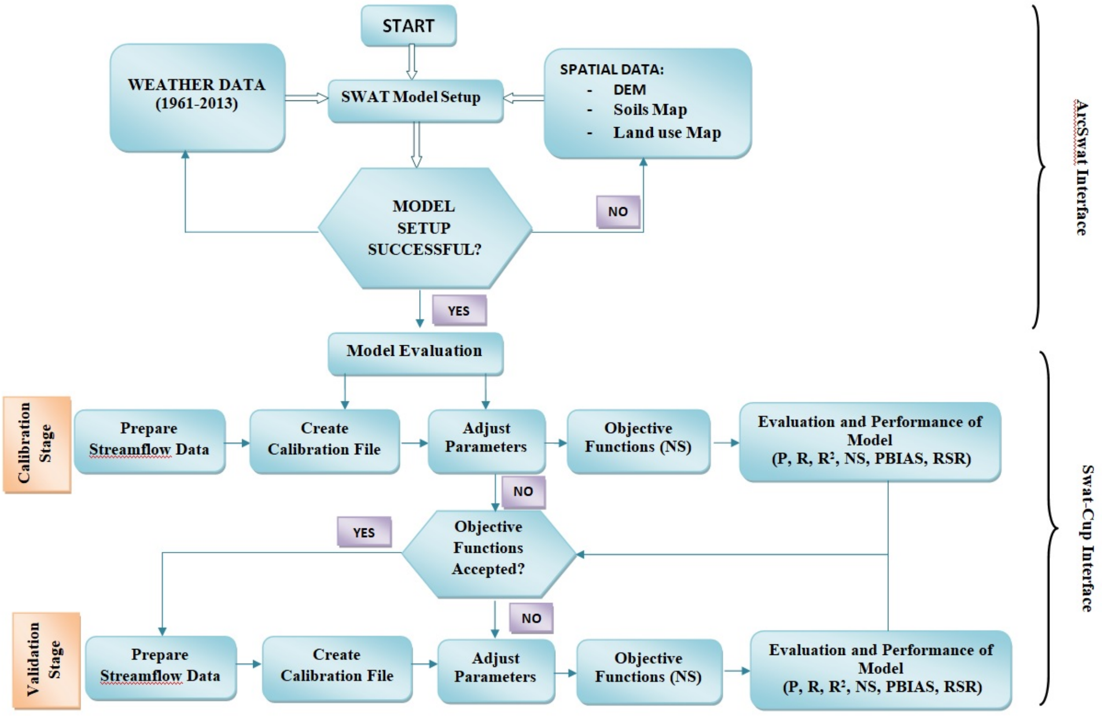


Figure 2.Diagramof SWAT model

The major components of the model include (Gassman et al., 2007; Golmohammadi et al., 2014;):

- Digital elevation model;
- Climate data;
- Soil properties and characteristics;
- Land management.

3. Building the SWAT database

3.1 The Digital Elevation Model (DEM)

To perform the simulations, SWAT requires a digital elevation model (DEM). For the study area, the digital elevation model was obtained from 10 m resolution situation plans (INHGA database).

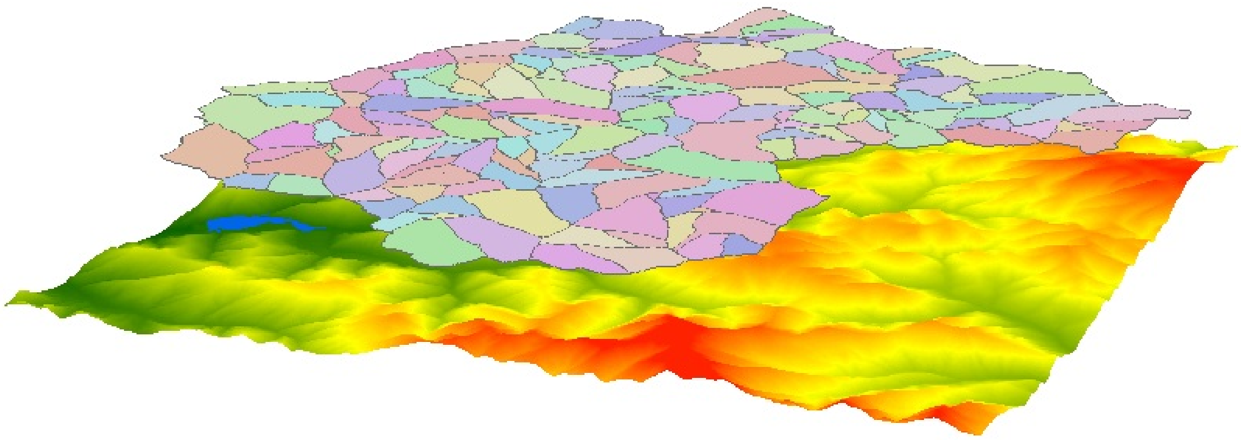


Figure 3. DEM layer and subbasins layer for Tărlung river watershed

ArcSWAT is an ArcGIS extension tool. It also represents a graphical tool which allows to every user to input and process the graphical interface of the SWAT model (Arnold et al., 1998).Using the watershed delineation tool in ArcSwat, the river basin was divided into 169 sub-basins (Figure 3) and 2419 hydrological response units (HRUs) throughout the entire Tărlung catchment. For each sub-basin, the morphological parameters were calculated and flow direction and streams were delineated.

3.2 Climate data

Climate data input was retrieved from the ROCADA dataset V 1.0 (Birsan and Dumitrescu, 2014; Dumitrescu and Birsan, 2015) spanning the years 1961 to 2013, which is a state-of-the-art homogenised gridded climatic dataset encompassing Romania at a spatial resolution of 0.1°. Since its creation, ROCADA has been used in various studies on the climate of Romania, which has validated its accuracy in several publications (Popa et al., 2017; Sfîcă et al., 2017). Some other discontinuous climate data (precipitation 1988-2010) and discharge (1974-2015) were provided by the National Institute of Hydrology and Water Management (INHGA), and was recorded at the Babarunca and Săcele Reservoir hydrological stations.

3.3 Soil properties and characteristics database

The soil database used in the present study was sourced from the forest and pastoral management plans developed by National Institute for Research and Development in Forestry INCDS for the Tărlung River Basin. The spatial distribution of soil types was retrieved from maps included in the aforementioned studies (Forest Management Plan, 2009, 2013; Silvopastoral Management Plan, 1989). The physical and chemical characteristics of soils were taken from the analysis bulletins attached to the planning studies mentioned above. Some of the soil characterisation parameters required by ArcSwat were taken directly from the soil profile analysis bulletins. For parameters not determined through laboratory analysis, the following procedure was followed:

- The parameters SOL_BD (bulk density), SOL_K (hydraulic conductivity), SOL_AWC (water content) were determined based on certain soil characteristics (organic matter, percentage of sand and clay, soil texture, etc.) using the SPAW application;
- The hydrologic group (HYDGRP) for each soil type was obtained according to the depth of the soil layer and the sand and clay percentage (SWAT Soil Database);

- The albedo (SOL_ALB) was calculated for each soil layer by applying an equation which accounted for the colour of each horizon (https://web.ics.purdue.edu/~vmerwade/education/fao_soil_tutorial.pdf):

$$Sol_{Alb} = 0{,}069 * (the soil horizon color value) - 0{,}114$$

- The soil erodibility factor (K_USLE) was determined as the product between the percentage of sand, clay, and dust applying the following formula for each soil layer (https://web.ics.purdue.edu/~vmerwade/education/fao_soil_tutorial.pdf):

$$\mathbf{K_{USLE}} = \boldsymbol{f_{csand} * f_{cl-si} * f_{orgc} * f_{hisand}}$$, where:

$$f_{csand} = (0.2 + 0.3 * \exp\left(-0.256 * m_s * \left(1 - \frac{m_{silt}}{100}\right)\right)$$

$$f_{cl-si} = \left(\frac{m_{silt}}{m_c + m_{silt}}\right)^{0.3}$$

$$f_{orgc} = \left(1 - \frac{0.0256 * orgC}{orgC + \exp\left(-5.51 + 22.9 * \left(1 - \frac{m_s}{100}\right)\right)}\right)$$

$$f_{hisand} = (1 - \frac{0.7 * (1 - \frac{m_s}{100}}{\left(1 - \frac{m_s}{100}\right) + \exp\left[-5.51 + 22.9 * \left(1 - \frac{m_s}{100}\right)\right]}$$

Where: m_s = sand percentage from the total;

m_{silt} = silt percentage from the total;

m_c = clay percentage from the total;

orgC = organic carbon layer percentage from the total.

After completing the database in ArcSwat (Figure 4) a raster soil type for the Tărlung River Basin was obtained (Figure 5).

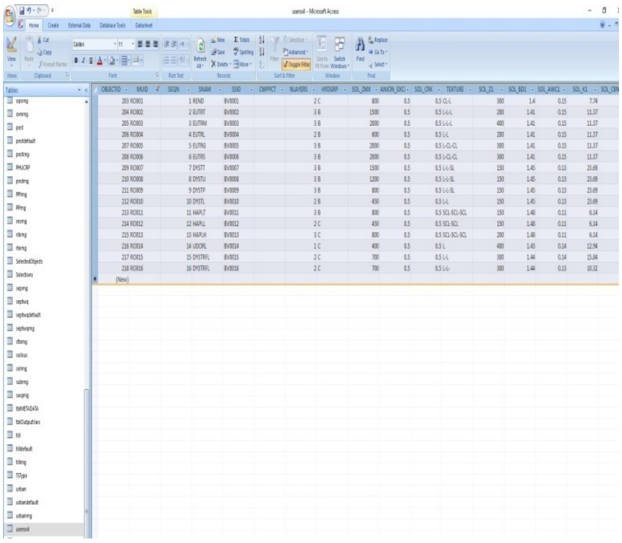


Figure 4. Soils in the ArcSwat database

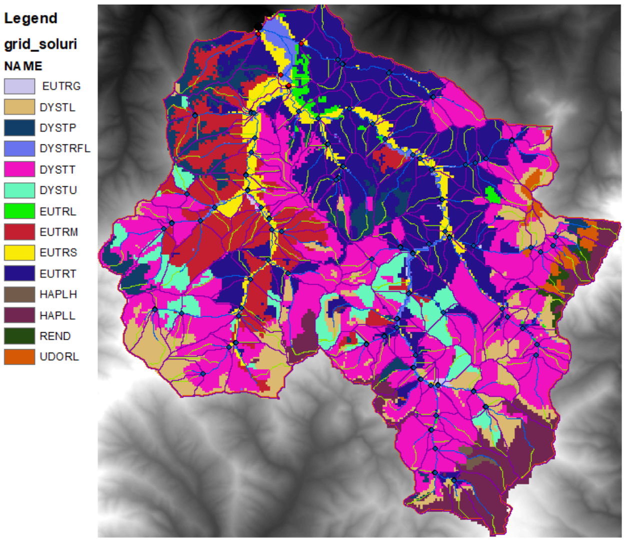


Figure 5. Soil types from Tărlung river basin (INCDS, Forest Management Plans 2004)

3.4 Land use database

In order to determine land use categories in the studied area, data from the forest management plans (forests and other lands intended for administration and forest management), from forest-pastoral management plans (meadows, pastures, and forested meadows), and observations made on satellite images (roads, buildings, water bodies, etc.) were used (Figure 6).

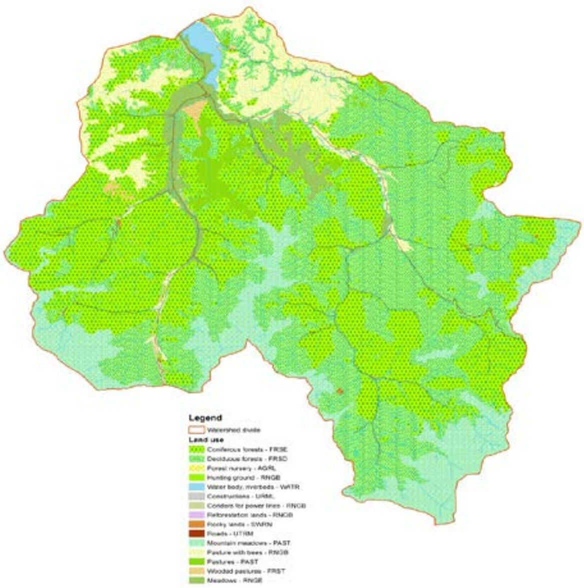


Figure 6. Actual land use map

The main land use categories were: forests, namely evergreen and deciduous forests, which occupy 36% and 37% of the studied area, respectively (Table 1).

Table 1. The main land uses within the studied area

Land use	Surface		Correlation with SWAT
	Ha	%	
Forest nursery	5,3	0	AGRL
Deciduous forests	6702,6	37	FRSD
Coniferous forests	6552,4	36	FRSE
Corridors for power lines	41,4	0	RNGB
Reforestation lands	6,1	0	RNGB
Hunting grounds	19,2	0	RNGB
Forest roads	27,7	0	UTRM
Rocky lands (waste lands)	8,7	0	SWRN
Wooded pastures	66,2	0	FRST
Mountain meadows	2286,5	12	PAST
Pastures	426,4	2	PAST
Pasture with scattered trees	1445,9	8	RNGB
Meadows	689,7	4	RNGE
Build-up area	0,2	0	URML
Public roads	23,1	0	UTMR
Water bodies	120,6	1	WATR
Total	18422	100	-

Generally, the deciduous forests include beech forests, next to which appear sycamore forests or evergreen maples (Norway spruce, European silver fir), and evergreen forest composed of spruce forests or mixed spruce-fir. These forests are managed as a silvicultural system, respecting the principles of continuity and rational management.

Alongside the aforementioned forests, other lands such as nurseries, high power line corridors, reforestation fields, hunting fields, forest roads, and unproductive landscapes were also included. Combined, these lands represented a total of 108.4 ha (0.6% of the area under analysis).

The high power line corridors, reforestation fields, and hunting fields were covered with herbaceous vegetation and were either partly or entirely filled with shrubs or small trees.

Agricultural lands were represented by:

- Mountain meadows located at altitudes above 1300 m, on peaks and plateaus above the forest boundary; covered with herbaceous vegetation (predominantly *Nardus stricta*, *Festuca ovina*, and *Agrostis tenuis*) mixed with blueberries and juniper berries, which are used in summer as sheep pastures;
- Grasslands covered by herbaceous associations having *Festuca rubra* and *Poa pratensis* as the dominant species; situated on peaks and hillslopes with altitudes ranging from 800 to 1300 m; used as pastures for sheep and large cattle;
- Pastures with trees and wooded pastures formed by the invasion of meadows by forest vegetation, birch, and tremulous poplar in the first phase, and then by beech and spruce.
- Meadows used for harvesting feed (grass) and less frequently as pastures, located on flat land at the base of slopes and on riverside areas.

Small areas of land are occupied by buildings or public roads, while water bodies (talvegs, lakes) occupy approximately 1% of the studied area.Thereafter, the correspondence between specific types of land uses at the basin level and the types defined in ArcSwat (Figure 7) were achieved. The completed database was exported in raster format (Figure 8).

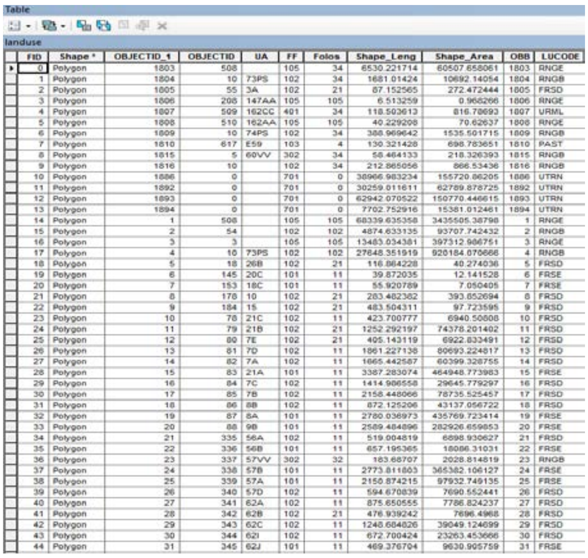


Table
landuse

FID	Shape *	OBJECTID_1	OBJECTID	UA	FF	Folos	Shape_Leng	Shape_Area	OBB	LUCODE
0	Polygon	1803	508		105	34	6530.221714	60507.658061	1803	RNGE
1	Polygon	1804	10	73PS	102	34	1681.01424	10692.14054	1804	RNGB
2	Polygon	1805	55	3A	102	21	87.152565	272.472444	1805	FRSD
3	Polygon	1806	208	147AA	105	105	6.513259	0.968266	1806	RNGE
4	Polygon	1807	509	162CC	401	34	118.503613	816.78693	1807	URML
5	Polygon	1808	510	162AA	105	105	40.229208	70.62637	1808	RNGE
6	Polygon	1809	10	74PS	102	34	388.969642	1535.501715	1809	RNGB
7	Polygon	1810	617	E59	103	4	130.321428	698.783651	1810	PAST
8	Polygon	1815	5	60VV	302	34	58.464133	218.326393	1815	RNGB
9	Polygon	1816	10		102	34	212.865056	866.53436	1816	RNGB
10	Polygon	1886	0		701	0	38966.983234	155720.86205	1886	UTRN
11	Polygon	1892	0		701	0	30259.011611	62789.878725	1892	UTRN
12	Polygon	1893	0		701	0	62942.070522	150770.446615	1893	UTRN
13	Polygon	1894	0		701	0	7702.752916	15381.012461	1894	UTRN
14	Polygon	1	508		105	105	68339.635358	3435505.38798	1	RNGE
15	Polygon	2	54		102	102	4874.633135	93707.742432	2	RNGB
16	Polygon	3	3		105	105	13483.034381	397312.986751	3	RNGE
17	Polygon	4	10	73PS	102	102	27648.351919	920184.070668	4	RNGB
18	Polygon	5	18	26B	102	21	116.864228	40.274036	5	FRSD
19	Polygon	6	145	20C	101	11	39.872035	12.141528	6	FRSE
20	Polygon	7	153	18C	101	11	55.920789	7.050405	7	FRSE
21	Polygon	8	178	10	102	21	283.482382	393.652694	8	FRSD
22	Polygon	9	184	15	102	21	483.504311	97.723595	9	FRSD
23	Polygon	10	78	21C	102	11	423.700777	6940.50808	10	FRSD
24	Polygon	11	79	21B	102	21	1252.292197	74378.201402	11	FRSD
25	Polygon	12	80	7E	102	21	405.143119	6922.833491	12	FRSD
26	Polygon	13	81	7D	102	11	1861.227138	80693.224817	13	FRSD
27	Polygon	14	82	7A	102	11	1665.442587	60399.328755	14	FRSD
28	Polygon	15	83	21A	101	11	3387.283074	464948.773983	15	FRSE
29	Polygon	16	84	7C	102	11	1414.986558	29645.779297	16	FRSD
30	Polygon	17	85	7B	102	11	2158.448066	78735.525457	17	FRSD
31	Polygon	18	86	8B	102	11	872.125206	43137.056722	18	FRSD
32	Polygon	19	87	8A	101	11	2780.036973	435769.723414	19	FRSE
33	Polygon	20	88	9B	101	11	2589.484896	282926.659853	20	FRSE
34	Polygon	21	335	56A	102	11	519.004819	6898.930627	21	FRSD
35	Polygon	22	336	56B	101	11	657.195365	18086.31031	22	FRSE
36	Polygon	23	337	57VV	302	32	183.68707	2028.814819	23	RNGB
37	Polygon	24	338	57B	101	11	2773.811803	365382.106127	24	FRSE
38	Polygon	25	339	57A	101	11	2150.874215	97932.749135	25	FRSE
39	Polygon	26	340	57D	102	11	594.670839	7690.552441	26	FRSD
40	Polygon	27	341	62A	102	11	875.650555	7786.824237	27	FRSD
41	Polygon	28	342	62B	102	21	476.939242	7696.4968	28	FRSD
42	Polygon	29	343	62C	102	11	1248.684826	39049.124699	29	FRSD
43	Polygon	30	344	62I	102	11	672.700424	23263.453666	30	FRSD
44	Polygon	31	345	62J	101	11	469.376704	9630.905759	31	FRSE

Figure 7. Land use database

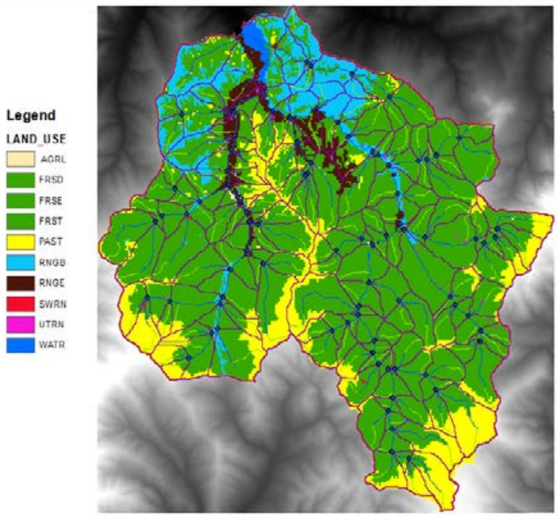


Figure 8. SWAT land use raster

3.5 Running the SWAT model

After completing the requested databases, the next step involved running the SWAT model in order to obtain hydrological parameters at the sub-basin level (Figure 9) and to identify possible errors (Figure 10). The model was run for a 53-year period (1961 - 2013) to obtain average monthly flows.

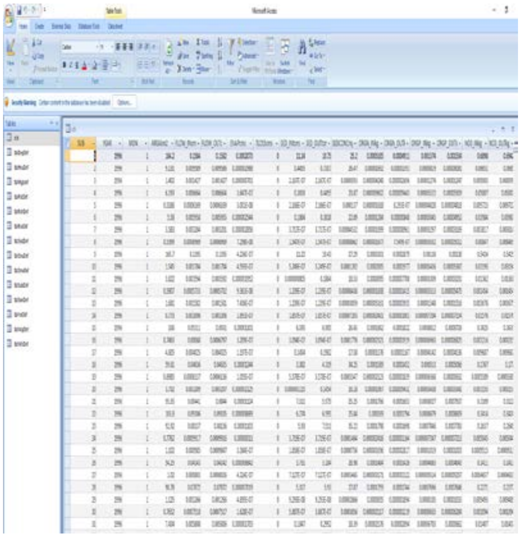


Figure 9. Hydrological parameters at sub-basin level

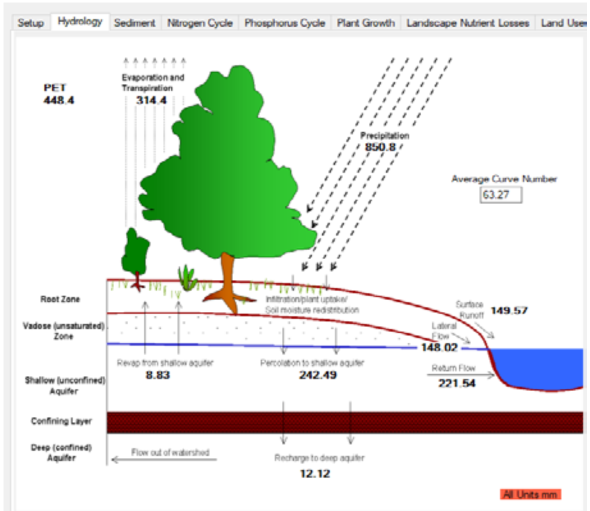


Figure 10. Swat error check

4. Calibration and validation of the SWAT model

4.1 SWAT calibration

After running the model and checking for errors, we continued onto the calibration step. Model calibration was performed for monthly liquid flows calculated for a period of 15 years (1996-2010), the time intervals for which there were continuous flow measurements with a 5-year warm up period (1996-2000) (Figure 11).

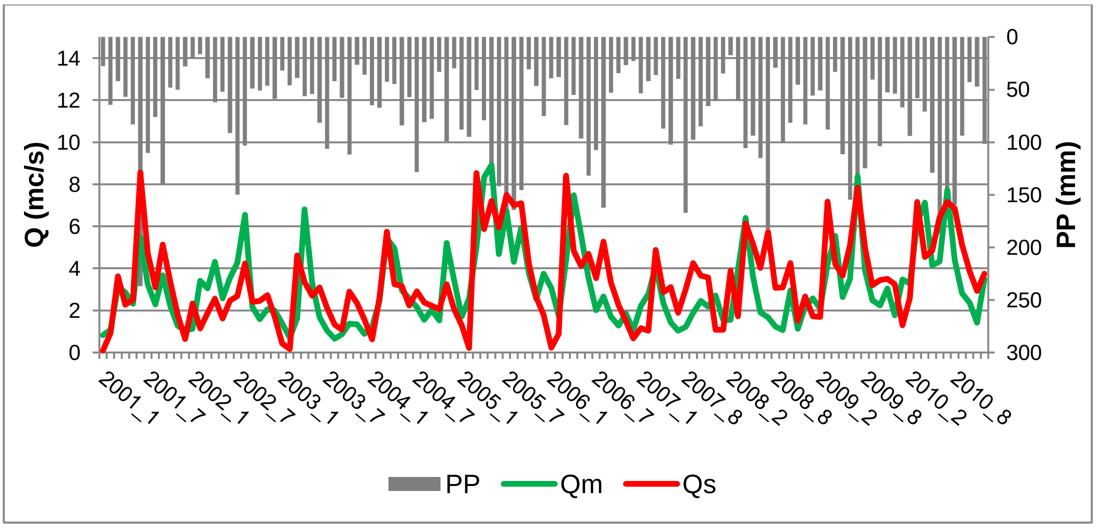


Figure11. Simulated flows (Qs), measured flows (Qm) and precipitations (pp) for the Tărlung river between 2001-2010

The values of lake inflows were the primary data source for model calibration, and these values were determined by indirect methods. In the case of small surfaces such as the Săcele Reservoir catchment, discharges rates are very sensitive to precipitation values in the basin. Any small error in rainfall will generate an incorrect discharge value. In large river basins, water resources are more homogeneous and reflected by a larger set of rainfall measurement points.

The correlation between initial Q and simulated Q was 0.404. The highest error obtained in the simulation was for March 2007, when the measured inflow was 10.31 m^3/s, while simulated inflow was 2.91 m^3/s. Model calibration was performed using the SWAT calibration uncertainty procedure (SWAT-CUP) with the Sequential Uncertainty Fitting ver.2 (SUFI-2) algorithm (Thavhana et al., 2018). The SUFI-2 algorithm was also used for the calibration, validation, and analysis of sensitivity and uncertainty.

The first step in the calibration and validation process involved determining the most sensitive parameters at the sub-basin level. Parameter sensitivity analysis is a process that determines the rate of change in model outputs based on the variance of a model's input parameters (Arnold et al., 2012).In the first stage, the sensitivity of 16 parameters was analysed. In order to determine the most sensitive parameters, we applied the method of global sensitivity analysis - a mathematical technique used to investigate how variation in the output of a numerical model can be attributed to variations of its inputs (Figure 12).

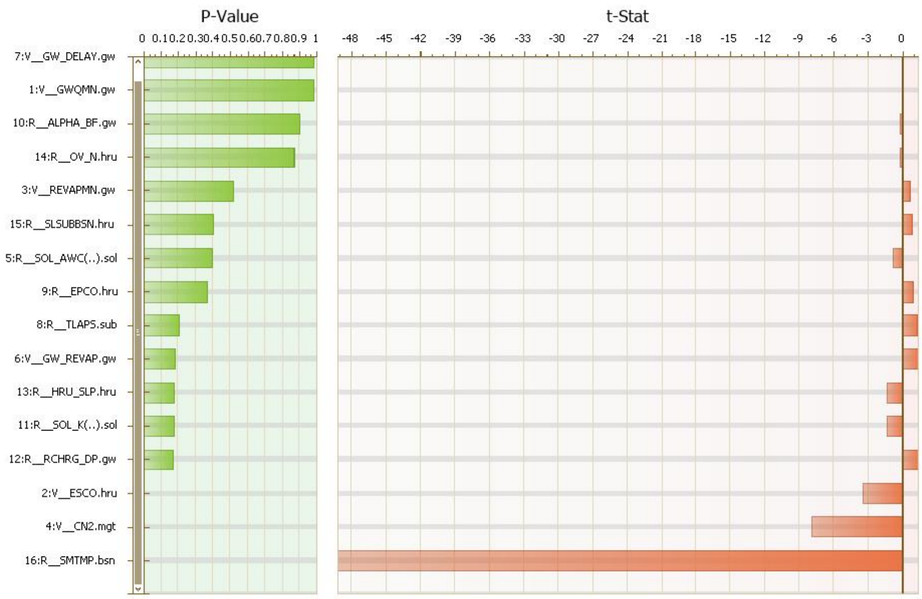


Figure 12. Global sensitivity analysis and ranking of SWAT parameters

Sensitivity analysis is useful to identify and rank those parameters that have significant impact on model outputs. A t-test was used to identify the relative significance of each parameter. In our analysis, the larger value of t-stat and the smaller value of p-value indicate the greater sensitivity of a certain parameter. In this way, we identified the 10 most sensitive parameters that influence surface runoff: ESCO; CN2; GW_REVAP; EPCO; SOL_K; RCHRG_DP; OV_N; SMTMP; SLSUBBSN; and HRU_SLP.

After establishing the most sensitive parameters and benefiting from the parallel processing module, we performed seven iterations (2000 simulations each) using the NSE (Nash-Sutcliffe efficiencies) function in order to obtain the parameters of values that provided the best estimates of simulated flow relative to the measurements (Figure 13).

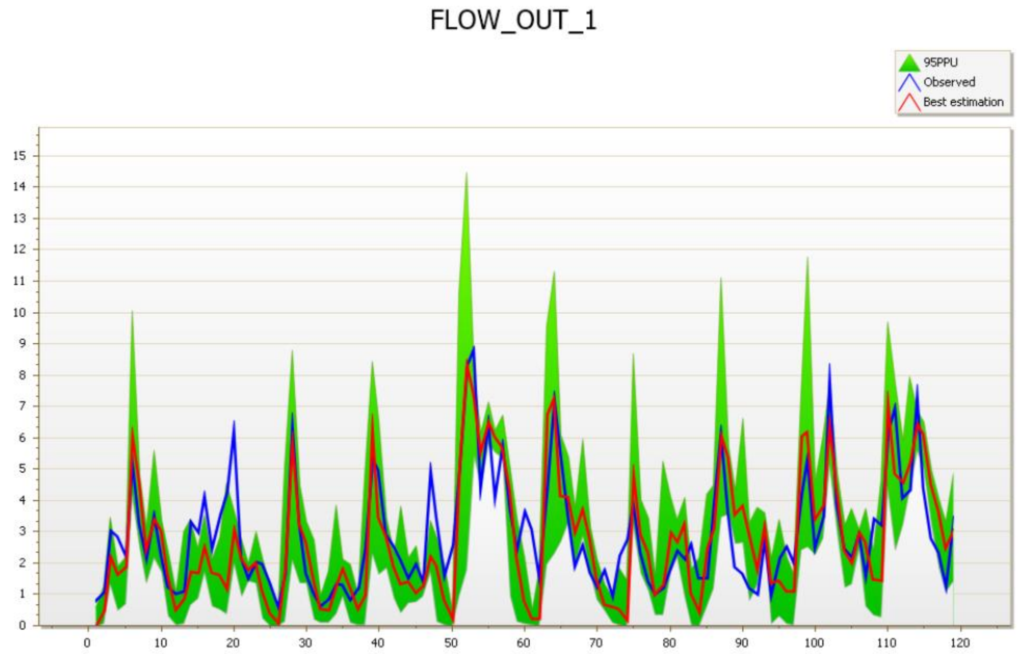


Figure 13. The 95PPU plot between observations and best simulation flow

Model calibration accuracy was judged using two indices: p-factor and r-factor. The p-factor is the fraction of measured data (plus its error) bracketed by the 95PPu band and values ranging between 0 to 1, where 1 indicates 100% bracketing of the measured data within model prediction uncertainty (Abbaspour et al., 2004, 2015;SzezesniakandPiniewski, 2015 in Thavhana et al., 2018). For model acceptance, the authors recommend a value of p-factor> 0.70.

The r-factor is the ratio of the average width of the 95PPu band and the standard deviation of the measured variable. With r-factor< 1.5, the model will be accepted (Abbaspour et al., 2004, 2015; Szezesniak and Piniewski, 2015 in Thavhana et al., 2018). During the calibration step for the Tărlung River Basin, the value of p-factor was ***0.74***, and the value of r-factor was ***1.46****.* These values indicate a low degree of model uncertainty and a high performance level for the model.

The performance and efficiency of the model was analysed according to the statistical parameters of the Nash-Sutcliffe efficiency (NSE) coefficient, the RMSE-observations standard deviation ratio (RSR), and the per cent bias (PBIAS, %) for monthly time steps according to Moriasi et al. (2007)(see Table 2).

Table 2. General performance ratings for criteria ASCE (1993) and Moriasi et al. (2007)

Performance rating	*RSR*	NSE&R^2	PBIAS
Very good	0.00≤RSR≤0.5	0.75<NSE≤1.00	PBIAS< ±10
Good	0.5<RSR≤0.60	0.65<NSE≤0.75	±10≤PBIAS<±15
Satisfactory	0.6<RSR≤0.7	0.5<NSE≤0.65	±15≤PBIAS<±25
Unsatisfactory	RSR>0.7	NSE≤0.5	PBIAS≥±25

The values of the three statistical parameters for calibration were ***R^2=0.65 (satisfactory), NSE=0.56 (satisfactory), RSR=0.67 (satisfactory) and PBIAS=6.1 (very good)***. Overall, it can be stated that these four parameters indicate that the results, efficiency, and performance of the model were between satisfactory and good.

4.2 SWAT validation

The validation step has the role of confirming results obtained by calibration. Performance and validation efficiency are also quantified using the p-factor, r-factor, and the values of the statistical parameters according to the objective of the chosen function (Figure 14) (Abbaspour et al., 2017).

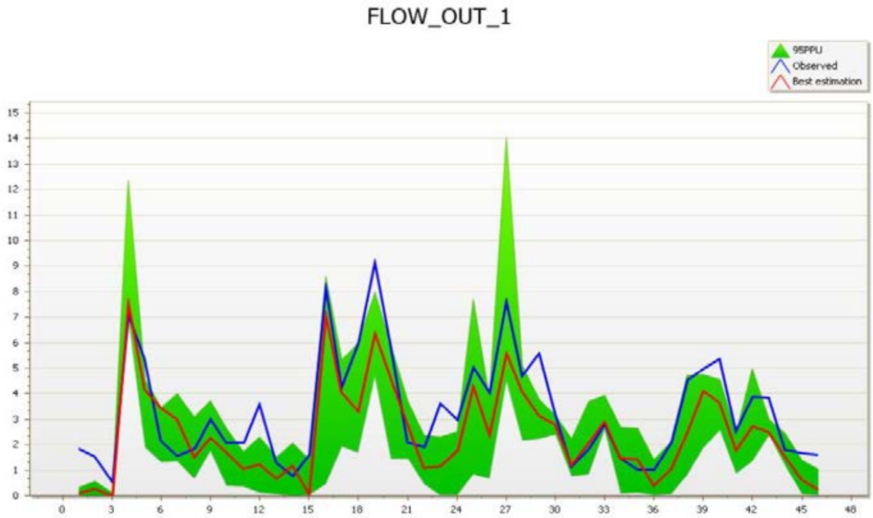


Figure 14. The 95PPU plot between observations and best simulation flow

The validation was performed monthly for the 1996-1999 period. For this period, the following values were obtained: ***p = 0.67 (satisfactory), r =1.22(good), R^2=0.78 (very good), NSE=0.62 (satisfactory),*** and ***RSR=0.62 (satisfactory)***.The percentage of observed data grouped together by 95PPU during validation was 67%, which remains short of the > 70% recommended by Abbaspour et al. (2015) and ASCE (1993). However, this value may be due to iteration because, for the validation process, a single iteration of 2000 simulations was performed "*as SUFI-2 is iterative, each iteration results in a reduction of parameter uncertainties causing a narrower 95PPU band, which subsequently results in a smaller p-factor" (*Abbaspour et al., 2015).

Moreover, it is evident that the values of the statistical parameters, which measure the efficiency and performance of the model, have increased during validation; therefore, the efficiency and performance of the model is confirmed.

5. Integrated river basin modelling framework for analysing interactions in the Water-Energy-Land Nexus

The SWAT integrated hydrological model is used to analyse interactions within the River Basin. The model focuses on water yield in the river basin, and accounts for external factors and interaction between the nexus (Figure 15).

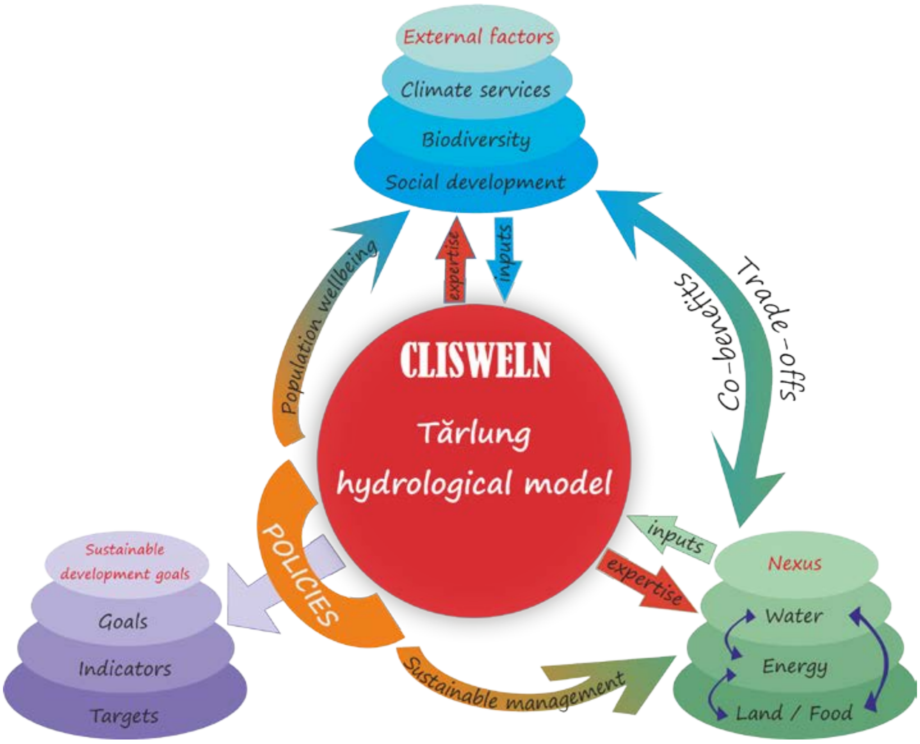


Figure 15. Framework from WEL nexus interaction in Tărlung study case

Using data on weather parameter evolution and scenarios regarding the dynamics of land uses from the river basin, forecasts regarding water balance throughout the river basin were made.

Hydrological modelling aims to identify the optimal scenario regarding land use structure in order to ensure a balanced hydrological regime (constant discharges, with peaks as low as possible) in the context of climate change (Table 3).

Table 3. Challenges and Opportunities for Tarlung river basin

Future challenges	Results	Drawback	Benefits
Increased food requirement	Increased pasture areas on land with slope below 16 degree	Decrease in water quality Unbalanced discharges Lake sedimentation	Increase in food production Raising incomes for the population
Tourist development of the area Urbanization of the area	Increased built-up surfaces Increased water consumption	Decrease in water quality Unbalanced discharges Increased water pressure from drillings (additional GHG emissions)	Additional jobs in the area Raise incomes for the population and city hall
Raising the average air temperature	Extending the area occupied by deciduous trees to the resinous detriment	Reducing the hydrological quality of land uses Decrease in water quality Unbalanced discharges	Increase the forest stands productivity
	Fast melting of snow	Decrease in water quality Unbalanced discharges	-
Intensification of extreme phenomena	Precipitation and torrential leakage	Decrease in water quality Unbalanced discharges	-
Extending the water supply network	Increased water consumption	Increased water pressure from drillings (additional GHG emissions)	Increasing the quality of life Higher income for the city hall
Urban and industrial development of the metropolitan area			Additional jobs Decreased pressure on the forest
Increased consumption of wood (industrial, firewood)	Reducing forests age Increasing of the area to be forested	Reducing the hydrological quality of land uses Decrease in water quality Unbalanced discharges	Additional jobs Raising incomes for the population
Management and extension of protected areas	Restrictions on land uses exploitation	Diminishing the income of the population	Increased the hydrological quality of land uses Increased water quality
	Restrictions regarding arrangement torrential streams	Increasing of water turbidity Accumulation of alluviums in the lake	Protecting the riparian habitats

The model addresses two climate change scenarios derived from the greenhouse gas trajectories adopted by the IPCC 5th Assessment Report (AR5) (IPCC, 2014), namely the

Representative Concentration Pathways RCP4.5 and RCP8.5. Temperature and precipitation data at 0.11°- spatial resolution computed within the Coordinated Regional Climate Downscaling Experiment (CORDEX). Daily temperature and precipitation data were retrieved from two regional circulation models (RCMs), namely CCLM and REMO, nested in two general circulation models (GCMs), namely EC-Earth r12 and MIROC5 r1. The analysis compared the model outputs over three periods: 2011-40, 2041-71, and 2071-2100.

The climate change perspective based on quantified model outputs develops an important climate service as a tool for supporting regional and local stakeholders in the decision process. The increased temperatures predicted by all proposed climate change scenarios will lead to the spatial extension of the area occupied by deciduous forests to the resinous detriment, which is reflected in the decrease of retention capacity and intensification of surface leakage (Zhang et al., 2017).

The SWAT will be used to estimate the volume of water supplied by the river basin in the context of the two previously presented climatic scenarios, while accounting for various possible scenarios for land uses management (scenarios discussed with decision-makers in the area) as follows:

1. Increasing the area occupied by pastures to approximately 3500 ha (20% of the River Basin's surface) to the detriment of lands occupied by forests;

2. Increasing the area occupied by built land as a result of increasing the accessibility of the area and the realisation of Paltinu Tourist Resort (approximately 1400 ha) at the expense of forests, meadows, and pastures.

Furthermore, two different forest management practices will be introduced in the simulations. The first forest management practice was substantiated on the sustainable management principle, considering intensive (close to nature) silvicultural treatments (progressive cuttings and, where possible, single tree selection, and a production cycle of 120 years or more), thus promoting a "close to nature" forest regeneration, which should lead to uneven forest age structure. The second forest management practice is substantiated on maximising the economic efficiency of forests (in terms of timber production), and considers the extension of extensive silvicultural treatments (e.g. clear-cutting, 100-year production cycle), which should lead to an even forest age structure. The forests in protected areas will remain natural structures in which forestry interventions will be as minimal as possible.

In order to emphasise the impact of forest management practices on water and sediment yield inside the Tărlung Reservoir Catchment, local values for the curve number (CN) will be assessed.

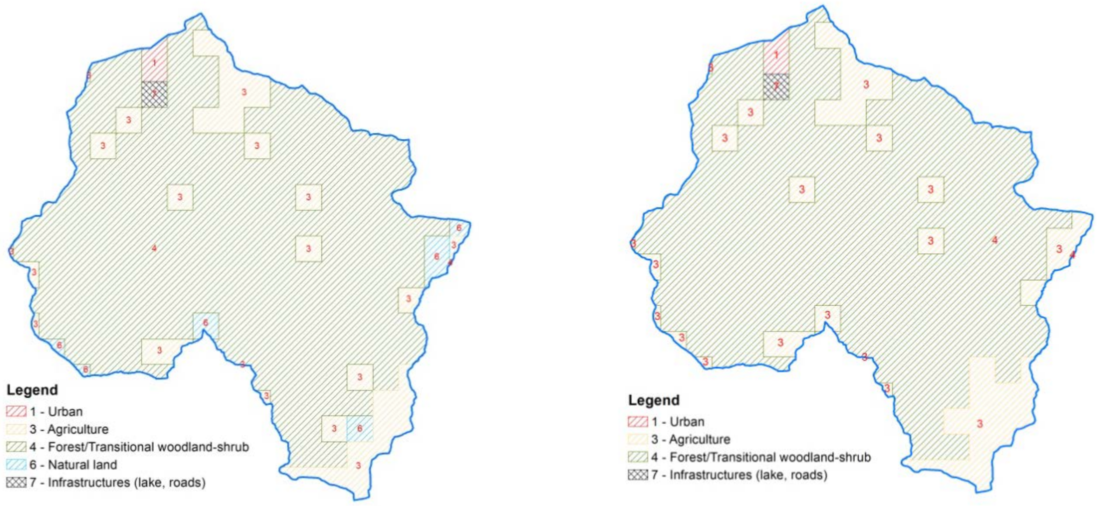
These values will be determined according to the following factors for each stand: stage of development (age classes), forest type (resinous or hardwood), and average CN values obtained from the hydrological calibrated model for each soil category (A, B, C, and D).

Considering these factors will result in nine scenarios related to land use and forest management (Table 4).

Table 4. Land use and forest management matrix

Scenarios		Land use		
	Scenario type	*Current situation (C)*	*Extended pasture (EP)*	*Extended urbanization (EU)*
Forest management	*Current situation (C)*	Scenario 1 (C.C)	Scenario 2 (C.EP)	Scenario 3 (C.EU)
	Close to nature (CN)	Scenario 4 (CN.C)	Scenario 5 (CN.EP)	Scenario 6 (CN.EU)
	Economic efficiency (EE)	Scenario 7 (EE.C)	Scenario 8 (EE.EP)	Scenario 9 (EE.EU)

We focused only on the aforementioned scenarios since changes to land use will be minimal in future developments, according to the Land-Use Based Integrated Sustainability Assessment (LUISA) platform of the European Commission's Joint Research Centre (JRC) (Figure 16).



Year 2010 **Year 2050**

Figure 16. Land use evolution according to LUISA from 2010 to 2050

6. Energyconsumptionforwatersupply

The water supply for the city of Brasov and neighbouring localities is provided by S.C. Apa Brașov S.A., a trade joint-stock company whose main shareholders are: Brașov County (42% of shared capital) and Brașov Municipality (42% of shared capital) and the rest of 16% are represented by localities close to the metropolitan area. (www.apabrasov.ro, 2018).

Company Apa Brașov S.A. purchases raw water from the National Department of Romanian Waters to be treated and transformed into drinking water and provided to clients.

In 2017, the level water consumption in Brașov and nearby communities (served by Compania Apa S.A.) was approximately 50.3 million cubic meters. Of the total invoiced water, 74% was delivered to the population, while 7% was delivered to institutions, and 19% to economic operators.

The water supply system consists of:

1. Springs sources:

- Răcădău: installed flow rate of 22l/s, average flow rate of12 l/s, permanent operation, supplies Răcădău reservoir;

- Solomon: installed flow rate of 27.8l/s, average flow rate of 4.5 l/s, permanent operation, supplies Solomon reservoir;

- Ciucaș: flow rate of 60-80/s, permanent operation, supplies Pleasa reservoir and Tărlungeni community;

- Baciului Valley, 7 springs, Angelescu Glade, Gârcini: installed flow rate of 23l/s, average flow rate of 18.3 l/s, permanent operation, supplies Săcele municipality; due to difficult access to sources, challenging maintenance, and reduced flow during the summer, these sources with the surface source (namely the Tărlung reservoir) has been proposed;

- Parcul cu Umbra and Parcul cu Soare springs: installed flow rate of 15 l/s, supplies Codlea Municipality.

2. Surface sources:

- Tărlung Lake: the most important source, covering over 90% of water demand; the maximum authorised daily volume is 2200 l/s, and the average volume is 1585 l/s;

Underground water (drilling wells):

- Hărman-Prejmer drilling wells: consist of 45 wells operating at 35-45 m depth, equipped with submersible pumps; installed flow rate of 1900 l/s (ANIF Brașov property);

- Măgurele drilling wells: 3 wells with a maximum flow rate of 45 l/s, average flow of 12 l/s, serves only Poiana Brașov;

- Ghimbav drilling wells: 3 wells operating at 45 m depth and at a maximum flow rate of 26 l/s;

- Sânpetru-Hărman drilling well: 15 wells operating at 150 m depth and an installed flow rate of 25 to 40 l/s;

- Sânpetru-Stupini drilling well: 14 wells operating at 150 m depth and an installed flow rate of 25 to 30 l/s;

The Sânpetru-Hărman and Sânpetru-Stupini drilling system account together total capacity of 810 l/s, though they are used only partially, with the wells running alternately at 2-3 wells at a time.

The Hărman-Prejmer drilling front is owned by ANIF, and consists of 45 drillings equipped with electric submersible pumps, of which 32 are functional and 13 require repairs. At present, these drillings (F0-F18) provide the necessary water for the Prejmer commune. Under special conditions, they can also supply water for the Brașov and Săcele municipalities (as was the case in March 14th-18th2018, when water from the Tărlung reservoir had a higher degree of turbidity and the water plant's filtration capacity was exceeded).

The volume of water supplied to Prejmer community by this source and the electricity consumption for the 2015-2017 period is presented in Table 5(data according to ANIF's address No. 647/ April 3th2018).

Table 5. Water volume supplied by the Hărman-Prejmer drilling front and specific energy consumption

No. crt.	Year	Water supplied m^3	Energy consumption kWh	Unit energy consumption kWh m^{-3}
1.	2015	792 800	228 415	0,29
2.	2016	752 210	216 434	0,29
3.	2017	737 811	212 798	0,29

The main sources of water used by the company "Apa Brașov SA" are the Tărlung reservoir and the Stupini, Sânpetru, and Hărman drillings.

In 2017, "Apa Brașov SA" acquired 45.2 million cubic meters of the Tărlung reservoir and pumped 5.2 million cubic metres of the Sânpetru-Hărman and Sânpetru-Stupini drilling fronts. Energy consumption for water treatment from the accumulation of Tărlung (in the Săcele Water Treatment Plant) was 1.7 million kW/h, while the consumption for pumping water from drilling was 1.35 million kWh (Table 6 - data supplied by Company "Apa Brașov SA").

Table 6. Water supplied from Tărlung reservoir and Stupini, Sânpetru and Hărman drilling wells and related energy consumption during 2017

No. crt.	Water source	Water supplied	Electricity consumption for water treatment / pumping		Electricity consumption for water transport		Total electricity consumption	
			total	unit consumption	total	unit consumption	total	unit consumption
		million m^3	million kWh	kWh m^{-3}	million kWh	kWh m^{-3}	million kWh	kWh m^{-3}
1	Tărlung Reservoir	45.17	1.75	0.039	1.10	0.024	2.85	0.063
2	Drilling wells	5.22	1.35	0.259	1.76	0.338	3.11	0.597

Water transport from the Săcele Water Plant to water supply tanks is largely gravitational, and only requires the pumping of water to a small extent. Due to the fact that water drilling here occurs at lower altitudes compared to water tanks, additional energy consumption is required for the transport of water.

The energy consumption is roughly10 times higher for drilling water compared to water from the Tărlung reservoir. For water pumping, processing (decanting, filtration, disinfection), and transport, electric energy is used from the national electricity distribution network. The primary sources of energy for the production of electricity include coal, natural gas, nuclear, hydroelectric, and renewable resources (wind, solar, biomass, etc.). The production of electricity using coal or natural gas generates CO_2 emissions, while electricity produced from nuclear, hydroelectric, or renewable resources does not generate greenhouse gas emissions (Table 7).

Table 7. Primary energy sources and emissions for electric power generation to national level

No. crt.	Year	Primary energy source					CO_2 emission
		Coal	Natural gas	Other sources (crude oil)	Nuclear	Hydro and other renewable	
		%	%	%	%	%	g kWh^{-1}
1	2005[1)]	35,8	14,7	2,8	9,6	37,1	485
2	2006[1)]	39,6	16,7	2,5	9,2	32	547
3	2007[1)]	41,7	17,4	2,0	13,1	25,8	566
4	2008[1)]	39,5	14,0	1,3	17,3	27,9	496
5	2009[2)]	37,8	11,4	2,1	21,3	27,4	490
6	2010[2)]	32,7	10,4	1,2	19,1	36,6	370
7	2011[2)]	37,3	12,5	0,8	18,4	31,0	403
8	2012[2)]	37,6	13,8	1,1	19,6	27,9	391
9	2013[2)]	21,8	14,4	6,6	19,6	37,6	312
10	2014[2)]	26,1	11,5	1,2	18,0	43,2	292
11	2015[2)]	26,9	13,5	0,3	17,8	41,5	299
12	2016[2)]	24,5	15,0	0,6	17,5	42,4	287
13	2017[2)]	26,6	15,2	1,9	18,1	38,2	315
14	2030[3)]	9	11	-	12	68	-

1) http://www.anre.ro/download.php?f=fqiEhg%3D%3D&t=vdeyut7dlcecrLbbvbY%3D
2) http://www.anre.ro/ro/rapoarte/rezultate-monitorizare-piata-energie-electrica (Reports on the results of the electricity market monitoring in December 2009-2016)
3) Energy Strategy of Romania 2016-2030, with the perspective of 2050, Ministry of Energy, 2016

Average CO_2 emissions resulting from the production of a 1 kWh are closely correlated with the share of primary energy sources (see Figure 17), while a higher share of coal and natural gases leads to higherCO_2 emission levels.

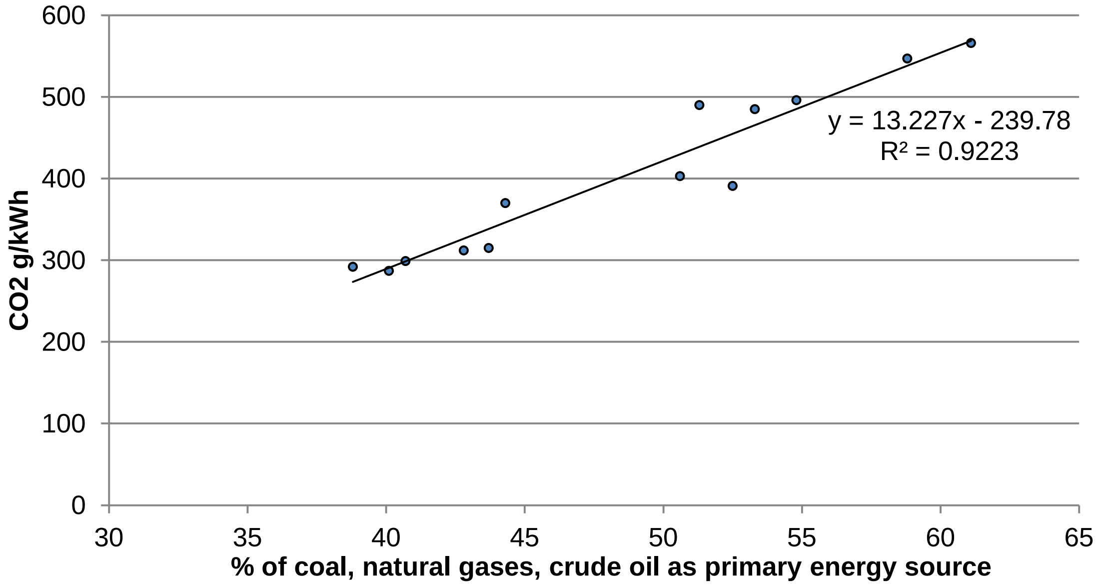


Figure 17. The correlation between primary energy source and CO_2 emissions in electricity generation

As a result of the commissioning of reactor 2 of the Cernavodă Nuclear Power Plant (2007) and of the expansion of wind and solar capacities for the production of electricity, CO_2per kWh emissions have continuously decreased since 2005from approximately 550 g/kWh^{-1}to approximately 300 g/kwh^{-1} (see Figure 18).

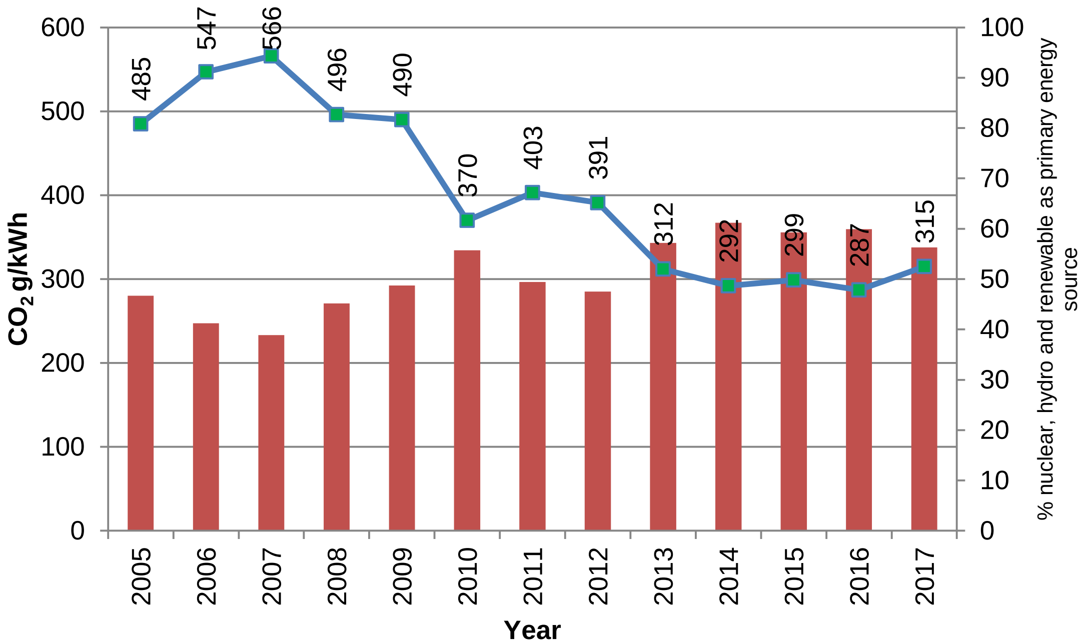


Figure 18. CO_2 emission associated with electricity production

By 2020, major changes are not expected in the share of primary energy sources used to produce electricity and, in this context, we consider that the carbon emissions related to electricity generation will be 300 g/kwh^{-1} (Table 8).

Table 8. Estimation of emissions related to the processing and transport of drinking water (for 2017 year)

		Units	Water source Drilling Wells Prejmer	Drilling Wells Stupini-Sânpetru-Hărman	Tărlung Reservoir
Water supplied		m^3	737811	5216121	45173490
Electricity for water processing (treatment or pumping extraction)		kWh	212798	1350937	1745949
Electricity for water transport		kWh		1761764	1101766
CO_2 emissions for water treatment/pumping	per unit	g CO_2 $m^{3\ -1}$	90,85	81,58	12,17
	total	kg CO_2	67031	425545	549974
CO_2 emissions for water transport	per unit	g CO_2 $m^{3\ -1}$	0	106,39	7,68
	total	kg CO_2	0	554956	347056
Total CO_2 emissions	per unit	g CO_2 $m^{3\ -1}$	90,85	187,97	19,86
	total	g CO_2 $m^{3\ -1}$	67031	980501	897030

The CO_2 emissions associated with electricity production were 315 g/kWh^{-1}in 2017 (see Table 7)

7. Climate services and the Water-Energy-Land Nexus in the Tărlung river basin

For the sustainable management of natural resources, and in particular for the adoption of just and coherent strategies, the Water-Energy-Land Nexus (WELN) components of the nexus complex must be assessed as a integer in order to better understand how they condition and influence each other (Howells et al., 2013 in Rasul and Sharma, 2016).

Understanding these links is an important tool for local and regional decision makers to determine the decisions and policies necessary to preserve the integrity of the nexus in the context of climate change. In order to understand the trade-offs and benefits to preserving the integrity of the WELN complex, local stakeholders and decision-makers require assistance in making decisions, with climate service as a decision aide (Hellmuth, 2011), which is derived from: climate information (climate scenarios downscaled to the regional level), land use scenarios, forest management, and their integration into a hydrological model.

By running the hydrological model for Tărlung river basin while accounting for the aforementioned factors will provide local stakeholders with decision support (personalised climate services) in the following forms:

- Thematic maps with the spatial distribution of land use for the scenarios mentioned in § 5;
- Forest management plans for forest land and another management plan for the remaining land;
- Distribution of surface runoff, taking into account the scenarios mentioned in § 5;
- Hydrological balance of the watershed for different climatic, land use, and forest management scenarios;
- Sedimentation rate for the reservoir;
- Water available from the reservoir for different sectors as well as its supply from groundwater pumping;
- The energy requirements for pumping groundwater;

- An automated weather station (AWS) and other sensors placed in the area of interest to provide continuous access to meteorological data measured as World Meteorological Organisation (WMO) condition;
- Permanent monitoring of meteorological conditions used for real-time monitoring of forest ecosystems, extending the climate services to ecosystem services;
- Warnings and alerts on the state of forests and other ecosystems;
- Predicted impacts of climate variability.

However, the aforementioned support will not materialise in the form of climate services, and the nexus will not be part of this, if local and regional stakeholders and decision makers are not involved. In the case study area, stakeholders have been involved since the co-design phase of the project. On the basis of a matrix (Table 9), key stakeholders in the case study area were identified and will remain permanently involved in project development.

Table 9. Key stakeholders involved in the case study

Sectors	Organizations
Water	Water Company of Brașov
	Water Administration of Brașov
	Water Factory of Brașov
	National Institute of Hydrology and Water Management
Forest	Local Forest Administrator
Decision makers	City Hall Săcele
	City Hall Brașov
	Metropolitan Agency of Brașov
NGOs	Manager of protected area

The results of the model will be addressed by the stakeholders, who will identify the opportunities and challenges they will face in the context of various scenarios. Based on the experience and needs of the stakeholders, action lines (based on the aforementioned climatic services) will be developed to provide an appropriate framework for the sustainable development of the area. Sustainable development implies the existence of common policies for the WELN nexus. Currently, there is no integrated approach for the nexus, and each of the sectors involved in the management of the components of the nexus has specific policies that sometimes adversely affect the work of other sectors (e.g. protected area management severely limits torrent management).

Through the present case study, we propose climate services to support local and regional decision-makers in adopting policies that ensure the stability and integrity of the WELN complex in the face of future climatic, social, and economic challenges.

8. Conclusion

The SWAT hydrological model was applied in the Tărlung River Basin for the 1963-2010 period to estimate surface runoff. In order to calibrate the hydrological model, we used the 1996-2010 interval with a 5-year warm-up period. This interval was chosen because it had continuous data on discharges, as well as rainy years, dry years and average precipitations years intervals, which is essential for the calibration and validation of the model (Abbaspour et al., 2004, 2015, 2017).

Thereafter, sensitivity analysis, model calibration, and uncertainty analysis were performed using the SUFI-2 algorithm integrated with SWAT. The following conclusions were obtained:

(1) Results of sensitivity analysis indicated that 10 parameters (ESCO; CN2; GW_REVAP; EPCO; SOL_K; RCHRG_DP; OV_N; SMTMP; SLSUBBSN; and HRU_SLP) were more sensitive.

(2) During the calibration step, the value p-factor was ***0.74*** and the value of r-factor was ***1.46***.These values indicated a low degree of uncertainty for the model and a high performance level.

(3) Calibration and validation results indicated that R^2= 0.65 and NS = 0.56 for the calibration period, while R^2= 0.78 and NS = 0.62 for the validation period. As such, the simulation results were satisfactory.

Available water in the River Basin coupled with the urban dynamics (manifested by the dynamics of water consumption for the needs of the population) will allow the establishment of an extra volume of extraction water from boreholes and, implicitly, the extra energy consumption for processing it. Additional power consumption for drilling water is reflected in increased GHG emissions.

Electrical power requirements for the processing and transport of drinking water are much higher for the water from drilling (0.6 KWh*$m^{3\ -1}$) in contrast to the water provided from the Tărlung Reservoir (0.03 KWh*m3 -1). As a result, CO_2 emissions are higher in the case of drilling water (187.97 g CO_2 m^{3-1}) than that from the reservoir (19.86 g CO_2 m^{3-1}).

The results provided by the model based on various climate and land use scenarios will be analysed with the key stakeholders identified in the case study area.

Discussions with stakeholders will focus on the benefits and trade-offs that must be taken into account to ultimately achieve sustainable management of the river basin, as expressed by policies that aim to achieve indicators and targets derived from the Sustainable Development Goals (SDGs) set by the UN.

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***Forest Management Plan, 2009, 2013; Silvopastoral Management Plan, 1989

Annex

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CONCLUSIONS AND RECOMMENDATIONS ON THE RESULTS OF HYDROLOGICAL MODEL DEVELOPMENT FOR THE TĂRLUNG CATCHMENT

The Tărlung river - with a basin area of 485 km^2 - flows from the Ciucaș Mountains into the Negru river, and the main tributaries of Ramura Mica (Babarunca), Dracu, and Doftana flowing upstream of the Săcele Reservoir. The hydrographic network of the entire catchment drains an area with altitudes ranging between 502 m and 1887 m, resulting in an average altitude of 957.5 m.

In Săcele Reservoir lake section, the Tărlung River Basin, has an area of 184 km^2, with an average altitude of 1170.6m (H_{min} = 727.4m; H_{max} = 1887.1m) (see Figure 1).

Săcele Dam is an earth-fill dam, whose bottom is composed of rocky and stony rocks with clay soil shores, with an accumulation lake spanning an area of 148 hectares. The dam has a height of 45 m and a canopy length of 709 m, and has the main purpose of supplying water to Brașov and Săcele, as well as the production of electricity.

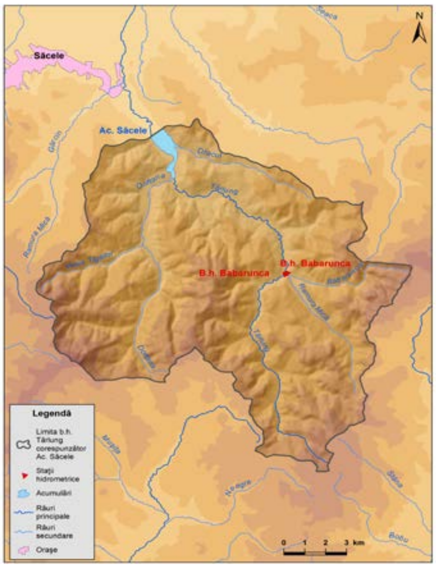

Figure 1. The catchment corresponding to the Tărlung river in the reservoir lake section

The SWAT model was used to simulate water resources for applied future climate data sets and to obtain the effects of climate change on water volumes in Săcele Lake. This is a basin-scale model than can also be applied to a part of the basin. It has the advantage of being an open source physic model that uses readily available inputs relatively and allows users to study long-term impacts. However, it is a model that has often been used for large basin areas and even at the continental level; thus, it must be carefully calibrated.

In the case of small surfaces such as Săcele Lake's catchment, discharges rates are very sensitive to precipitation values in the basin. Any small error in rainfall will generate an incorrect discharge value. In the case of large river basins, water resources are more homogeneous, which is reflected by a larger set of rainfall measurement points.

The selected calibration period (2001 – 2010) is a suitable period with data recorded for both daily and monthly extreme values, as well as a balanced average value, compared to 10-year periods (Table 1).

Table1. Multiannual average values determined at hydrometric stations in Romania, for different time intervals and for the entire analysis period

River	Hydrometric station	2011-2015	2001-2010	1991-2000	1981-1990	1971-1980	1961-1970	Average
Someș	Satu Mare	**83.9**	143.6	133.2	117.2	134.0	126.0	**126.5**
Crișul Alb	Chișineu Criș	**16.4**	26.9	23.4	20.1	24.2	25.1	**23.3**
Mureș	Arad	**121.0**	210.3	189.5	170.7	217.9	179.7	**187.0**
Timiș	Lugoj	**30.3**	45.3	37.4	38.4	44.5	40.2	**40.2**
Jiu	Podari	90.6	93.5	**75.0**	77.2	89.1	94.4	**86.3**
Olt	***Feldioara***	***30.4***	***40.7***	***40.4***	***41.7***	***50.5***	***35.6***	***40.8***
Argeș	Budești	51.4	54.3	**43.7**	45.3	64.5	51.1	**51.8**
Ialomiţa	Slobozia	38.9	45.3	**38.0**	38.5	54.8	41.2	**43.1**
Siret	Lungoci	**188.4**	224.8	237.1	202.5	252.4	190.5	**218.5**
Jijia	Victoria	**3.8**	6.9	8.2	7.0	8.7	7.0	**7.2**

Upstream of the lake, there are 2 hydrometric stations; however, they unfortunately lack a continuous data set (from April 2006 only). These stations are:

- Babarunca on the Ramura Mică (Chiscan) River, S = 25.16 km^2, H_m = 1245 m.
- Babarunca on Tărlung river, S = 45.73 km^2, H_m = 1266 m.

Upstream of the lake, the basin difference is monitored by measuring inflow into the lake. In addition, the two stations have a 113.45 km^2 area, with an average altitude of 1115.7 m. Lake inflows were determined using indirect methods. These are calculated for daily and monthly average values, and they exist for the entire calibration period (2001 – 2010). Lake inflow values were the main source of data for model calibration.

The values of this parameter were of good quality, as shown in Figure 2. The average difference between inflows and the sum of discharges for the two hydrometric stations (Babarunca on the Tărlung River and Babarunca on the Ramura Mică River) for 2006 - 2010 period was 1.27 m^3/s. These two stations have been functioning since April 2006.

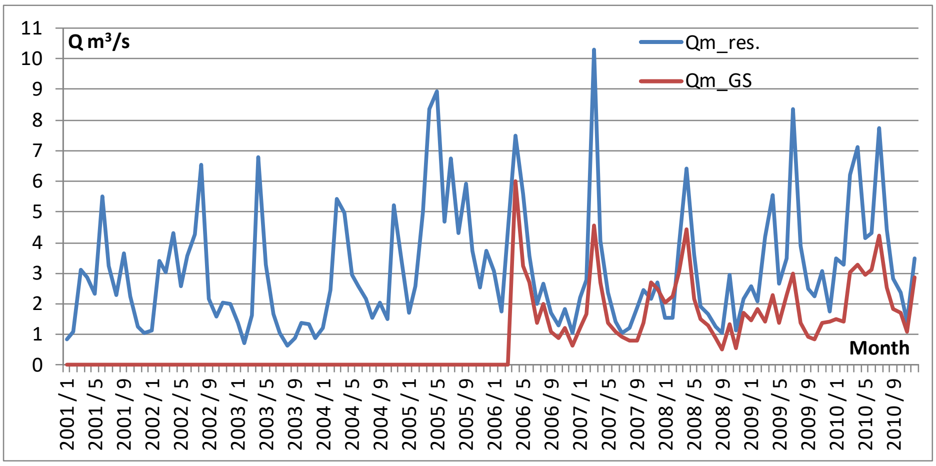

Figure 2. Average monthly discharge in the lake (Qm_res.) compared to the sum of the average monthly flows at the two gauging hydrometric stations (Qm_GS)

The correlation between initial Q and simulated Q is 0.404. The highest error obtained through simulation was in March 2007, when the measured inflow was 10.31 m^3/s, while the simulated inflow was 2.91 m^3/s. It is obvious that no matter how robust the calibration methods are, they will not be able to correct these differences.

Such large differences could be caused either by precipitation errors or in determining inflows. Notably, inflows are not directly measured, but they are instead determined based on water balance calculations between spilled volumes and lake water level. Moreover, recorded rainfall did not justify a discharge of 10.31 m^3/s. In March 2007, rainfall values were 91-92 mm (and 42 - 70 mm a month earlier) (Table 2).

However, the degree of correlation (R^2) between inflows and calibrated discharges rose to 0.613. If the pair of values specific to that month were eliminated, an R^2 of 0.446 is obtained between the inflows and simulated flows, respectively (0.678 with those calibrated).

Table 2. Rainfall values in between February and April 2007

Month	Rainfall mm (ROCADA)	Rainfall mm (INHGA)
February 2007	41.91	70.00
March 2007	**92.20**	**91.10**
April 2007	36.22	33.50

This was the reason for recommending the removal of this point and analysing it to identify similar points (if any exist) in discussions with the specialists who implemented the modelling work.

Many of the observed differences between measured and calibrated flow are specific to winter months, when rainfall is in the form of snow, or when snowmelt is a strong phenomenon (Figure 3). Eliminating discharge data from December, January, and February from the analysis results in an increase in R^2 from 0.678 to 0.713.

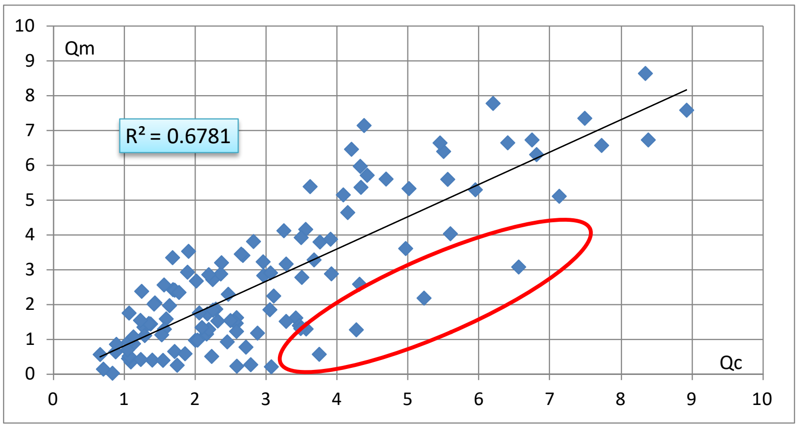

Figure 3. The correlation between the measured average monthly flows (Qm) and the calibrated ones (Qc)

The volumes of water entering rivers depend not only on the rainfall, but also on the types and characteristics of the surrounding soil and vegetation (based on results from the application of different hydrological models). From this perspective, calibration of the SWAT model for the Săcele Lake watershed has the advantage of an extremely detailed approach. The defining soil parameters were obtained based on information from the field (data from ICAS National Forest Research Institute "Marin Drăcea") and from the present project (Climate Services for the Water-Energy-Land-Food Nexus - CLISWELN). Notably, the accuracy of data related to the soil erodibility factor was been obtained as the product between the percentage of sand, clay, and dust. The degree of detail for this data—better than those used nationwide (maps at 1:200.000 scale)—facilitated results quite close to those measured due to the application of the hydrological model.

Furthermore, land use was identified based on detailed data from forest management plans, for forest lands, and for lands outside of forests, as well as other land uses (roads, pastures, buildings areas, etc.), all of which were identified based on available aerial (satellite) images.

The main conclusions of the present research are:

For January 2001, the measured discharge should either be equal to the calibrated one, or be specific to warm-up years (NYSKIP).

It is recommended to run the model in two variants: one with ROCADA rainfall and one with rainfall recorded at the hydrometric station related to Săcele Reservoir.

Since the Nash-Sutcliffe efficiency parameter (NSE) has dimensionless values and it is better suited to comparing the results of the same model on different areas, its use is highly recommended. The INHGA generally recommends an NSE value of approximately 0.7 or greater; however, these values are specific to much larger catchments with higher discharges. Here, rainfall is measured in a larger number of locations, while discharge rates are homogenised and errors are minimised.

Given the small catchment size and considering the only location for rainfall measurement, there may be cases where the recorded rainfall does not fully reflect the discharge values, taking into account that rainfall that generates the maximum discharges may be recorded elsewhere in the basin than precipitation station. Under these conditions, we believe that the NSE results show a good simulation and calibration. It should be noted that NSE values were higher at validation (0.62) than at calibration (0.56).

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