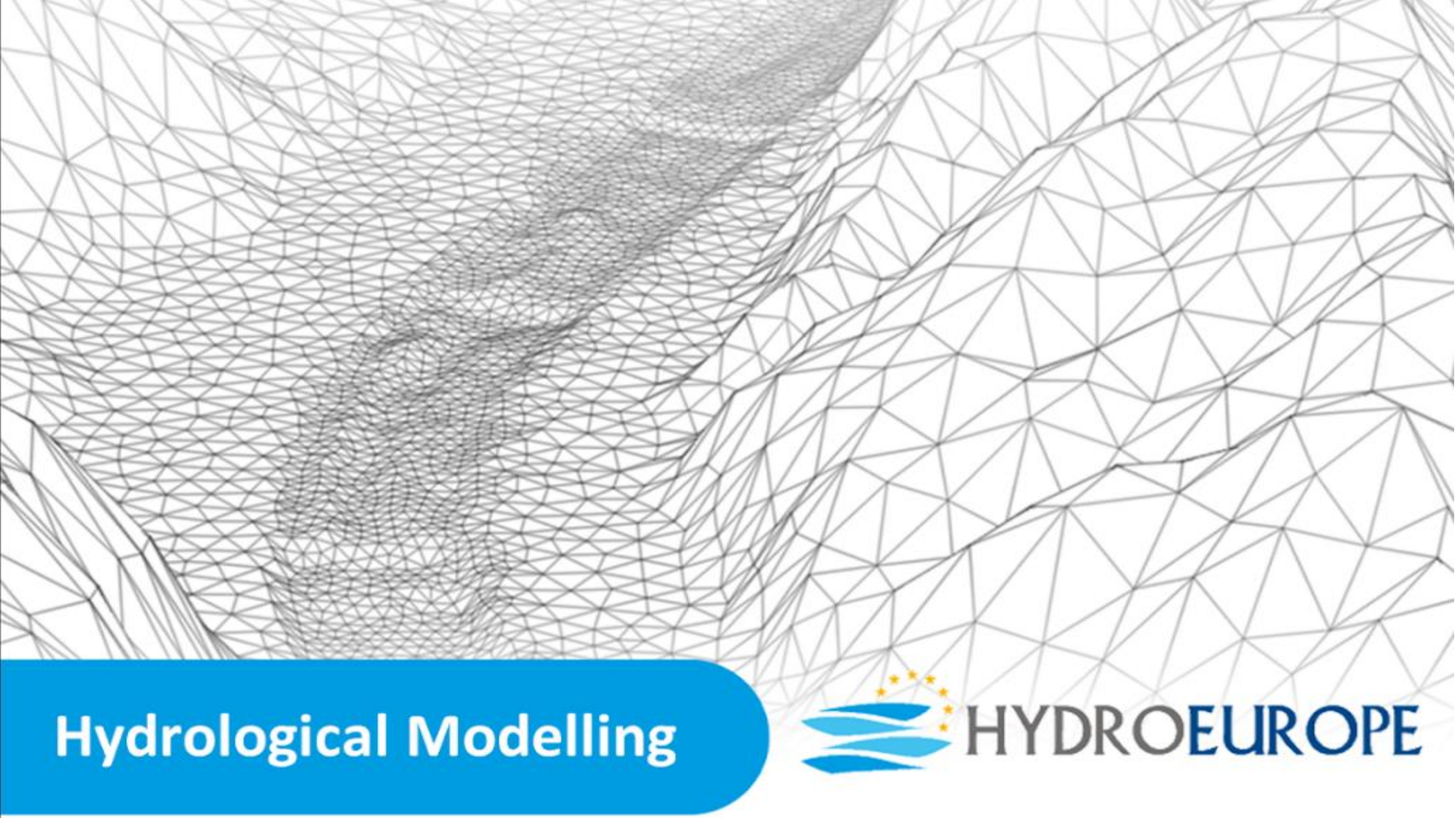


WATEREUROPE
Hydroinformatics for water resources and water related hazards management in Europe

Erasmus+ Programme Cooperation Partnerships
2022-1-FR01-KA220-HED-000089658
HydroEurope

Case Study: Upper Skawa Catchment (Poland)

Team 7 – Engineering Report
Impacts of Landuse Restoration and Climate Change on Catchment Flooding.

Davarend, T., Dufour, R., Fouret, J., Knibbs, J., Komey, K, A. Kustina, R., Matuszczyk, A., Mohib, K, M., Ossoria, Y., Stachowicz, M., Stitou, Z. - Team 07
Version 2.1 - 01 March 2024

Contents

List of Figures

List of Tables

1. Project Introduction

This report has been formulated as the summation of the works completed during the HydroEurope (2024) project by Team 7 during the in person phase of HydroEurope (2024).

1.1 Aim of the study and catchment introduction

The study area was the Upper Skawa catchment, which is located in southern Poland, in the Western Carpathians region (Fig. 1). The Skawa River has a mountainous hydrological regime and is the right tributary of the Vistula River, which is the longest river in Poland. The catchment has an area of approximately 240 km^2 and is divided into 6 sub-catchments.

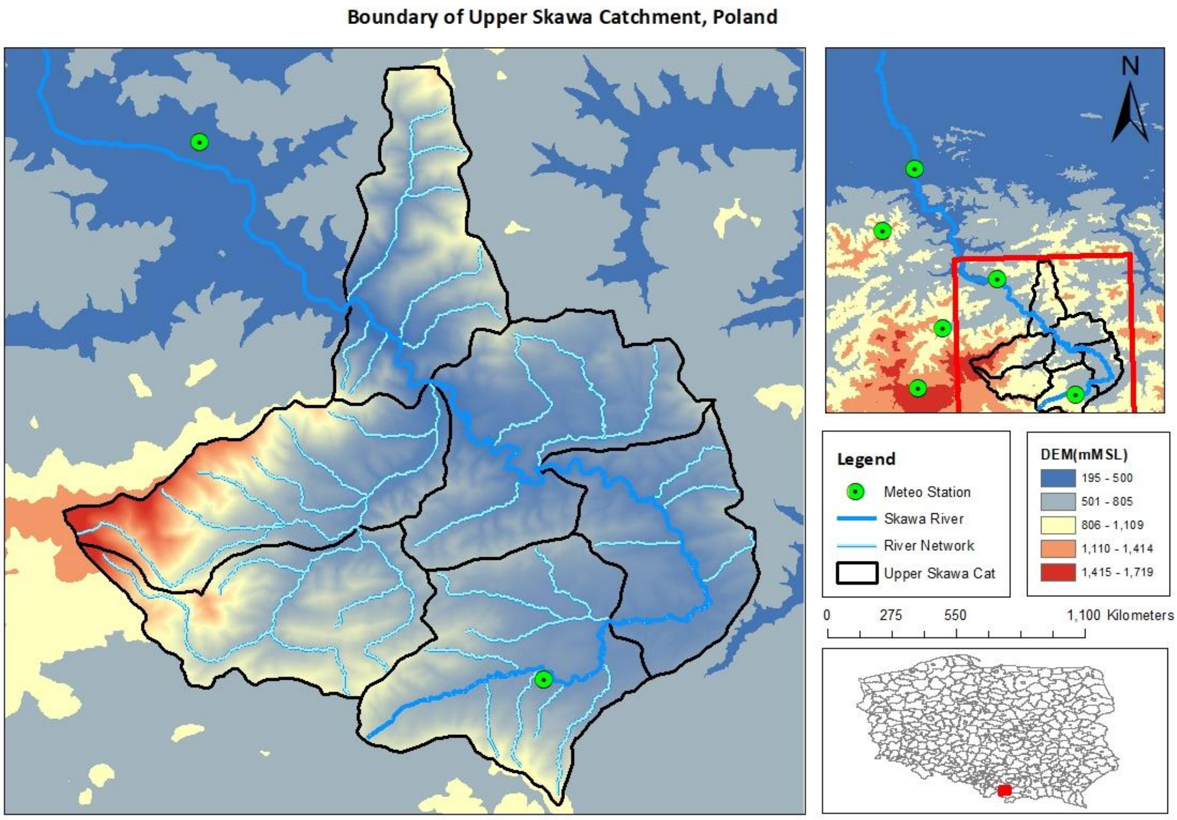


Figure 1: Map of the study area and sub-catchments.

The region's climate is diverse due to its varied terrain, which creates numerous microclimate areas. Annual precipitation in the Upper Skawa catchment ranges from 800 to 1400 mm. The nature of the catchment poses a threat of flash flood events, as reported in the past (Franczak, 2020). Given the potential changes in precipitation patterns in the region, the intensity and frequency of these events may increase. Potential alterations in the hydrological regime should be analysed.

The aim of the study was to set up a hydrological model for the study area and to assess multiple factors influencing the discharge and peak flow of the river, including the impact of landuse change, application of a restoration scenario and application of different climate change projections.

1.2 Tasks and tools

Main tasks:

- Analysis of land cover change from 1990 to 2018 and its impact on discharge
- Analysis of the impact of catchment restoration on runoff formation
- Analysis of the IPCC scenarios in the context of discharge changes

The full objectives and given information can be found in the appendix, as can the daily activity reports detailing the teams progress towards completing these objectives.

The tool used for hydrological modelling in the project was HEC-HMS software, which allows to simulate precipitation-runoff processes.

2 Hydrological modelling

2.1 Model setup

The HEC-HMS model provided was initially lacking a number of input values that were provided and simply needed adding and then calibrated for the given storm event (date of event). While the initial calibrations involved changing only the curve Number (CN), the lag time (Tlag) and initial abstraction provided a relatively good match to the observed event, this form of calibration had no roots in reality. The Tlag is dependent on calculated and measured parameters within the basin and often is not subject to change, similarly the CN is dependent on the area's landuse and hydrological soil type and cannot simply be changed to suit data without cause. These results of this are displayed in the results section 2.2 as they were considered as a goal for the next phase of calibration even if a match of that level was unattainable.

2.2 Results

The next phase of set up was to complete a calibration more grounded with realism. This was done using the Corine landuse Database to inform the creation of a landuse map that was used to calculate the area of each landuse type in each sub-basin. This was done for three given years; data was collected so that the changes in landuse could be observed within the basin, and modelled so their impact of flooding could also be observed. These results were then used with a provided Excel document containing a number of empirical equations designed specifically for the catchment. While the functionality of this tool was opaque to us it was successfully used to create a model for each time period in the Upper Skawa catchment, where the results can be seen (Fig.7). The 2018 landuse model was then used for the following restoration task as it best represents the current state of the area.

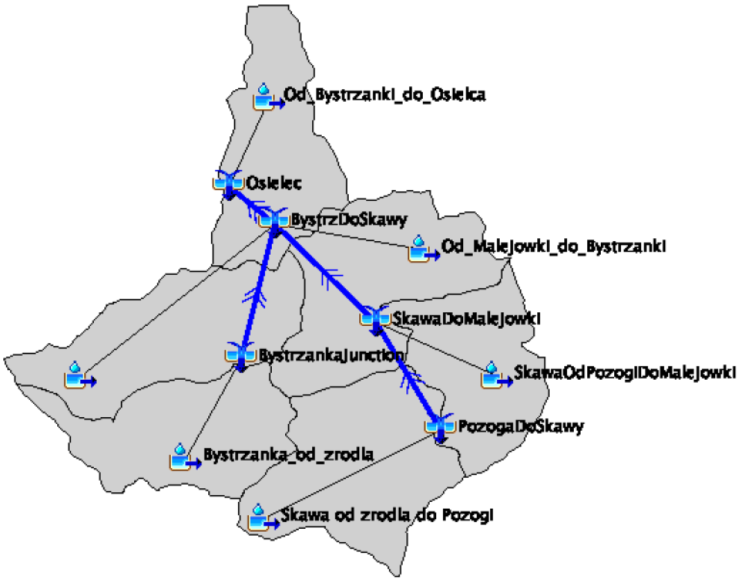


Figure 2:Model setup in HEC-HMS.

Table 1: Initial values of the model parameters.

Catchment	**Initial Abstraction (mm)**	**Curve Number**	**Imperviousness (%)**
Skawa od źródła do Pożogi	18.4	50.8	1.1
Skawa od Pożogi do Malejowki	17.0	52.8	1.6
Od Majówki do Bystrzanki	17.4	51.5	12.1
Bystrzanka z Ciśniawa	27.2	41.2	2.3
Bystrzanka od Źródła	25.2	43.0	1.5
Od Bystrzanki do Osielca	17.8	51.7	2.0

2.2 Initial model setup

Figure 3 shows the non-calibrated results for the satellite data integrated multi satellite retrieval for Global Precipitation Measurements (GPM). This showed initially that the model provided a poor match for the flow peak and volume that would need to be calibrated as a priority.

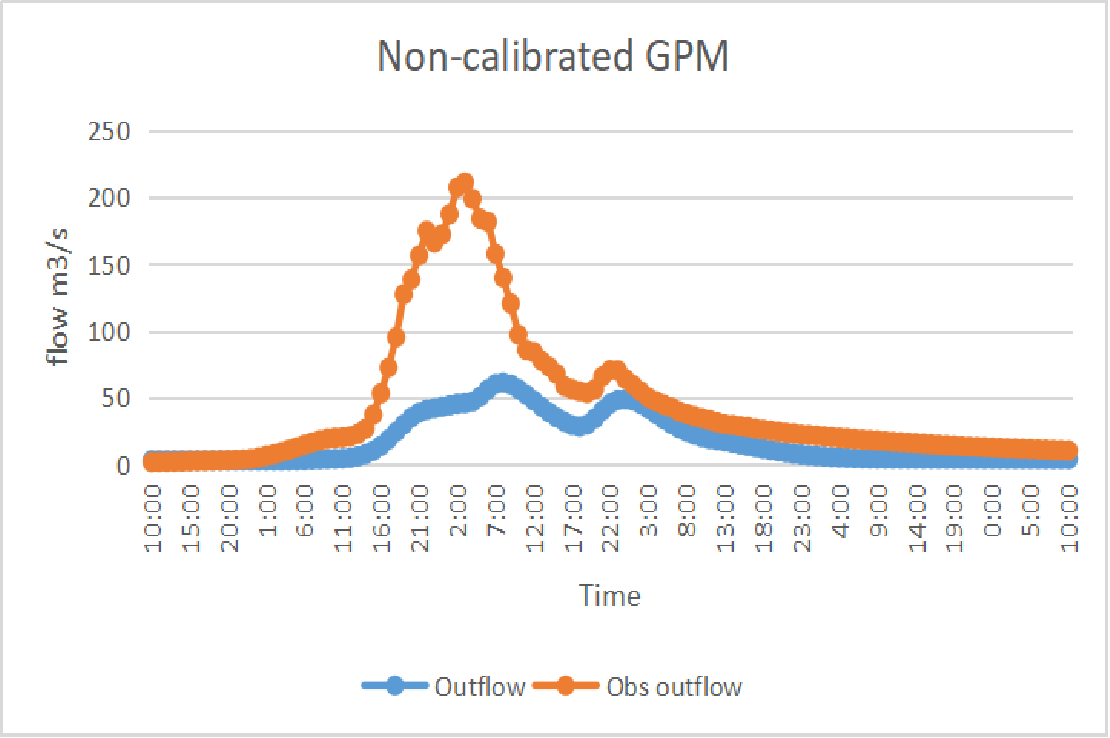


Figure 3: Non-calibrated model based on GPM data.

The initial model also showed similarly poor matches to the observed data when using the provided radar data, as can be seen in Figure 4, however, it can be seen that later part of the event is more representative of the observed data.

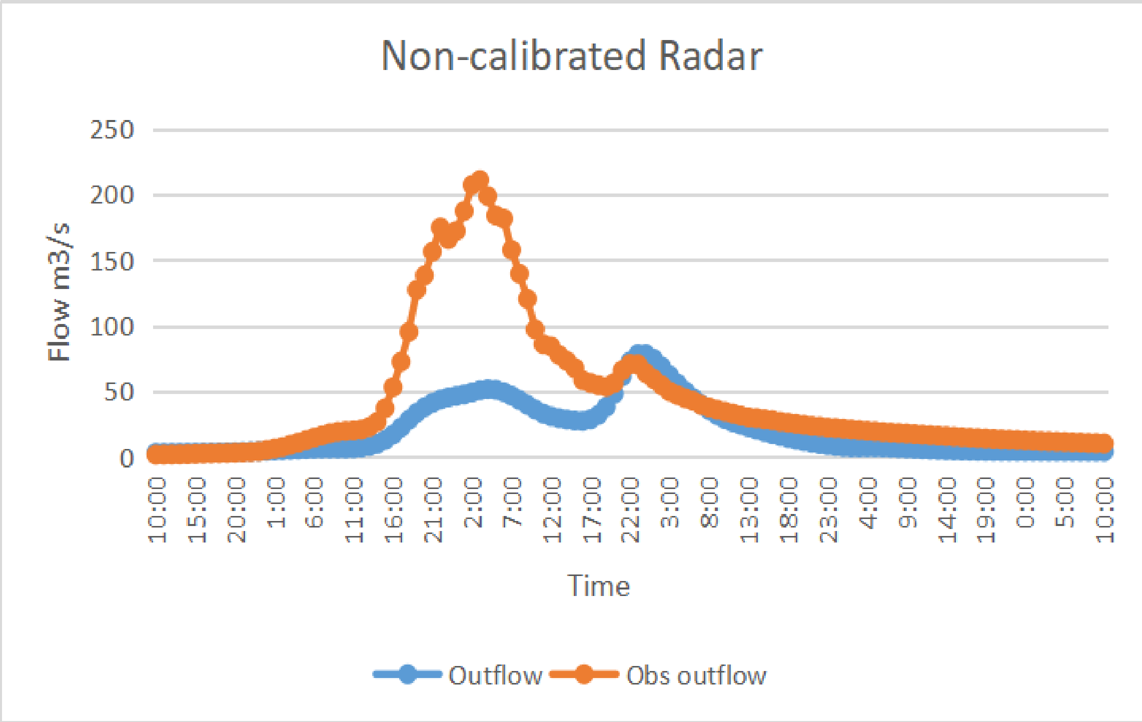


Figure 4: Non-calibrated model based on radar data.

2.3 Calibration

2.3.1 Curve number calibration

As it has been observed in our previous tasks, the CN number is a much more sensitive parameter than any of the others that could be changed. Thus, it was changed first and then others were fine-tuned later on. The final calibration can be seen below in Figure 5.

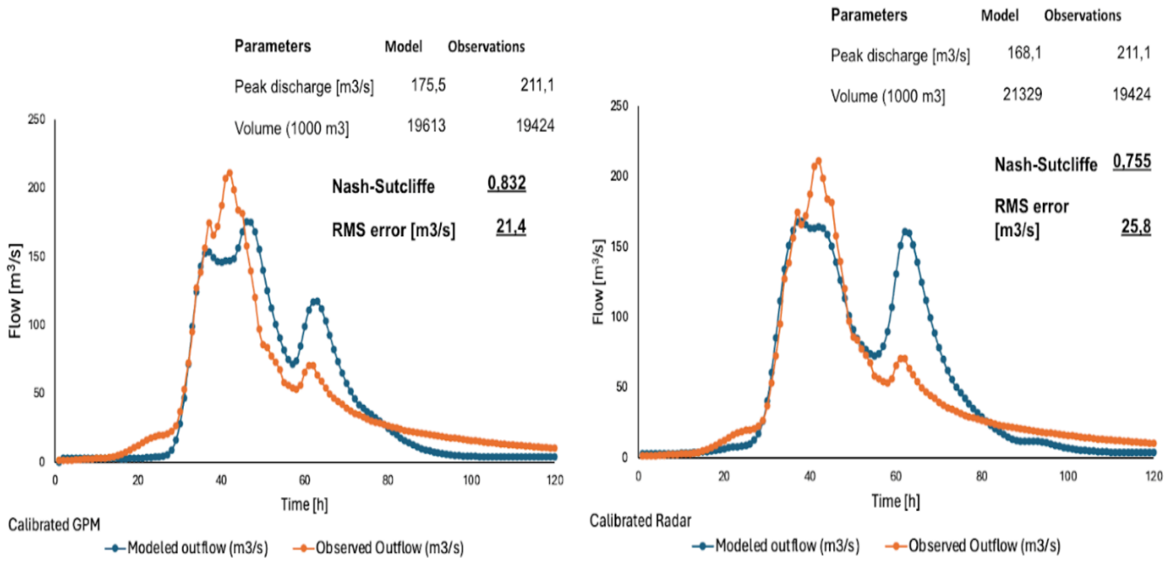


Figure 5: Calibration of the model with only CN values based on GPM and radar data.

We reach a Nash-Sutcliffe factor of 0.832 with GPM data and 0.755 with Radar data.

The Nash-Sutcliffe model Efficiency coefficients (NSE) attained for this model are well above the 0.6 threshold that is generally considered an adequate fit. A perfect match would not be expected or realistic when only changing the CN number is redistributed. The GMP data was used for the main calibration as it is known that the radar data overestimates the second peak flow. It must be noted there was a focus on matching the greatest peak as it was considered the most important and it is known that HEC-HMS does not preform optimally when modelling multiple flow peaks.

2.3.2 Global calibration

When calibrating with the additional parameters of lag time (Tlag) and initial abstraction (IA) a minor increase in the match was achieved, taking the NSE value from 0.832 to 0.848 with GPM data. NSE value for the calibration with Radar data decreased from 0.755 to 0.728. While this operation did provide an enhanced fit there was debate over whether or not the Tlag could reasonably be changed as it typically a calculated parameter that depends on the catchments physical properties, however as this is usually done empirically it was concluded that small changes may remain plausible within the Upper Skawa catchment.

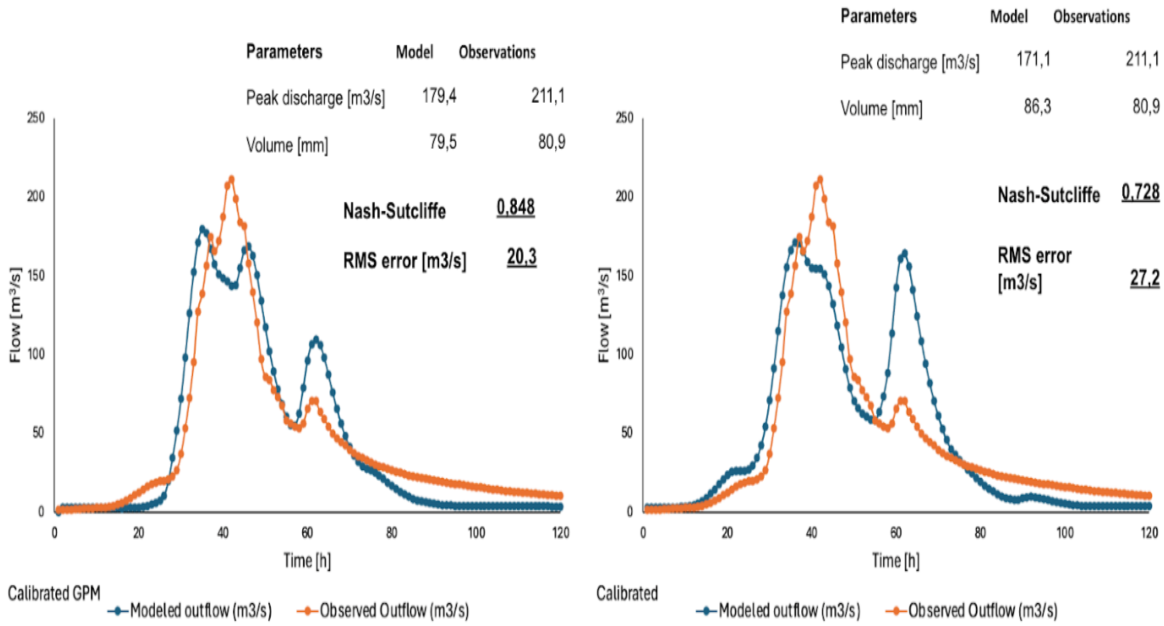


Figure 6: Calibration of the model with CN values, initial abstraction and Tlag based on GPM and radar data.

3 Landuse study

3.1 Historic landuse analysis

We downloaded landuse data on our watershed with the Corine Land Cover Data database. The data is for the years 1990, 2012, and 2018. This was then mapped in QGIS to assess the changes in landuse across the last 28 years and see how landuse, and by proxy, the areas CN changes have affected flooding in the basin.

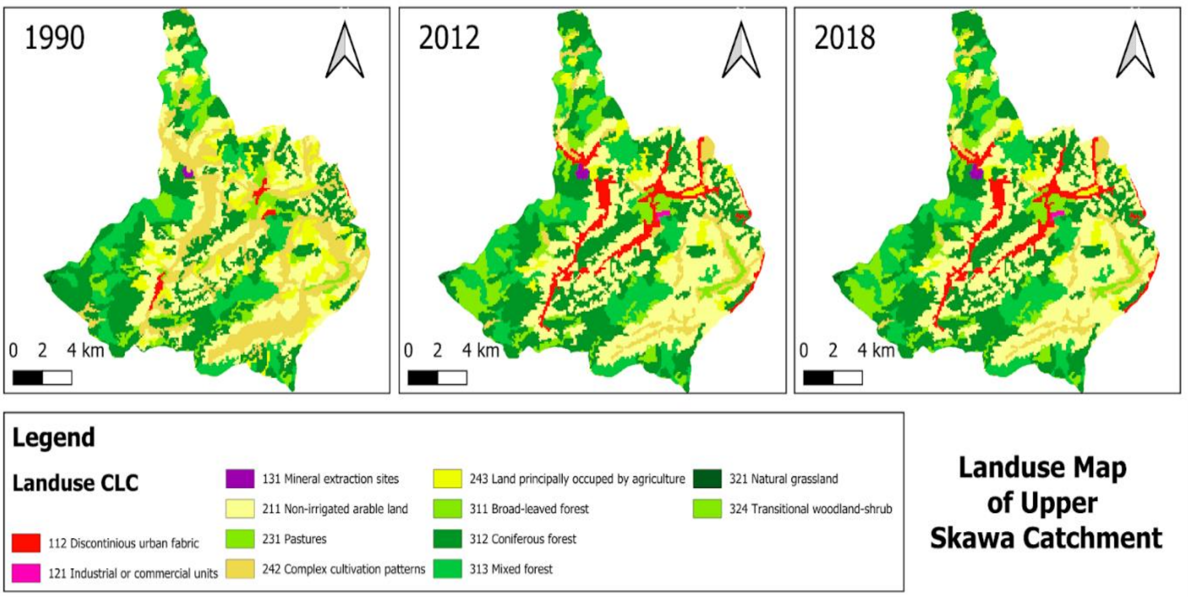


Figure 7: Landuse map comparison of the study area.

In Figure 7 it can be seen that the most impactful changes that occur in the area are the significant increase in urbanised areas and the changes in agricultural habits. Both of these changes significantly increase the CN in the affected areas from their prior values, reducing losses in the model and increasing surface run off. More detail on these impacts can be seen in Table 2, as seen below.

Table 2: Land cover type and area in temporal variation

CLC code	Land cover	1990		2012		2018	
		Area Km^2	Area as %	Area Km^2	Area as %	Area Km^2	Area as %
112	Discontinuous urban fabric	1.63	0.68	14.00	5.81	13.97	5.80
121	Industrial or commercial units	0.00	0.00	0.33	0.14	0.33	0.14
131	Mineral extraction sites	0.32	0.13	0.58	0.24	0.58	0.24
211	Non irrigated arable land	55.98	23.23	71.56	29.71	70.80	29.40
231	Pastures	11.28	4.68	12.90	5.36	12.90	5.36

242	Complex cultivation patterns	48.12	19.97	12.86	5.34	12.49	5.19
243	Land principally occupied by agriculture	18.23	7.56	8.06	3.35	8.08	3.36
311	Broad leaved forest	6.95	2.88	7.99	3.32	7.90	3.28
312	coniferous forest	67.65	28.07	69.67	28.93	69.24	28.75
313	Mixed forest	30.63	12.71	37.52	15.58	37.47	15.56
321	Natural grasslands	0.23	0.10	0.17	0.07	0.17	0.07
324	Transitional woodland	0.00	0.00	5.19	2.16	5.34	2.22
	Unknown landuse	0.00	0.00	0.00	0.00	1.55	0.64
	Total	**241.02**		**240.8**		**240.8**	

By assessing the changes in landuse over time and its impacts on the modelled discharge, as seen in Figure 7 (need to get hydrographs for the 1990, 2012 and 2018), it was confirmed that these landuse changes did drive changes within our modelled results. This also gave an insight into which elements within the basin could be regenerated or restored. As the peak discharge with the 1990 conditions were significantly less, it was determined that a return to the previous or similar conditions would be beneficial for reducing flooding in the basin while remaining feasible for local people.

It was decided that the area's hydraulic soil types could not be changed as there was lack of data on the area as well as a lack of expertise within the team on how to do so in a realistic manner. It was also decided that reducing the urbanisation that occurred within the catchment would also be unrealistic both socially and financially.

3.2 Landuse Restoration

It was decided the restoration would take place in the form of exchanging some of the non-irrigated arable lands (211) to complex cultivation patterns (242), aiming to try to go back to the situation from 1990 (Tab. 3).

Table 3: Changes in areas of non-irrigated arable land and complex cultivation patterns across 1990-2018.

LUid	Name	1990		2018		1990-2018			Trend
		Area	%	Area	%	Difference [%]	Difference [km2]	Increase/ decrease [%]	
211	**Non-irrigated arable land**	55,7	23,2	70,7	29,6	6,5	15,1	27,0	↑
242	**Complex cultivation patterns**	48,1	20,0	12,5	5,2	-14,8	-35,6	-74,1	↓

It was decided that the restoration in this event would take place in the form of restoring agricultural areas from their current form as non-irrigated arable land (121) to complex cultivation patterns (242). The rationale for this is that the land could remain agriculturally active, thus maintaining local stakeholder's businesses, while simultaneously reducing the area's CN. This could also benefit the local ecosystems, as complex cultivation patterns introduce more biodiversity, compared to the current land cover that typically consists of monoculture crops.

The results in the form of peak flow discharge from this landuse changes can be witnessed in Figure 8 and 9 for the GMP data and radar data respectively. The area change shown in these figures is representative of changing the area of land cover equally in each sub-basin, and all 70km[2] were converted to just 15km[2] as the figure suggests.

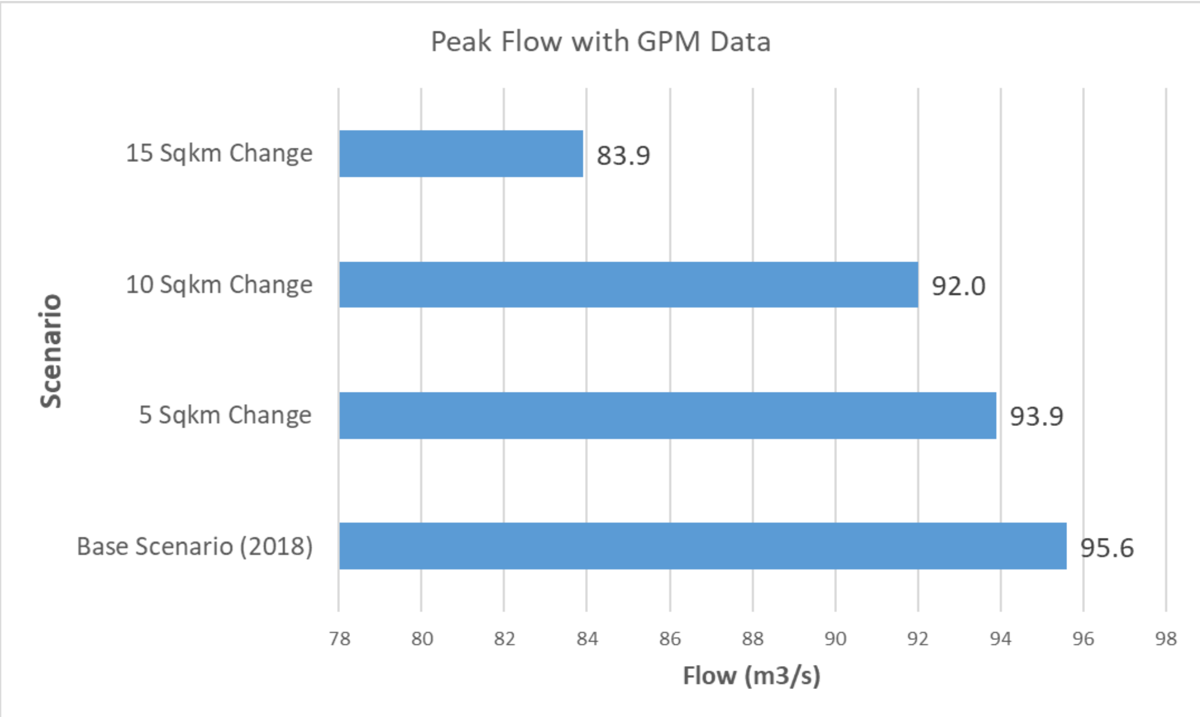


Figure 8: Sensitivity analysis of restoration scenario with GPM for landuse area change proportionally across all sub-catchments.

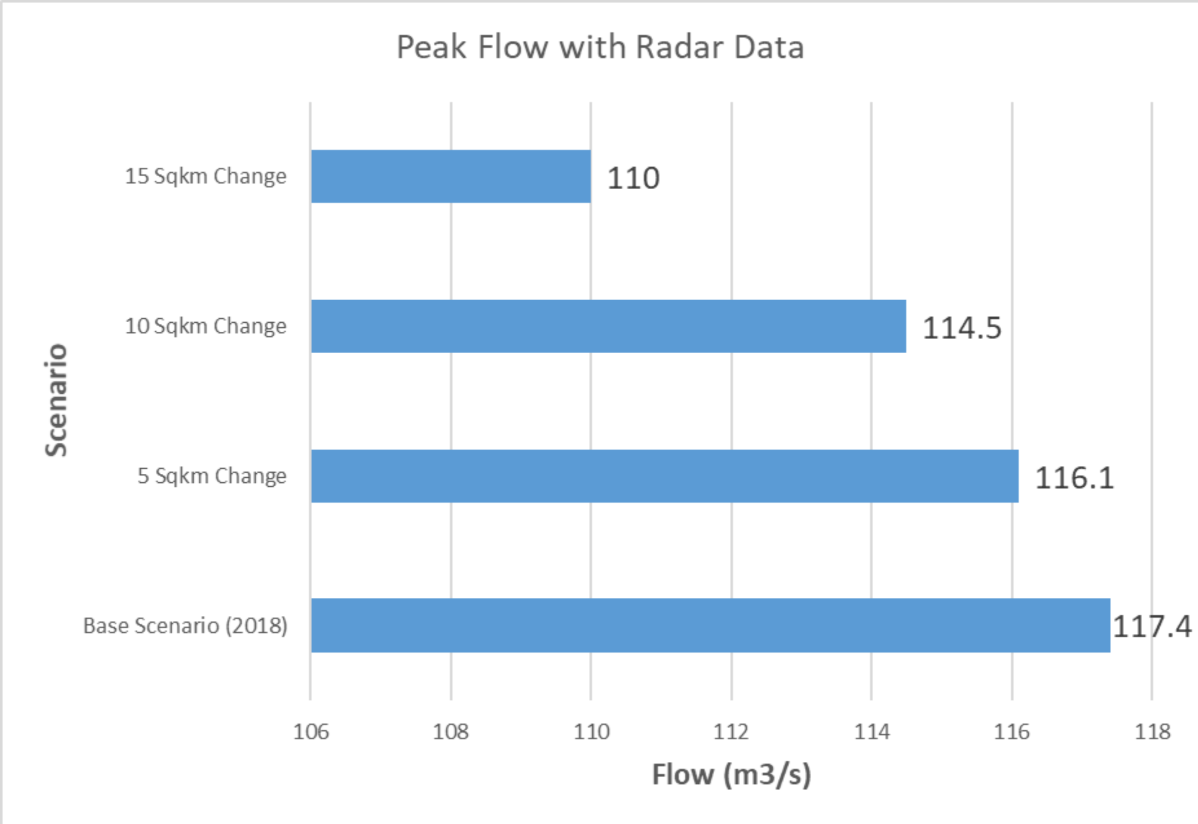


Figure 9: Sensitivity analysis of restoration scenario with radar data for landuse area change proportionally across all sub-catchments.

Across both (Fig. 8 and 9), despite the peak discharges showing higher values in Figure 9 than 8, they show the same pattern of results. This suggests that the more land restored, the more the peak flow discharge will be decreased. It could also be suggested that increasing the landuse change has a nonlinear relationship with the resultant reduction in peak flow discharge, however with only three results this claim is hard to support, and further testing would be needed to prove this relationship. Said further testing was not completed as a part of this project as there was only 15.2km^2 of land eligible for the classification change across in each sub-catchment.

4. First week conclusions

After completing the first weeks of objective, it can be concluded from the landuse analysis that the changes in landuse since 1990 have resulted in less losses (a higher average CN) which has resulted in higher peak flow discharges and thus greater the catchment will suffer greater impacts of flooding. This is primarily due to the increase in urban areas where high CN value land replaced areas with lower values. While this change would be the most obvious to revert and restore it is very unlikely to be an option that local stakeholders on any level would accept, hence the approach that better considers stakeholder interests and still affects roughly 30% of the area's land cover. The approach used should also help boost local biodiversity as a secondary impact.

It can also be confirmed that when the agricultural landuse types were returned to their 1990 states from their 2018 states the peak flow discharge was also reduced, although by very little despite affecting change across 30% of the catchment. It can similarly be concluded that making this change is likely not worthwhile unless a significant of land is converted in all sub-catchments as the results from 5km^2 (in all sub-catchments) did not show a significant reduction in peak flow discharge (2m^3/s) when compared to the reductions seen from 15km^2.

The main conclusion from completing this objective is that although landuse restoration will reduce peak flow discharge, this approach will not be adequate to reduce the peak flow discharge significantly alone, and thus the same will be true for the aspects of flooding. This approach, however, may work well as an additive measure for management alongside other management techniques and could be used to reduce the size of other expensive engineering works or attenuation schemes.

Week 2, Introduction

In the second week of the HydroEurope project , we were provided a new model, meaning that the first and second weeks workflow is not continuous. The model created and calibrated in the first week were not reused but some results were transferred into the new model. New data was provided then. The new model was set up with climate variables, on which the calibration and validation was based.

5. Model calibration

The model was calibrated for 3 different flood events in 2014 and 2015. We applied different parameters (CN value, Initial Abstraction, Tlag) for each event and then calculated the average of those parameters, which were later used for the validation of the model. The results of the calibration are presented in Table 4. Obtained NSE values were 0.268, 0.913 and 0.794 for Events 01, 02 and 03, respectively.

Table 4: Calibration of the model for 3 different flood events (2014-2015)

Results	**Event 01**	**Event 02**	**Event 03**
	May-14	Sep-14	May-15
Peak Flow (m^3/s)	197.4	9.1	26.9
Total Volume (m^3)	25152.9	2899.8	6961.3
NSE	0.268	0.913	0.794
Date of Peak Discharge	15 May 2014 22:00	29 Sep 2014 21:00	26 May 2015 22:00
Date of Peak Discharge (Obs)	15 May 2014 17:00	29 Sep 2014 16:00	26 May 2015 21:00

Next, 3 tables show values of CN, IA and Tlag used for the calibration of 3 events. Then the average of the values from 3 events was calculated. The average was later used for the validation of the model.

Table 5: CN values used for the calibrations of the flash flood events with the calculated average.

Sub Catchment		Calibrated Parameter CN Value			Average
		Event 01	Event 02	Event 03	
		May-14	Sep-14	May-15	
Sub Catchment 01	**Bystrzanka Z Ciśniawa**	60	70.006	47.173	59.05
Sub Catchment 02	**Bystrzanka od Źródła**	93.134	73.134	71.727	79.33
Sub Catchment 03	**Skawa Od Źródła Do Pożogi**	90.496	86.496	83.071	86.69
Sub Catchment 04	**Skawa Od Pożogi Do Malejowki**	89.794	89.794	86.238	88.61
Sub Catchment 05	**Od Majówki Do Bystrzanki**	67.567	87.567	84.099	79.74
Sub Catchment 06	**Od Bystrzanki Do Osielca**	63	87.941	84.72	78.55

Table 6: Lag Time used for the calibrations of the flash flood events with the calculated average.

Sub Catchment		Calibrated Parameter Lag Time (hr)			Average
		Event 01	Event 02	Event 03	
		May-14	Sep-14	May-15	
Sub Catchment 01	**Bystrzanka Z Ciśniawa**	0.3	28.2	1.1708	9.89
Sub Catchment 02	**Bystrzanka od Źródła**	0.174	17.4	1.9809	6.52
Sub Catchment 03	**Skawa Od Źródła Do Pożogi**	0.1	23.5	6.766	10.12
Sub Catchment 04	**Skawa Od Pożogi Do Malejowki**	0.1	17.7	7.744	8.51
Sub Catchment 05	**Od Majówki Do Bystrzanki**	0.1	19.9	7.8595	9.29
Sub Catchment 06	**Od Bystrzanki Do Osielca**	0.3	28.2	1.521	10.01

Table 7: Initial abstraction values used for the calibrations of the flash flood events with the calculated average.

Sub Catchment		**Calibrated Parameter**			**Average**
		Initial Abstraction (mm)			
		Event 01	**Event 02**	**Event 03**	
		May-14	**Sep-14**	**May-15**	
Sub Catchment 01	**Bystrzanka Z Ciśniawa**	7.21	24.489	5.442	12.38
Sub Catchment 02	**Bystrzanka od Źródła**	5.23	22.707	5.046	10.99
Sub Catchment 03	**Skawa Od Źródła Do Pożogi**	1.39	16.551	3.678	7.21
Sub Catchment 04	**Skawa Od Pożogi Do Malejowki**	7.01	15.309	3.402	8.57
Sub Catchment 05	**Od Majówki Do Bystrzanki**	1.39	15.651	4	7.01
Sub Catchment 06	**Od Bystrzanki Do Osielca**	1.77	15.993	3.554	7.11

Model validation

The model was validated with the average CN value, IA and Tlag for 3 events in the year 2016 happening in July, May and October. Obtained results of the validation are presented in Table 8.

Table 8: Validation results.

Results	**Event 01**	**Event 02**	**Event 03**
	Jul-16	**May-16**	**Oct-16**
Peak Flow (m^3/s)	21.3	6	58.9
Observed Peak Flow (m^3/s)	23.2	19.9	35.2
Total Volume (m^3)	3168.2	1059.9	13353.5
Observed Total Volume (m^3)	2099.6	2216.2	8333.8
NSE	-0.863	-0.503	-1.351

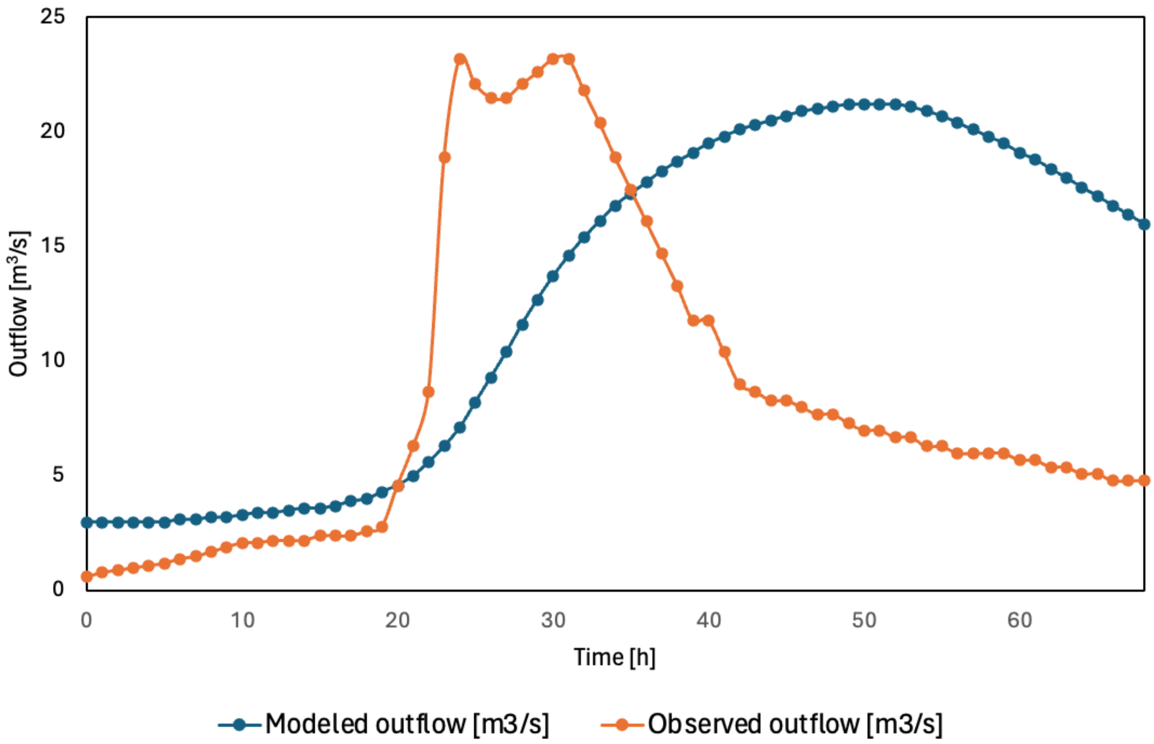


Figure 10: Validation of the July 2016 scenario.

The flow peak is respected but the model is more distributed and therefore has more volume. It is also more shifted to the right. But despite everything the model somewhat resembles the observed curve.

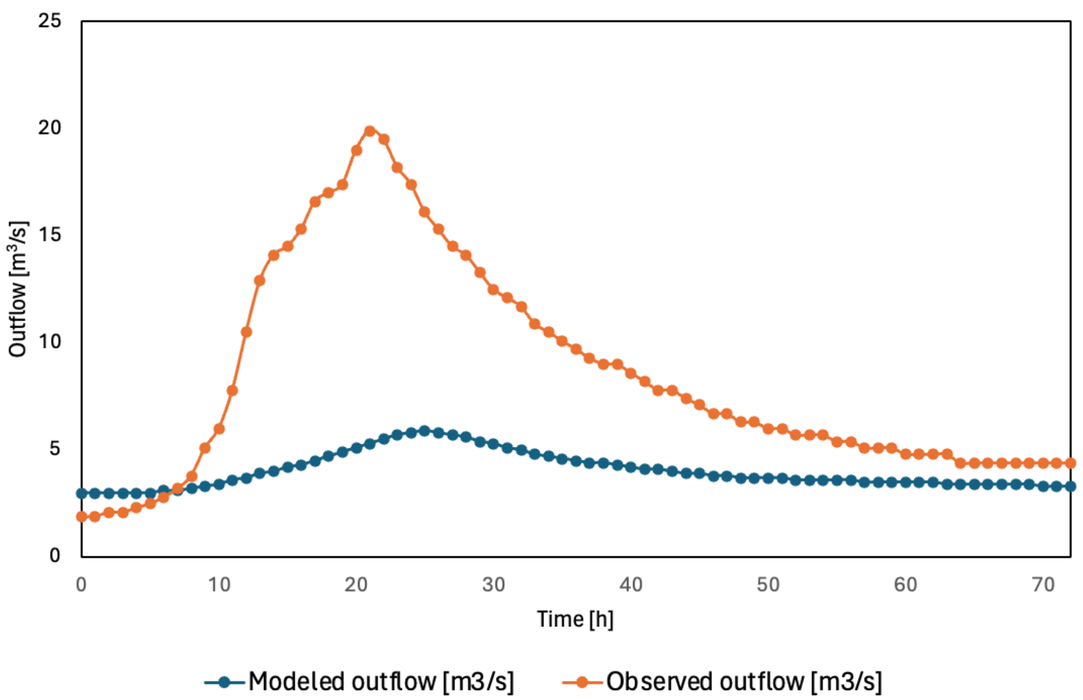


Figure 11: Validation of the May 2016 scenario.

Here, the moment of the flow peak is respected so the shape of the curves are correlated but its flow and the general volume of the curve is largely underestimated.

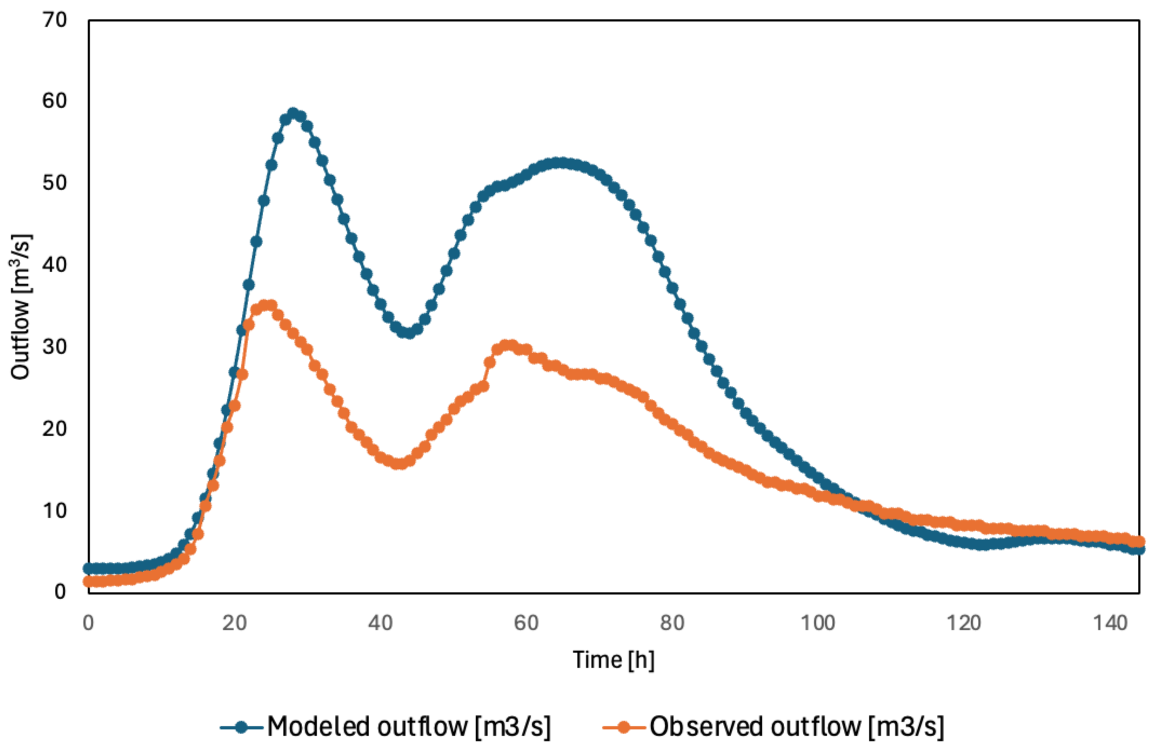


Figure 12: Validation of the October 2016 scenario.

The model is best suited to this graph. Here it can be seen that the two flow peaks are well represented and at the right time. The peak volume and flow rate are underestimated but importantly the profile matches well.

5.1 IPCC scenarios

The main task for the second week of the project was to analyse IPCC RCP4.5 and RCP8.5 scenarios in the Skawa catchment in the context of discharge change. Change in precipitation with different time span scenarios was used: near term from 2016 to 2035 (NT-1), near term from 2046 to 2065 (NT-2) and long term from 2081 to 2099 (LT). The NT-1 was not analysed for the RCP8.5 scenario, since it was excluded from Global Climate Models due to validation errors. Used values of the precipitation change in the study area are presented in Table 9.

Table 9: Percentage change in precipitation in different scenarios.

Month	RCP 4.5			RCP 8.5	
	NT-1	NT-2	LT	NT-2	LT
April	5	5	10	10	20
May	5	5	10	10	20
June	-10	-10	-15	-10	-20
July	-10	-10	-15	-10	-20
August	-10	-10	-15	-10	-20
September	5	5	10	10	25
October	10	15	20	10	35

Given values (Tab 9) are based on projected precipitation change in the region of the Skawa catchment. Projections show that a significant decrease in precipitation in summer months is expected, while the rest of the year can encounter increased precipitation (Fig. 13).

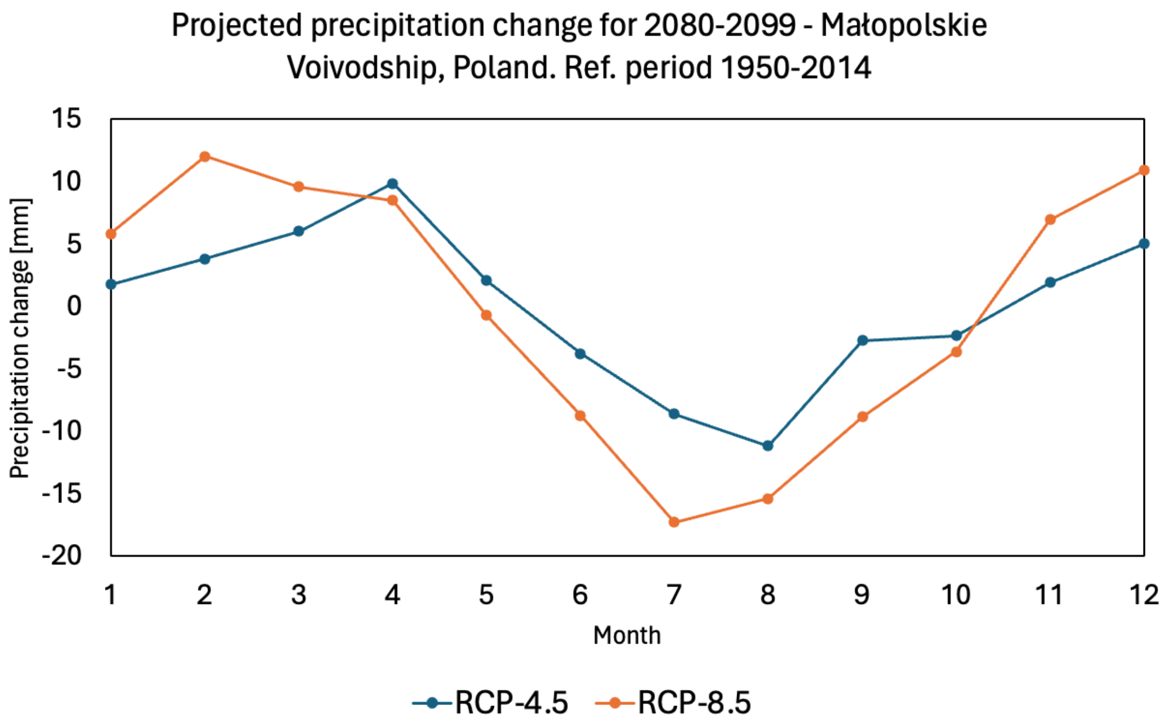


Figure 13: . Long-term projected precipitation changes in Małopolskie voivodeship.

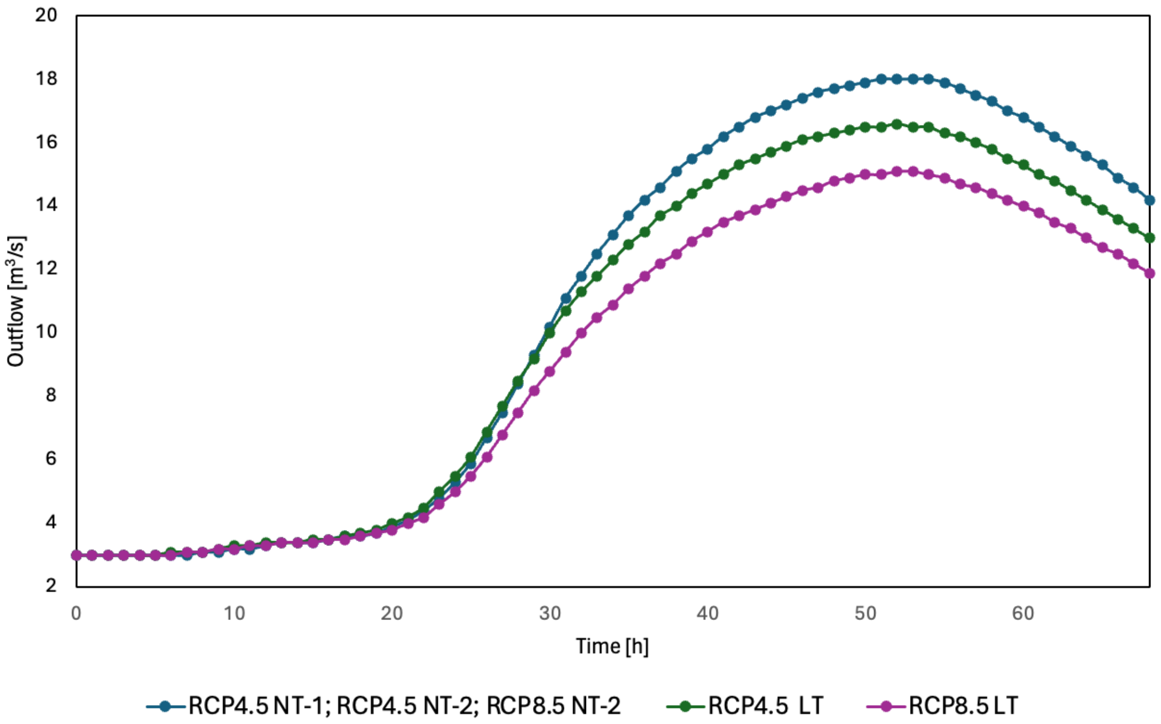
The simulation of different IPCC scenarios was run for 3 flash flood events from 2016: July, May and October. The results from implementation of climatic scenarios to the July 2016 event indicate that we can expect lower peak flows in the summer months and the lowest can be expected in the second part of the century (long term changes) in both RCP4.5 and RCP8.5 scenarios (Tab. 10, Fig. 14).

The difference between the RCP 4.5 scenario and the 8.5 scenario is the intensification of trends as the extremes are amplified. This results in heavier precipitation in winter and greater drought in summer.

Table 10: Results from implementation of different RCP scenarios to the July 2016 event.

July 16	RCP 4.5			RCP 8.5	
	NT-1	NT-2	LT	NT-2	LT
Peak Flow (m^3/s)	18.1	18.1	16.6	18.1	15.1
Total Volume (1000 m^3)	2704	2704	2484	2704	2267

Table 11: Implementation of RCP4.5 and RCP8.5 scenarios - July 2016 event



The results from implementation of climatic scenarios to the event happening in May 2016 indicate that we can expect higher peak flows in the spring months. The most profound changes in discharge and volume of water can be expected in the RCP8.5 long-term scenario (Tab. 11, Fig. 15).

Table 12: Results from implementation of different RCP scenarios to May 2016 event.

May 16	RCP 4.5			RCP 8.5	
	NT-1	NT-2	LT	NT-2	LT
Peak Flow (m^3/s)	6.4	6.4	6.8	6.8	7.7
Total Volume ($1000\ m^3$)	1096	1096	1134	1134	1217

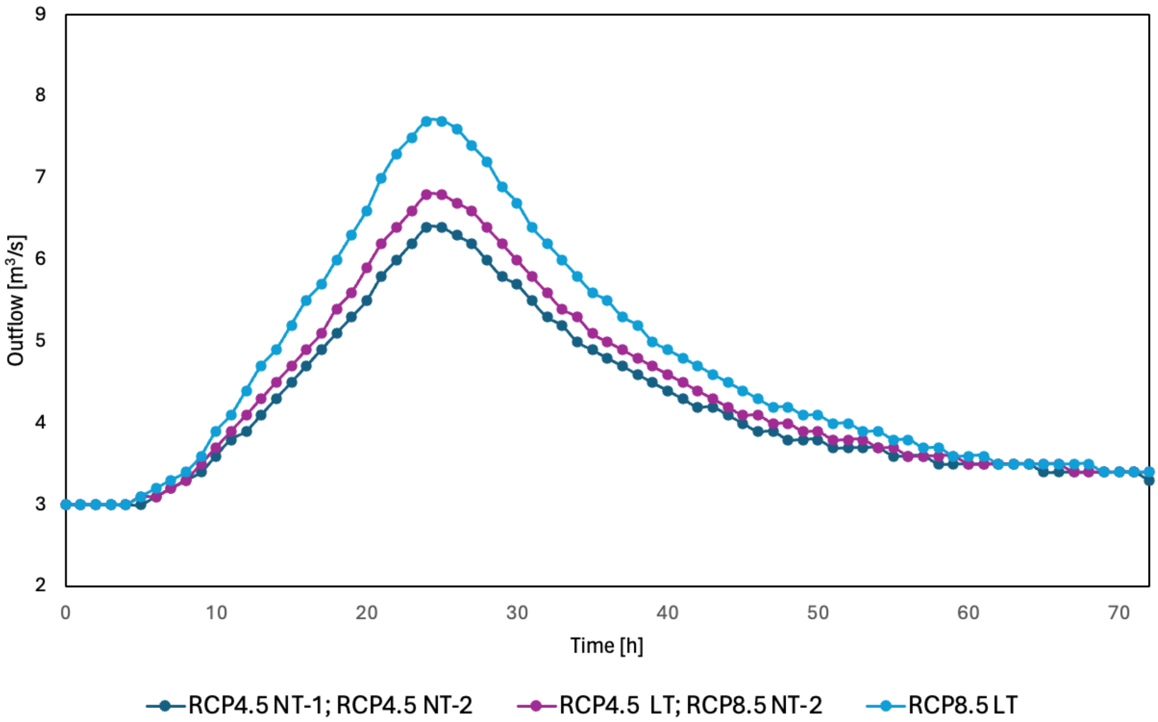


Figure 14: Implementation of RCP4.5 and RCP8.5 scenarios - May 2016 event.

The results from implementation of climatic scenarios to the October 2016 event indicate that, similarly to the spring months, we can expect higher peak flows in the autumn months. However, the change in peak flows and volume in October is expected to be much higher. The most profound changes can be expected in the RCP8.5 long-term scenario (Tab. 12, Fig. 16).

Table 13: Results from implementation of different RCP scenarios to October 2016 event.

October 16	RCP 4.5			RCP 8.5	
	NT-1	NT-2	LT	NT-2	LT
Peak Flow (m^3/s)	69	74.2	79.4	69	95.7
Total Volume (1000 m^3)	15 222	16 168	17 118	15 222	20 055

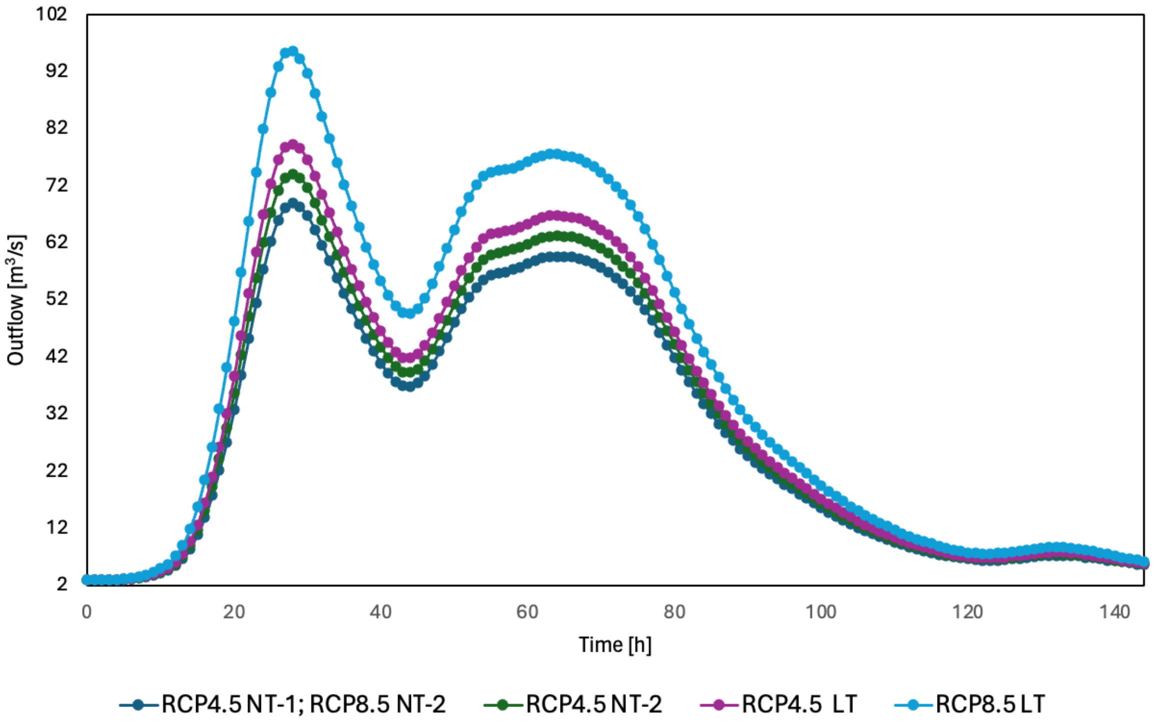


Figure 15: Implementation of RCP4.5 and RCP8.5 scenarios - October 2016 event.

Looking at the percentage change in flow in spring months, based on the May 2016 event and compared to the present, it is expected that the flow will increase by 7% with RCP4.5 in NT-1 and NT-2 scenarios and by 13% with RCP4.5 LT and RCP8.5 NT-2 scenarios. The highest change is expected in the RCP8.5 LT scenario (28% increase of flow) (Fig. 17).

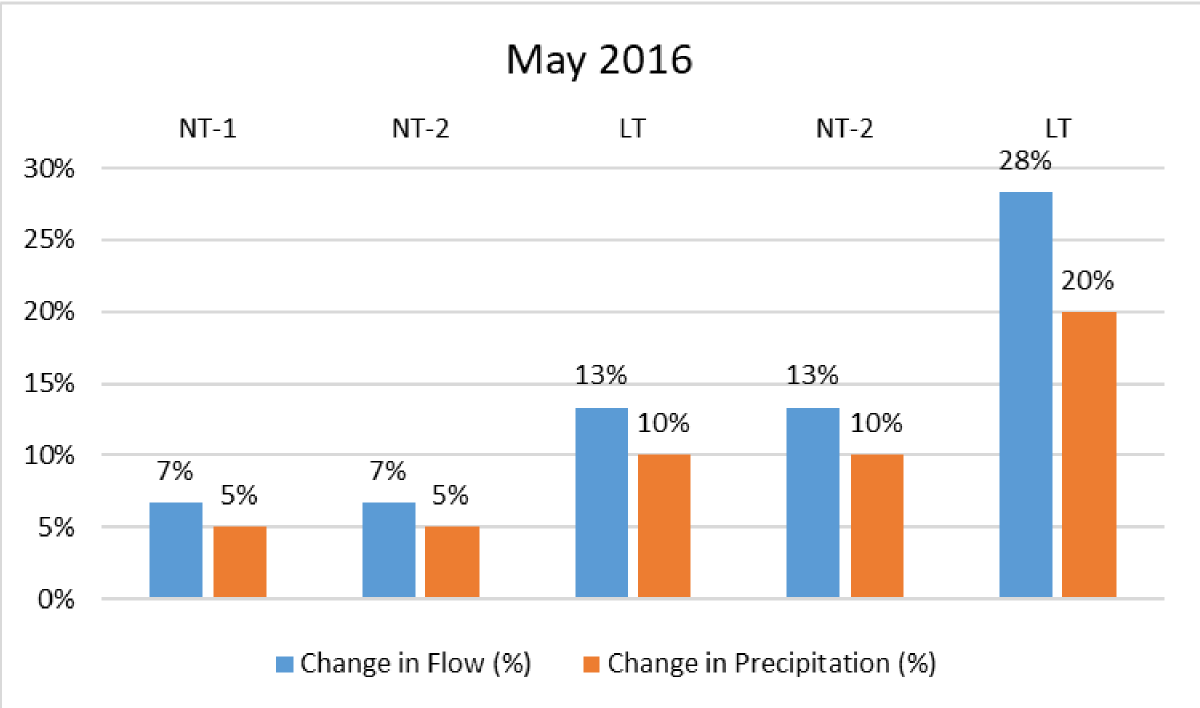


Figure 16: Comparison between change in rainfall & discharge for May 2016

In the summer months, based on the July 2016 event, it is expected that the flow will decrease by 15% with RCP4.5 in NT-1 and NT-2 and RCP8.5 NT-2 scenarios and by 22% with RCP4.5 LT scenario. The biggest change is expected in the RCP8.5 LT scenario (29% decrease in flow) (Fig. 18).

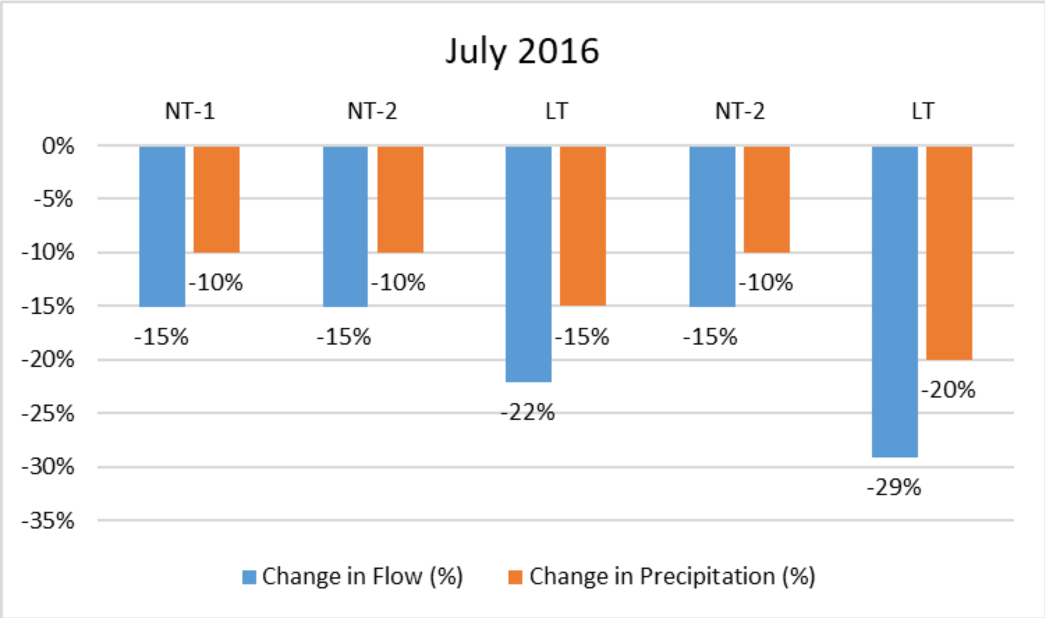


Figure 17: Comparison between change in rainfall & discharge for July 2016

In the autumn months, based on the October 2016 event, it is expected that the flow will increase by 17% with RCP4.5 in NT-1 and RCP8.5 NT-2 scenarios, by 26% with RCP4.5 NT-2 scenario and by 35% with RCP4.5 LT scenario. The most profound change can be expected in the RCP8.5 LT scenario (62% increase in flow) (Fig. 19).

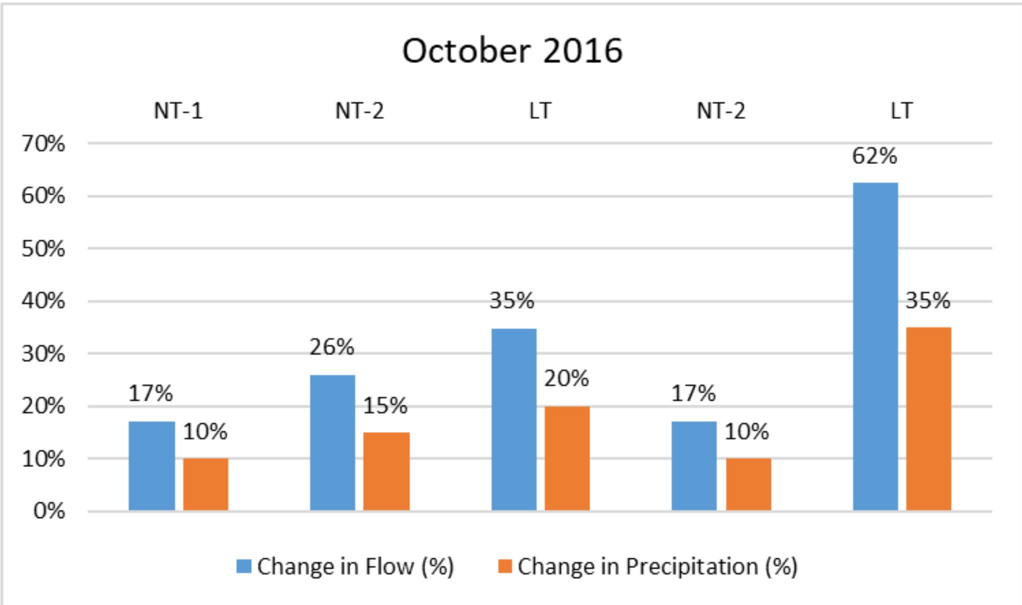


Figure 18: Comparison between change in rainfall & discharge for July 2016

6. Uncertainties of the Model

In the overall modelling approach, several uncertainties were identified in different phases of the work. The uncertainties are discussed below:

- **Land Use Change in Future**, In the model the impact on the flow due to the change in the rainfall (climatic variables) keeping the same landuse of the present time. However, the scenario will not be the same in the future. For better representation of the future scenario, the model can be simulated using the projected landuse of the area,

- **Resolution of the Climatic Data (GCM)**, for the modelling data from Global Climate Model (GCM) was used that has the resolution of 100 - 300 km^2 depending on the model, which is high for a smaller catchment like Skawa. Regional Climate Model (RCM) developed by downscaling of the GCM can give results on a resolution of 10-50 km^2. So, for a better result (higher resolution, RCM models can be used,

- **Inadequacy of Rain Gauge Station**, there was only one rain gauge station in the catchment and the catchment has several microclimate areas varying in topography and landuse. So, only the rain gauge station is not representative of the overall catchment. That creates uncertainty in the result where there is on accurate information of the rainfall. These can be reduced by establishing more rain gauge stations in the catchment to get better spatial variation of data sets,

- **Semi Distributed Model**, the model was developed in the semi-distributed approach. In this case, due to the variability of land cover and topography, a fully distributed model could eventually have a better representation of specific areas, which would be a good representation of the physical system,

- **Socio-Economic Factors**, factors like socio-economic development, climate change adaptation and mitigation, policies undertaken were not considered in the mode. The simulation of the model with Shared Socio-economic Pathway (SSP) could help to get results on the impact of these factors,

- **Interference in the Catchment**, in the catchment the peak flow was estimated using the hydrological model, however the flooding scenario was not assessed. Also, the different structures and the characteristics of the floodplain will also affect the flooding scenario. For these, development of a hydraulic model in the area can give a view of the inundation scenario,

- **Snow Cover,** in the model the snow cover was not considered where it is a major climatic event in central Europe, incorporation of the snow can present more realistic flow scenario in the model.

Over all Conclusions

From these modelling exercises a number of conclusions can be drawn. Regarding the restoration objective it has been clearly shown that the impact of restoration on a small scale that is likely to be considered easily financially and socially acceptable is low. This does show there is potential over a larger area or with more invasive landuse changes, however, the landuse assessment also showed there are only small areas of land that could feasibly be changed as the catchment. The restoration approach to managing flooding in the Upper Skawa could still provide a useful tool for reducing flooding if it were an additive feature to another scheme (e.g. to reduce the required scale of permanent structures), similarly the restoration could be justified via its other environmental merits.

In relation to addressing the climate change impact objectives it can be concluded that in climatic scenarios where the catchment is expected to receive more precipitation, flooding will worsen. It can also be seen that there is a non-linear relationship between increased precipitation and the increase in flood peak discharge, where the peak discharge will increase more than the actual increase in rainfall.

It should be noted that throughout these processes a number of modelling assumptions have been made and further research should be conducted before implementing any specific restoration schemes. Similarly, when calibrating the model for climate projections, only three calibration events were utilised and the model still followed a number of major assumptions, a key one being that the model could not take into account any future landuse conditions (changes in CN) and how the areas curve number may also change with time for example.

To further improve this body of work a number of actions could be taken and could include utilising more calibration events, increasing time series data lengths to help eliminate errors caused by initial conditions and much more. Some elements of this work could also be repeated in the near future such as when the updated Corine land cover data which is due to be released this year (2024) becomes available.

References

Franczak, P., 2020. The significance of extreme floods in the transformation of mountain valleys and causing flood risk, on the example of the July 2001 flood that occurred in the upper catchment of the river Skawa. Science, technology and innovation.

Digital Appendix

Daily activity reports can be found on the Team 07's website in the Reports section: https://sites.google.com/view/hydroeurope2024team07/collaborationreport?authuser=1

Link to objectives and given resources:

https://drive.google.com/drive/folders/1me5r3UUZBKsRrUY-87tJU1wGE2Y-9j08?usp=sharing