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Research Paper

Flood Forecasting in the Western Lowland of Albania with Application of the Hydrological Modelling

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Abstract: Floods are natural disasters with more consequences in Albania. The most risked areas, from river floods, lie mainly in the western lowlands of the country. These areas, which are mainly areas with agricultural development, are very important in the economic development of Albania. Historically, the hydrological forecast in Albania has been based on observations of the upstream of rivers. These methods do not provide the time needed for flood management because floods rutting time to the flood plain is relatively short, due to the large slope and short rivers. Only in the last decade, more advanced techniques have been used to forecast floods, including hydrological modelling. Analysis of the present status and existing methods, in flood forecasting, is necessary to determine where the forecasting system should be improved. Determination, if there will be flooding, is related to the flood hydrograph forecast in the river sections, which are of interest. Increased flood forecasting time can be performed with the help of HEC-HMS hydrological modelling and meteorological model ICON-EU. The hydrological model used as input daily hydrometeorological observed data for precipitation and temperature in the period 1990-2018. The hydrological historical data in the period 1990-2008 was used for calibrating the model. Flood forecasting has as its main objective information in time to the authorities, or the population to take precautions measures, and to be prepared in case the forecast on the likelihood of a flood, including the size and timing of the event, at key locations of watercourses.

Keywords: *hydrological model, flood forecasting, hydrograph, discharge*

Introduction

In many parts of the world, flooding can have devastating consequences for society, the economy, and the environment. On average, around 21 million people worldwide are affected by river floods each year. The effects of floods are particularly severe in developing or low-income countries, due to their vulnerability to these phenomena (Luo, 2015). The most risked areas, from river floods, lie mainly in the western lowlands of Albania. These areas, which are mainly areas with agricultural development, are very important in the economic development of Albania. Demographic movements after the 1990s have increased population density, and expanding urban constructions in these areas, increasing the risk of flood damage. To analyse floods, it is necessary to identify areas that are historically flooded, based on historical data. It is also known that these areas have major infrastructural interventions for flood protection. Successful flood management requires the application of modern engineering methods, which prepare and protect against floods, and minimize losses related to human life and health, environmental damage, cultural assets, and economic activity of the affected community. River floods in Albania occur in the wet season of the year, from October to May, while the rest of the year is mainly affected by flash floods, which occur in the upper parts of the basins after storms, and are characterized by short duration. In Albania, the river floods, have a duration from daily up to more than two-week, in the biggest rivers. In the lower parts, the floods come out of the riverbanks, causing a lot of economic damage, and threatening life to the population living in the areas of the flood plain. The first river flood protections, as a wide range of investments, in Albania, began after the historic floods of 1962-1963 (IHM, 1984). Information on the position of the flood protection infrastructure is needed to assess the risk of flooding. Historically, the hydrological forecast in our country has been based on observations of the upstream of rivers. These methods do not provide the time needed for flood management because floods rutting time to the flood plain is relatively short, due to the large slope and short rivers. Only in the last decade, more advanced techniques have been used to forecast floods, including hydrological modelling. Analysis of the present status and existing methods, in flood

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forecasting, is necessary to determine where the forecasting system should be improved. Determination, if there will be flooding, is related to the flood hydrograph forecast in the river sections, which are of interest. Increased flood forecasting time can be performed with the help of hydrological modelling, in basins that are not modelled. For this purpose, the flood forecasting has as its main objective information in time to the authorities, to take precautions measures, and to be prepared in case the forecast on the likelihood of a flood (general prediction or a detailed forecast of floods), including the size and timing of the event, at key locations of watercourses.

Materials and Methods

Albania's relief is mostly mountainous and these conditions the structure of the hydrographic network. The soil layer that can increase rainfall infiltration is found mainly in river basins in the pre-mountainous part, in the lakeside part along the eastern border, and the narrow hilly belt, between coastal areas and inland mountains. Average annual flow values have a big variation across the country, following precipitation distribution. Most rivers have irregular annual flow distribution. River inflows are highest in winter or early spring IHM, 1984). Rivers that have a high hydrographic density often have a hydrograph with a higher peak of the discharge than a low-density one, and it is an indicator that signals an increased potential risk of flooding. The biggest discharges in Albanian territory, have has been those of the years, 1962-1963 floods (Selenica, 2010)

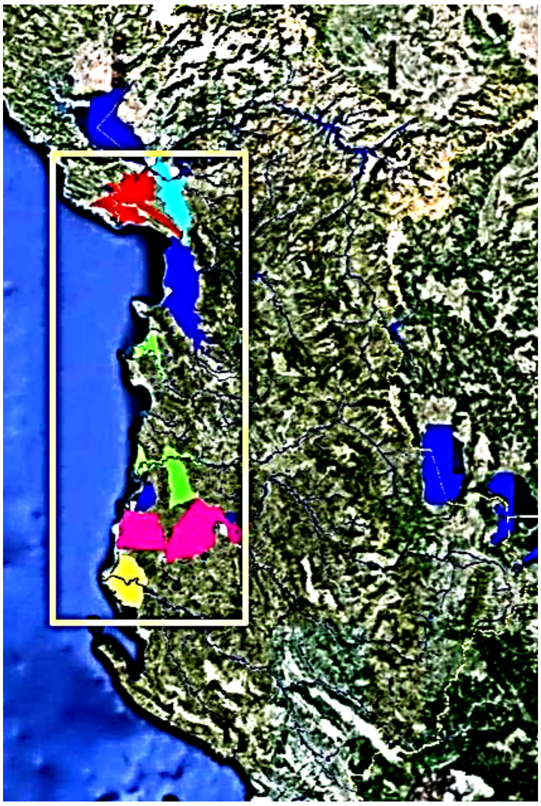

Figure 1. Flooded areas from different rivers in the western lowland based on historical floods

An operational flood forecasting system exists only in the Drin and Buna rivers based on the Panta Rhei hydrological model forecasting system (Meon, 2013). This model is active, and there is currently no need to apply a new hydrological model in this basin. In all Albanian basins, river flood forecasting is using the European Flood Warning System EFAS, a 5 km spatial resolution. There is no detailed river flood forecasting system at basin level, implemented in the Mat, Ishëm, Erzen, Shkumbin, Seman, and Vjosa river basins. The program chosen in this study for this type of analysis is an open-source HEC-HMS, by the U.S. Army Corps of Engineers USACE, which is designed to simulate the full hydrological processes of river systems. Model, it can simulate a continuous series of data, but also can simulate singular hydrological events that have occurred and linked to storms (USACE, 2000). In the case of this study, we are more interested that in addition to the treatment of complete hydrological cycles in the parameterization of the model, we also focus on specific events, with maximum discharges in the basin. This is for a better fit of the model, in extraordinary events when the whole river system will be treated once again in abnormal conditions. In these cases, the parameters set by the initial evaluations and corrected parameters, in the calibration process may have a difference, as a result of deviations from the complete hydrological cycle. HEC-HMS hydrological modelling is applied for rivers Mat, Ishem, Erzen, Shkumbin, Seman, and Vjosa with individual models for each basin.

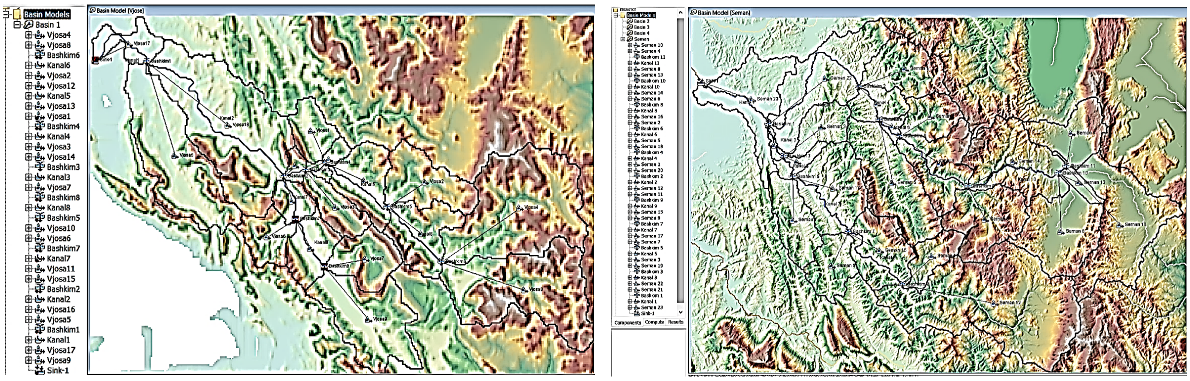

Figure 2. Example of application of HEC-HMS models in the Vjosa and Seman river basins.

The sub-basin hydrographic network was developed using the program (HEC-GeoHMS) that is an extension of ArcGIS 10.1 (USACE, 2018). For each basin, a separate model has been created, which physically represents the river basin, and a meteorological model, which has been applied through HEC-DSS software with meteorological data of the years, 1990-2018. Validation of the model was performed through hydrological data during the period 1991-2008. The hydrological model for river basins (Mat, Ishëm, Erzen, Shkumbin, Seman, and Vjosa), has used three components: "Soil moisture accounting SMA, SCS Unit hydrograph, and Recession". The SMA method is used to represent the infiltration characteristics within the basin. The SCS unit hydrograph method was used to represent the transformation of the hydrograph. The recession method has been used to represent the baseflow characteristics of the basin. During the calibration of the model, modifications were made to the parameters, to better match the simulated hydrograph, with the observed hydrological data. The SCS unit hydrograph method, with PRF Standard 484, was used in each basin as the initial parameter and was adapted throughout calibration. For evaluation of the performance of the model is used the NSE coefficient (Nash Sutcliffe Efficiency), (USACE, 2018).

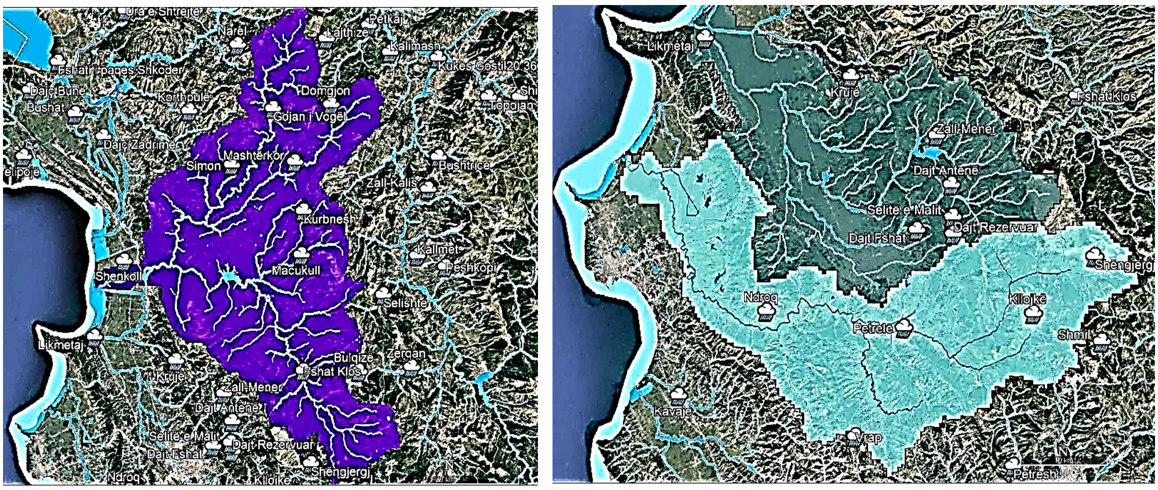

Figure 3. Example of the stations used for the creation of the meteorological model in HEC-HMS models of rivers (Mat and Ishëm-Erzen,)

Division of the subbasin takes into consideration the position of the hydrometeorological network to follow the process of the creation of a meteorological model, maximum precipitation for each basin, and the hydrological stations for the calibration of the model. The Mat river meteorological stations considered for hydrological modeling, are Domgjon, Fshat Klos, Gojan i Vogël, Kurbnesh Lajthizë, Macukull, Mashtërkor, Shënkoll, Bulqizë, and Simon with maximum 24-hour precipitation observed in Domgjon station, with 256 mm / 24 hours that belong to the Fan River branch. For Mat river basin, the divisions have been conditioned by the positioning of the hydrological station located in Shoshaj.

For Ishëm river are Dajt Fshat, Dajt Reservuar, Krujë, Likmetaj, Selitë e Malit and Zall Mener. For the river Erzen, stations used for analysis are Kllojkë, Ndroq, Petrelë, and Shëngjergj. The maximum observed precipitation in 24 hours for Ishem is in Kruje station with 197 mm / 24 hours and the maximum observed precipitation in 24 hours in Erzen is in Petrelë station, with 180 mm / 24 hours. For Ishëm River basin, the hydrological station used for calibration is the Gjole Bridge. For Erzen River basin, the hydrological station is located in Erzeni, Ndroq.

For Shkumbin river meteorological stations used are Belsh, Cërrik, Librazhd, Peqin, Petresh, Përrenjas, Qarrishtë, Shmil, and Stravaj. The maximum observed precipitation is in Shmil station, with 180 mm / 24 hours. In the Shkumbin river basin, are used two hydrological stations, located in Shkumbin Papër, and Shkumbin Librazhd.

For the Seman River meteorological stations considered for hydrological modeling, are Ballsh, Barç, Bilisht, Dardhë, Dushar, Frasher, Grabovë e Sipërme, Grekan, Jaronisht, Potom, Shtyllë, Sinjë, and Vithkuq. Maximum precipitation is observed at the Grabova e sipërme station, with 150 mm / 24 hours, and belongs to the Devoll river branch. For Seman River basin, the divisions have been conditioned by the positioning of the Osum hydrological station located on the Vajgurore Bridge.

For the Vjosa River, meteorological stations considered for hydrological modeling, are Brataj, Çarshovë, Fratar, Hoshtevë, Kardhiq, Këlcyrë, Krahës, Kuç, Llongo, Muzinë, Nivice, Petresh, and Tepelenë. The maximum precipitations are observed in Kuç station, with 277 mm / 24 hours, and belongs to the Shushica River branch. In the case of the Vjosa River Basin, the divisions have been conditioned by the positioning of two hydrological stations located in the Drino, Lekli Bridge, and Vjosa Përmet.

Results and Discussions

For evaluation of the performance of the model with NSE coefficient was evaluated the maximum peak of the hydrograph and the total volume of the event. Results for Mat branch in Shoshaj, which in this model has been treated separately, have used hydrological measurements to calibrate the model. The NSE performance coefficient values are 0.99-1.0, which are very good modelling values. Deviations in peak, go up to 12.5%, in special cases, but generally, these deviations are lower. In the part of the total volume in Shoshaj, a good connection of the simulation with the measured values is seen. From the flow analysis, it is noticed that the risk of flooding in this river basin, increases in those cases when we have the agreement of concentration-time, from the two main directions Fani and Mati. We also have cases of complete separations from the two branches, wherein the lower parts there are no problems with floods.

For Ishem river at the Gjole Bridge station, a very good correlation of the simulated flow is observed, from the observed flow. The NSE performance coefficient value is 0.99. The deviations at the peak go up to 11.1%. In the part of the total volume, a good connection of the simulation is seen, with the measured values. From this analysis, it is clear that the risk of flooding in the river basin increases with the intensity of rainfall, rather than by the accumulation time. This is a typical flash flood behaviour for these relatively small rivers. Assessing the real peak is difficult, judging only by the average daily values.

For the Erzen Ndroq station, a very good correlation of the simulated flow is observed, from the observed flow. The NSE performance coefficient value is 0.99. The deviations in the peak go up to 10.8%. In the part of the full volume in Ndroq, a good connection of the simulation is seen, with the measured values. From this analysis, it is clear that the risk of flooding in the river basin increases in parallel with the intensity of rains more than the accumulation of the precipitation factor. This is a typical flooding behaviour for these relatively small rivers.

For the Shkumbin Librazhd branch, a very good correlation of the flow simulated by the observed flow is seen. The NSE performance coefficient values are 0.97-1, which are very good modelling values. The peak, go up to 9.3% in specific cases. The volume in Librazhd, there is a good link simulation with the measured values. Like the above station, we have deviations at the acceptable level of peak and full volume. The NSE performance coefficient values are 0.99-1. Deviations in the peak go up to 10.3%. Also, in the part of the total volume in Papër, a good connection of simulation is seen, with the measured values. From this analysis, it is clear that the risk of flooding in this river basin increases in the Papër area, as a result of the joining of inflows from the middle part of the basin. Also, we have cases of complete separations from the two upper branches of Rapun, and Librazhd, wherein the lower parts there are no problems with floods.

For the Seman basin, the Osum branch of Ura Vajgurore, the NSE performance coefficient values are 0.97-0.99. Deviations at the peak go up to 11.8% but generally, these deviations are lower. The volume in Ura Vajgurore, there is a good link simulation with the measured values. This branch of the Seman river is often affected by the storm's floods, especially typical ones that are a result of a confrontation with the mountains after the Myzeqe plain. Often, deviations from modelling are related to the initial conditions during the dry season and the representation of the infiltration capacity of the soils. For improvements, data on soil moisture at different depths are needed. This conditions the graph especially in the declining part of the hydrograph, where the observed values generally give a faster decrease of the discharge than the simulated value. Calibration checks were carried out only in one branch of the Seman River, but the parameters changed by the value optimization were applied throughout the basin, including the other sub-basins of the Devoll branch.

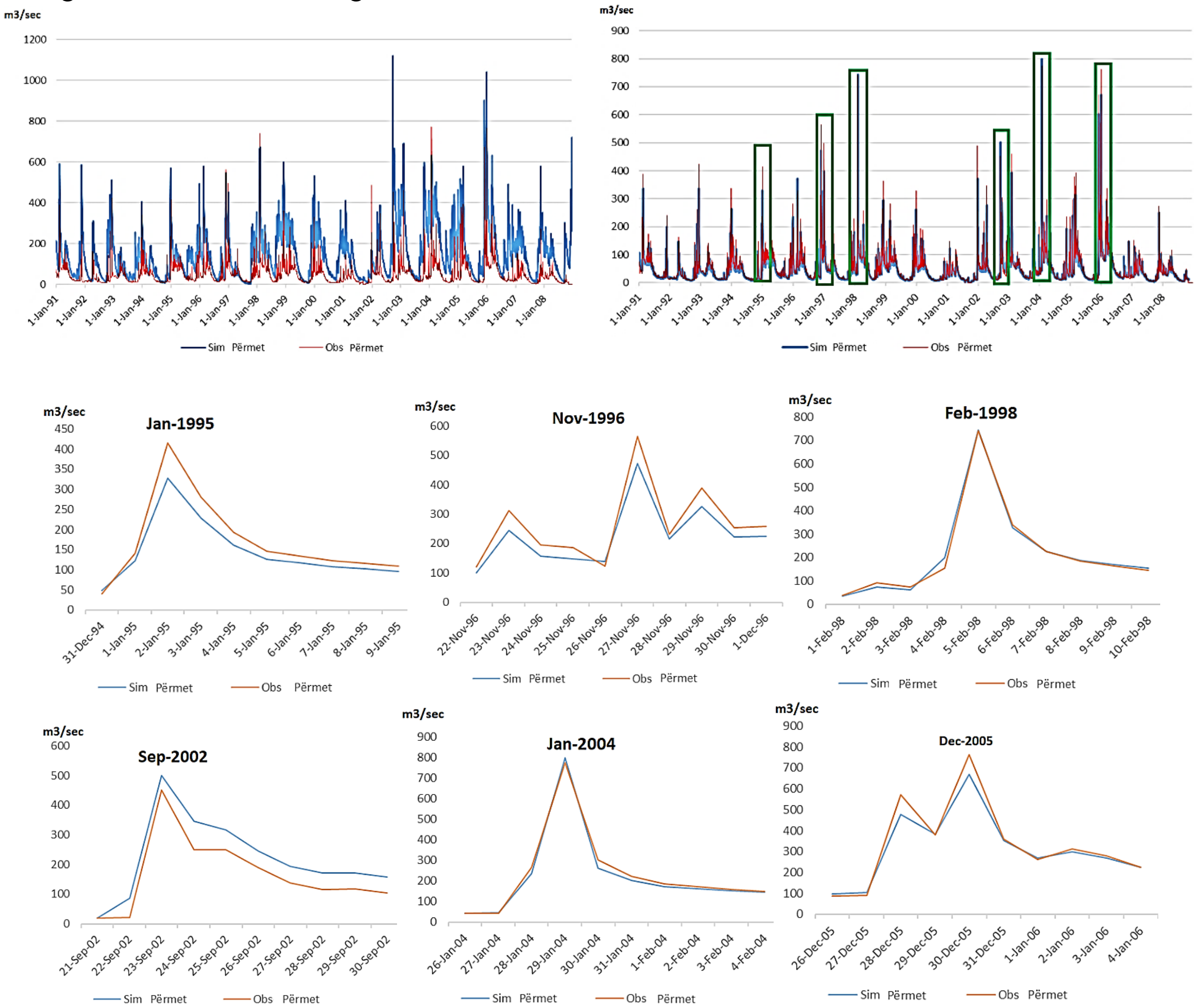

Figure 4 Example of the continuous simulations, model calibration, and the singular storm events for Permet station in the Vjosa river.

From the flow analysis, it is noticed that the risk of flooding in this river basin, increases in those cases when we have the flood hydrograph arrival, from the two main directions Osumi and Devolli. We also have cases of complete separations from the two branches, wherein the lower parts there are no problems with floods. Seman river, have a significant peak discharge flattening due to the expansion of the riverbed, and the low slope in the part of the confluence of the two branches, and along the Myzeqe plain. From the analysis of the observed data, some events at the beginning of May, September 2004, and 2005, are not taken into account in the calibration processes. Most likely, errors may have occurred in the registration or processing of level values for these cases.

The most important tributaries of the Vjosa River are the Drinos, which in this model have been treated separately, and the part of the Vjosa in Përmet, which has used hydrological measurements to calibrate the model. In the Vjosa Përmet branch, we can see a very good correlation between the simulated flow, from the observed flow. The NSE performance coefficient values are 0.92-1, which are very good modeling values. Change of the peak, go up to 20.8% in exceptional cases, and generally, these deviations are much lower. This is believed to be due to a lack of detailed meteorological information (the model includes two stations, Ioannina and Kozani in Greece), in the Vjosa River basin in Greece. The volume in Përmet shows a good connection of simulation with the measured values is seen. A special feature of the watershed of the Vjosa River is the presence of karst, mainly in the Drino River branch. Results in these branches are generally very good with reference coefficient NSE. Just like the other branch, here too we have deviations at an acceptable peak level and total volume. As a result of the action of the karst, the modelling becomes complicated due to the lack of initial information, above the groundwater level, in the aquifer of this branch. Acknowledging that the karst phenomenon greatly affects this branch, a maximum approximation of the graph has been achieved, which generally gives the peak and volume of the hydrograph lower than observed in the flood period. This problem in the tentative correction by using different parameters was not possible to be resolved due to the big change in the normal conditions. This fact has limited the approximation of the curve to increase its peak in the hydrograph, admitting an error for the effect of karst, in this branch. In the forecast, this branch can be calculated with different boundary conditions, knowing the preliminary information of groundwater levels. Parameters altered by value optimization have been applied throughout the basin, although calibration checks have only been performed at these two stations, including the following other subbasins, up to the western lowlands. Since two of the biggest floods in this river basin are those of February 2015 and December 2017, this study included the following two separate events, where simulation for these events is done with, processing data only from meteorological stations.

Table 1 Example of the performance of the model for Permet station in the Vjosa river

Station	**Storm event**	**Obs**		**Sim**		**Difference in peak %**	**Difference in volume %**	**NSE Nash Sutcliffe Efficiency**
		Peak m^3/sec	**Total Volume (million)**	**Peak m^3/sec**	**Total Volume (million)**			
Përmet	2-Jan-95	414.9	147.0	328.5	124.6	-20.8	-15.2	0.97
	27-Nov-96	565.2	228.4	473.3	195.0	-16.3	-14.6	0.97
	5-Feb-98	740.9	185.9	744.7	188.7	0.5	1.5	1.00
	23-Sep-02	451	143.3	500.2	191.1	10.9	33.3	0.92
	29-Jan-04	773.5	200.0	798.0	191.7	3.2	-4.1	1.00
	30-Dec-05	762.6	288.1	670.1	272.4	-12.1	-5.5	0.99

The objective of this hydrological modelling is to be used for flood forecasting, in the western lowlands of Albania. In the simplest case, the forecasted peak can be compared to a predetermined threshold discharge. This threshold (if this information exists), maybe the height at which water may come out of the riverbanks, or embankments and damage property, or threaten the lives of the population. If the discharge is forecasted to reach the threshold, then an alarm is issued.

The maximum warning time varies from storm to storm, and the catchment response varies by its characteristics. For example, if the flood plain is close to the center of the storm, the maximum warning time of the warning will be small, and generally the larger the river basin, the bigger the warning time. On the other hand, if we apply the quantitative precipitation forecast before the event occurs, the maximum warning time, for the same flood plain, will be bigger.

The application of meteorological forecasting, in the hydrological model, creates sufficient time for early warning, acknowledging even bigger uncertainty of forecasting. Hydrological simulation for the future is applied through the meteorological model, or in special cases when there is time available, through combined procedures (forecasting and observation network). The meteorological model ICON-EU performs 8 (eight) simulations per day and is also a basic forecasting model on the European forecasting platform of floods EFAS. Other meteorological models are not limited. Any other type of meteorological information (temperature and precipitation), can be used in the HEC-HSM model in GRID, or subbasin level. The best combination of the use of this information is being used together with the information of the measured precipitation, by the automatic hydrometeorological stations.

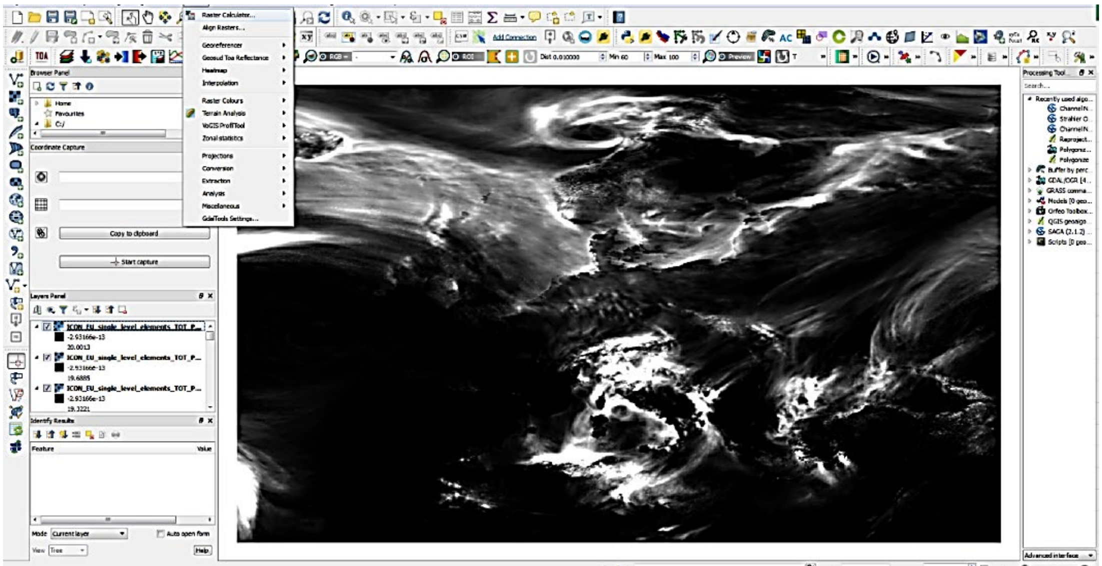

Figure 5 Application of the 3 hours precipitation for the next 5 days using ICON-EU data in QGIS software and geodesic system WGS84 UTM.

HEC-HSM and ICON-EU advantages are obvious in comparison with other commercial models because are open-source, and without limitation of the user and the methods he uses. The use of hydrological modelling in flood forecasting complements a part of the territory, which was not covered in Albania. The model's deviations from reality are acceptable, but in no case can we say with certainty that meteorological situations are the same and standard. For the correction of meteorological inputs, detailed information from the terrain is required, and especially in those areas where the mountainous heights increase the quantity and type of precipitations (IHM, 1985). HEC-HSM is built based on sub-basins and represents the high mountain areas covered by snow, as a percentage of the surface and the average height above sea level. This is a method that the model to get closer to reality, but it is known that covered areas with snow are dynamic and not fixed. Often, there are cases in which these precipitations, do not follow the rules observed by creating anomalies that the model cannot predict.

Deviations from reality are accessible only in those areas where we have hydrological stations, while for the rest of the basin territory, the hydrological behaviour is a conjectured simulation, based on the analogy of the basin, acknowledging that there are no substantial changes from one modelled basin, to the other. Their correction can only be done on a smaller scale of the subbasin, with the right information of hydrological observation. Further optimization is a challenge for any forecasting model.

Ground monitoring networks are the starting point for these details, which make the difference between a simple model, and a fully distributed and representative model. Alternative satellite methods are always the last resort for experts in the field, and they need ground reference points, without which information correction BIAS is not possible. Normally, the model is used by any type of operating system, even though it is built into the Windows system. Since Windows servers cost more than other devices, the model can use even free servers like LINUX.

Conclusions

Urban displacement of people in areas at risk of flooding, and lack of plans to respond to floods, increase the potential for damage, as floods occur regularly in Albania. In the current situation in the basins, the European-scale EFAS model has been applied. There is no dedicated flood forecasting system at the basin level, implemented in the Mat, Ishëm, Erzen, Shkumbin, Seman, and Vjosa river basins. To model these basins, the hydrological model HEC-HSM was used as an open-source. The application of HEC-HSM is carried out at subbasin levels - with optimal surface area, oriented by hydrographic scheme and observation stations. Further separation and detailing of sub-basins do not increase the quality of the model, as long as there is no additional information that can be applied to those surfaces. The construction of the hydrological model in the hydrological planning model has used almost all stations operating in Albania, excluding only a small number of stations, which in terms of their values showed significant anomalies, compared to other stations (mainly values very small abnormal rainfall). It was not possible, the use of all hydrological stations operating in Albania, although part of the information has been digitized only for levels, processing rating curves for these series did not exist. Even after strict quality control, the discharge series show numerous anomalies. This is due to the passage of a long time of updating the flow rating curves, or for inaccuracies in the observers' notes. Contradictory, or unreliable streaming discharges are excluded from the calculations. Although HEC-HSM, in this study aimed to model flood situations, it has been applied in a complete form of water balance calculation. Application through the complete hydrological cycle gives priority in optimizing the hydrological parameters, and thus avoids the subjectivism of the expert on the calculated values. Qualitative controls, in the case of a flood hydrograph, have taken precedence by performing complete and partial optimizations. The main problems have appeared in karstic areas, or those areas without hydrological measurements. Infrastructure impacts have been limited to the Mat River, for the Ulëz hydropower plant, which has been used in this study. In other cases, there are no significant accumulation impacts, as they are low-capacity dams for strong impacts. However, the use of calculations for the series 1991-2008, takes into account in the water balance the effect of these reservoirs. To enable the forecast of the hydrological model, the model was applied to the forecast phase of modelling. For this application was chosen tools that are freely available like ICON -EU meteorological model. The use of hydrological modelling, in flood forecasting, complements a part of the territory, which was not covered in Albania. As a final result, the flood forecast was completed successfully, and the risk of flood damage can be reduced through the application of hydrological modelling.

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