Forest – Water Interactions

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Acknowledgements

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1

Introduction and background

The project "*Generating momentum on water and forests in the Balkans*" is financed by Deutsche Bundesstiftung Umwelt (DBU) trough Research Institute for Forest Ecology and Forestry of Rhineland- Palatinate (FAWF), Germany.

The Project is implemented by CNVP (Connecting Natural Values & People Foundation). Its mission is to use evidence-based analysis to improve the sustainable livelihoods of rural communities in the Western Balkans affected by ongoing environmental and climate change.

Republic North-Macedonia, Serbia and Albania are confronted with a multitude of challenges in terms of closely related forest and water management. In these countries, such challenges need to be tackled jointly by forestry and water management through greater synergy potential between forest and water administrations including concerned stakeholders.

Forest planning in North-Macedonia, Albania, and Serbia shall include water management aspects in order to provide improved ecosystem services around the resource water.

The first specific objective is to develop model measures for water protection in forest areas by an integrative forestry and water management within forest planning.

As a second specific objective, forest planning capacities in North-Macedonia, Albania, and Serbia are to be extended by an integrative forest management strategy with a special focus on water retention in forests.

2

Basics of forests hydrology

Both **river basins and watersheds** are areas of land that drain to a particular water body, such as a lake, stream, river or estuary.

In a river basin, all the water drains to a large **river**. The term **watershed** is used to describe a smaller area of land that drains to a smaller stream, lake or wetland.

According to the WFD - typology A, basin based on the area in km^2 could be :

- small (10-100),
- medium (100-1000),
- large (1000- 10000),
- very large basin (> 10 000 km^2).

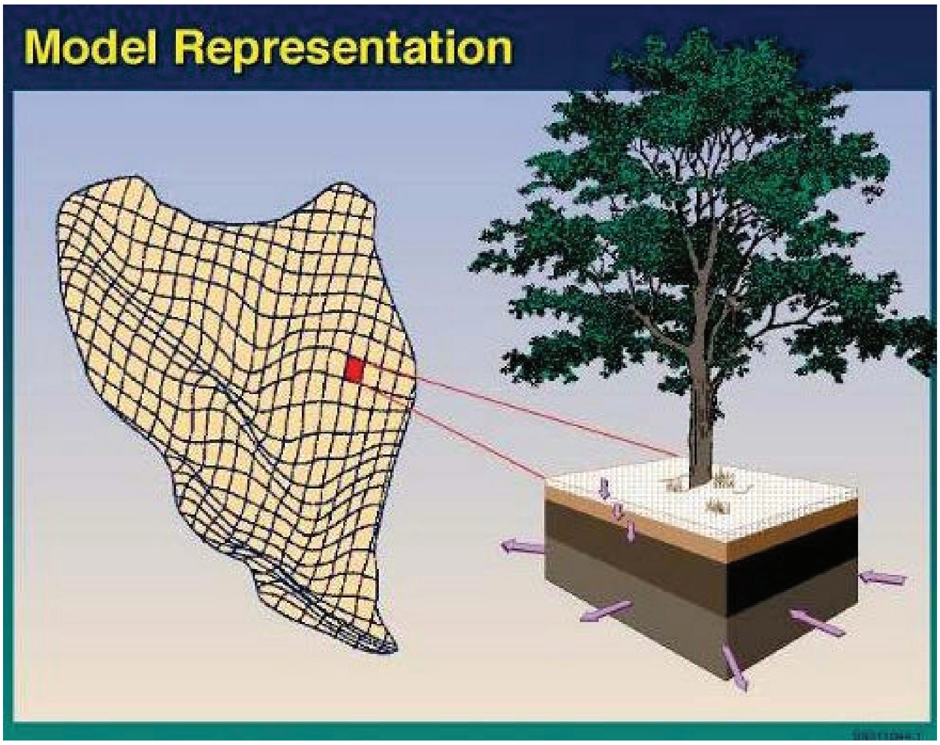


Figure 1 - Model presentation of watershed

Watersheds are dynamic systems constituted by a complex arrangement of fluxes between the land and water environment. There are essentially three interconnected fluxes, not only of water but also of sediments/nutrients and pollutants. Surface runoff carries sediments, nutrients, and pollutants from the land through the drainage networks. It is important to note that those fluxes are varying over time and space.

Natural geomorphologic processes influence those fluxes to vary degrees. Human alterations of the catchment area can significantly contribute to changes to all those processes through large scale land-use changes and land-use practices.

2.1. Water cycle and water balance

The water cycle plays a key role in ecosystem functions and processes. Forests in turn, are vital to the water cycle and to water quality. In essence, the forest acts like a giant sponge, filtering and recycling water.

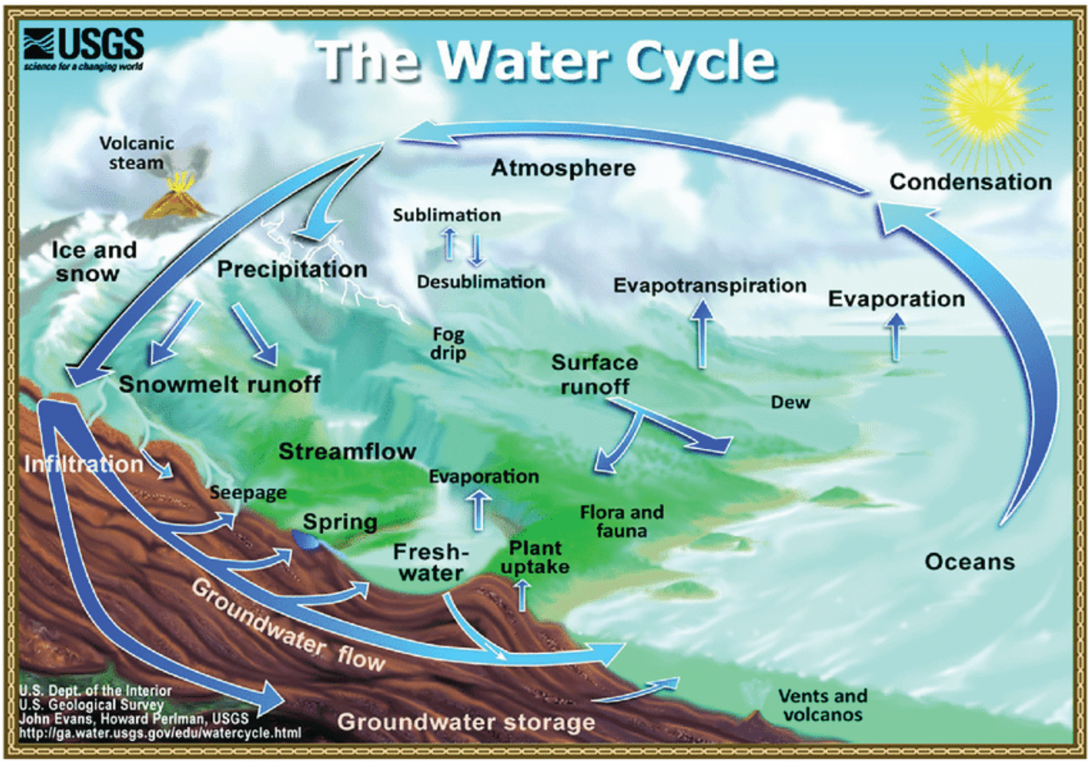


Figure 2 – Water cycle
https://www.usgs.gov/media/images/water-cycle-natural-water-cycle

Basic parts of the general water balance are:

- atmospheric precipitation,
- the interception,
- transpiration,
- evaporation,

- infiltration,
- surface and ground runoff.

The general basic equation of water balance is as follow:

$$P = E + F + \Delta S \text{ (mm)}$$

Where: P – Precipitation [mm]; E - Summarized evaporation (mm); F - General water runoff (mm);

ΔS–Change in water storage (mm);

More details on water balance elements are presented in the Figure 3.

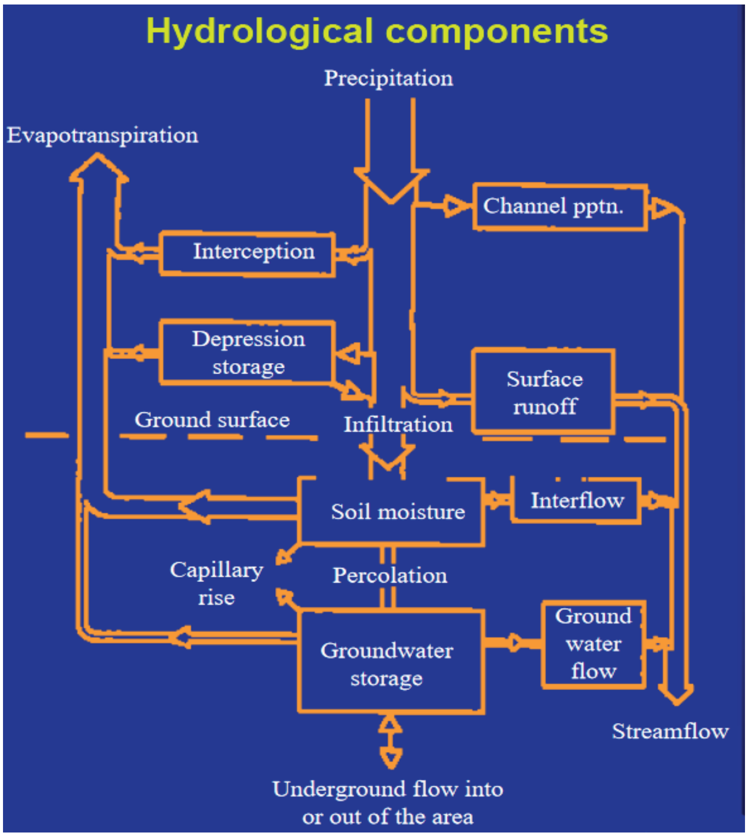


Figure 3 – Components of water balance

2.2. Forest ecosystems and hydrological components

In the forest ecosystem, the main hydrological components are analyzed in more detail.

P – Precipitation [mm] P = Pv + Ph + Fst
Pv – vertical precipitations (rain, snow, hail ...)
Ph - horizontal precipitation (fog, drifting ...)
Fst – leaking along the tree branches and stem)

E - Summarized evaporation (mm) $E = Ei + Es + Et$
Ei - evaporation of the water retained on the crown and stems
Es - evaporation from the beginning
Et – transcription

F - general water runoff (mm) $F = Fov + Fg$
Fov - surface runoff
Fg - ground runoff

ΔS – Change in water storage (mm)

The final expression of the equation is :

$$\mathbf{P = Fst + Ei + Es + Et + Fov + Fg \pm \Delta S(mm)}$$

The water balance ensures complex processes from the general hydrological cycle of water circulation.

These processes are especially complex of the forest ecosystems and depend on:

- the physiographic conditions, originating from the purchase on the terrain-development of the relief, the above sea level;
- pedological-geological background;
- characteristics of vegetation;
- the degree of comprehensiveness;
- the number of returns, the air regime, the temperature and humidity of the air and the start;
- the manner of management and management of the areas in the catchment area;
- hydro-meliorative works on the catchment etc.

Within the forest ecosystems, there are differences in the water balance, depending on:
- the structure, composition, cover, age of the forest stands,
- characteristics of location and
- other characteristics of the plantations (natural and artificial).

The **interception** depends on the type, composition and structure of the forest vegetation and its cover. It is known that 1/3 of the total amount of annual returns is retained by forest vegetation, which directly influences the retention value.

Various researchers have studied the interception dependance on tree species or stand composition parameters. Based on researches conducted by Eitengen, Brechtell, Gop, Intribus, Nairfalise, Molcanov and Seafimov, Voronkov, Idzon, Protopopov, Albes, Florov, Dimitrov, Raev, Serafimov, Kimpage and other Raev I. (1988) defined the minimum, the maximum and the average values of interception by species (Figure 4).

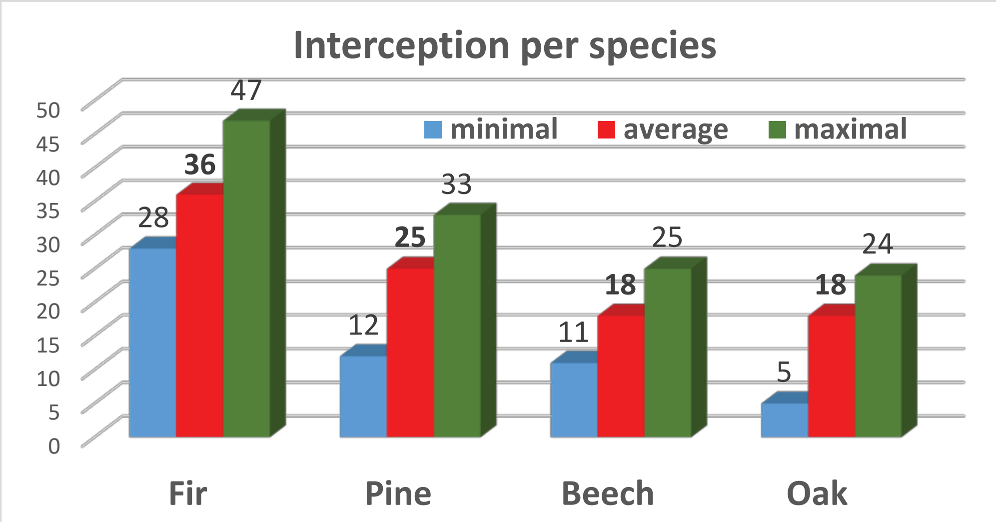


Figure 4 - Interception per species (based on Raev, I. 1988)

Evaporation from the forest litter depends on the characteristics of forest stands and environmental conditions. According to Russian scientists (Molcanov et al, ex-cite Raev, 1988), evaporation from "open land" (grassland) achieve 40% of the total precipitations, in pine stands up to 12,9%, and in spruce stands up to 5,5% of the total precipitations, in mature oak stands up to 17,6%, in beech stands up to 6,8%, mostly in the vegetation period.

The **transpiration** depends on the biological characteristics of the wood species and bushes (litters, cetins) and certain conditions of location (temperature and relative humidity, wind velocity, exposure, annual time (vegetation or non-vegetation period, etc.). For forest vegetation, these values are within the range of 31,3% - 45,0% of the total annual amount of returns, which also directly affects the retention.

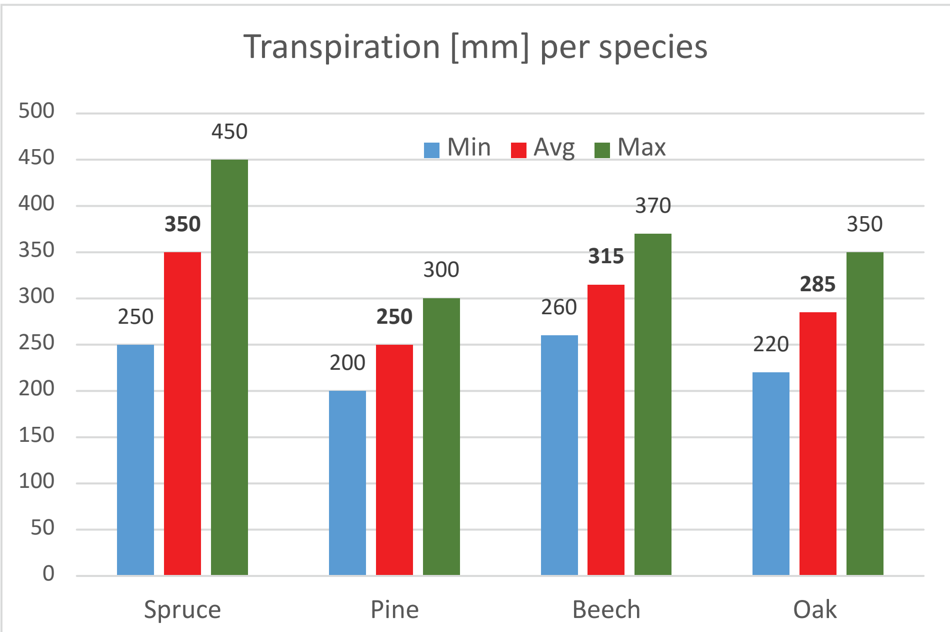


Figure 5 – Transpiration per tree species

One of the characters of forest soils is the better structure than other soils, with a large presence of parts of root systems of forest trees and shrubs. Forest soils have a much better air-water regime compared to other types of soils. The more the soil is able to retain a larger amount of water, the greater the retention capacity is. According to Embermaer data (excite Raev I.), the **absorption capacity** of the forest starts up to 25% in relation to the total average annual return quantity. The values of the water infiltration in the forest are different and range from 25-44% of the average annual return quantity.

The speed and amount of **infiltration** are different depending on the type of trees. This is conditioned by the root system, the quality of the forest, as well as the conditions for chimerization and mineralization in the forest floor.

According to Klotzli, the infiltration time of 100 mm of water (t) and the percentage of surface runoff (p) from the total runoff are:

- pasture with compacted soil, t = 3 ^{h}; p = 51-78 %
- normal pasture , t = 2 ^{h}; p = 3-15 %
- coppice beech stand , t = 20 ‘ ; p = 10 %
- high beech stand, t = 2 ‘ ; p = 0 %.

Runoff, in hydrology is the quantity of water discharged in surface streams. Runoff includes not only the waters that travel over the land surface and through channels to reach a stream but also interflow, the water that infiltrates the soil surface and travels by means of gravity toward a stream channel (always above the main groundwater level) and eventually empties into the channel. Runoff also includes groundwater that is discharged into a stream; streamflow that is composed entirely of groundwater is termed base flow, or fair- weather runoff, and it occurs where a stream channel intersects the water table. The total runoff is equal to the total precipitation less the losses caused by evapotranspiration (loss to the atmosphere from soil surfaces and plant leaves), storage (as in temporary ponds), and other such abstractions. (https://www.britannica.com/science/runoff)

According to the http://www.geographynotes.com/precipitation-2/runoff/runoff-meaning-types-and- factors-rainfall-geography/6037, based on the time delay between the instance of rainfall and generation of runoff, the runoff may be classified into the following three types:

1. Surface Runoff: It is that portion of rainfall, which enters the stream immediately after the rainfall. It occurs, when all losses are satisfied and if rain is still continued with the rate greater than the infiltration rate; then excess water makes ahead over the ground surface (surface detention), which tends to move from one place to another following land gradient, is known as overland flow. As soon as the overland flow joins to the streams, channels or oceans are termed as surface runoff.

2. Sub-Surface Runoff: That part of rainfall, which first enters into the soil and moves laterally without joining the water-table to the streams, rivers or oceans, is known as sub-surface runoff or interflow. Sometimes sub- surface runoff is also treated under surface runoff due to the reason that it takes very little time to reach the river or channel in comparison to groundwater. The sub-surface runoff is usually referred to as interflow.

3. Base Flow: It is delayed flow, defined as that part of rainfall, which after falling on the ground surface, infiltrates into the soil and meets the water-table; and flows to the streams, oceans, etc. The movement of water in this type of runoff is very slow, that is why it is also referred to as delayed runoff. It takes a long time to join the rivers or oceans, say for as years. Sometimes, base flow is also known as groundwater flow.

Meteorological, physical and anthropogenic factors affect the runoff.

Meteorological factors affecting runoff: Type of precipitation (rain, snow, sleet, etc.); Rainfall intensity; Rainfall amount; Rainfall duration; Distribution of rainfall over the watersheds; Direction of storm movement; Antecedent precipitation and resulting soil moisture. There are other meteorological and climatic conditions that affect evapotranspiration, such as temperature, wind, relative humidity, and season.

Physical characteristics affecting runoff: Land cover; Vegetation; Soil type; Drainage area; Basin shape; Elevation; Slope; Topography; Direction of orientation; Drainage network patterns; Natural ponds and lakes.

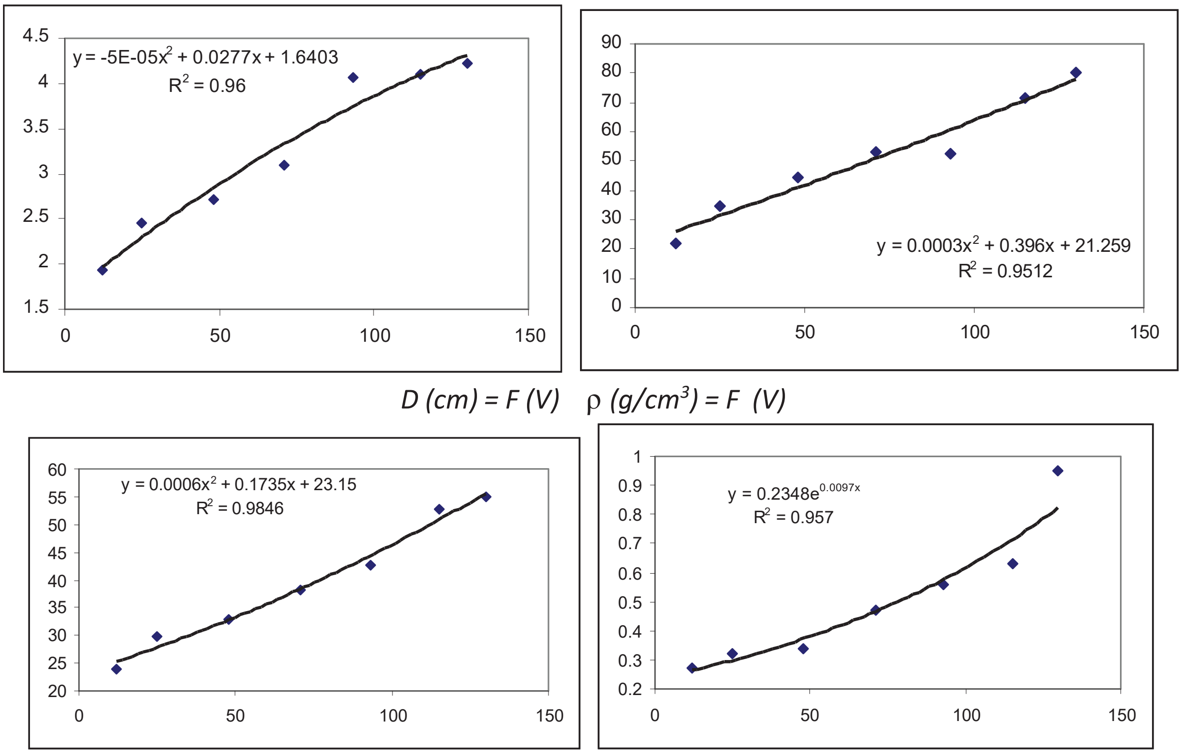
Human management activities in agriculture, forestry, water economy, constructions, transport, and others significantly affect runoff.

According to Angelov and Petkov (1960), the surface runoff in acacia stands is 2 times lower than black pine plantations under the same conditions. According to Marinov (1984), in the Melnik river basin, the coefficient of surface runoff in oak, beech and acacia stands on the inclination of 64-75% ranges from 0.01 - 0.22, while in the case of black pine plantations at the same conditions, the runoff coefficient ranges from 0.21 to 0.45.

According to Schaffhauser (1982) in Austria, the surface runoff in forest stands tend to 0, on bushland 0.017, in treeless plantations 0.187, on ski slope 0.364, and on a grassland used for grazing 0.601. Similar results are given by Raev and Ruseva (1984), as well as Eschner and Madertes.

According to Serbian researches, in broadleaved forests with canopy cover of K = 85%, runoff coefficient is
0.342, while at the mixed forests with K = 98%, coefficient of the surface runoff is 0.313, on the mountain pastures the runoff is 0.412, and on the bare lands scarce vegetation the runoff is 0.518.

Raev, Dimitrov, and Mihajlov, studied the correlation between the characteristics of forest floor and runoff in various spruce stands by age. The following graphs show changes to some of the important physical properties of the forest floor: Depth - D [cm]; Density - ρ [g / cm3]; Non - capillary porosity - NP [%] and permeability – Kp [mm /s], depending on the age on the spruce stand V – [years].



D (cm) = F (V) ρ *(g/cm³) = F (V)*

NP (%) = F (V)Kp (mm/s)= F (V)

Figure 6 - Correlation between the characteristics of forest floor and age (based on RAev I., 1988)

According to the Russian researches (Molchanov, 1975, ex-cite Raev I., 1988)), in the full covered Scots Pine stands, the runoff coefficient is only 0.07-0.08, in a cover of 49-56% it increases to 0.41-0.43, on bare land it reaches 0.75. In addition to this, the maximum runoff module at K= 90% is 1.1. l/s/ha, at K= 57% increase to 3.1 l / s / ha, and on the bare land it reaches 6.0 l / s / ha.

Table 1. Runoff coefficient depend on various slope and forest

Type	η – Runoff Coeficient - on various slope of the terrain in percents - % (grade°)			
	17.6 (10)	36.4 (20)	57.7 (30)	83.9 (40)
Grassland	0.82	0.90	0.95	-
Scots Pine stand	0.17	0.25	0.33	0.48
Spruce	0.03	0.05	0.08	0.34
Beech	0.02	0.03	0.04	0.05

2.3. Water balance in Vevcanska Reka catchment - an example - exercise

The inclination is 60%.
The average value of precipitations on the catchment is 812.8 mm.

The surface area of the watershed is 1213 ha.

On the terrain, there are forests (various species), rocks, pastures: beech 64%, pine 2%, oak 1%, bare land 7% and grassland 26% of the surface.

For various elements of the water balance are accepted average values by various researches.

Table 2 - Various elements of water balance [%]

	Interception	Evaporation	Transpiration	Total evapo-transpiration	Retention	Runoff	Total
1	2	3	4	5	6	7	8
Beech	18,2	6,8	38,7	63,7	21,4	14,9	100,0
Pine	25,2	12,9	30,8	68,9	10,7	20,4	100,0
Oak	15,0	17,6	35,1	67,7	12,3	20,0	100,0
Grassland		20,0		20,0	19,0	61,0	100,0
Bareland.		2,0		2,0	8,0	90,0	100,0

Table 3 - Value of various elements of water balance [m3]

	Interception	Evaporation	Transpiration	Total evapo-transpiration	Retention	Runoff	Total
1	2	3	4	5	6	7	8
Beech	11424404	4292041	24426765	40143211	13507307	9467738	63118256
Pine	387987	50050	474206	912243	165498	461889	1539630
Oak	170741	200336	399534	770611	140008	227655	1138274
Grassland		1450035		1450035	1377533	4422607	7250176
Bareland.		511316		511316	2045265	23009230	25565811
TOTAL	**11.983.132**	**6.503.778**	**25.300.505**	**43.787.416**	**17.235.611**	**37.589.119**	**98.592.640**

Source: - Blinkov I., 2005

2.4. Forest activities and hydrological components

Land use practices in smaller catchments (<100 km^2) have a significant impact on average flow, peak flow, base flow, groundwater discharge and sediment load.

Table 4: Spatial Dimensions of land use effects
(Source: http://www.fao.org/3/y3618e/y3618e07.htm)

Impact	Basin size [km^2]						
	0.1	1	10	100	1 000	10 000	100 000
Average flow	x	x	x	x	-	-	-
Peak flow	x	x	x	x	-	-	-
Base flow	x	x	x	x	-	-	-
Groundwater recharge	x	x	x	x	-	-	-
Sediment load	x	x	x	x	-	-	-
Nutrients	x	x	x	x	x	-	-
Organic matter	x	x	x	x	-	-	-
Pathogens	x	x	x	-	-	-	-
Salinity	x	x	x	x	x	x	x
Pesticides	x	x	x	x	x	x	x
Heavy metals	x	x	x	x	x	x	x
Thermal regime	x	x	-	-	-	-	-

Legend: x = Obervable impact; - = no observable impact

Generally speaking, a natural, expansive forest environment can enhance and sustain relationships in the water cycle because there are fewer human modifications to interfere with its components.

A forested watershed helps moderate storm flows by increasing infiltration and reducing overland runoff. Further, a forest helps sustain streamflow by reducing evaporation (e.g., owing to slightly lower temperatures in shaded areas). Forests can help increase recharge to aquifers by allowing more precipitation to infiltrate the soil, as opposed to rapidly running off the land to a downslope area.

2.4.1. Silvicultural activities and runoff

According to Maran and Loth, the change in the density and the cover of the spruce stand has a large impact on the surface runoff, so with the intensity of thinning up to 0.5 cover, the runoff increased to 2.5 times, while in further decrease of forest cover up to 0.2, the runoff increase up to 7 times. According to Raev (1975), after thinning and total cut of the spruce stand with cover 0.8-0.9, the runoff is increased by 9 - 11 times. The deterioration of the hydrological conditions of the slopes is related to the reduction of the forest floor, lowering the water-permeability, decreasing the non-capillary porosity and the upper soil horizons.

According to Lall (1970), after a clear cut: in North Carolina, the river runoff increased by 152-432 mm, in Western Virginia 203-406 mm, in New Hampshire 203 - 356 mm. Apart from the increase in the river runoff, the result of cut is the deformation of the forest ecosystem. In the case of intensive precipitations, the extreme occurrences of the runoff are increased, and the dangers of flooding and erosion are multiplying in many ways.

Patric (USA), conducted experiments in mixed broadleaf forests (oak and maple) with a slope of 40-65% in two basins with an area of 34.7 and a controlling 38.8 ha. Average returns amounted to 1450 mm. The average annual runoff amounted to 630 mm with a runoff coefficient η = 0.41. After that, selection cut was carried out to 13% of one basin. After 5 years from the beginning, there were notably significant changes in the outflow. Then was realized clear cut and all wooden material was removed. The first year after the clear cut, the runoff increased to η = 0.609, as opposed to the control basin, where it was 0.434. As the humus and forest rugs are preserved, over the years with the growth of the subgenus, the runoff is reduced, so after 10 years of the clear cut, from the hydrological aspect, the plant is returned to the original situation.

According to Tarasvili (1955), in the Caucasus, in the Beech-Carp forest with a high intensity of thinning, the non-capillary porosity is 5.6-11.0%, and in the un-thinned same forest is 11.6-16.6 %. Cegelisvili (1967), state that even 15-20 years after the clear cut, the non-capillary porosity is from 5.1 to 6.1%, after the gradual cuts of 6.6 - 8.8%, and after the selective cut, practically is 12,5 – 115, 8 (as in the control forest). (Raev., 1988)

Table 5 – Type of cut and percentage of various hydrological elements (by Poljakov)

Hydrological element	Selective Cut	Shelterwood logging	Clear Cut
Interception in crown(% of total precipitation)	8	5	0
Part of precipitation retention in the forest floor (%)	10	7	4
Infiltration (%)	76	63	53
Surface runoff (%)	6	25	43

2.4.2. Forest transport and runoff

The use of heavy machinery in the forest causes major disruptions in hydrological balances. Some tractors through movement and attraction destroy the young trees and the forest floor. Thus, the use of 1 or 2 drum rollers in these machines minimizes the destruction of the forest floor which also reduces the disruption of hydrological balance.

Isaev (1970, 1973), claimed that on the road covered with residues of logging, the runoff coefficient is 0.013, on uncovered with residues road achieve 0.32, while on the main roads, reaching 0.79.

According to Bulgarian authors (Zeljaskov, Shipkovenski, Raev ...), at a slope of 10^{O} (17.6%) and cut in the intensity of 15-20%, the use of tractors (with collars) cause serious changes in the initial - hydrological properties. At the intensity of cuts of about 30%, and especially on slopes over 20 ° (36.4%), many of the initial hydrological potentials are lost and the porous layer is destroyed.

Improperly engineered roads in forests can increase erosion and significantly increase the risk of landslides. Both of the adverse effects are more severe when roads are numerous, and when they either cross or run parallel to streams. For example, heavy precipitation in

Oregon and Washington during the mid-1990s resulted in many landslides, with a correlation between the slides and the frequency and density of roads. With respect to erosion and sedimentation, water runoff flowing along and across roads picks up sediment, which can then be deposited in nearby lakes and streams. This siltation can degrade or destroy habitat for aquatic organisms that require clear water and silt-free benthic (bottom) substrates. Proper road engineering and following good practices (such as the U.S. Forest Service Guidelines for Best Management Practices) can reduce or eliminate the risk of erosion, landslides, and stream degradation due to excess siltation. Unfortunately, many roads in U.S. national forests were built before the practices were in place. http://www.fao.org/3/a1598e/a1598e02.htm

According to Zemke J. (2016) compared to undisturbed sites, where the mean runoff coefficient during 43.6 l of rainfall was 0.037, forest roads showed mean runoff coefficients up to 0.92. While undisturbed forest soils showed only negligible erosion rates (4.7 g/m^2)of eroded soil (after 90 min of simulated rainfall), distinctly higher rates were measured on forest roads (118.5–272.2 g/m^2). Skid trails on the other hand also showed increased runoff coefficients, but mainly in the compacted, rutted parts up to 0.60. Here the mean runoff coefficient was 59.9%, Despite the increased runoff coefficients, there was no clearly detectable rise of soil erosion rates, as rutted skid trails only showed a mean sum of eroded sediment of 21.4 g/m^{2}and unrutted skid trails a mean sum of 5.1 g/m^{2}after 90 min of artificial rainfall (https://www.mdpi.com/2306-5338/3/3/25/pdf)

3

Methodology for identification of flood relevant forest areas and forest features by Schueler

An extract from paper: *Schueler, Identification of flood-generating forest areas and forestry measures for water retention, For. Snow Landsc. Res. 80, 1: 99–114 (2006) 99.,*

3.1. Runoff processes in forest ecosystem

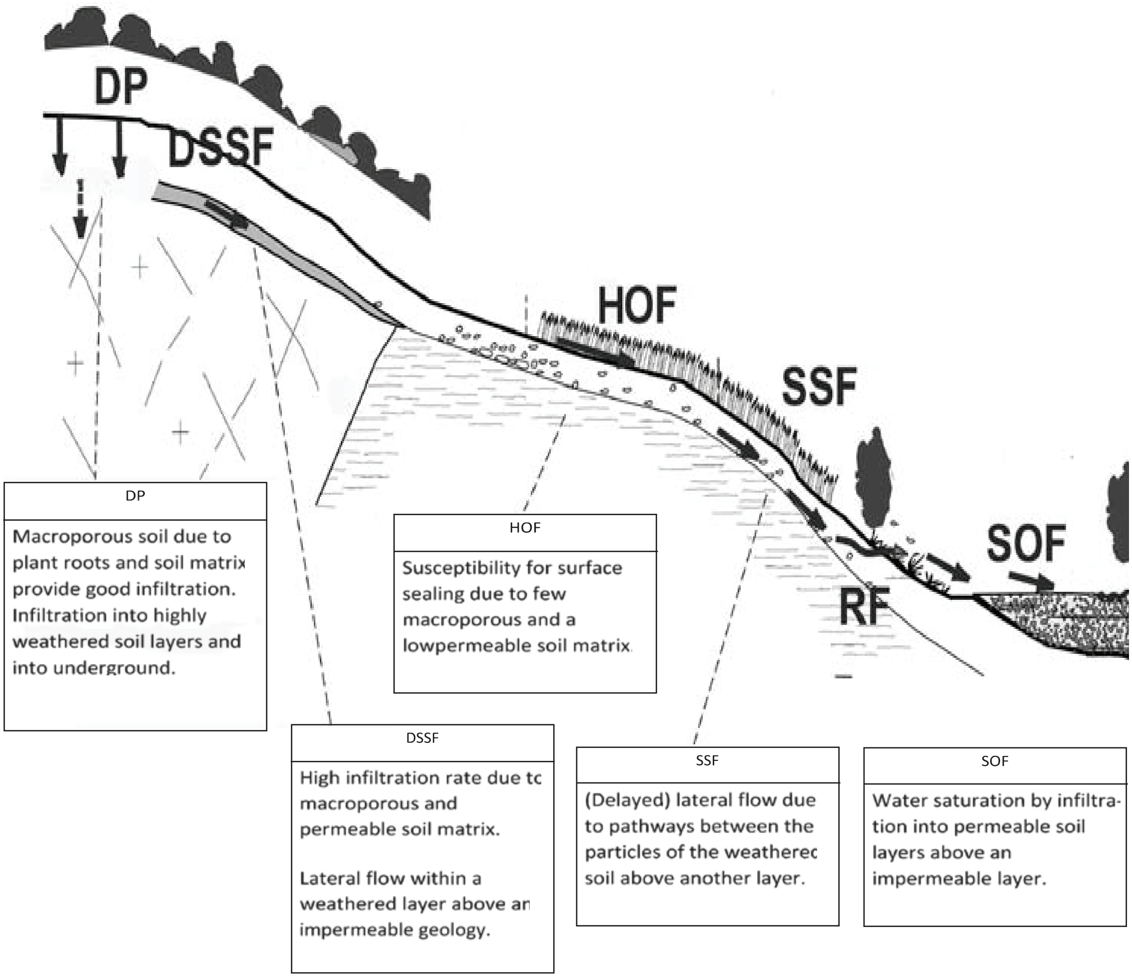


Figure 7. Runoff processes in forest ecosystems. Origin: Federal Institute of Technology, 2001 modified.

Runoff processes in forest ecosystem could be as follow:

- DP - Deep Percolation
- DSSF – Deep subsurface flow
- HOF - Hortonian overland flow
- SSF – Subsurface flow
- SOF - Saturated overland flow

In forests soils with high infiltration capacity, no impermeable layers and permeable bedrock, water percolates to a great depth (DP = Deep Percolation). Deep, permeable soils have a good retention capacity and peakflow delaying potential. In winter, when evapotranspiration is decreased and soils are saturated, these void and crack systems discharge water through springs. If voids dominate in the soil, the main discharge is controlled by hydraulic pressure, whereas, if cracks dominate then it is based on direct runoff (SCHUELER et al. 2002).

Overland flow can be found on forested, steep slopes with poor drainage, generally combined with extremely high rainfall (BOTT 2002). Even forest soils with minimal infiltration rates of 50 mm·h–1 have sufficient drainage capacity (DVWK 1985; WEILER et al. 2000). The infiltration rate of the upper soil horizons depends on the soil texture and on the bulk density (e.g. dense clay soils have a low infiltration capacity). However, it is normal for forest soils formed under the weathering conditions of a humid climate to have relatively low bulk densities (up to 1.2 g·cm–3). Drainage is generally only reduced by compaction from heavy forest machinery. This is why the location and density of logging trails requires close consideration by forest planners.

Hortonian overland flow (HOF) (BEVEN 2004; HORTON 1933;) requires a low infiltration capacity and/or steep slopes in combination with high rainfall intensities. Low infiltration rates can be found on:

- impermeable soils,
- compacted soils without structure,
- soils with clay substrates in the upper soil horizons,
- forest roads and log trails.

On sites with low field capacity, with impermeable clay or loamy layers and without preferential seepage pathways, saturated overland flow (SOF) occurs once water saturation is reached. The lower the void capacity of a soil, the faster and more intensive the runoff that develops after rainfall (BOTT 2002).

On perched sites with higher field capacity, but impermeable soil horizons or bedrock, water is transmitted laterally in the soil as long as the soils are not saturated with water. The water flows preferentially in pipes or in permeable layers, with runoff velocities of up to 2 cm·s–1 (WHIPKEY 1965; BEASLEY 1976; MOSLEY 1979; FEYEN 1998).

In this paper, water flow in soil above an impenetrable layer is termed subsurface flow (SSF), and interflow above bedrock is termed deep subsurface flow (DSSF).

3.2. Identification of runoff-generating plots and discharge-contributing areas by forest site survey

In assessing the hydrological sensitivities of catchments in low mountain ranges, a distinction can be made between runoff-generating plots and discharge-contributing areas: runoff-generating plots need not necessarily also be contributing areas. The runoff-generating plots are those locations where a process occurs, under given site and precipitation conditions, while the contributing areas are responsible for the discharge depending on water saturation as shown by NAEF and SCHERRER (2003), WALDENMEYER (2003) and SCHMOCKER-FACKEL (2004).

Water from runoff-generating sites on hilltops may either infiltrate or merge with several other runoff-generating sites further down-slope in areas with runoff accumulation. If selective precautionary forestry management mitigates runoff from runoff generating areas to contributing areas, the discharge will indirectly be delayed and decreased. Therefore an expert system was developed to indicate the dominant flow process and the potential runoff velocity for runoff generating plots as a basis for the planning of retention and delaying measures in forests. The process determination at the plot scale does not consider influences from neighboring process areas nor whether the area is connected by linear structures (e.g. roads and ditches). Even if the influences between neighboring plots are known, it is difficult to infer the discharge process at catchment scale from the processes at the plot scale.

The discharge process with the interaction between neighboring process areas can be captured by a rainfall runoff model (CASPER 2004). Although this approach is part of the WaReLa-project, it is not the subject of this paper.

The expert system begins with the identification of the flood plains of rivers and brooks as sensitive water-accumulation and discharge-contributing areas using an automated GIS algorithm (SCHUELER 2004). This GIS tool adopts the ecological identification of flood plains from the forest site survey. In situations where the forest site survey does not have information about flood plains, the tool automatically derives the floodable river environs from a digital elevation model by evaluating the elevation of the flood plains and banks above the normal water level. The consequence of this designation is that flood plains will be managed with a view to their function as retention areas for peak-flow water – not as production forests.

The core of the expert system is a decision scheme that is based on special investigations to map the dominant runoff processes at the plot scale according to the methods used by SCHERRER (1997) and SCHMOCKER-FACKEL (2004). This method assesses runoff as a complex process dependent on soil surface sealing, topsoil-compaction, matrix-permeability, bulk-density, water- storage capacity in the soil, macroporosity, lateral flow-paths, barriers to vertical flow, and the underlying geology. This information can be collected during a standard forest site survey. Spatial runoff sensitivities are generated and visualized with GIS using the digital information from the forest site survey.

As part of the expert system, the spatially relevant runoff sensitivities are derived with a decision tree. Normally, several flow processes are observed in a plot. The decision tree summarizes all the necessary steps and decisions for a systematic determination of the dominant runoff processes in a plot using "yes/no" decisions. Long-term or seasonal fluctuation criteria, such as vegetation cover, which do not change the potential sensitivity of the sites, are not taken into account by the decision tree. The scheme captures in detail the very complex nature of runoff formation. Key site parameters are matrix permeability, hydraulic conductivity, stagnant moisture, and water storage capacity. The decision tree expresses the water storage capacity as productive field capacity. This capacity includes all soil pores with a size of 0.2–50 µm. These pores are filled with slowly moving capillary or adsorbed water. The large macropores (>50 µm) also have a significant storage capacity, but typically these pores drain very quickly, so that they do not represent an effective flow-delaying storage capacity. The productive field capacity can be derived from forest site maps with this information. One aim of the expert system is to automate the process determination using existing digital forest site maps.

To derive hydrological interpretations, the decision tree uses key questions such as "drainage/hydraulic conductivity in the upper soil – moderate to rapid (> 5 cm·d–1) – yes/no?" Possible answers to these key questions are summarized in a simple Excel sheet with soil substratum characterizing properties edited by the forest site survey.

The first key question that has to be answered for the process determination is: "Soils with impermeable layers without coarse cracks and voids – yes/no?" If the answer is affirmative, the decision tree leads to either overland flow (SOF, HOF) or subsurface flow (SSF) above impermeable layers. If the infiltration of water is inhibited by stagnant moisture, groundwater or low hydraulic conductivity in the upper soil, overland flow will be the resulting answer. If the answer to the next key question "drainage/hydraulic conductivity moderate to rapid" is yes, then infiltration is possible and subsurface flow is the dominant runoff process. The decision tree leads to saturated overland flow (SOF) only for shallow soils in flat areas that have a low water storage capacity and that are quickly saturated. On very steep slopes the possibility increases that water will not infiltrate, indicating Hortonian overland flow (HOF).

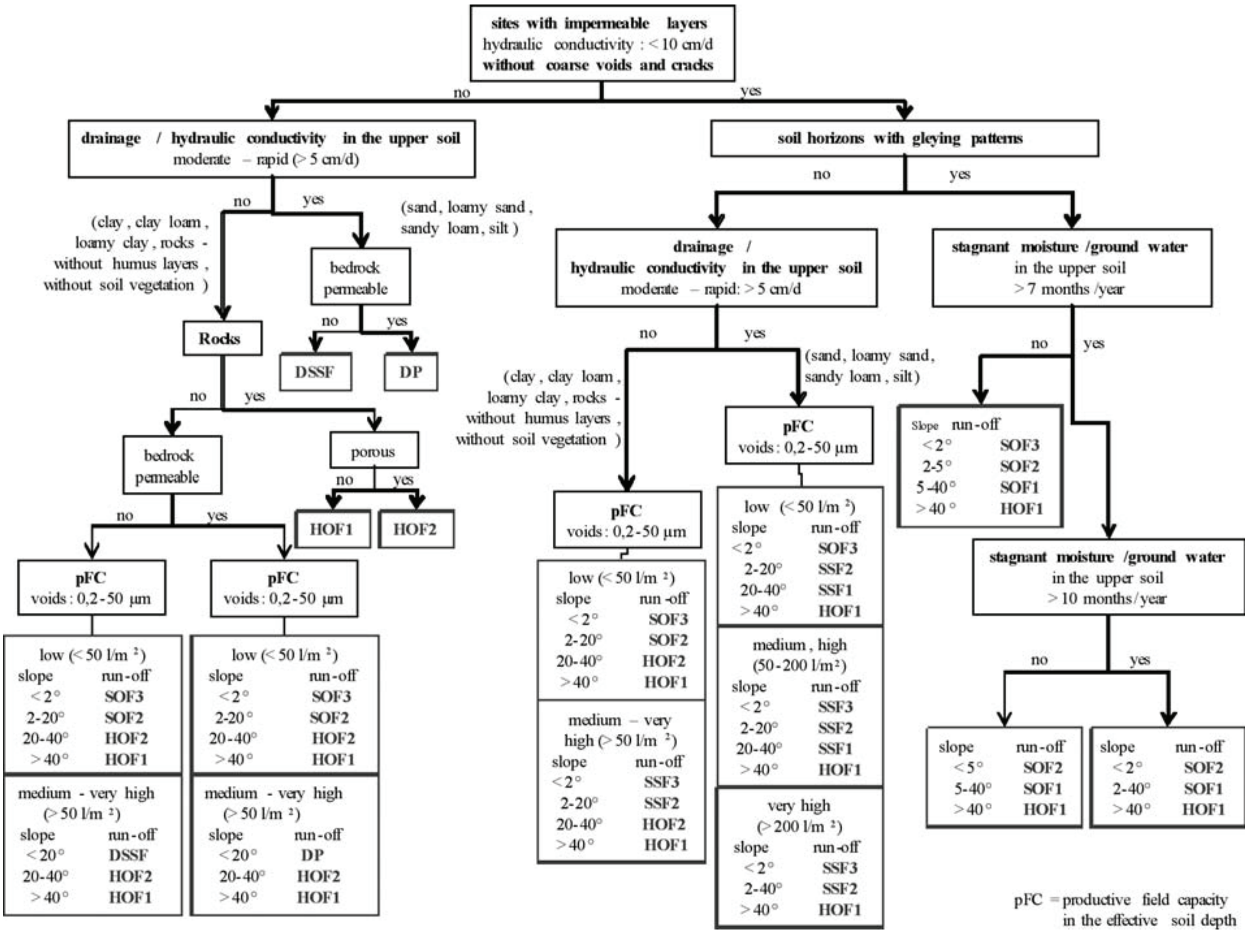


Figure 8 - Decision tree for defining runoff process

If the answers to the first key questions identify that the soils have no impermeable layers and that the infiltration of water is not inhibited, deep percolation (DP) is indicated. If water movement may be stopped or delayed above impermeable bedrock, then deep subsurface flow (DSSF) is indicated. If the infiltration of surface water is inhibited, then the danger of overland flow (SOF, HOF) increases, particularly on shallow soils with a small water storage capacity. On sites that are not excessively steep, and on soils with a greater storage capacity, water can move downslope, within the runoff-generating plot. Here, the decision tree leads to either deep percolation (DP) or to deep subsurface flow (DSSF) if water movement is above impermeable bedrock.

To grade the runoff processes, the velocity of runoff development is estimated with respect to the slope of the particular runoff-generating plot. For slopes up to 2°, erosion is limited (GRYSCHKO 2000). Runoff will be greatly delayed. This is marked as degree 3 for runoff processes: SOF3 and SSF3. On gently (>2°) to steeper slopes (<20°), runoff has a slight delay. This is expressed as degree 2: HOF2, SOF2, and SSF2. For sites >20°, or highly sensitive areas with slopes as low as 5°, runoff starts immediately (degree 1: HOF1, SOF1, and SSF1). On very steep slopes there is the potential for rapid overland flow with a strong likelihood of erosion. Here, the decision tree follows the Universal Soil Loss Equation (USLE) (WISCHMEIER and SMITH 1978). Compared with a “standard slope” of 4°, the USLE shows a 20-fold increase in erosion danger on slopes of 20° and a 90-fold increase on slopes of 40°. In addition to slope gradient, soil surface roughness and the infiltration rate influence runoff velocity. In addition to slope and soil physical properties, which are responsible for runoff, the starting velocity of subsurface flow (SSF) depends on water tension and gravity, as well as horizontal and vertical hydraulic conductivity, which is influenced by the size, distribution, and continuity of the voids (NOGUCHI et al. 1999).

It is not possible to derive the starting velocity of deep subsurface flow (DSSF) from surface geomorphology – this requires hydrogeomorphic mapping. However, this is not considered necessary in retention measure planning, because deep subsurface flow is not influenced by surficial land-use measures. The spatial information pertaining to runoff processes and runoff velocities can be linked and evaluated, within GIS using the decision tree. The GIS presents the spatially related plot runoff sensitivities. These digital maps are the basis for planning runoff retention and attenuation measures in forests (Fig. 3).

3.3. Discharge accelerating linear structures

The planning of water retention precautionary measures requires an inventory of discharge-accelerating linear structures – drainage and road ditches, pipes, runoff lines and erosion channels, forest roads, and logging trails (BOTT, 2002). A decision tree with "yes/no"- key questions was developed to evaluate runoff from forest roads (BACKES,2005). The underlying premise is that forest roads promote rapid runoff. This negative effect can be diminished with special construction methods and precautionary measures. The first question of the decision tree asks if a road seals the forest soil surface. If it does, then a forest road causes Hortonian overland flow (HOF). If the road and accompanying ditches enable the surface water to be widely diffused back into the forest, the runoff is estimated to be comparable to that of the surrounding forest sites. For dirt forest roads, the next question asks if the road has a humus layer, branch-wood reinforcement, or vegetation cover. Our investigations showed that these can improve the runoff reaction (BACKES, 2005). Surface water on bare dirt roads becomes overland flow (SOF, HOF), and the steeper the road the faster the runoff.

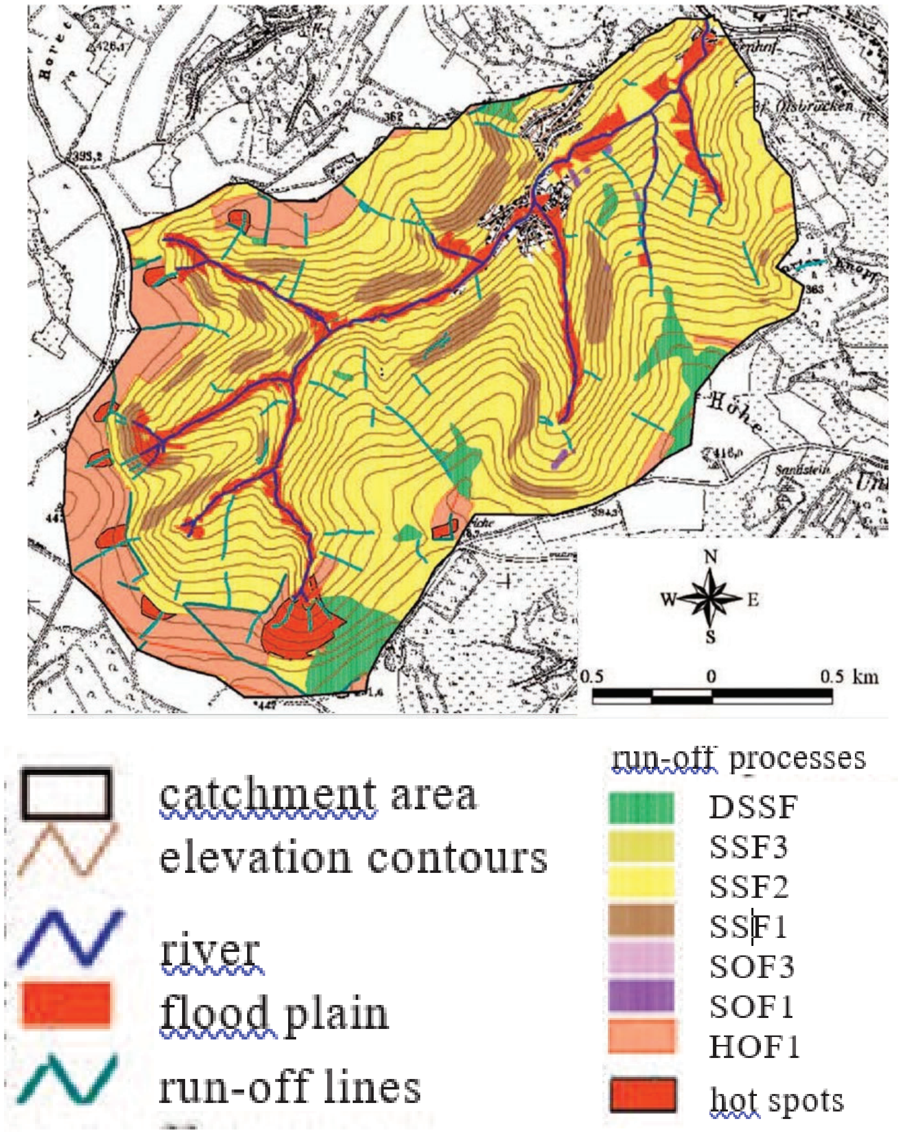


Figure 9 - This map, produced within the WaReLa-project, displays runoff sensitivities in a test site in the south west of Germany. It is the result of linking the spatially explicit information of the forest site survey with the decision tree of runoff sensitivity

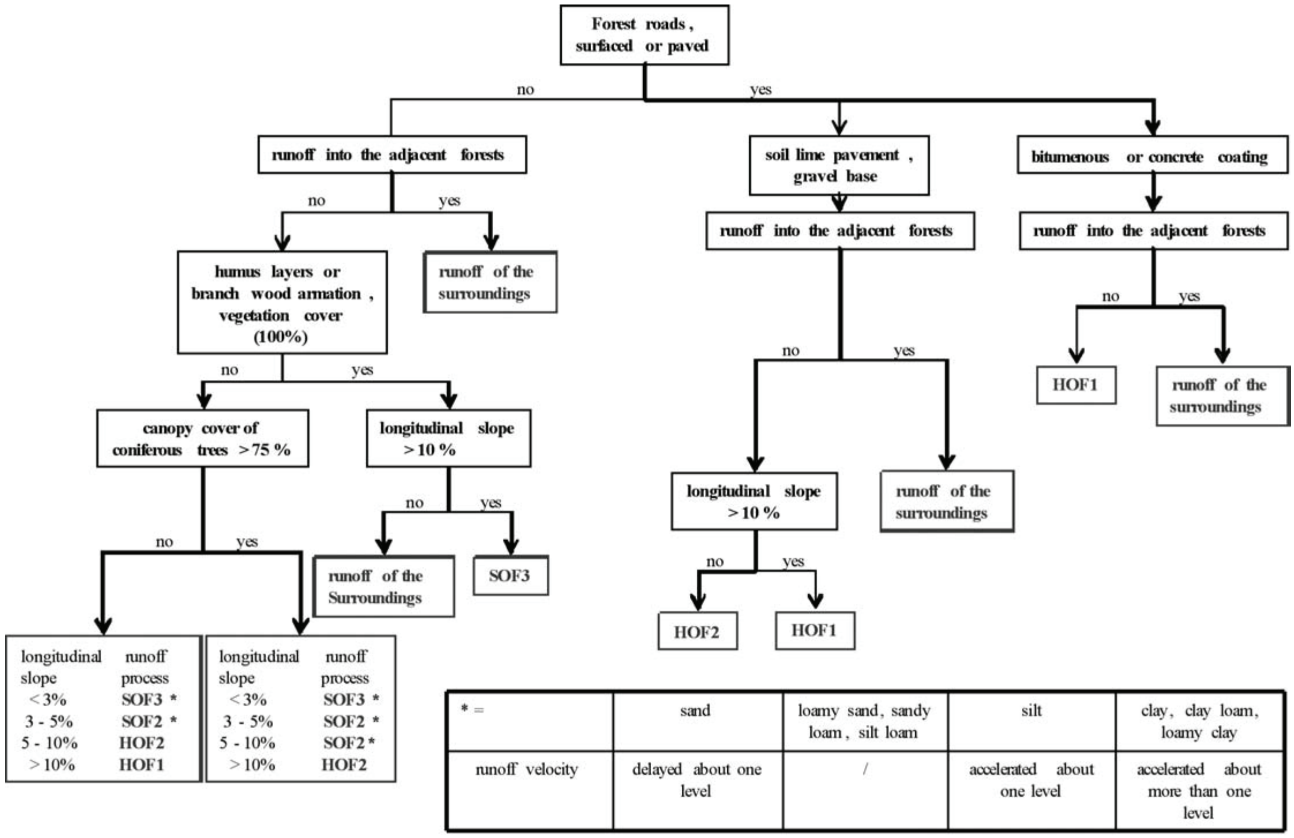


Figure 10 - Decision tree to derive the runoff from forest roads (Backes and Schubert 2005 unpublished)

Forest management is a spatial activity – harvesters, skidders and forwarders operate in the forest area. The operation of heavy equipment, especially on siltu and loamy soils, compacts the soil to deep soil horizons (HILDEBRAND and WIEBEL 1986).

The volume of rapidly draining macropores is decreased and the continuity of the soil pore system is disrupted (HILDEBRAND 1983). All extraction trails lose their water retention function, and as they are intensively used linear structures, they increase the velocity and the amount of runoff (BOTT 2002).

The inventory of linear structures and incorporation of the data into digital planning maps are key steps, because precautionary measures to deactivate the drainage function of linear structures are likely to be highly efficient in decreasing discharge from catchment areas.

4

GIS MODELLING

GIS (Geographic information system) nowadays is the basic tool for describing spatial relationships, spatial analyses and mapping. So the main idea behind the term GIS modeling is to make a connection between the main input parameters which can be represented in spatial terms and establish the spatial relationships and finally do spatial analysis and represent the results on a map and also extract quantifiable data about the impact.

The first step is to establish the theoretical background of the model. The general theoretical background should be modified to be applicable to local conditions. Generally, there are quite extensive models that require a lot of input parameters. The established methodology where it was developed, maybe it was quite common to collect on a regular basis several types of data. In our case, the input parameters should be adjusted to what is locally available and it does not require outsourcing of human resources.

4.1 Collection of available data

The main spatial input parameters (GIS layers) which are available in the country and should be considered:

- Soil map, developed by Ss. Cyril and Methodius University in Skopje: Institute of agriculture, Faculty of food and agriculture, http://www.maksoil.ukim.mk/masis/, 1:50,000;
- Geological map, developed by Geological institute of RNM, 1:100,000;
- Forest management plans, developed by Public Enterprise National Forests, 1:20,000, including forest management units and forest road network;
- DEM (Digital elevation model) of the country; there are several DEM's which can be downloaded on-line, but the best resolution which can be obtained in the country is 5m spatial resolution DEM from MAFWE (Ministry of Agriculture, Forestry and Water Economy);
- Soil erosion map, developed by a team from the Faculty of Forestry through the UNDP project "Erosion Study and Action Plan for the City of Skopje", 2017;
- Other ancillary GIS layers: Hydrographic network, Inhabited areas, Land cover/use, Climatic data, etc.

4.2 Incorporating base layers into the modelling environment

The next step is to reclassify the base layers into meaningful classes into the model. The soil and geology classes should be assigned with permeability code: 1 – impermeable, 2 – permeable soil and 10 impermeable, 20 – permeable geological surface. Next, these two layers are combined (union) and the code for the permeability is with four possible combinations (11, 12, 21, 22) in which the first number represents the geology and the second is the soil.

The DEM is used to extract the slope of the terrain. The slope is produced in two variants: slope in degrees and slope in percent. Next, the slope in degrees is classified into four classes with the following breaking points: 2, 20, 40 degrees which later will be used for establishing the type of run-off.

The road network that was taken from the management plans or digitized from satellite or aerial images later should be split into segment not longer than 200 m'. These segments are overlayed with the slope in percent and the roads are assigned with an average slope of the section. Then all of the segments are classified in slope classes with the following break values: 3, 5, 10 percent. Further on, these classes are assigned with run-off processes.

The soil erosion map is used to assign hot spots in the catchment area by extracting the most severe erosion types (class I and II). The methodology is elaborated in details in the previous chapter.

5

CASE STUDY - NORTH MACEDONIA

5.1. DESCRIPTION OF STUDY AREA IN NORTH MACEDONIA

5.1.1. Introduction

The study area is located only a few kilometers from the city of Skopje, on the mountain of Skopska Crna Gora. In August 2016, after heavy rainfalls on the mountain with intensity P > 110 mm, torrents caused catastrophic flood with lot of damage and 22 fatalities. (Blinkov I., 2016)

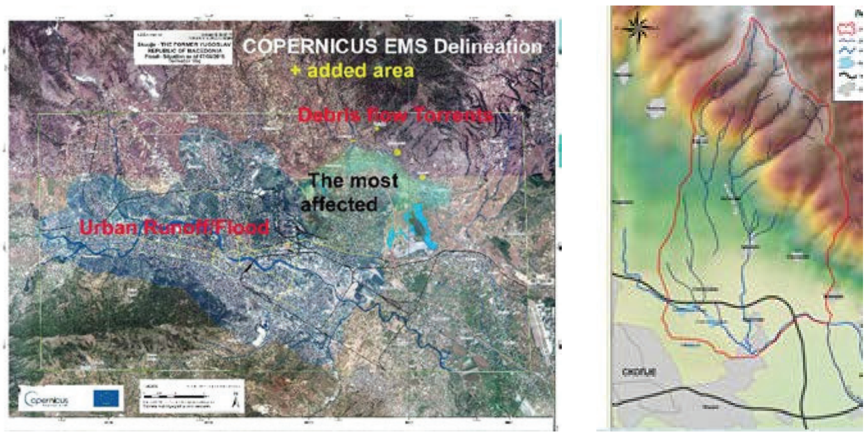


Figure 11 - Flooded Area, 2016

Figure 12 - Sediments near the ring-road

Figure 13 - Consequences of torrent flood in downstream settlement Stajkovci

5.1.2. Location

The study area is located northeast of the city of Skopje. Study area encompass two neighboring catchments located on the mountain Skopska Crna Gora: Creshevska Reka (A = 1537 ha) and Vinicka Reka (A = 609 ha). During the flood in 2016, these 2 catchments caused the most catastrophe flood in the region.

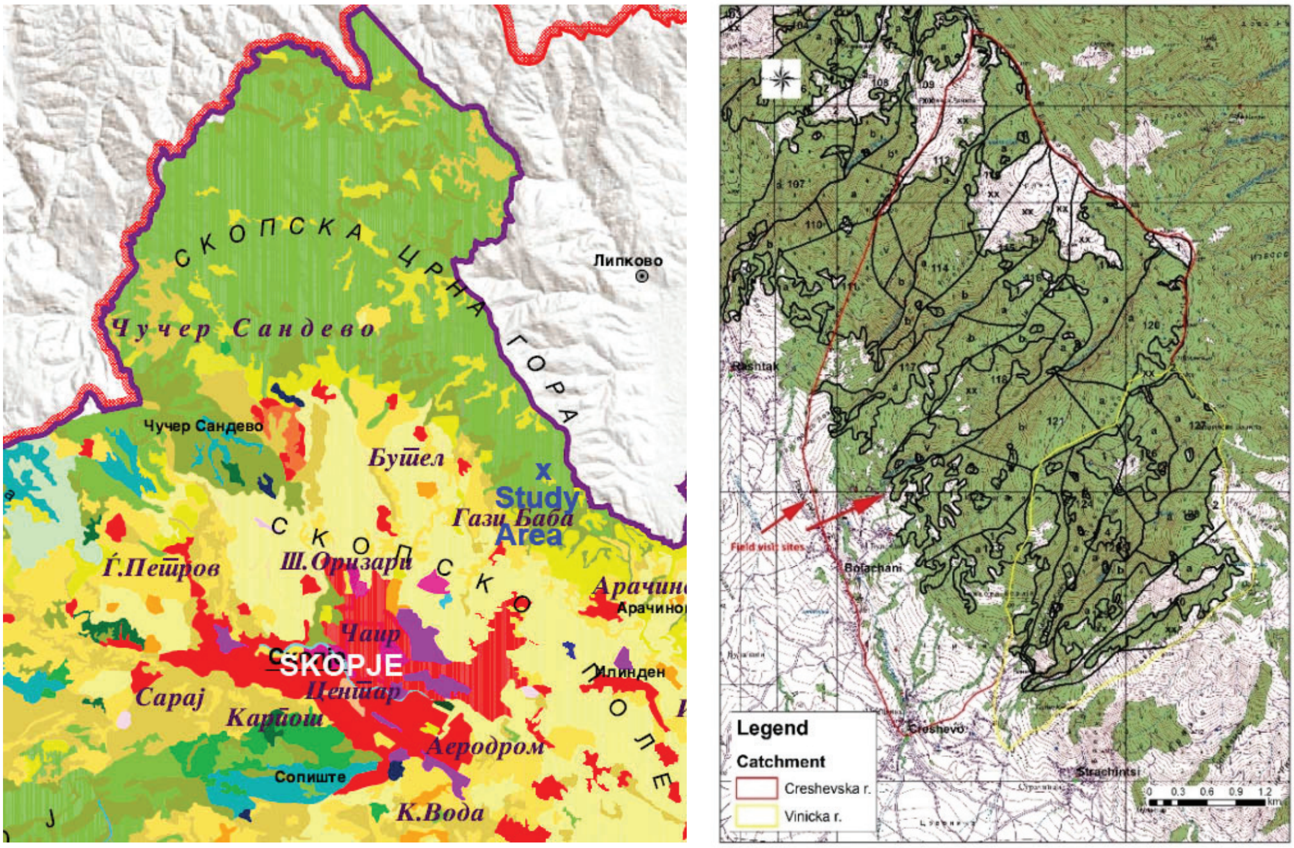


Figure 14 - Location of the study area and catchments

These catchments cover the southeast part of the Forest Management Unit (FMU) “SkopskaCrna Gora”.

Within Cresevska Reka catchment are located the following compartments: 112, 113, 114, 115, 116, 117, 117, 118, 119, 120, 121, 122, 123 (western part).

Within Vinicka Reka catchment are located the following compartments: 123 (eastern part), 124, 125, 126, 127, 128, 129 and 130.

Following the rules and practice in the forest management planning in the country, areas that are not covered with forests or woodland especially in the downstream area are not included in the FMU.

Figure 15–Part of Forest management unit “SkopskaCrna Gora”

5.1.3. Topography and Hydrography

Both catchments are exposed to the southwest. The extreme altitudes of the catchments are as follow:

- Cresevska Reka: 350 m asl, 1579 m asl,
- Vinichka Reka: 370 m asl; 1317 m asl.

Having in mind that FMU doesn’t cover the whole catchment, the extreme altitudes within the compartments form the FMU are as follow:

- Cresevska Reka: 530 m (compartment 123); 1579 m asl,
- Vinichka Reka: 440 m (compartment 129); 1317 m asl.

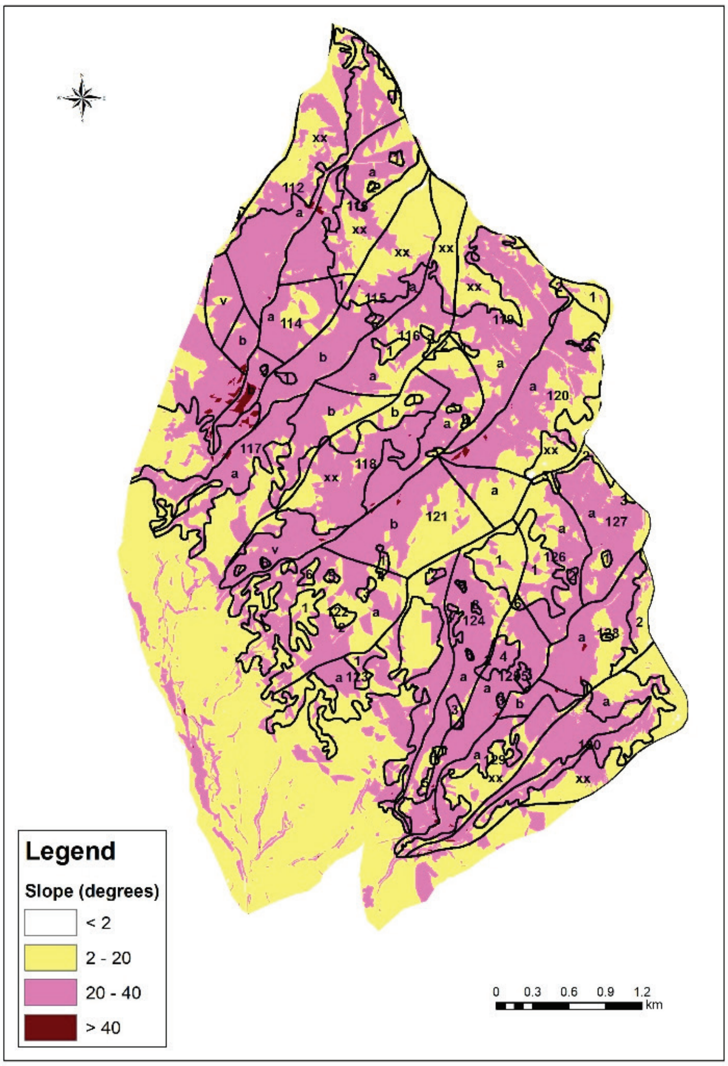


Figure 16 - Slope map (o)

Slopes are different, but dominantly between 2-20^{o} and 20-40^{o}.

Only on a small area slopes are over 40^{o}. Cresevska Reka has an irregular shape of the catchment (ratio between left and right side). In the upper part, two parts (Surinska Reka and Bulancanska Reka) confluent and flow downstream. Then the river receives the largest left tributary Straska Reka in the village of Bulacani. Near of Cresevo, there are few small left tributaries.

Vinicka Reka origin from the area “Vrelo”. Near the village of Vinice, river is receiving 2 similar tributaries (1 left and other is right tributary). The shape of the catchment is uniform.

5.1.4. Climate

The climate in the study area starting from continental-submediterranean in the lower part, warm continental up to cold continental climate in the highest altitude.

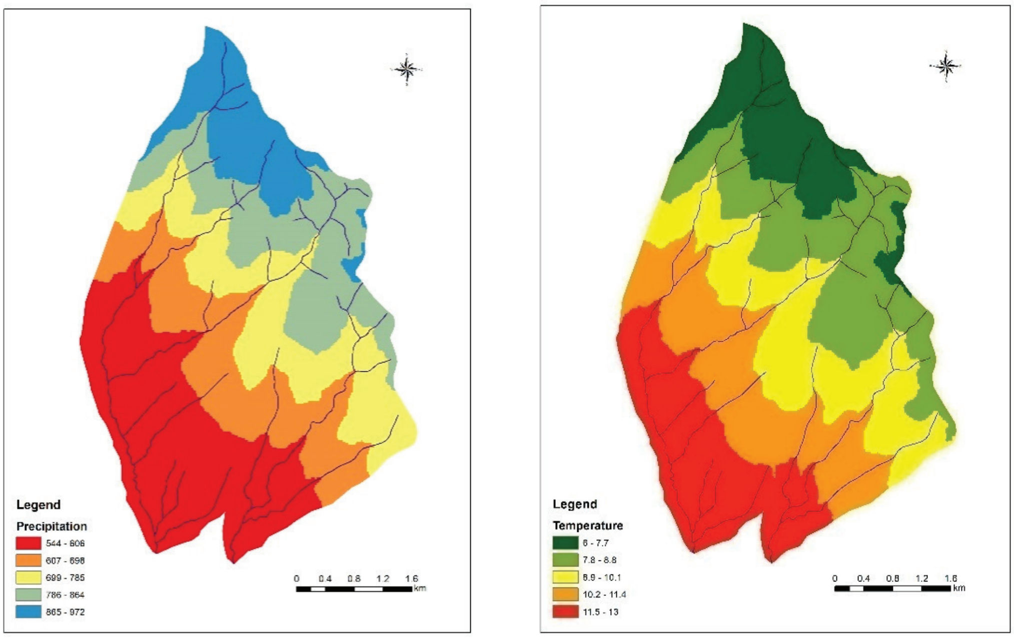


Figure 17 - Isohyet and isotherm map of the study area

The Skopje valley is a very dry area with an annual rainfall of around 500 mm with a non uniform distribution. On the Skopska Crna Gora Mountain, precipitations rise up to over 850 mm in the high mountain area. The recent climatic changes brought several downpours during the spring-summer period which is bringing higher risks and prone to rain-related natural hazards. Temperature is another climatic factor influencing erosion. While, frozen soil is highly resistant to erosion, rapid thawing of the soil surface brought on by warm rains may lead to serious erosion.

Table 6 – Intensive rainfalls with various duration and probability for Skopje Blinkov I., 1997)

Prob.	element	5`	10`	20`	40`	60`	90`	150`	300`	720`	1440`	24 h
	mm	23.04	39.16	53.21	65.04	69.53	71.61	75.19	84.07	109.76	125.19	104.29
0,1%	mm/min	4.61	3.92	2.66	1.63	1.16	0.80	0.50	0.28	0.15	0.09	0.07
	mm	17.25	28.94	39.49	48.27	51.71	53.49	56.70	63.40	81.63	93.30	82.90
1 %	mm/min	3.45	2.89	1.97	1.21	0.86	0.59	0.38	0.21	0.11	0.06	0.06
	mm	15.50	25.85	35.33	43.19	46.31	48.01	51.10	57.14	73.12	83.65	74.56
2 %	mm/min	3.10	2.59	1.77	1.08	0.77	0.53	0.34	0.19	0.10	0.06	0.05
	mm	13.73	22.74	31.15	38.08	40.88	42.48	45.47	50.84	64.54	73.93	66.15
4 %	mm/min	2.75	2.27	1.56	0.95	0.68	0.47	0.30	0.17	0.09	0.05	0.05
	mm	9.47	15.22	21.05	25.73	27.76	29.14	31.86	35.62	43.83	50.46	45.85
20 %	mm/min	1.89	1.52	1.05	0.64	0.46	0.32	0.21	0.12	0.06	0.04	0.03

Taking into consideration, the time of concentration of the selected catchments, the most relevant area precipitations is with duration 60 – 150'.

5.1.5. Geology

Parent material influence soils through its mineralogical composition, coherence, and permeability for water. Mineralogy influences the amount, particle size distribution and type of weathering products wherein the soil profile develops; coherence or hardness determines the resistance to weathering and speed of disintegration; permeability influences the intensity of physicochemical transformations within the original rock residue.

Catchments of the both torrents that are part of the FMU generally consist of **impermeable rocks** as follow: Quartzite (olive green - all compartments), Quartz-sericite-biotite schist (dark red – all compartments), Meta- Quartz-porphyry (light blue - 119, 120), Marbles (dark violet -123,124, 130)and Turbidite molasses-claystone, vapor (light violet – 123, 129).

Only a small part of the catchments consist of **permeable rocks,** but these areas are almost completely out of the FMUs as follow: Pliocene sediments – sands, gravel, clay (light green) and diluvium-proluvial sediments (blue).

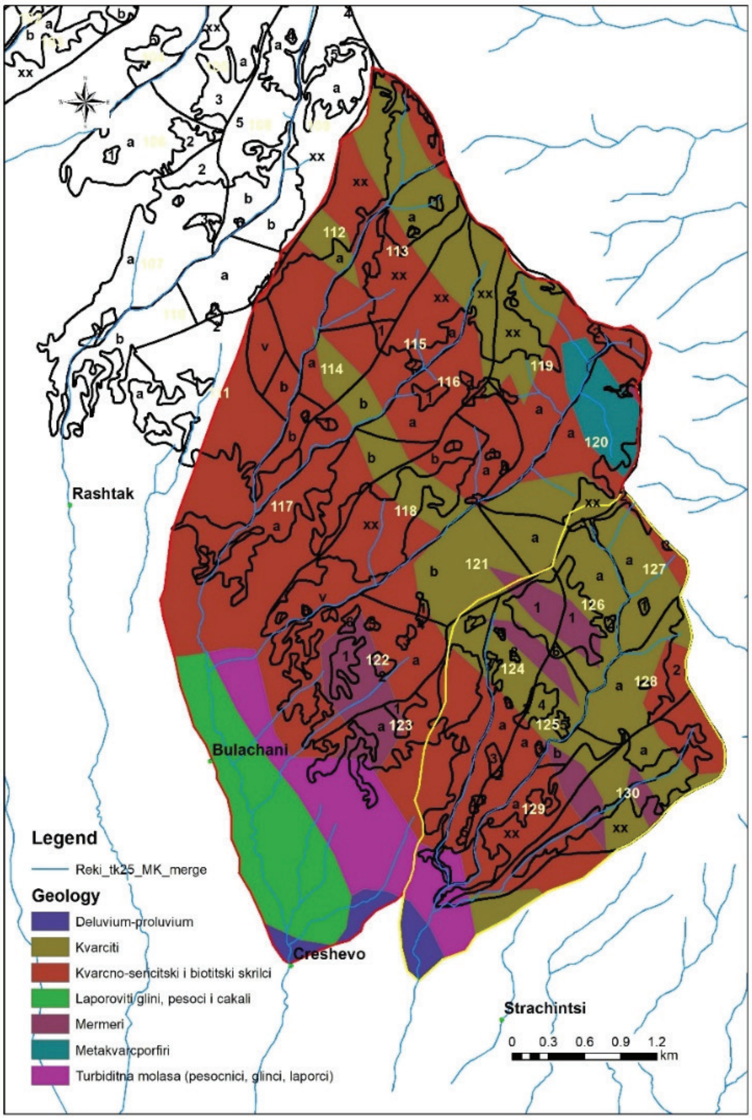


Figure 18 - Geology Map

5.1.6. Soils

Within the Cresevska and Vinicka reka catchments are defined as the following soil types and soil complexes. Soils within the FMU:

- The complex of Cambisol, Humic Eutric, and Umbric Regosol (on the highest parts of the catchments)
- The complex of Cambisol, Humic Eutric, and Umbric Regosol and Leptosol (the greatest part of the catchment)
- Small areas in the lowest part of some compartments: Complex of Vertisol, Chromic Luvisol and Regosol

Soils out of the FMU:

- Humic calcaric regosol (near Cresevo)
- The complex of Vertisol, Chromic Luvisol on saprolite and Regosol (in the lowest part of the catchment)

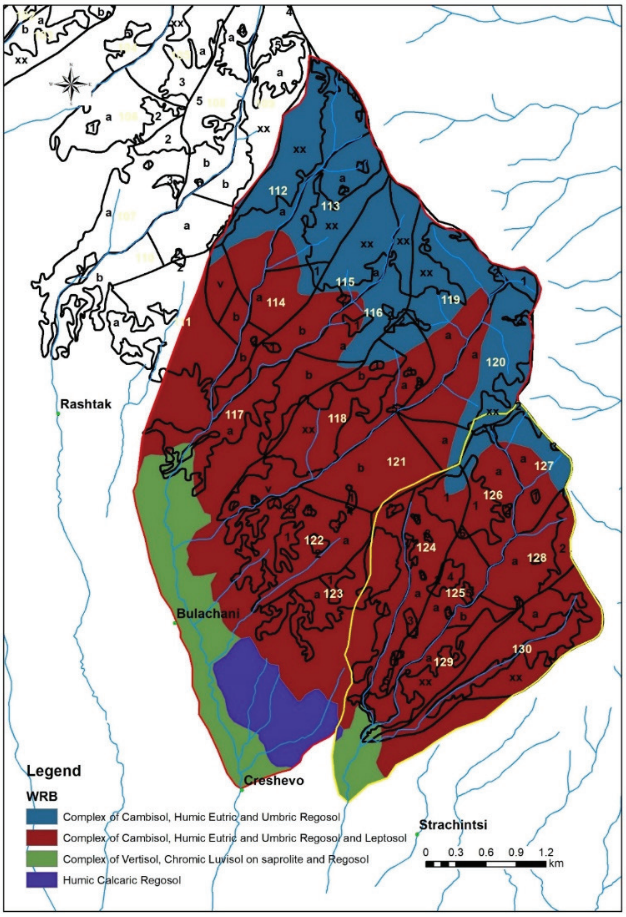


Figure 19 – Soil Map

Soils within the FMU are shallow to mid shallow. According to the texture, fine sand and skeleton dominate in both soil types (rankers and cambisols). Cambisol is characterized by high acidity and depends on a profile of various content of organic matter. Rankers are high acid too. Permeability of the soils within the forest management unit is high.

Table 7- Basic characteristics of soil (MAKSOIL., 2015)

Profile nro	Type of Horizont	Depth of horizon	organic Matter	pH in H2O	pH in NKCL	Sceleton >2 mm	Soild sand 0.25-2	Fina sand 0.02-0.25	Silt 0.002-0.02	Clay <0.002mm	Hygroscope moisture
		cm	%			%	%	%	%	%	%
Leptoosol (Ranker)											
OO5.20	A	0-15	3,82	5,55	4,57	14,56	28,02	47,13	21,57	3,28	2,47
OO5.21	A	0-16	3,17	6,08	4,67	37,61	35,63	35,86	21,73	6,78	1,05
Cambisol											
OO5.24	A	0-15	2,16	3,80	2,97	30,03	23,30	47,67	23,73	5,29	1,35
	(B)v	15-31	1,80	4,72	3,42	27,30	23,29	45,39	23,63	7,69	1,33
OO5.25	A	0-16	5,04	6,40	5,27	33,46	23,64	39,84	27,96	8,56	2,56
	(B)v	16-34	2,83	5,80	5,20	43,74	22,57	35,76	34,00	7,67	2,79
Humic calcaric regosol											
B 117.Sk	Ap	0-36	2,74	8,06	7,1	8,64	7,11	19,69	43	30,2	3,16
	AC	36-64	1,57	8,25	7,26	3,06	5,72	17,58	42	34,7	2,76
	C	64-92	0,41	8,40	7,38	0,4	0,64	18,16	48,5	32,7	2,06

5.1.7. Land Cover/Use and vegetation

The greater part of the area is covered by broadleaved forests with significant appearance of transitional woodland. The lower part of area is used for agriculture. The high mountain area is under natural grasslands. All forests are coppice forests. Dominant tree species are:

- Sesile Oak (*Quercus petrea* Matt.) in the altitude up to 1250 m asl.
- Clear stands or mix stands of Common hornbeam (*Carpinus betulus* L.).
- Beech *(F. sylvatica* subsp. *moesiaca* (K.Malý) Szafer) is spread on higher altitude, somewhere beech appears in mix stands of Sesile Oak even with Common Hornbeam.
- Only on a few locations in the lowest altitude can be found Downy Oak (*Quercus pubescencs* Willd.).

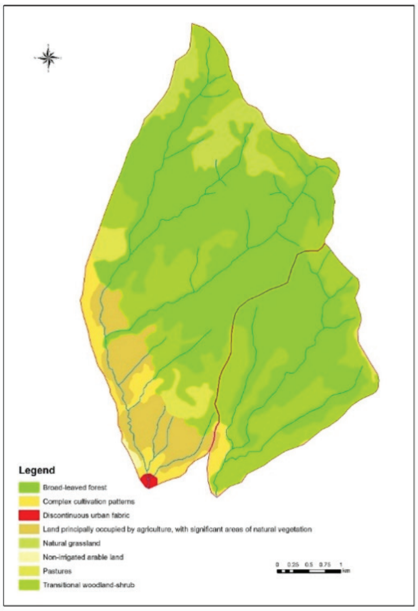


Figure 20 - CORINE Land Cover/Use distribution

5.1.8. Hydrology

In this chapter are presented only parts of hydrological parameters necessary for the calculation of maximal water discharge and mean annual produced and transported sediments. These parameters provide an overview of the catchment characteristics.

Table 8 - Basic hydrological characteristics of catchments

Parameter	m.u.	Cresevska	Vinicka
A - Catchment area	km^2	16.50	7.41
Lt – Length of thethe river	km	8.73	5.99
U – Distance from the center to the profile	km	4.56	3.25
O – catchment perimeter	km	21.02	14.23
B = A/0 mean width	km	0.78	0.52
Hav – Mean altitude	m asl	890.67	815.76
Hmax – maximal altitude	m asl	1579.00	1317.00
Hmin – minimal altitude	m asl	302,00	285.00
Δ H – mean altitude difference	m	588.67	530.76
K – coeff. of concentration in the catchment		0.34	0.32
Iav – Mean slope of the catchment	%	34.00	36.00
Tc - Time of concentration	hours	1.89	1.38
d – Moisture deficit	mm	67.52	127.95
CN – Curve number		79	66
S1 – coef. of permeability (0.4-1)		0.43	0.41
S2 – coef. of vegetation cover (0.6-1)		0.62	0.67
η – runoff coefficient		0.38	0.39
Q100 – maximal water discharge (1% probability)	m^3/s	42.94	24.32
Pa – mean annual precipitations on the catchment	mm	748.00	748.00
Z – coef. of erosion by Gavrilovic (0,05 -1,5+)		0.45	0.44
W – mean annual produced erosive material	m^3	11590.00	5205.03
G – mean annual transported material to profile	m^3	8767.62	3605.66

Note: Data in the above table is taken from the project “Erosion Study and Action Plan for the city of Skopje”, (Blinkov et al 2017) and “Feasibility study for solving torrent floods form SkopskaCrna Gora”(GeoMap design, 2019)

As a relevant profile is accepted the village of Cresevo. This is a point from where floodwater flow in the field taking into consideration although there is a channel. On the exit from the village there is a S-curve and in a case of huge discharge and high-velocity water exit from the bed and flow everywhere in the lowland.

As relevant profile for Vinicka Reka is accepted the village of Vinice. There is a similar situation. Unlike Cresevska reka, there is no regulation of Vinicka Reka, and water flows everywhere in the lowland field.

5.1.9. Erosion

Various erosion processes (sheet, rill, gully erosion, stream bank erosion....) are spread on both catchments. The highest categories (I – very strong erosion or II – strong erosion) are located mostly in the mid parts of the catchments, on the various bare lends within the catchment or where vegetation is composed of shrubs with low coverage. The III category (moderate erosion) is unaccepted too, is defined in a greater part of the catchment that is generally under grasslands in the catchments. In the mid part of the catchment, where the land is under good forest cover are defined processes of an acceptable level of erosion (IV – weak and V – very weak erosion).

Taking into consideration, the low distance from the settlements and the downstream area, the highest categories of erosion (I and II) from map left (where erosion intensity = erosion hazard map) were selected to be developed actual erosion risk areas. Logically, a great portion of erosive material produced on the catchment achieves downstream section like in 2016.

All other territories of the catchments are delineated as potential erosion risk areas.

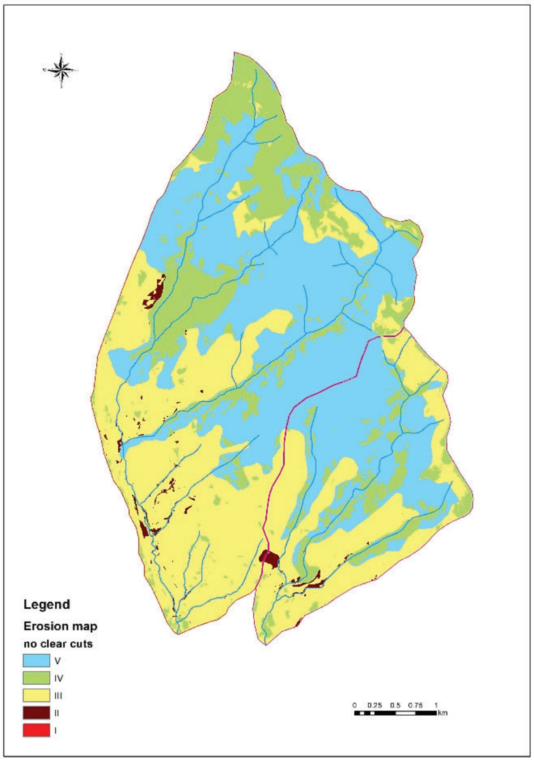


Figure 21 - Erosion Map of the area

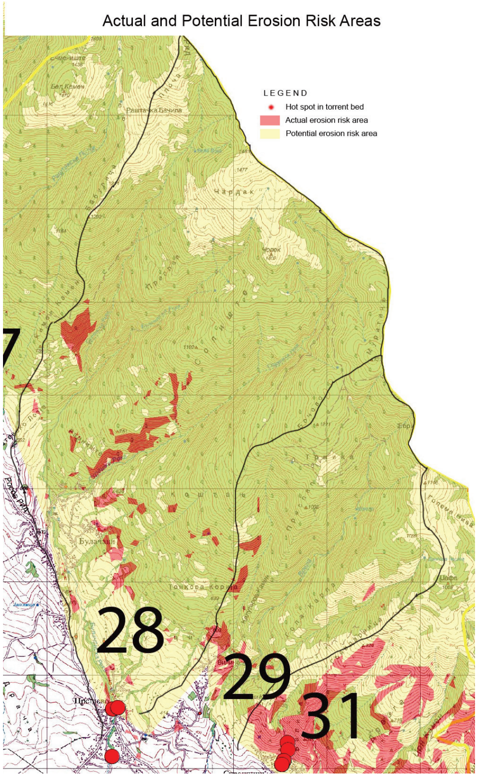


Figure 22 - Map of Actual and Potential Risk Areas

Note: These maps are developed through the project "Erosion Study and Action Plan for the city of Skopje" (Blinkov et al 2017)

5.2. Identification of flood generating areas

5.2.1. Identification of runoff-generating plots and discharge-contributing areas by forest site

Delineation is done following the approach by Schueler. Taking into consideration that gley soils are spread in the valleys in the country and are out of the forest management area, the right side of the logical tree.

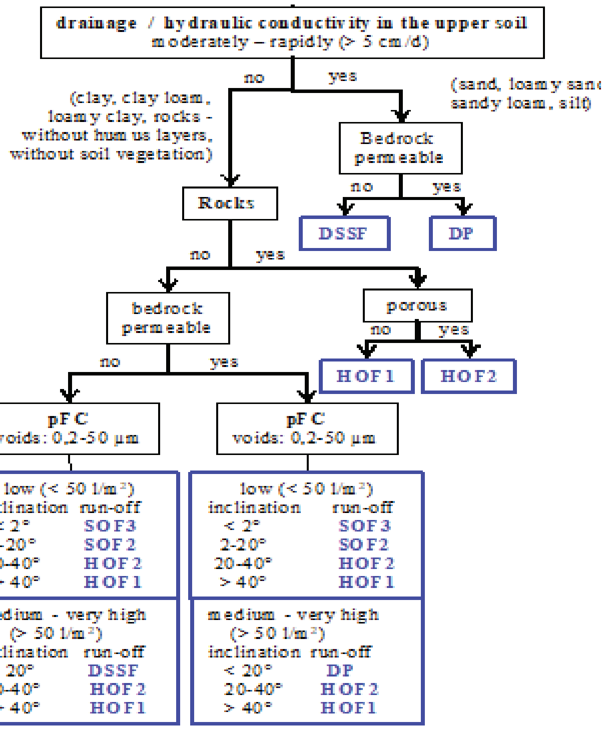


Figure 23 – Decision tree for identification of Runoff process

Table 9 - Runoff process within the forest management unit

Soil	Rock	Permeability		Runoff process
		Soil	Rock	
Cambisol	Quartzite, schists, Marbles, Metaquartzporfirite	Y	N	**DSSF**
Leptosol	Quartzite, schists, Marbles, Metaquartzporfirite	Y	N	**DSSF**

Within the FMU, soils (cambisol and leptosol) are permeable, while rocks are impermeable and according to the decision tree, the runoff process is assigned as DSSF – deep sub-surface flow.

DSSF – Deep Sub Surface Flow - High infiltration rate due to macroporous and permeable soil matrix. Lateral flow within a weathered layer above and impermeable geology.

Out of the FMU are defined in various soils. There is a soil type humic calcaric regosol (rendzina) that is developed over the geology type: turbidite mollasa (sands, claystone, and vapor) and on Vaporized clay, sands and gravel. Common characteristics for these soil type is the appearance of carbonates. The permeability of this type of soil is low. Beside it, is defined Complex of Vertisol, Chromic luvisol on saprolite and Regosol, developed over geology features Deluvium-proluvium (probably regosol), Turbiditemollasa - sands, claystones and vapor (Vertisol) and over saprolite – porous rocks (Humicluvisol). It is difficult and uncertain to delineate various soil types on the complex.

Table 10 -Runoff process out of the Forest Management unit

Soil	Rock	Permeability		Roc ks	pF C voids 0,2-50 μm Low / Med-High	Inclination o	runoff process
		Soil	Rocks				
Humiccalcari cregosol	Vaporized clay, sands or turbididemollasa	N	N	N	Medium to high	< 20 20-40	DSSF HOF 2
SOIL : Complex of Vertisol, Chromic Luvisol on saprolite and Regosol							
Vertosols	Vaporized clay, sands or turbididemollasa	N	N	N	*Medium to high*	<20 20-40	DSSF HOF2
Chromic luvisol on saprolite	Sediments	Y	Y				DP
Regosol	Sediments	Y	Y				DP

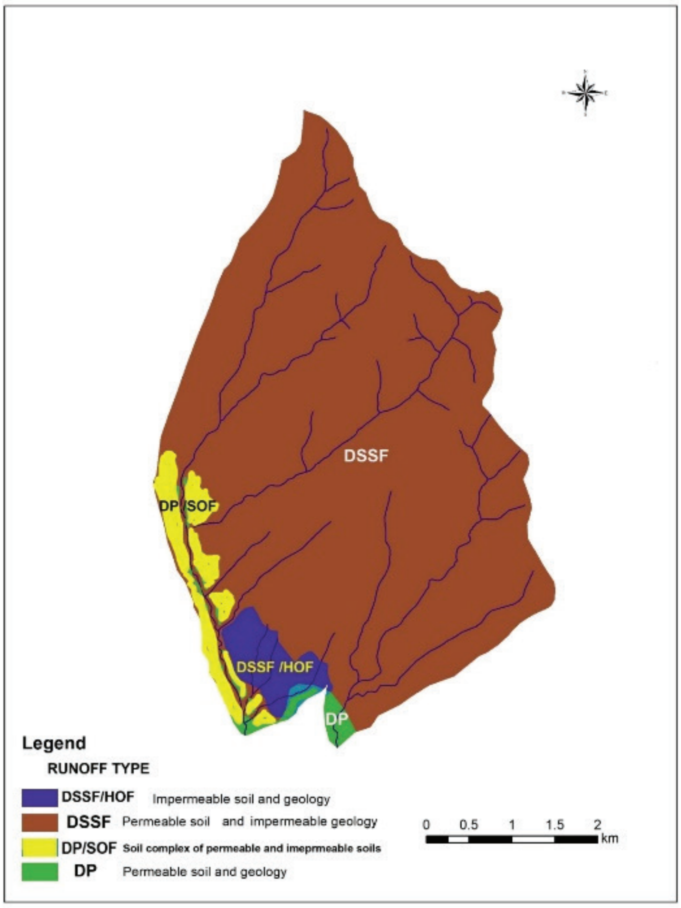


Figure 24 - Map of runoff process in the study area

DP – Macroporous soil due to plant roots and soil matrix provide good infiltration. Infiltration into highly weathered soil layers and into underground.

HOF – Hofman overlay flow, susceptibility for surface sealing due to few macroporous and a low permeable soil matrix.

SOF - Water saturation by infiltration into permeable soil layers above an impermeable layer.

Taking into consideration that in a part of the catchments, especially in the lowest part of the mountain that is out of the forest management unit is delineated soil complex of various soils per permeability (permeable + impermeable) or various slope is assigned as combined runoff process. Hot-spot areas - areas with high actual erosion risk are taken from the map of erosion risk.

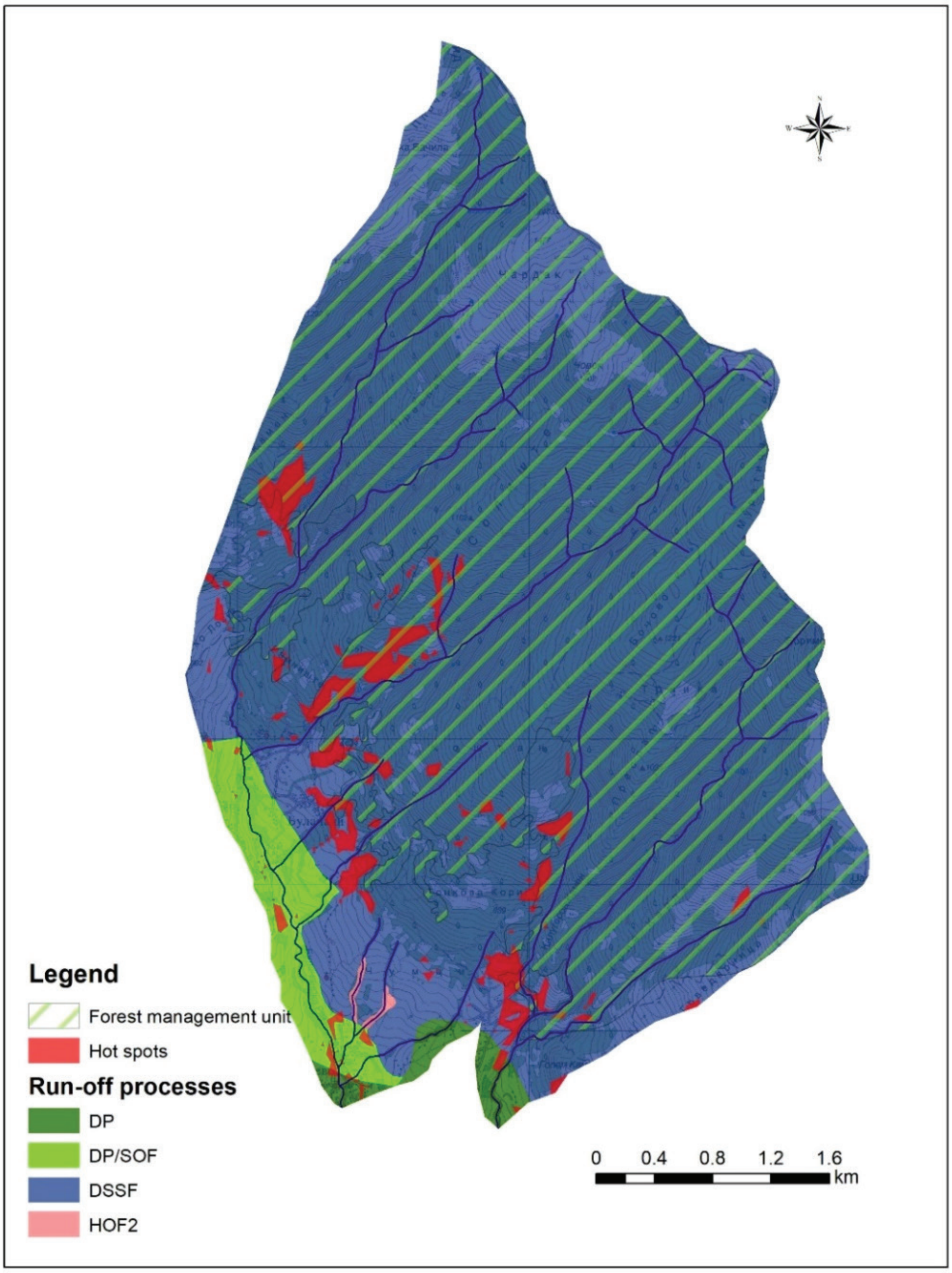


Figure 25 – Map of identified types of runoff process and hot spots

5.2.2. Discharge accelerating linear structures - forest roads

Within the study area there is a local road that connects villages Creshevo – Bulachani and on the west continues to the village of Rashtak. On the other side of the village of Creshevo there is a local road to village Viniche and on south to the village Stajkovci. These roads are paved by asphalt, are used for public transport and for forest transport too, although they are out of the FMU. The other roads are nonpaved roads. The underlying premise is that forest roads promote rapid runoff. This negative effect can be diminished with special construction methods and precautionary measures.

A decision tree with "yes/no"- key questions were developed to evaluate runoff from forest roads (BACKES 2005).

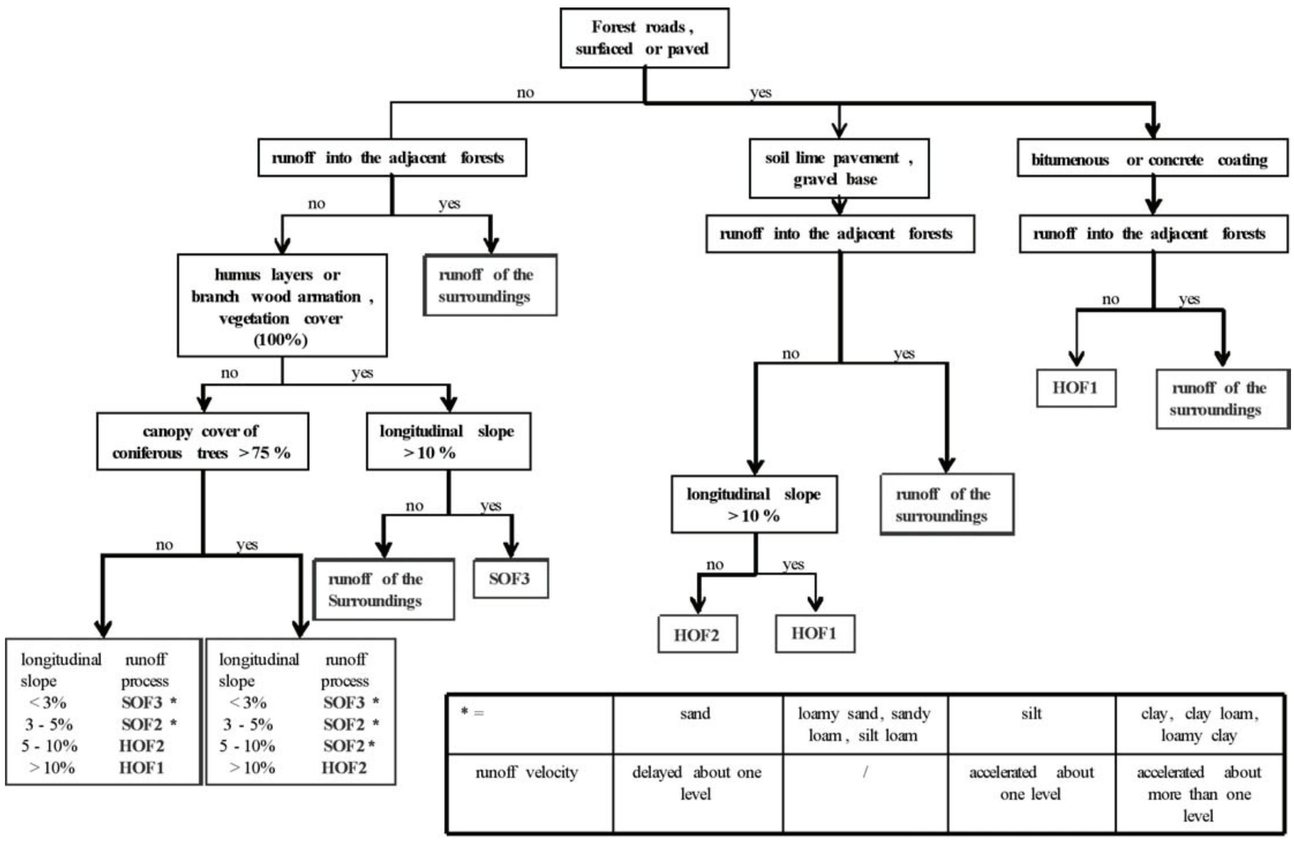


Figure 27 - Decision tree to derive the runoff from forest roads (Backes and Schubert 2005 unpublished)

The first question of the decision tree asks if a road seals the forest soil surface. If it does, then a forest road causes Hortonian overland flow (HOF).

None of the forest roads in the country including those within the FMU Skopska Crna Gora is paved. If the road and accompanying ditches enable the surface water to be widely diffused back into the forest, the runoff is estimated to be comparable to that of the surrounding forest sites. For dirt forest roads, the next question to be asked is if the road has a humus layer, branch-wood reinforcement or vegetation cover. Our investigations showed that these can improve the runoff reaction (BACKES 2005). Surface water on bare dirt roads becomes overland flow (SOF, HOF), and the steeper the road the faster the runoff.

Due to the irregular construction of forest roads in the country in general, most of the roads become overland flow partially. Consequences of overland flow are visible after heavy rains when rills on the road appear. Depend on the configuration of the surrounding terrain, some ditches are constructed with the aim to discharge water to the forest or to any stream in the forest. In some parts, foresters pave the road with branches.

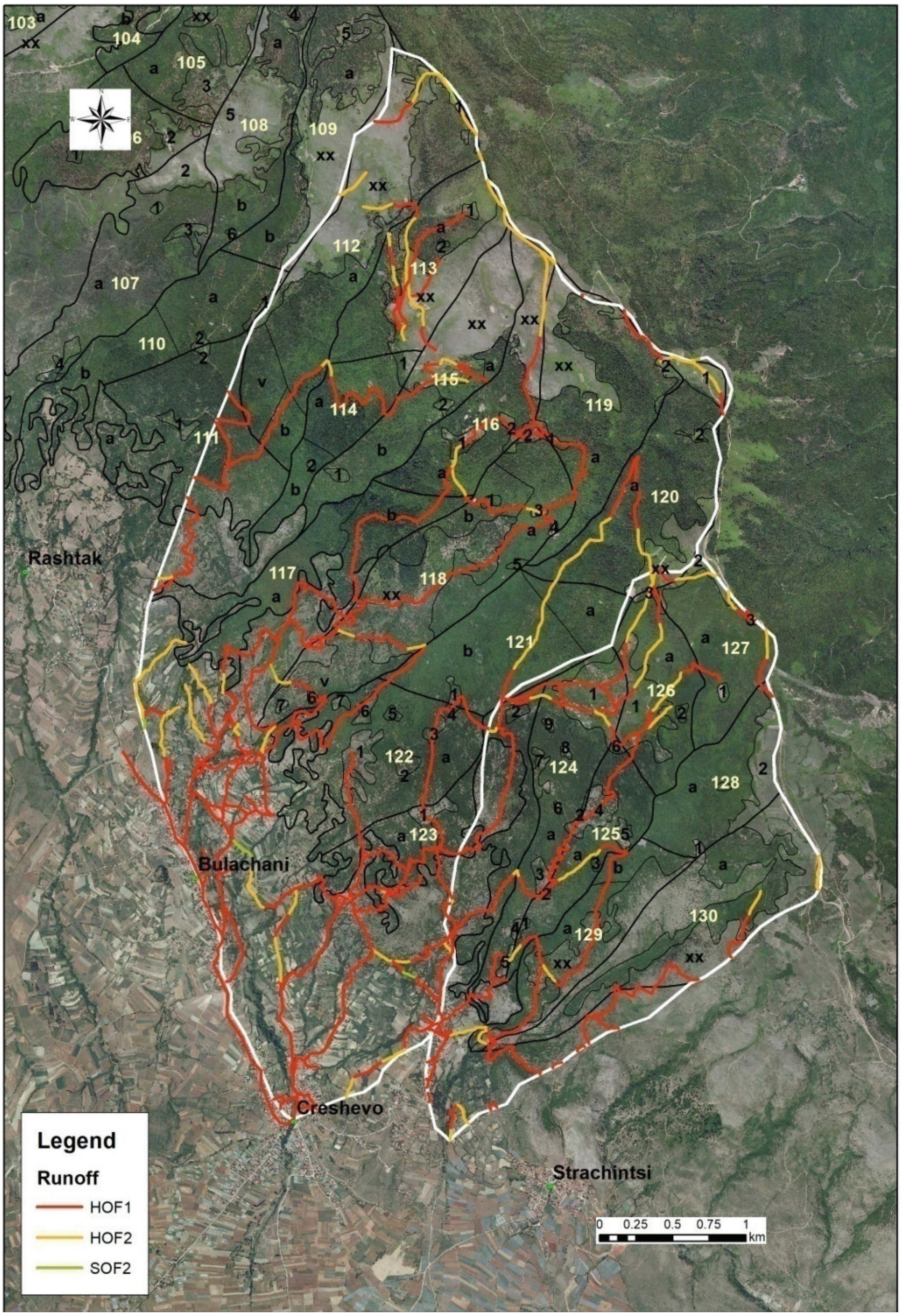


Figure 28 - Runoff process on forest roads

5.3. FOREST MANAGEMENT ACTIVITIES

5.3.1. Common forest management practices in the country

Forest management in North Macedonia is mostly focused on economy and production, while consideration to other forest services is not necessarily described in the content of the forest management plan (FMP) for the FMU. Some of the aspects that are not related to forest products and can be found in the content of the FM plan are related on monitoring of the health of the forests, silviculture aspects and some rough descriptions of allocations of the water springs, creek and river streams, appearance of some non-timber products, etc. According to current practice and regulation, not all aspects of sustainability are taking part in forest management planning, including forest ecosystem services for water and soil. Through our experience, during the preparation of the content of the FM plan there are no wider consultations with local stakeholders conducted.

This is a common practice in North Macedonia, where separate sectors are dealing with natural resources and often are neglecting internal connections and influence of the management with one natural resource with others.

In the forest legal framework, there are provisions that consider forest protective functions. In such cases, where management of forest will have an objective to enforce forest protective functions, protective forests shall be declared. In everyday forest practice, including forest planning, this is not implemented. There are simply no regular methods existing to define what are the main objectives for forest management in certain areas: is it only productive or it shall be conservation of nature, provision of tourism services, protection of water springs, water quality, erosion protection, etc. In addition to this, there is no Strategic Environmental Assessment Study conducted for the content of the FM planning, while the legal provisions (Law on environment and bylaws) are asking for that.

During the decision of the forest planner in the selection of the harvesting methods, there are no provisions that would limit the type of harvesting in relation to the soil type, slope, forest canopy, erosion potential, etc. There are so many cases where large forest complexes are harvested by clear cut and by that watersheds are immediately exposed to the effects of soil erosion.

That is why the importance of this project is so relevant to improve the current practice in forest planning. Common silvicultural felling in the country are:

Felling for offspring lighting (should be realized up to 10-years age; mostly on curved, physiologically weak stems);

Offspring clearance logging, (should be realized in the age 10-20 years; mostly on curved, physiologically weak stems);

Thinning (should be realized in age 20-40 in even-aged forest stands; based on intensity there are: low intensity, medium, and strong intensity thinning)

Space felling, (felling in mature stands, similar to thinning; trees that will remain in the stand are selected for future seed generation and should provide significant fructification)

A common measure for non-degraded forest (coppice or high forest) is partial felling, i.e thinning, space felling, etc. with various intensity. On the other hand, a common practice in degraded coppice forests is resurrection through clear cut.

Note: Within many years, after clear cuts almost nowhere further silviculture measures were applied

Depending on the way the mature trees are removed from the forests and the way young forests occurs, there are:

- clear cut, (on a wide area, on belts, on circles);
- insemination cut (realized in 3 phases: preparatory cut, insemination cut, final cut; sometimes in 2 or 4 phases; on a wide area, on belts, on circles);
- selective thinning (10-30% intensity of cut, extensive or intensive..)

Depending on management form, rotations in the high forest are longer than 60-70 years even 200 years, f..e for production of beech timber is 120 years). On the other hand for degraded coppice forest especially oak, the usual rotations are up to 50 years.

After logging, the next phase is skidding. Skidding in the country is realized mainly through animal skidding (horses) and log skidder tractors, while very rare with mobile cable for skidding etc.

Planning of forest road network within the forest management plans is a common practice, but it is not realized through any deeper analyses (f.e. taking in consideration various factors that influence this as follows: wood mass, slope, erosion susceptibility, geology, soil physical characteristics, landslide/landfall susceptibility, distance from streams, distance from fault, etc.). Usually planners set point A and B and any intermediate point and based on slope connect selected points, but very often incorrect.

Although according to the legislation, forest road construction should be realized based on a final design, not one road in the last 30 years is constructed based on any design. Somewhere engineers on filed design the alignment using a clinometer, but usually bulldozer machinist construct forest roads individually.

Regarding the maintenance of the roads, somewhere ditches are regularly cleaned and reconstructed, but usually maintenance occurs only after any huge damage of the road due to heavy transports, water runoff etc.

5.3.2. Planed activities in the study area and their effects

According to the current Forest management pLan for FMU " SkopskaCrna Gora", within the study area clear cuts are planned in the following compartments:

- 114 and 126 (management class M2 – coppice Sesile oak stands) and in
- 116 and 118 (management class N2 - coppice beech stands)

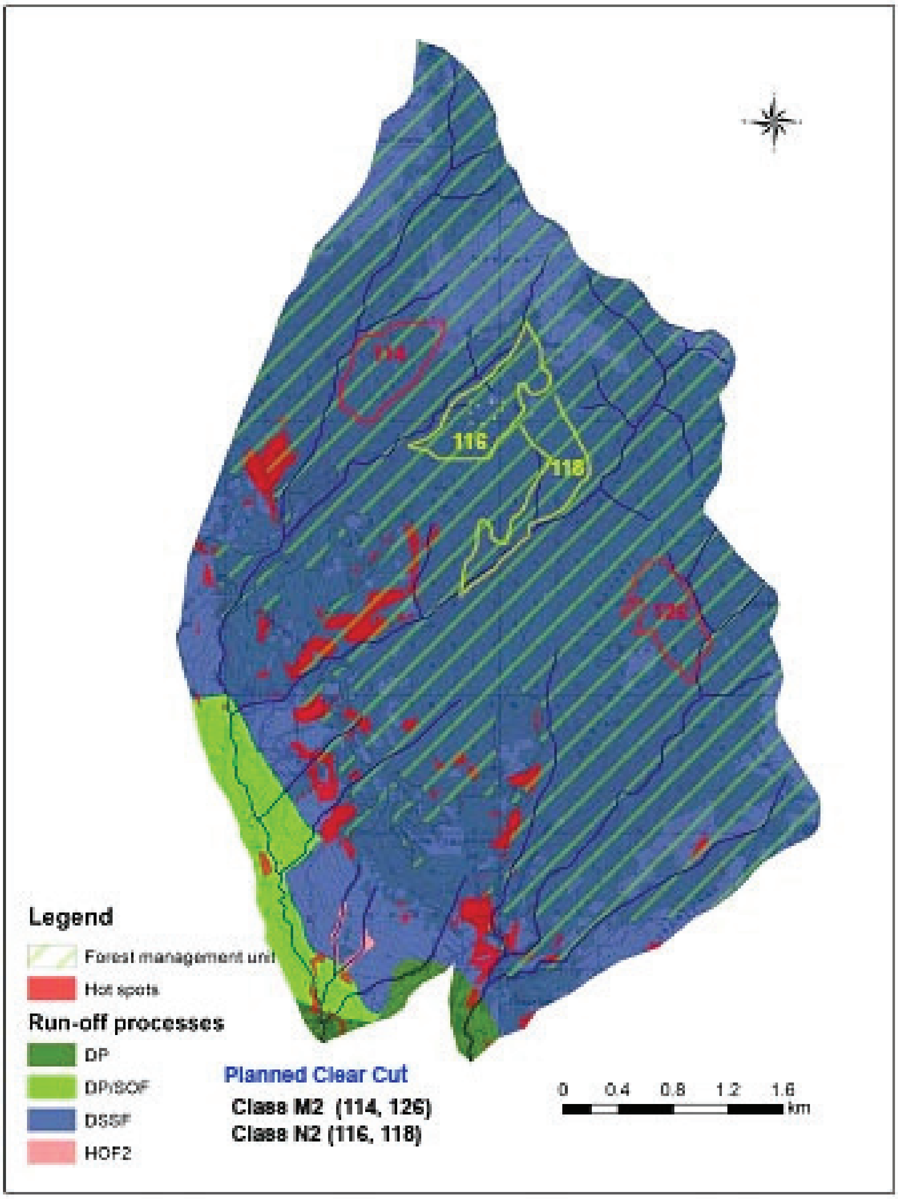


Figure 29 - Location of Planned activities - clear cut

Planed activities are in the areas where DSSF runoff process exists. As a consequence of clear cut, evapotranspiration will be reduced and will tend to increase runoff.

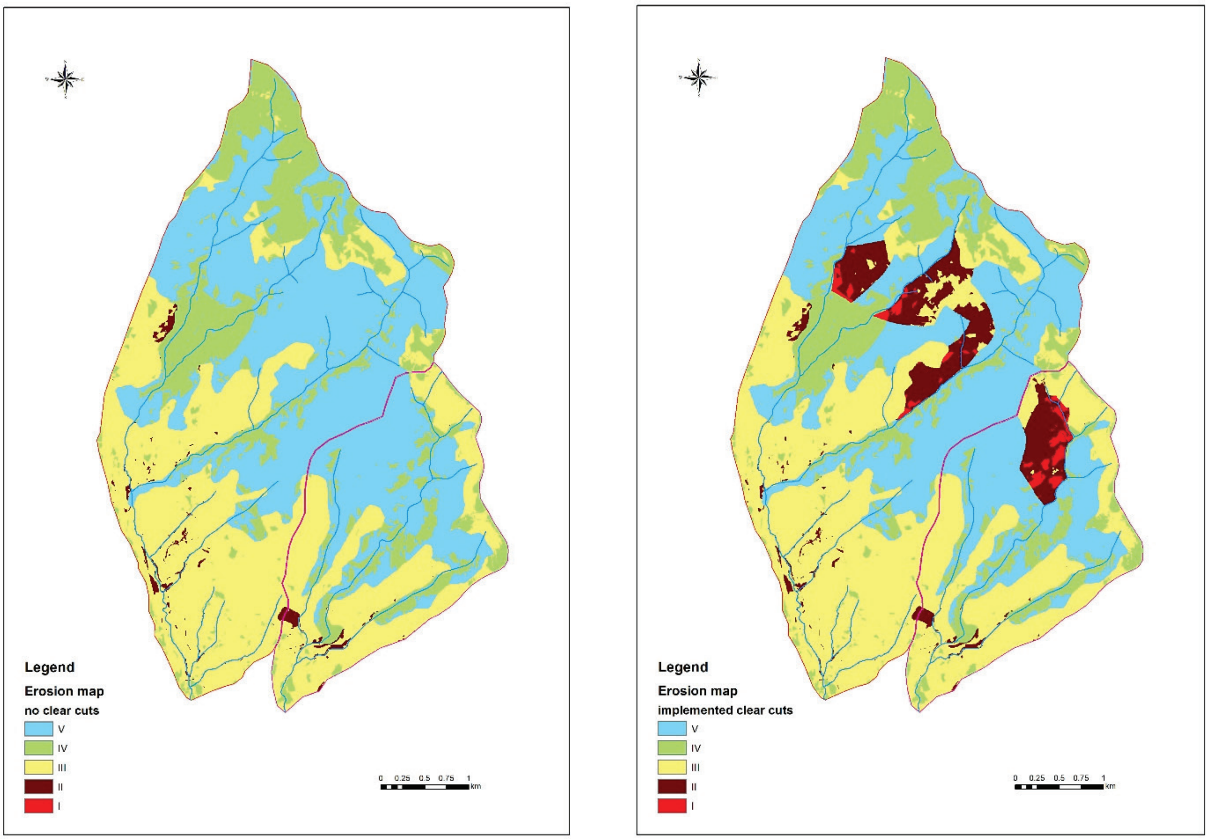


Figure 30 - Erosion intensity in current situation and after clear cut

On the other hand, erosion hazard will be increased significantly. In all compartments planned for clear cut, intensity of erosion processes will increase from V category (very weak erosion) up to I category (very strong) and II (strong erosion) processes.

Table 11 – Influence of clear cut on erosion processes and transported sediments

Catchment	Area – A -	Erosion Coeff. – Z - before and after clear cut		Incre-ase of Z	Transported annual sediments till lowest profile before and after clear cut - G		Increase of annual transported sediment– G	
		Before	After		Before	After	in total	percent
	ha			%	m^3/ann.	m^3/ann.	m^3/ann.	%
CreshevskaReka	1537	0,32	0,38	16.9	5063	6398	1335	26,4
VinickaReka	610	0,35	0,42	20.1	1845	2428	583	31,6

Generally on a catchment level erosion intensity will be increased for 16,9% (CreshevskaReka) and 20.1% (VinichkaReka). Soil loss expressed as produced sediments will increase for 1809 m^3 (cresevskaReka) and 931 m^3 (VinickaReka).

Besides the higher production of sediments, it will increase the quantity of total annual sediments transported to the lowest profile of the selected catchments (v. Cresevo and v. Viniche) for 26,4% and 31,6%. The first 2 years after the clear-cut, risk of appearance of high-intensity processes is very high and further will be reduced up to the 5^{th}-6^{th} year.

6

CASE STUDY - ALBANIA

6.1. DESCRIPTION OF STUDY AREA

6.1.1. Introduction

The study region is within the catchment area of the Ulza reservoir and belongs to the Mat river basin. The Ulza Hydro Power Plant (HPP) is located on Mat River upstream from the mouth of the Fani River and near the village of Ulza and Burrel town. It is a 64 m high concrete gravity dam with a straight axis with impounded volume of 240 mil m3. The reservoir created serves as a head pond for the Mat river cascade. Downstream from Ulza Dam is located the Shkopeti dam that is a 50 m high concrete gravity dam with an impounded volume of 40 mil m3. The Ulza dam has been constructed in the period of the year from 1952 to 1958. It is a concrete gravity dam with a straight axis. The water tightness of the dam foundation is achieved by a grout curtain.

Figure 31 – Location of Study Area

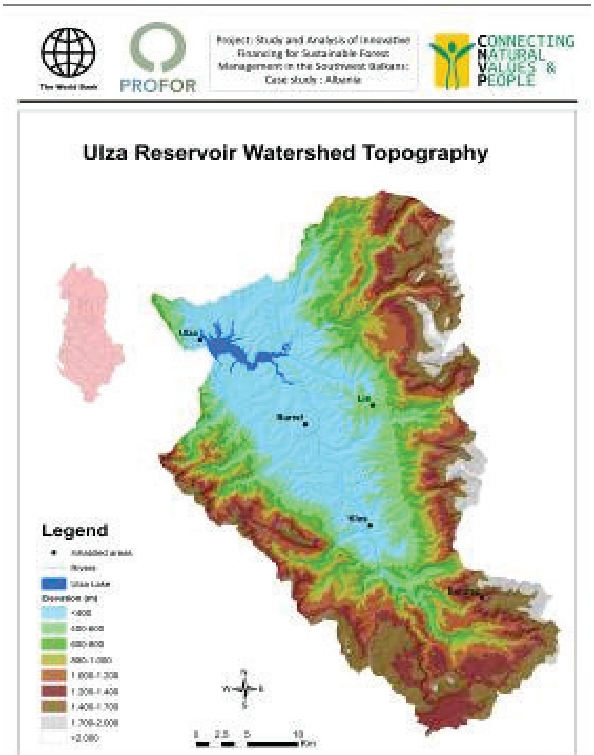


Figure 32 – ULZA reservoir basiin

For Ulza reservoir, the average annual inflow in the reservoir is 1 274 million m^3, the total storage is 170 million m^3, the maximum operation water level is 129.5 m a.s.l. and the minimum operation water level is 117.0 m a.s.l.

According to the study by CNVP (2014), erosion in the basin is huge and value of annual total produced sediments (erosion material on the catchment) is 1,8 million m^3. Out of them 1,36 million m^3 annually are transported to the reservoir Ulza or 1.112 $m^3/km^2/y$. Bathymetry done in 2013 shows that at least 31% of the reservoir storage is fulfilled with sediment i.e. cca. 75 million m^3 are deposed and consolidated within the storage in period from 1958-2013. The remaining lifespan of the reservoir is 121 years. (*Source: CNVP project – **"**Study and Analysis of Innovative Financing for Sustainable Forest Management in the Southwest Balkans", 2014).*

In 2018 a bathymetry was done by Beta studi s.r.l. and E.B.S Shpk. The total storage volume, from 1958 to 2018, was reduced of about 63 million m^3 or from 240 to 177 million m^3, with at least 26,2% of the total reservoir storage filled with sediment (Beta Studio – E.B.S Shpk 2019). The total lifespan of the reservoir was evaluated for 228 years. Based on this study, taking into consideration the climate change scenarios, the mean annual sediment siltation could increase from 1 315 000 m^3/year (RCP4.5 scenario) to 1 370 000 m^3/year (RCP8.5 scenario). Based on this predictions, the remaining lifespan of the Ulza reservoir would reduce from 134 or 119 years respectively. (Source: *"Conducting hydrological models and bathymetric measurements (Bovilla and Ulza Reservoirs*)" from BETA Studio s.r.l. and E.B.S Shpk, 2019).

The sediment yield estimated by Renfro model (1 607 784/1.2[1]= 1 339 820 m^3/year) was much closer to the results obtained by bathymetric measurements by CNVP (2014), where the average annual quantity of the reservoir siltation (effective annual sediment yield) was evaluated in 1 362 182 m^3/year, then in study by Beta (2018) where sediment yield is estimated as 1 052 175 m^3/year.

Various studies have reported a wide range of soil loss and sediments transport level from rivers in Albania. Thus, Bockheim (2001) states a national average soil erosion rate of 27.2 tons per hectare per year, which results in an annual sediment flux of 60 million tons carried by the Albanian watercourses. Moreover Bruci et al. (2003) reported a soil loss range of 20-100 tons per hectare per year for Albania. They also computed for the north, middle and south-east region of the country an annual average agricultural erosion rate of 15, 53 and 37 tons per hectare per year, respectively. Poulos and Collins (2002) reported that 83 million tons per year suspended sediment fluxes are transported by the main Albanian rivers into the Adriatic and Ionian seas. Whereas Pano et.al.(2004), published a lower average load entering the seas with a value of 52 million tons per year, however, the fluxes can vary in a wide range between 30 and 120 tons per hectare per years. The estimated value of potential soil loss for Ulza catchment (35.45 tons/ha/year) is much higher than the mean annual rate of soil loss due to water erosion for the EU countries (2.46 t/ha/year).

The mean soil loss estimated by experimental monitoring sample plots IN THE Bovilla reservoir watershed for the period from 2016 to 2019 was accounted to 430-435 tons/year (DIAVA Consulting 2019). The results indicated that, bare land (16.34 tons/ha), agriculture land (6.45 tons/ha), orchards (6.42 tons/ha), and degraded forest lands (4.72 tons/ha), were the most eroded compared to forest (2.89 tons/ha) and pasture lands (2.43 tons/ha), giving also the major contribution in soil loss at watershed level. These findings indicated that vegetation cover in forest and pasture lands play a very important role in soil protection from erosion. By contrast, agriculture lands and orchards have a higher soil loss, due to land management and irrigation practices applied by local farmers. On the other hand the results of soil loss by RUSLE model, showed that the average potential soil loss was 35.45 tons/ha/year which is equivalent with 4 176 804 tons for watershed level (Baloshi et al, DIAVA Consulting 2019).

6.1.2. Location

The study area is located close to the reservoir on the immediate south part of the basin.

Figure 33 – Study area

The study area encompass two neighboring catchments as follow:

- Catchment 1 – cca A = 780 ha and Catchment 2 – cca A = 490 ha

6.1.3. Topography and hydrography

Both catchments are exposed to north. The extreme altitudes of the catchments are as follow:

Table 12. Catchment data regarding area(ha) and elevation(m a.s.l)

Catchment	Area(ha)	Elevation range (m a.s.l)	
		Min	Max
Catchment 1	780	122	329
Catchment 2	490	122	306

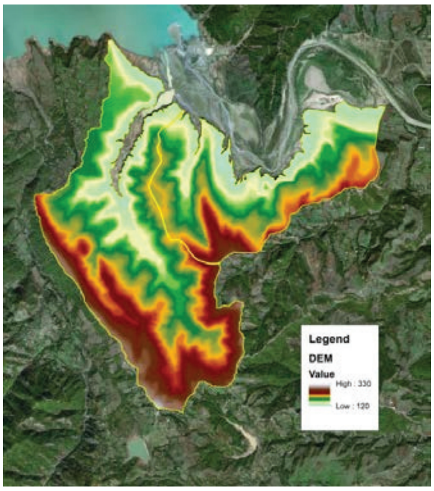


Figure 34 – DEM of the catchments

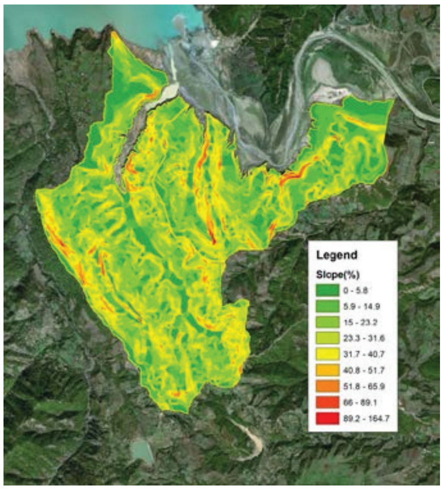


Figure 35 – slope map (^{O})

Generally, slopes between 2^{O} and 20^{O} are dominant, while slopes between 20 ^{O} and 40^{O} occurs partially. Within catchment 1 is delineated one stream that originated from the vicinity of village Bazi. This stream consists of 2 parts that confluent near the mouth to the reservoir. Beside this stream, there is another no-named small stream in the most western part. Within catchment 2 there is 1 stream that origin near the top point. Beside it, there are few ephemeral streams.

6.1.4. Climate

Ulza Dam is situated in the North Mediterranean Hilly Climate Sub-Zone (Climate Division of Albania, in “Climate of Albania, published by Institute of Hydrometeorology of Tirana, 1984).

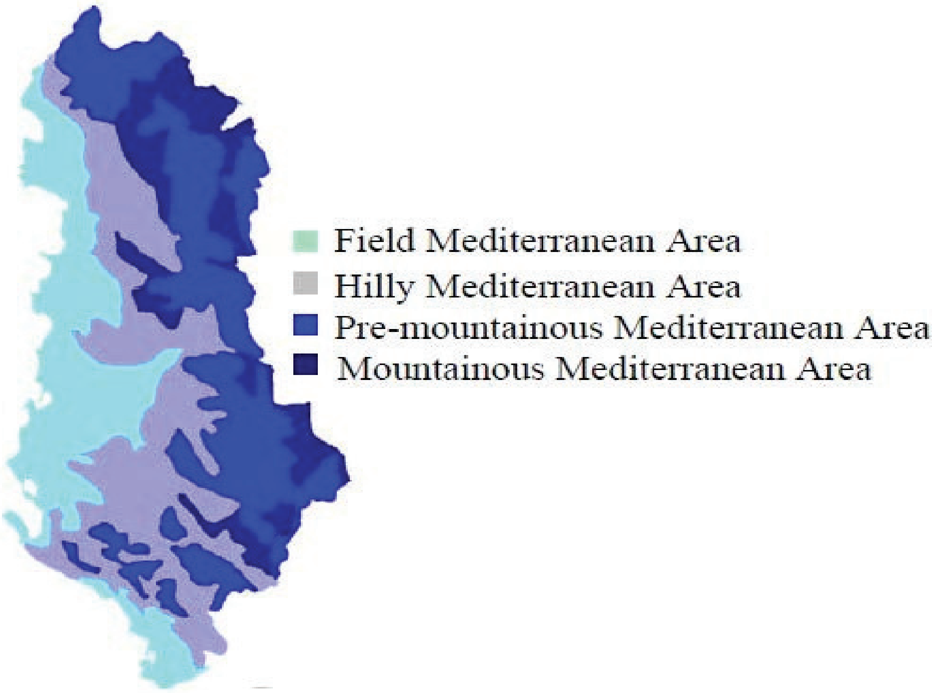


Figure 36 - Climate division in Albania (source Institute of Hyderometeorology)

It encompasses the western part of North Albanian low mountain areas which elevation varies mostly from 200 to 600 m asl. This sub-zone is characterized by relatively warm and wet winter as well as dry and hot summer. The following description of the climate elements is based on the data of the nearest to Ulza dam climate station of Burrel. The annual amount of precipitation in the region for the period 1931-1965 in Burrel is 1148 mm (Climate of Albania). A typical characteristic for the local climate is the non-uniform distribution of the precipitation; most of them (about 70% of yearly precipitations) fall during the period October – March, while during the summer months (June – August) fall usually less than 10% of the yearly precipitations. The precipitation is practically rain, and snow consist of less than 5% of the yearly precipitation. Storm events are a characteristic of the climate of Albania, but there are not records for all the territory of the country.

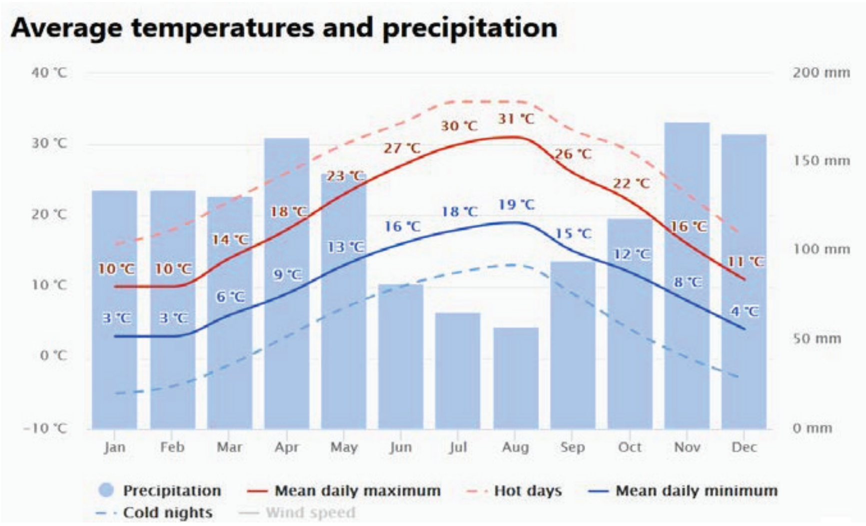


Figure 37. Average temperatures and precipitations – Burrel,

(https://www.meteoblue.com/en/weather/historyclimate/climatemodelled/burrel_albania_783493)

According to climatic data provided from Burreli Meteorological Station, the rainfall intensity in various time scales has been:

- the 15 minutes rainfall is about 30 to 40 mm,
- the 30 minutes rainfall may reach up to 80 mm,
- the 60 minutes rainfall may reach up to 120 mm
- the 120 minutes rainfall may reach up to 152 mm
- the 180 minutes rainfall may reach up to 161 mm

6.1.5. Geology

From the geological point of view, the project area started to develop during the Mesozoik period. Throughout the Middle Jurasic (J2), from 170 to 145 million years ago were formed the magmatic ultrabasic rocks, basic and igneous/volcanic that are at the same time the oldest rocks in the project area. These rocks make up the west side of the project area and are dispersed up to surface at both sides of the road from Baz village to Bushkash and up to the Ulza reservoir in the north. On the eastern side of the project area in the villages named

Karice, Baz and Urake are dispersed the deposits of the Kenozoic period (Tortoninan & Pliocen) formed from 22 to 2.6 million years ago. The latest deposits are those formed during the Kuaternar period which has e geological age less than 2.6 million years and are situated in the bottom of slopes and watercourses that percolate the project area.

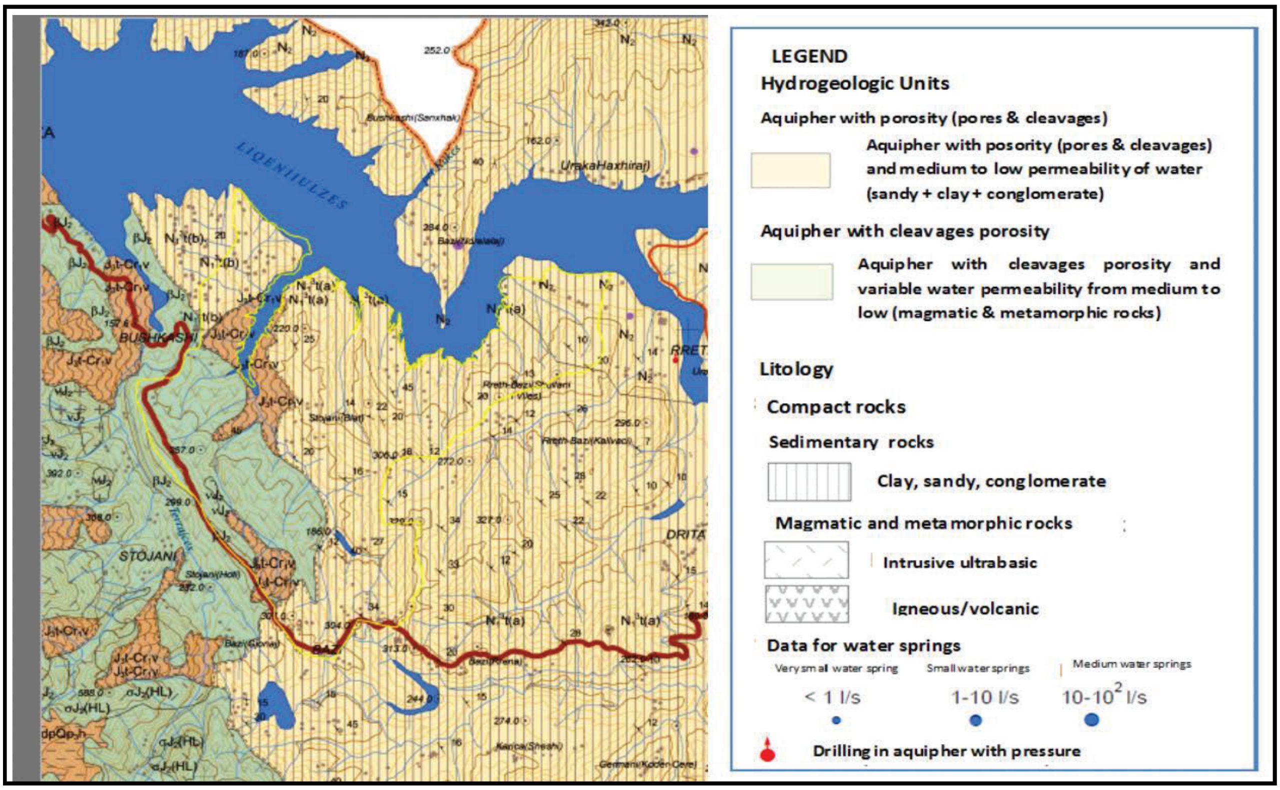


Figure 38 – Hydrogeology Map

The underground water is situated in the gaps/spaces of the geologic environment such as: pores, cavities or carst. When these cavities communicate between each other and allow the circulation of underground water, the geologic environment is called aquifer (Castany, 1976, Law 112/2012). In the project area are present these types of rocks and lithological.

- Clay, vegetal soils of Holocen (Qh)
- Mixed alluvial deposits -proluvial, sand, gravel, allevrites of Upper Pleistocen (Qp-h)
- Sandy and Conglomerat of Upper Tortonian $[N_1{}^3t\ (b)]$
- Combination of clays, allevrolite, sand and conglomerate of Upper Tortonian $[N_1{}^3t\ (a)]$
- Ofiolitic with combination of mergelo-sandy-conglomerate of Upper Jurasic Titonian-under Cretak $(J_3t\text{- }Cr_1v)$.
- Volkanik rocks of basalitic series of Middle Jurasic (β J2).
- Norite, gabro norite, gabro, gabro amphibolic, gabro quartz of Middle Jurasic (υJ2)
- Ultrabasic rocks (harzburgit, lelrcolit) of Middle Jurasic(σ J2).

In the study area, the aquifers are different not only from porosity but also for their water-carrier capacity. In this area exist these types of aquifers:

(i) Aquifere with porosity (pore-cavity) from low to very low water permeability;
(ii) (ii) Aquifere with porosity of cavities and low water permeability
(see the hydrogeologic map)

Aquifers with porosity (pore-cavity) from low to very low water permeability, are lithologically represented by: (i) clay, sand & conglomerate of the Pliocen and Upper Tortonian; (ii) combination mergeloro-sandy- conglomerate of Titonian-Valanzhinian and (iii) formation volcanic-sedimentar of Jura. This aquifer has the largest dispersion in the area and is located in the central and eastern part of the project area from Karice village versus north in Baz village in the eastern of Bushkash village up to Urake village. The thickness of this aquifer is 540 m and is percolated by many deep watercourses with steep slopes facilitating the underground waters drainage. From this aquifer are originated water springs with low water-carrier capacity ranged from 0.01 - 0.1 l/sec to 0.5 – 1.0 l/sec, mostly with different cleavages that percolate the aquifer. The water springs are mainly originating from the lower parts of the erosional cuttings. The underground waters occur during drillings in the Baz village. The water permeability of this aquifer is low ranging from 1.20 – 4.15 m^2 /day, while the specific debits ranged from 0.013 l/sec/m to 0.04 l/sec/m. The waters of this aquifer have good physical and chemical features. The general durability varies from 7.7 – 8.5 dH and are classified as water with medium durability. The general mineralization vary from 500 to 550 mg/l and for that reason, these waters are considered sweet waters. The hydrochemical type of the water (over 20 % mg/eq/l) is of hydrocarbonate to tiff-magnesial type (HCO 3 – Ca – Mg). The underground waters feeding is mainly from rainfall and from other underground waters coming from other aquifers. The hydro-dynamic point of view is with pressure.

Aquifer with a porosity of cavities and low water permeability is composed by ultrabasic formations (dunite, harzburgite) and less from bazic formations (gabro, gabronorite). It is situated in the western part of the project area from Bazi village to Stojan and Bushkash villages. The water springs are very rare and closely related to cleavages which are very few developed. The primary cleavages are created during the phase of formation and those secondary have a good system well-connected especially in the upper part and allow the circulation of the underground waters.

The water-carrier capacity of water springs is less than 0.2 l/s. The quality of waters in this aquifer is good. They have a low level of mineralization ranged from 100 në 360 mg/l, pH from 8 to 8.5 and durability from 4 to 14 dH^0. The underground water temperatures are closely related to the elevation of the water spring and ranged from 10 to 14 ^{o}C. The hydrochemical type of waters is mainly hydrocarbonat - magnesium (HCO3 – Mg), but is noticed even the hydrocarbonat-tiff-magnesium type.

6.1.6. Soils

Soils within the study area are divided on

- Permeable soils:
    - Moliccambisol
    - Dystric Regosol
- Impermeable soils
    - Eutric vertisol

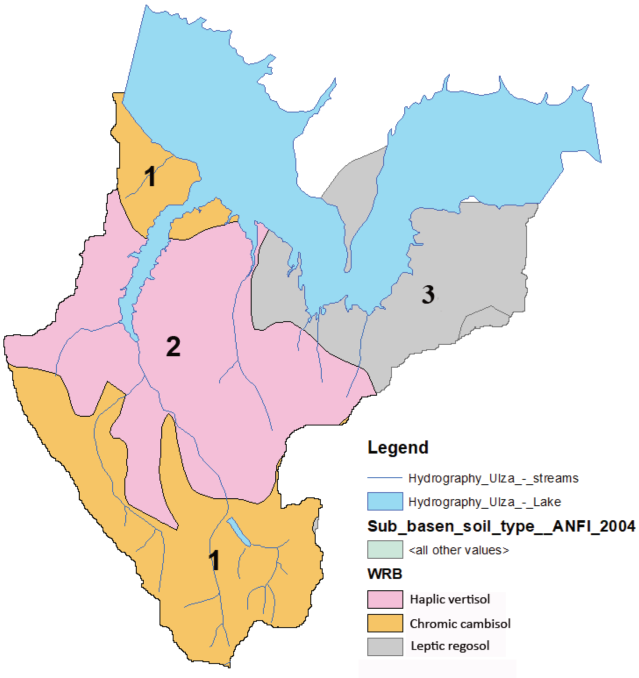


Figure 39 – Soil Map

6.1.7. Land Cover/Use and vegetation

The major part of the area is under the broadleaved forest with a significant appearance of transitional woodland (bushland). In the upper part, there is agricultural land and pastures. The western part of the catchment is dominated by bare land.

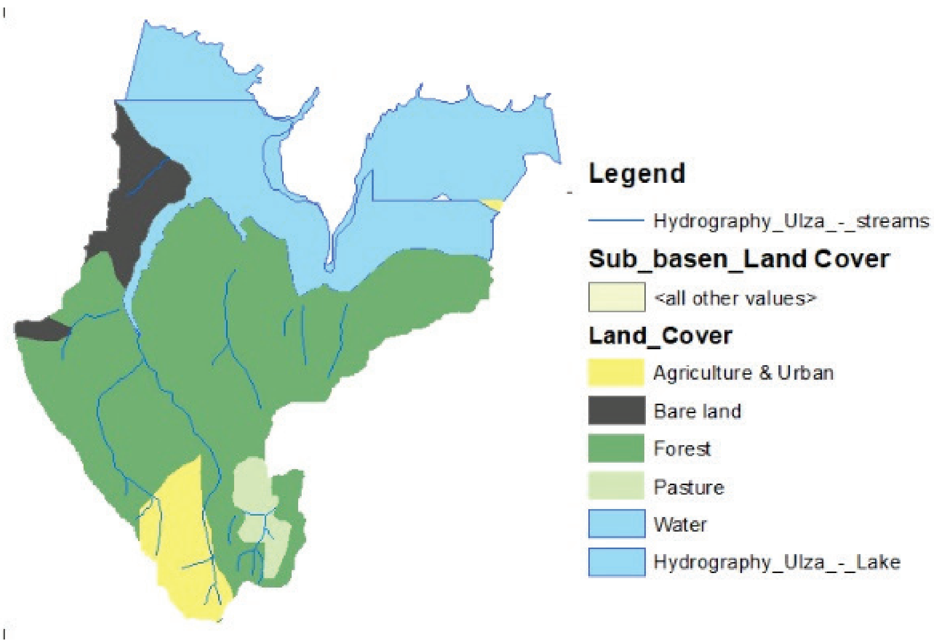
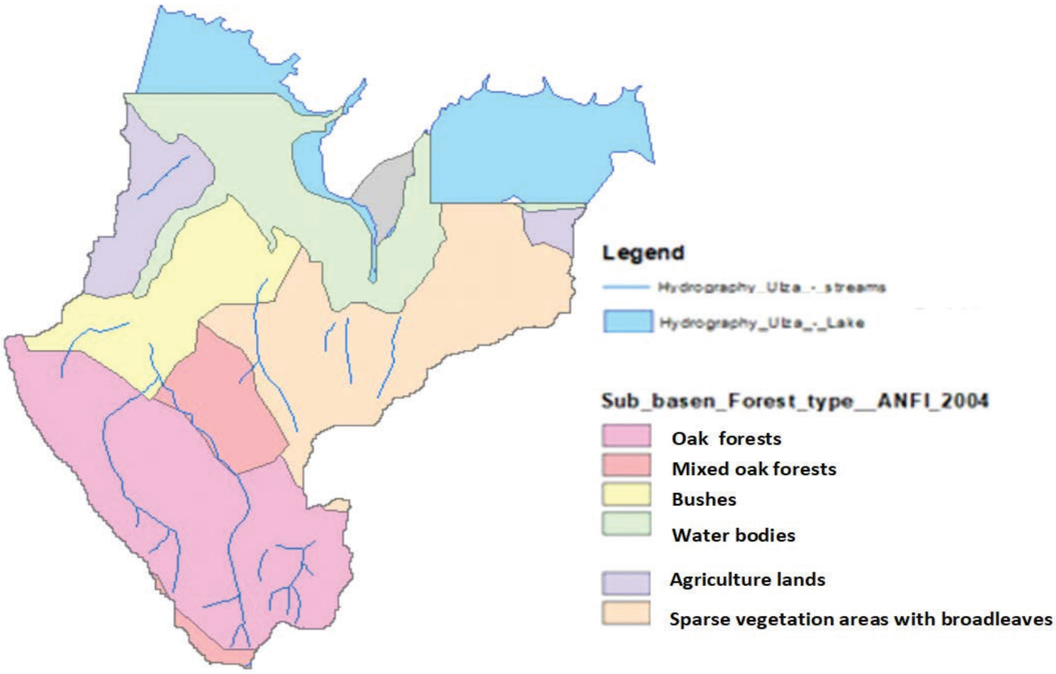


Figure 40 - CORINE Land Cover/Use

Generally, the forest area is predominated by coppice forests where *Quercus cerris* L. is mixed with *Quercus frainetto* Ten., *Carpinus betulus* L., and *Fraxinus ornus* L. The understory is represented by bushes like *Rosa canina*, and ground vegetation.



igure 41 – Forest types within the study area

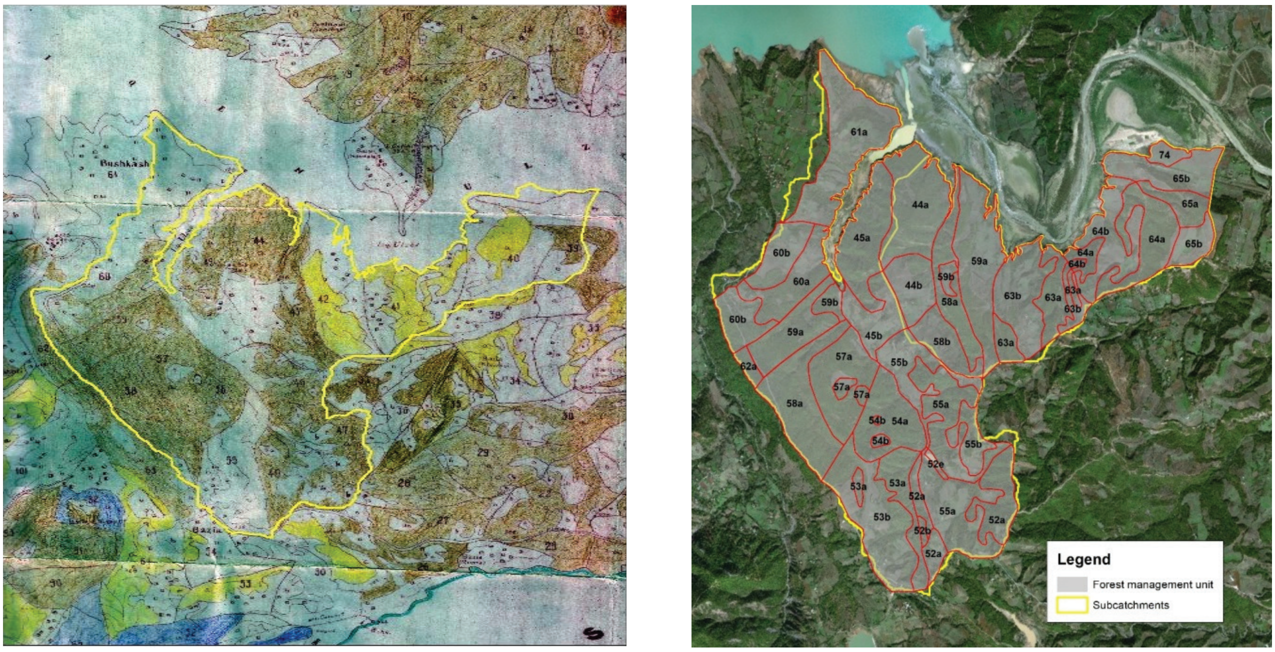


Figure 42 – Forest management unit and compartments

These catchments cover the southeast part of the Forest Management Unit of Ulza and Bazi administrative units. Within Catchment 1 are located the following forest compartments: 44, 45, 46, 47, 48, 55, 56, 57, 58, 59, 60, 61. Within Catchment 2 are located the following compartments: part of 39, 40, 41, 42 and eastern part of 43.

6.1.8. Erosion

Various erosion processes (sheet, rill, gully erosion, stream bank erosion....) are spread on both catchments. Taking into consideration the short distance from the reservoir, a great portion of erosive material produced from the catchment achieve to the reservoir.

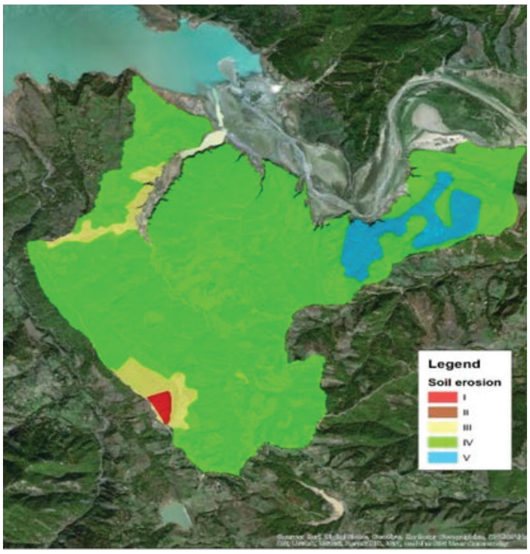


Figure 43–Erosion Map of the study area

Figure 44 – Gully erosion

Figure 45 - Erosion map and Some cases of Gully erosion in the abondoned agriculture lands in the study area

Sediment transportation is linked with the elevation difference of the catchment as well as with convex shape. Both these factors enhance sediments transportation because of the transport capacity increases downslope (Medeiros et.al. 2010). The study area has a steep slope gradient which reduces travel time of available sediments. The study area is located closer to the reservoir and the increase of sediment transport is favored by slope and the difference in elevation. It is well known that in such cases the catchments closer to reservoir export most of the sediments delivered to and originated from them than other catchments located far from the reservoir (Merten et.al.2014).

6.2. IDENTIFICATION OF FLOOD GENERATING AREAS

6.2.1. Identification of runoff-generating plots and discharge-contributing areas by forest site

This delineation is done following the approach given by Schueler. Taking into consideration that gley soils are spread in the valley in the study area and out of the forest management area, the right side of the logical tree is excluded.

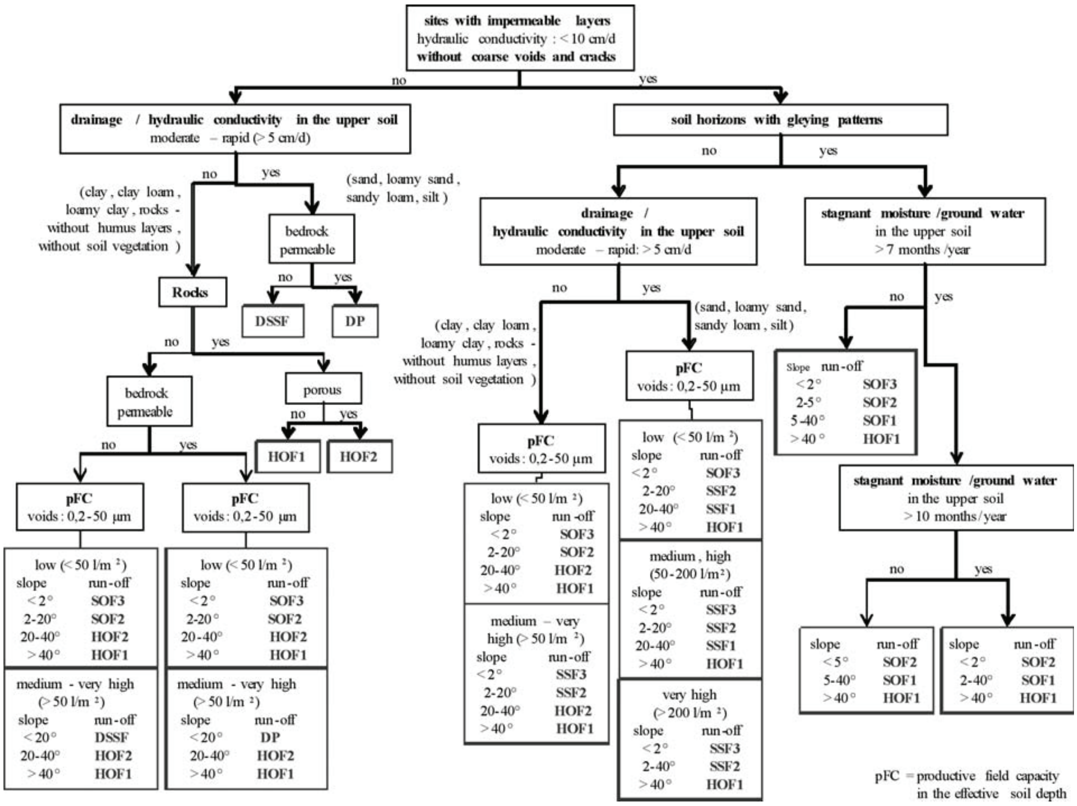


Figure 46 - Identification of Runoff process – Decision tree

Runoff process - Permeable soils

Soil	Rock	Permeability		Runoff process
		Soil	Rocks	
Cambisol (Typical Cinnamon mountain soils – chromic cambisol)	Sediments Magmatic rocks	Y	N	DSSF
Regosol (Cinnamon meadow)	Sediments	Y	N	

Runoff process - Impermeable soils

Soil	Rock	Permeability		Rocks	pF C voids 0,2-50 µm Low / Med-High	Inclination (degree)	Runoff process
		Soil	Rocks				
Vertisol (Magnezial Cinnamon mountain soils)	Sediments Magmatic	N	N	N	Medium to high	2 – 20 20-40	DSSF HOF2

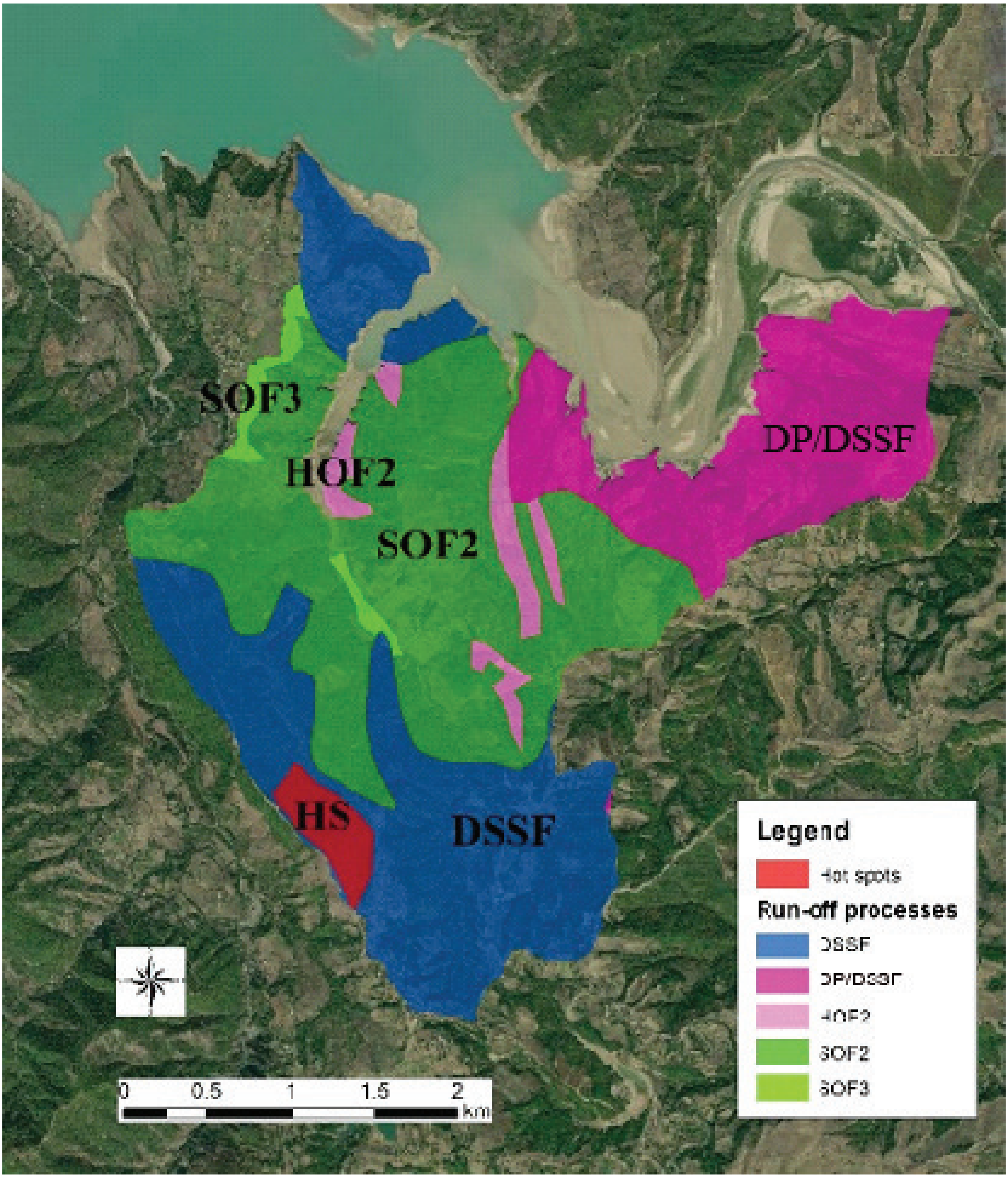


Figure 47 - Map of runoff processes and hot spots in the study area

DSSF – Deep Sub Surface Flow - High infiltration rate due to macroporous and permeable soil matrix. Lateral flow within a weathered layer above.

HOF – Hofman overlay flow - Susceptibility for surface sealing due to few macropores and a low permeable soil matrix

SOF -Water saturation by infiltration into permeable soil layers above an impermeable layer

6.2.2 Water holding capacity

The type of runoff process can be changed in a case of saturation slowly or faster depending on a percentage of soil moisture, water holding capacity and intensity of the precipitation.

If all soil pores are filled with water the soil is saturated. The period of saturation of the topsoil usually does not last long. After the rain has stopped, part of the water present in the larger pores will move downward. This process is called drainage or percolation.

The water drained from the pores is replaced by air. In coarse-textured (sandy) soils, drainage is completed within a period of a few hours. In fine-textured (clayey) soils, drainage may take some (2-3) days. Simply defined **soil water holding capacity** is the amount of water that a given soil can hold for crop use. **Field capacity** is the point where the soil water holding capacity has reached its maximum for the entire field.

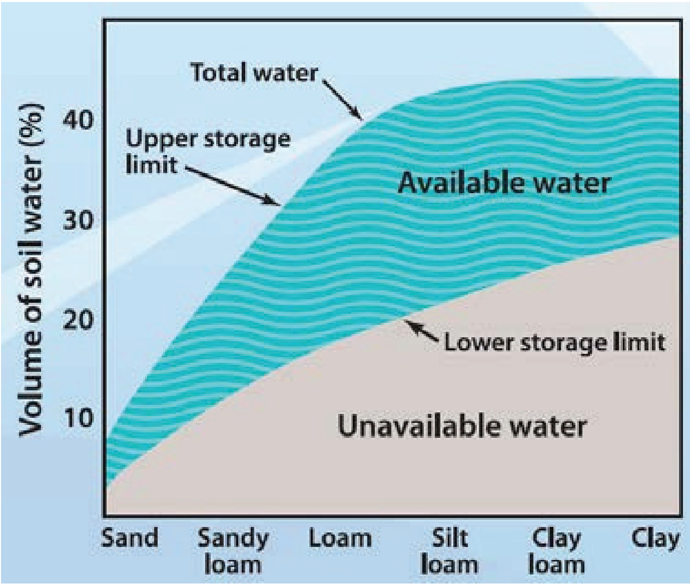


Figure 48 - Volume of soil water depend on a texture

Soil texture and organic matter are the key components that determine soil water holding capacity. In terms of **soil texture**, those made up of smaller particle sizes, such as in the case of silt and clay, have a larger surface area. The larger the surface area the easier it is for the soil to hold onto water so it has a higher water holding capacity. Sand, in contrast, has large particle sizes which result in smaller surface area. The water holding capacity for sand is low.

6.2.3. Discharge accelerating linear structures - Forest roads

Within the study area, there is a local asphalt road that connect villages Bushkash and Baz and go almost along the boundary of the catchment 1 in the southern part. From Bazi continue slightly along the watershed boundary and then curve out of the study area in direction to the village Drita or further. Other roads are unpaved. The underlying premise is that forest roads promote rapid runoff. This negative effect can be diminished with special construction methods and precautionary measures.

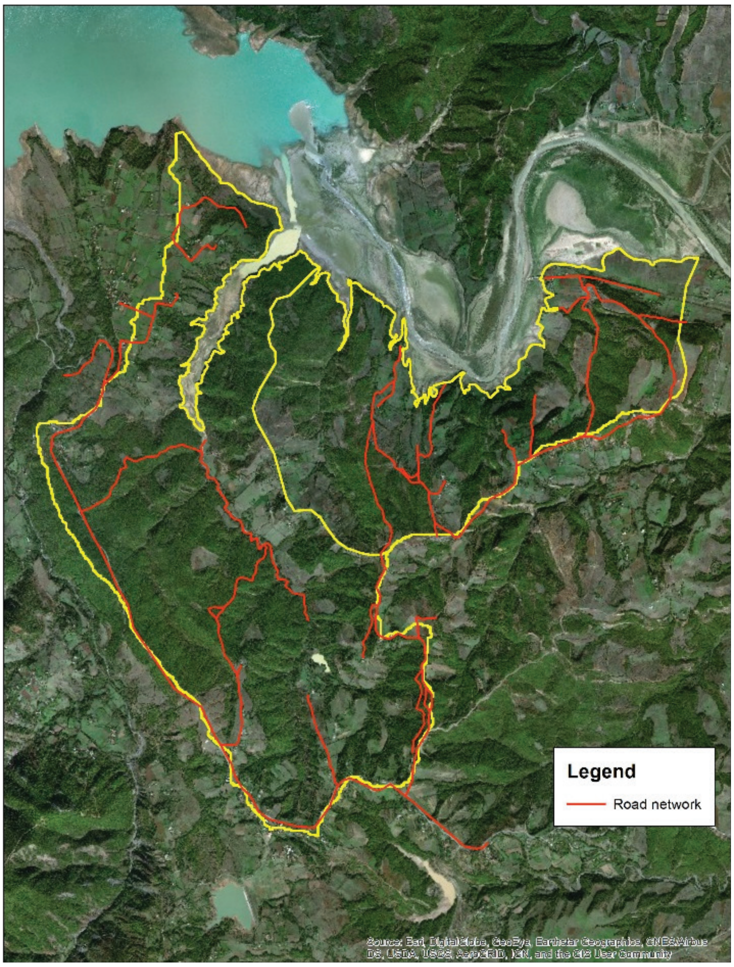


Figure 49 - Road network in the study area

A decision tree with "yes/no"- key questions were developed to evaluate runoff from forest roads (BACKES 2005).

The first question of the decision tree asks if a road seals the forest soil surface. If it does, then a forest road causes Hortonian overland flow (HOF).

If the road and accompanying ditches enable the surface water to be widely diffused back into the forest, the runoff is estimated to be comparable to that of the surrounding forest sites. For dirt forest roads, the next question asks if the road has a humus layer, branch-wood reinforcement, or vegetation cover. Our investigations showed that these can improve the runoff reaction (BACKES 2005). Surface water on bare dirt roads becomes overland flow (SOF, HOF) and the steeper the road the faster the runoff.

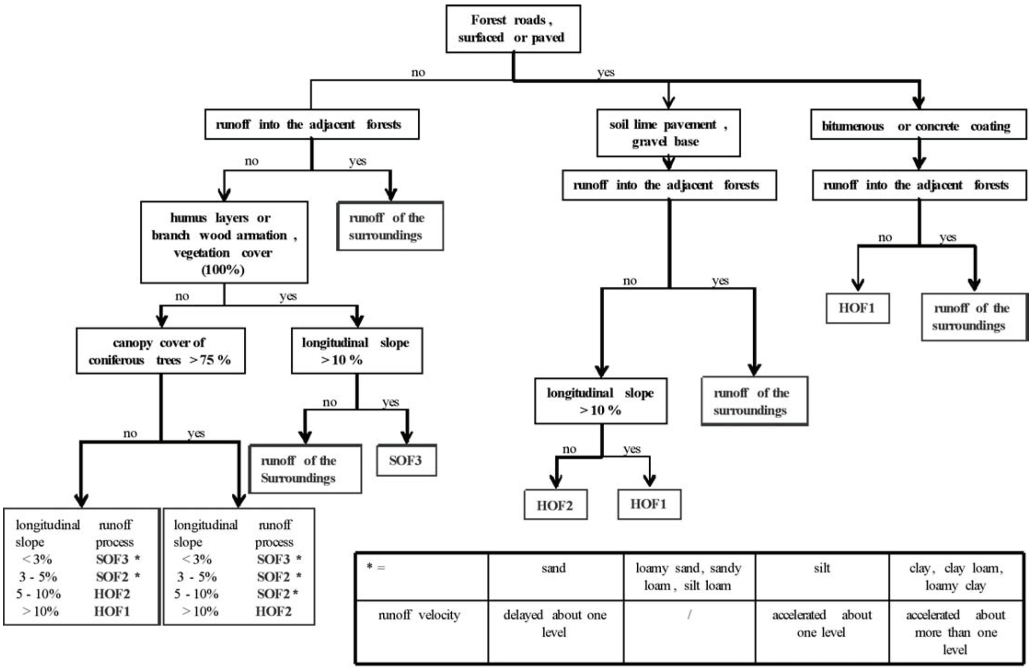


Figure 50 - Decision tree to derive the runoff from forest roads (Backes and Schubert 2005 unpublished)

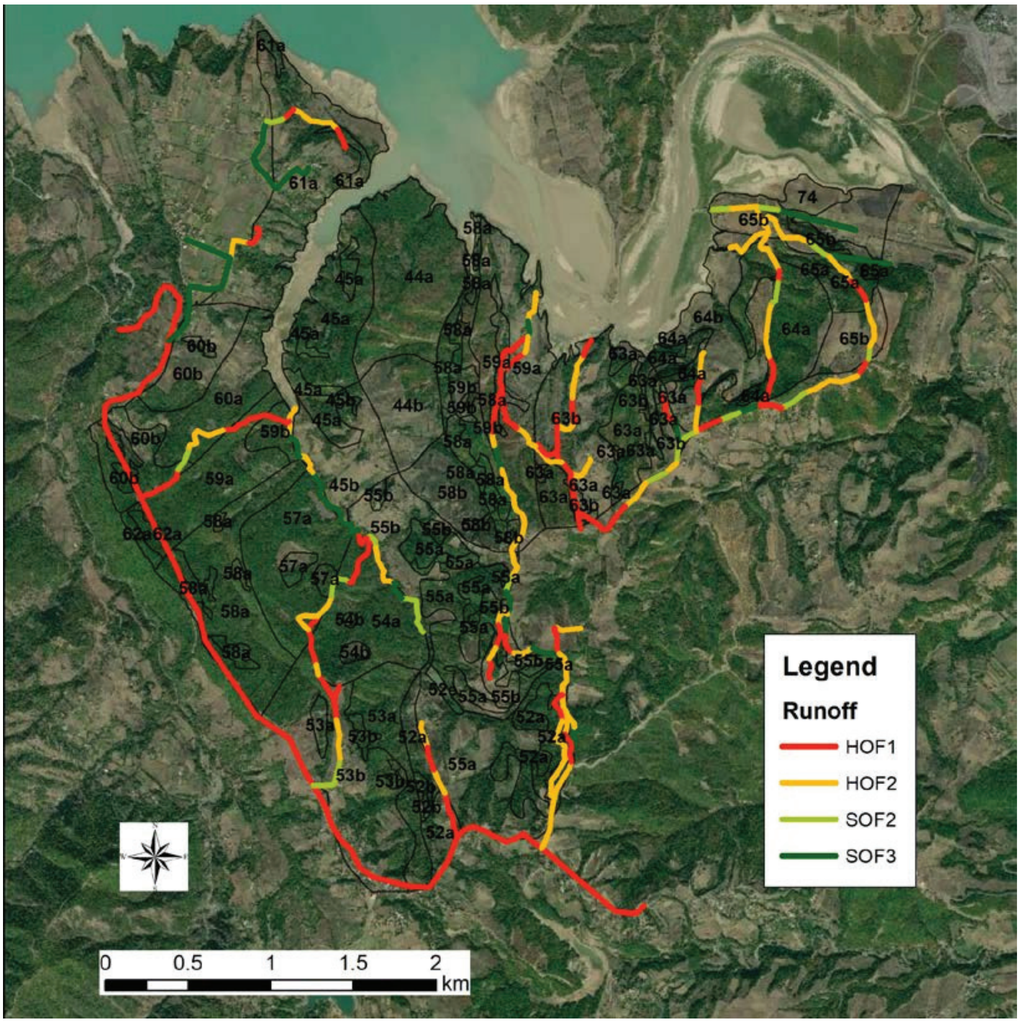


Figure 51 - Runoff type on forest roads

6.3. FOREST MANAGEMENT

6.3.1. Common practices of forestry in Ulza watershed

Forests in the Ulza Forest Management Unit, cover 81% of the territory, while the rest is occupied by non- productive lands, agriculture lands, and settlements. The total forest area is 4548 ha divided into three management forms respectively: high forest (1516.5 ha), coppice (2659 ha) and shrubs (325 ha). Due to human intervention and conventional management, the forest stands are young with mixed origin (seed and sprouts). For this reason, the forest resources are nearly natural and mostly regenerated by sprouts.

The forest stands in the study area have protection and recreation function, because are located close to the Ulza reservoir, and might be used as buffer zone. Besides the protection function due to human intervention, these forest stands have been used traditionally to provide firewood and fodder for livestock.

The main forest species in the study area are: *Quercus petraea* Liebl.; *Quercus cerris* L.; *Pinus nigra* Arn.; *Robinia pseudoaccacia* L. The common practices applied in the forest stands have been: cleaning; thinning in young forest stands; afforestation of degraded lands, and construction of water dams. The main problem has been the limited fund by the state budget or municipality, and for that reason, all measures provisioned in the management plans are not properly applied.

6.3.2. Planed forest activities in the study area

The main forest activities planned in managmement plan for the study area are given in the Table 15.

Table 13 - Forest activities planned for each parcel in the management plan

Forest Parcel	FMU	Area (ha)	Elevation	Species	Measures proposed
44	Ulez	44	140-600	*Q.frainetto+Q.cerris+P.nigra*	Cleaning
45	Ulez	45	160	*Q.frainetto+Q.cerris*	Cleaning
46	Ulez	26	300	*Q.frainetto+Q.cerris+P.nigra*	Cleaning
47	Ulez	26	280-420	*Q.frainetto+Q.cerris*	Cleaning
48	Baz	29.37	460	*Q.petraea+F.ornus*	Selective thinning
53	Baz	75.64	275	*Q.frainetto + Q.cerris*	Cleaning
54	Baz	37.16	200	*Q.frainetto + Q.cerris*	Cleaning
55	Baz	40.66	225	*Q.cerris + Q.frainetto*	Cleaning
56	Baz	61.51	245	*Q.cerris + Q.frainetto*	Cleaning
57	Ulez	41	210	*Q.frainetto+Q.cerris*	Cleaning
58	Ulez	50	290	*Q.frainetto+Q.cerris*	Cleaning
59	Ulez	37	290	*Q.frainetto+Q.cerris*	Cleaning
60	Ulez	66	140	*Q.frainetto+Q.cerris+Robinia pseudoaccacia*	Cleaning and afforestation (5 ha)

Forest Parcel	FMU	Area (ha)	Elevation	Species	Measures proposed
61	Ulez	207	140	*Q.frainetto+Q.cerris+Robinia pseudoaccacia*	Cleaning and afforestation (7 ha)
63	Ulez	36	220	*Q.frainetto+Q.cerris*	Cleaning
64	Baz	44.39	145	*Q.frainetto+Q.cerris*	Cleaning
65	Baz	16.93	145	*Q.frainetto+Q.cerris*	Cleaning
74	Ulez	26	200	*Q.frainetto+Buxus sempervirens*	Cleaning+protection from wildfire
39	Baz	11.71	625	*Q.petraea+F.ornus+C.betulus*	Cleaning
40	Baz	50.85	570	*Q.petraea+F.ornus+ C.sativa*	Cleaning
41	Baz	52.41	610-650	*Q.petraea+F.ornus*	Cleaning
42	Baz	52.5	540	*Q.petraea+F.ornus*	Cleaning
43	Baz	47.01	380-500	*Q.frainetto+Q.cerris*	Cleaning

These measures include:

- afforestation with *Robinia pseudoaccacia* L. (12 ha)
- cleaning in 1124 ha of oak forest stands with varying intensity
- construction of stone or concrete dams
- training of local communities to protect forests from wildfires

Cleaning is considered to be applied in those forest stands, where crown density is over 0.8. It is recommended that the understory must be remained untouched, in order to cover the ground, as well as to be a good shelter for wildlife. In addition, anti erosive measures will be applied along watercourses, agriculture lands, etc. Despite dams with concrete, is suggested the application of green fences (single or double rows), as well as planting of steep slopes with grass or their afforestation with species having a strong root system. All these measured will have short and long-term impacts on the forest stand status and will affect their environment, social and economic contribution in the livelihood of local communities.

7

Recommendations for planers and engineers

7.1. General recommendations (by Schueler):

Flood development should be minimized through the precautionary forestry management approach. Precautionary measures for water retention in forests must consider the various site conditions, meteorological events, and the present state of the soil water balance. The efficiency of retention measures varies according to precipitation events and site features (e.g. intensive or continuous rainfall on dry soils with further water storage capacity vs. saturated soils, or on sites with dominantly deep percolation vs. subsurface flow).

On sites with deep percolation, the avoidance of clear-cutting is less important, because the undisturbed soil and parent substrate is sufficiently porous that deep percolation dominates in contrast to subsurface or overland flow.

Other water retention concepts are necessary on sites with compact sub-soils, which tend to hold moisture and produce subsurface flow, and on sites with low infiltration or field capacity. On these sites clear-cutting should be avoided because reduced evapotranspiration will tend to increase runoff (MOLTSCHANOV 1966; HIBBERT 1967; VORONKOV et al. 1976; HOFFMANN 1982; ROSEMANN 1988; BENNECKE 1992; PECK and MAYER 1996; MOESCHKE 1998; MENDEL 2000).

A permanent forest cover composed of a structured successional mosaic of trees decreases the risk of runoff (BREDEMEIER and SCHUELER 2004). It is therefore essential to mimic the permanent cover principle of a mosaic cycle in close-to-nature silviculture management with horizontally and vertically structured forest stands using site-adapted tree species (EDER 1997). Vertically and horizontally structured canopies, with high leaf area indices, of a multi-storied stand improve the hydro-ecological efficiency of forests by maintaining high interception and transpiration rates (MÜLLER 1996). In addition to the canopy effects of mixed forest stands, the roots of different tree species exploit different layers and soil depths in the soil. A rapid turn-over of fine - roots promotes the creation of soil macro and mesopores (NOGUCHI et al.1999). Thus, these processes enhance the storage and retention capacity of multi-structured forest ecosystems, while bearing in mind that in close-to-nature silviculture, the harvesting and regeneration phases are occurring simultaneously within a forest stand. Investigations of different regeneration types demonstrated that runoff can be reduced in the hydro-ecologically sensitive phases of forest development (SCHUELER 2003).

Advanced regeneration in multi-storied stands and rapid establishment of regeneration after harvesting maintain the forest influence. Thus the soil will be protected, even if a catastrophic storm damage.

7.2. Recommendation for forest roads

Regarding the forest roads planning and construction, the Law on forest have to be followed and the road have to be constructed based on a main design.

Regarding existing roads network, draining hollow should be constructed to distribute water from forest roads into the adjacent forest. There are several management practices that are used in forestry operations to mitigate the impact of logging, forest roads and skid trail construction on stream water quality.

Generally two methods are in use as follows:

- Use of drainage culverts on forest roads and water diversions (water bars) on skid trails just after logging. This structure was found to be effective in controlling and reducing the runoff volume and soil erosion.
- Paving the traveled road with gravel or similar.

Depending on the slope and soil structure, cross drain structures on slopes >10% (like most of the forest roads) should be constructed on a distance not longer than 50 m. The following table can be useful for engineers.

Table 14 - Maximum surface cross drain recommendation (m) for native soil surfaced roads (Copstead et al. 1998)

	Road slope (%)			
	2–5	5–10	10–15	15-20
Haupt(1959)	41–47	24–41	18–24	14-18
Haussman and Emerson (1973)	95–	60–95	35–60	
Packer (1976)		17–44	11–39	
Rothwell(1978)	46	31–61	15–46	
Swift(1985)	67–85	37–67	6–37	

Table 15 - Guidelines for maximum distance between contiguous cross drains based on USCS soil erodibility groups (m) (Copsteadetal.1998)

Road grade (%)	GW, GP Aggregate surfacing	GM, GC	CH, CL	MH, SC, SM	SW, SP, ML
2	120	97	75	52	29
4	103	84	65	45	26
6	88	71	55	39	23
8	74	60	47	33	20
10	61	50	39	28	17
12	50	41	32	23	14
14	42	34	26	19	11

GW – gravel well graded, GP – gravel poorly graded, GM – gravel silt like, GC – gravel clay like, CH – clay high liquid limit, CL – clay low liquid limit, MH – silt high liquid limit, SC – sand clay like, SM – sand silt like, SW – sand well graded, SP – sand poorly graded, ML – silt low liquid limit

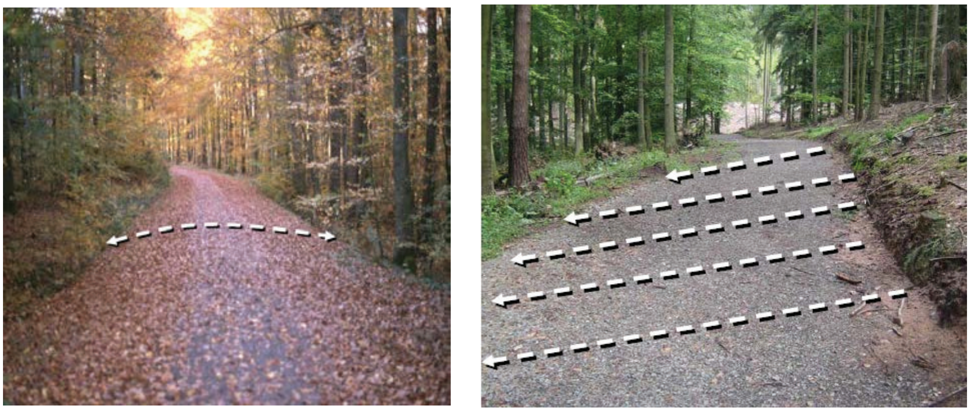


Figure 52 - Retention ditches

Figure 53 - Retention ponds along forest road

Figure 54 – Covering of forest road with rocks, gravel

Bladded skid trails Treatment	Actual Erosion T/A/Y*	Erosion Reduction (%)
Control (water bar only)	61.2	-
Grass Seed	14	77
Hardwood Slash	3.9	94
Pine Slash	2.6	96
Grass Seed and Mulch	1.3	98

Overland skidding Treatment	Actual Erosion T/A/Y*	Erosion Reduction (%)
Control (water bar only)	10.8	-
Grass Seed	6.1	44
Hardwood Slash	2.3	79
Pine Slash	2.4	78
Grass Seed and Mulch	1.5	86

Figure 55 - Covering of forest road with bio-materials and effects on reducing erosion on skid roads

7.3. Recommended activities for planers and engineers in Albania study region

Despite the proposed measures in the point 6.3.2, other measures recommended for planners or forest engineers are:

- planting of abandoned lands with fruit trees like: chestnut, hazelnut, cherry, in order to improve the local community livelihood.
- protection of forests along rivers, streams, and drainage channels from damages, because they may have implications on water quantity and may accelerate the soil erosion.
- application of low impact interventions and anti erosive measures friendly with environment for restoration of degraded areas. These low impact interventions include: jute matt, hydroseeding, drainage channels with concrete or stones, gabions, afforestation of steep slopes, utilization of deadwood or stones to construct crib walls, palisade, etc.

Figure 56 - Examples of low impact interventions for restoration of degraded areas

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