Interactions between mountain forests and flood protection


1 Contribution of protection forests for prevention of floods

1.1 Effects of forests on flood prevention

Forests play an important role in the regulation of water runoff. This applies especially for the alpine region with its high amount of precipitation and its steep slopes. But many factors do influence the processes of water runoff. Therefore the interrelations are rather complex. Important factors of the influence of forests on floods are

- the evaporation (interception and soil evaporation),
- the amount of consumption of water by the vegetation (transpiration) and
- the effects of forests on the retention of water in the soils.

The evaporation of forests is in general higher than of other forms of land use. By means of their huge surface tree crowns have a high interception. The effect of interception is higher for coniferous trees than for broad-leaved trees and is also effective during the winter if the coniferous trees are evergreen (Markart, 2016). With reduced percentage of crown cover the effect of interception by the tree crowns is decreasing but it can partly be compensated by ground vegetation (young trees, shrubs).

The older forests are, the higher is their consumption of water. In general the transpiration of coniferous tree stands is higher than that of broad-leafed tree stands. With the increasing number of mild winters the transpiration effect of coniferous trees is rising.

The retention capacity of soils also plays an important role for hydrologic budget. Because of their higher infiltration rate and retention capacity forest soils can store more water than most other soils (bare, pastures, agriculture). One reason is the higher transpiration of the trees which leads to a higher percentage of free soil pores under forest cover (Markart, 2016). Furthermore forest soils have a higher root penetration, a more porous structure and higher contents of humus, which also improve the pore volume and the retention capacity of the soils. Müller (2017) reports important

differences in the storage capacity: in mixed structured forest the average storage is 140 l/m² while in degraded spruce forest it is reduced to 60 l/m².

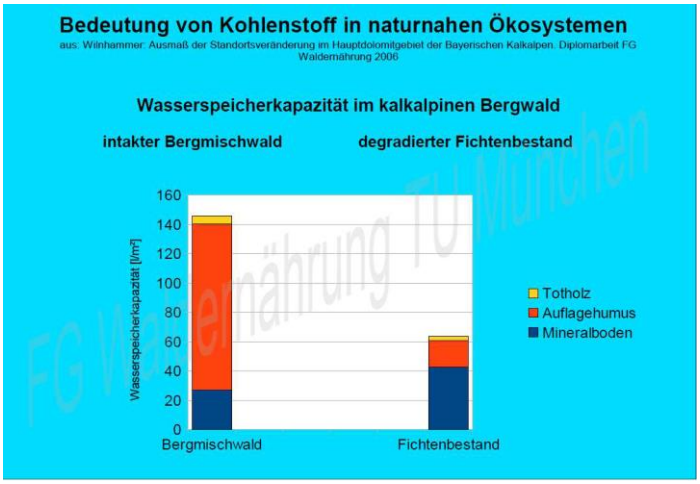

Fig. 1: Water retention capacity of mixed mountain forest and degraded spruce forest

Due to the higher infiltration rate under forests even high precipitation rarely causes surface runoff. This fact also leads to less erosion under forest cover.

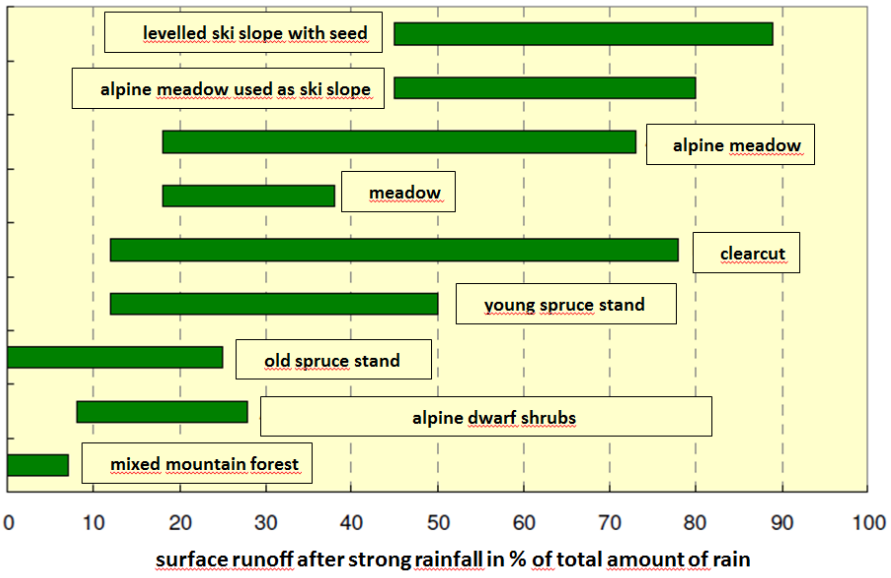

Fig. 2: Range of surface runoff in dependency of different types of vegetation and land use during strong rainfall (Kokai, 2009 after Bunza et al. 1989 cited in Patscheider, 2011

Forests and forest soils store large quantities of water, particularly forests with multi-layered structure with site-adapted species. So US data show a high effect of afforestation on peak discharge: it could be reduced from -41% to -85% (Lull, 1972). Disse (2017) reports an improved storage capacity on the landscape level through afforestation. Effects could be confirmed, but with large differences and uncertainty, particularly for basin's afforestation. For renaturation of riverbed the effect depends substantially on slope and riverbed area. In general reductions of peak discharge are limited, particularly for events with large return-period and for larger basins.

The influence of forests on water runoff in a watershed depends on the percentage of forest cover (Binder, 2013).

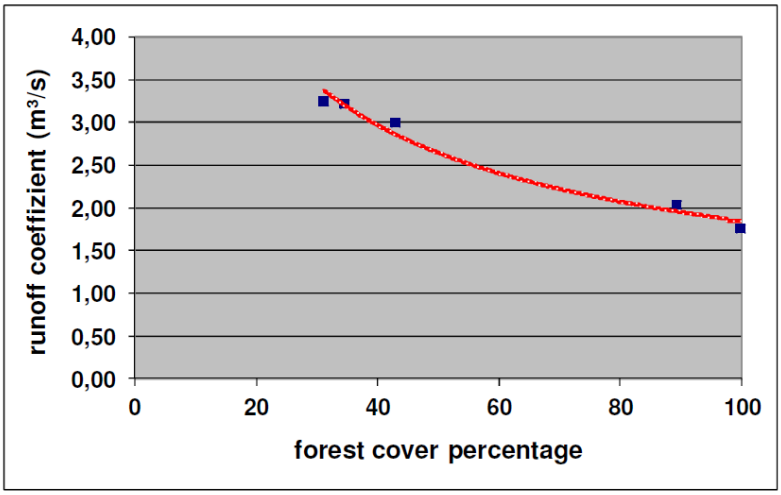

Fig. 3: Relationship between forest cover percentage and discharge (Binder, 2007)

In general the amount and intensity of precipitation and the distribution of precipitation in the period before an extreme event plays an important role for the water retention: the more empty the soil pores are, the higher is the retention effect of forests.

In total it can be said that forests have a positive effect on flood prevention. This is especially valid for smaller watersheds and short and heavy rainfall. But forests cannot absolutely prevent floods: after long periods of precipitation (constant rain) the soil pores are filled with water and the retention capacity of forests is exhausted.

1.2 Requirements on protection forests for prevention of floods

To support flood prevention forests should be managed in a way that it can work as a sponge as good as possible. That demands: maintenance of a good soil structure, improvement of infiltration rate and improvement of retention capacity.

Mixed and uneven stands with a high crown cover and a high percentage of regeneration are ideal for the prevention of floods (Binder, 2013). Forests that prevent floods should consist of trees that root deeply. Of special importance is the capability of rooting in soil horizons that partly are waterlogged. In mountain forests this is especially the case for silver fir, but also for ash and maple. Besides the root depth the intensity of root penetration is also important. For example the spruce has less root penetration as silver fir or beech. Large packages of raw humus can reduce the infiltration capacity of forest soils. Therefore trees with easy degradable leaves as maple and ash are important in mixed stands.

Mixed forests, unregular/unevenaged structures and the presence of wood debris have a positive influence on soil characteristic that improve water infiltration and retention.

For intensive root penetration and high interception a high forest cover percentage should be intended. Gaps in the forest cover should be held as small as possible. Clearcuts should be avoided, because after clear cuts the surface runoff is strongly increased. The risk of gaps by bark-beetles or windthrows should be reduced by mixed and uneven stands and permanent regeneration. Timber harvest should be practiced in a way that minimizes the soil compaction because soil compression

reduces infiltration capacity and retention capacity of the soils. Logging trails and roads should be planned in a way that concentration of surface runoff is prevented.

Forests cannot completely prevent floods. So the management of forest regarding flood protection can only be a part of an integral flood protection. A modern, future oriented flood prevention, is based on the actual condition of the catchment area, existing control works, existing risks and damage potential (Binder, 2017). Integral planning is composed of

- natural water storage, considering forest area increase and improvement of structure and soil condition
- technical works, considering maintenance of existing works and the necessity of additional works;
- flood management, considering residual risk, alert and emergency plan

The Bavarian flood prevention action plan 2020 (approved 2014) is a good example of an Integral Protection Plan. Forests play an important role in the improvement of natural water storage. So the adapted management and the restoration of protection forests is one of the measures of an integral protection plan.

1.3 Possible negative effect of input of wood in torrent beds

Trees and wood can also have negative impact on natural risks: during flood events in mountain catchments, driftwood can hinder water runoff. Therefore the monitoring of torrents to detect potential obstructions and the management of areas directly bordering torrents and rivers in order to reduce the possibility that trees fall in the torrents during flood events is very important.
Climate change has a powerful influence on both forestry and floods, with potential to change conditions and assumptions. Mauser (2017) reported that there is consent in the scientific community, based on the results of different climate models, that in the German Alps

- temperature will increase in the XXI century: less snow in winter and migration of climate belts toward the top of the mountains
- there will be less precipitation in summer and more in winter
- the combined action of temperature and precipitation will significantly change hydrological behaviour of the catchments (uncertainty on the new models)

The effect will be very important on floods: existing models and proceedings for flood protection have to be re-considered: possible changes in precipitation intensity and the hydrological effect of change in snow/rain precipitation must be verified.

On the other hand climatic change affects the growth conditions for tree species. Rising temperatures, changes in the amount and the distribution of precipitation and the increase of extreme events (storms, droughts) influence absence and presence of tree species and their distribution in the different altitudinal belts. The changed climatic parameters do also influence forest pest. The adaption of forests to the changing climate conditions is an important task. Climate change is a powerful source of new uncertainty.

2 Other risk factors for protection forests

There are several risk factors that reduce the protection effect of forests:

2.1 Hoofed game browsing, lacking regeneration

The influence of game browsing on forest regeneration can be a relevant problem. Winter-feeding that allows higher populations of hoofed game can make the problem even worse. Protection forests against flood risks should be of uneven age and with permanent regeneration. Too high wildlife stock prevents sufficient regeneration of forest trees or of trees species relevant for the protection functions (for example the silver fir). To prevent damages by hoofed game browsing several actions should be in focus:

- monitoring of hoofed game browsing,
- participation in setting-up of hoofed game shooting plans

2.2 Pure stands of (climatic) endangered tree species

Protection forests against flood risks should – if the natural site conditions allow it - consist of different tree species which are well adapted to climate change. Although during the last decades forest managers converted many pure stands into mixed and close-to-nature-forest stands, there are still relevant areas of pure stands of climatic endangered tree species in the alpine region. Their conversion into mixed stands is still an important task. Therefore it is very important that forest owners get financial support for this measure within the support for active and sustainable management (in the EU: Rural Development).

2.3 Wood pasture

In some parts of the Alps wood pasture is still in practice and can cause damages to forests. Particularly sheep and goats can cause severe damages to forest regeneration especially because they can reach the steep slopes and hinder the regeneration of protection forests. Also cows can cause harm to forest regeneration especially to young beech and sycamore maple.Even more important is the damage the cows can cause by their footsteps.

2.4 Lack of maintenance

An active and sustainable management of mountain forests is important for an optimum performance of their functions (this is also true for flood prevention). Natural development in selected areas should be a part of an integral forest management, but it cannot be a general solution: local conditions, forest functions and risks must be carefully considered and weighted. Monitoring is essential to detect negative change of the protection-function and must be provided by the public administration.

Mountain forests have to bear higher costs because of the steep and often difficult terrain, which leads to economically difficult forest management. Because of this many forest owners are no more willing to manage their property properly: there is a growing abandonment of forests, which dependening on the local conditions can result in lower protection and ecosystem services. The public therefore should provide financial support for the management of mountain forests: adequate infrastructure, machineries and training of owners, contractors and foresters is needed under the general objective to keep forests able to deliver their multiple functions.

2.5 Other critical issues

- The maintenance of the forest: the aging of coppices in the southern part of the Alps, especially on incoherent substrates and in high slope; the artificial forests of conifers; the repetition of fires that degrade ecosystems, damaging the protection functions and putting the slopes subject to heavy rainfall at risk of erosion;

- The maintenance of the water network: the clogging of the beams and the need for adequate sediment management plans; the loss of diffuse drainage systems that leads to the digression of surface waters with the risk of erosion phenomena;

- Forest road system:
The building and maintenance of forest roads influences flood protection. Roads can have a direct and strong impact in terms of modification of the morphology of the slope. This can lead to the risk of increase in surface run-off and water diversion. So the correct and careful planning and subsequent maintenance of the forest roads is important in mountain forests.

3 The necessity of a comprehensive and extended approach

The climate change is already causing intense meteorological episodes. The abandoning of forest management, which is rising in some regions of the Alps, might increase the impact of climate change, because correctly managed forests can provide better safeguard against natural hazards and are more stable against climate change.
Regional policies maintaining and improving the protection function of forests should be considered an important work for common welfare and therefor provided with adequate resources. Public awareness in the topic should be increased.

In particular:

- Programs at basin scale are necessary with a broad perspective and integrated policies, for the mitigation of the hydrogeological risk; measures should be continuous and widespread local communities involved and adequately supported;
- All stakeholders should be involved in the planning of appropriate prevention measures: the scientific community, the experts, the local administrations, farmers, environment associations, businesses and local citizens through awareness campaigns, information and education
-

Also at basin level comprehensive management plans should be adopted, considering the entire area and all functions of the watershed: land use, forest and water management should cooperate to reduce natural risks and generate ecosystem services, with special attention to forest areas connected to rivers and torrents. Plans should be funded to allow continuity of the measures.
Projects should have an ecosystemic approach and maintenance measures must be carefully designed and be harmonized with the stakeholders.

4 Definitions and organization in the alpine countries

There are significant differences between the Alpine Convention countries regarding the area and the importance of mountain forests for flood protection. So we tried to give an overview of the situation in some different countries.

Germany:	
Legal definition:	
With regard to flood prevention the following forests are protection forests: - Forests in catchments of dangerous torrents with flood and landslide danger that are covering slopes over 15° - Forests in catchments of slopes that are endangered of landslides, if landslides can be reduced by reducing the surface runoff. Forests with protection functions are under special legal protection. Clearcuts and transformation into other forms of land use are strongly restricted.	
Amount of forest with water protection functions:	
44.000 ha (28% of all protection forests)	
Organization	
Water management administration (Bavarian Ministry of Environment and Consumer protection)	Planning and realizing flood protection concepts on bigger water bodies, gives advice to local communities, makes flood predictions and flood warnings
Local comunities	Planning and realizing flood protection concepts on bigger water bodies
Forest administration	Consultancy of forests owners for the management of water protection forests. Restoration of protection forests.

Italy:
Legal definition:
The R.D.L. 30 december 1923, nr. 3267 recognised *senso latu* the protective function of the forest through the hydrogeological constraint: change of land use, works implying earth movements and forest management are subject to regulation. The regulation identifies also a more specific constraint aimed to special protection situations: *"woods, that due to the peculiar position, shield lands and buildings from avalanches, rockslides, strong winds, and those which are considered useful for the local hygiene conditions, may be subjected, if requested by Provinces, Municipalities, or other authorities and private entities, to limitations in their utilization"*. This kind of constraint has been however rarely applied and only in specific and sporadic occurrences. In the recent past, various regional administrations have started to apply, both in regulations and planning fields, a specific differentiation, according to the modern conception of the protective forest, but there is not e common definition on specific protection forests for flood prevention.
Amount of forest with water protection functions:
At alpine level forests subject to hydrogeological restriction by Royal Decree of 1923 are ha 2.670.630, 88,6% of the total.
Organization

The forest planning is in charge of the Regions that must provide them by integrating these plans with the Flood Risk Management Plans which are prepared, according to Directive 2007/60 / EC, by the basin authorities (2 in the Alpine area).

At the municipal level, emergency planning is also mandatory, while the interventions are generally carried out at local level by Municipalities or Union of Mountain Municipalities.

Liechtenstein:

Legal definition:

According to the Liechtenstein Forest Act (1992) the legal definition of protection forests is focused on the gravitational natural risk processes as rockfall, stone chipping, avalanches and mudslide. Such affected areas are recorded on the forest functions map within the Forest Development Plan (WEP, 2018). There are 3 different levels of protection: 1) direct protection of people and property, indirect protection of people and property and 3) site-protection.
Flood prevention is not particularly mentioned in the Act, as all forests play an important role in the restraint and storage of water, due to the special topography in Liechtenstein.

Amount of forest with water protection functions:

6'682 ha (100 % of all forests)

Organization:

Office of Environment Responsible for the conservation, restoration and management of all forests in the country. Close cooperation with Office of Civil Protection and local forest services.	**Office of Civil Protection** Planning, development and realization of flood protection concepts based on an integrated risk management. Close cooperation with Office of Environment regarding protection forests and with local torrent responsibilities.

Slovenia:

Legal definition:

According to *Rules on forest management plans and game management plans* (Uradni list RS, št. 91/10) the following forest functions are identified as flood protection forests:

- protection function against erosion processes, and
- hydrological function.

That are forests with special management plans.

Amount of forest with water protection functions:

518645.7 ha which is 77.5 % of Alpine convention area in Slovenia and 2.9 % of total area of Alpine convention (100 % of all protection forests)

Organizations

Slovenian Ministry of Environment and Spatial Planning
Operating: ARSO, Slovenian Environmental Agency & Concessionary services in Water Management (after 1.1.2016: Directorate for Water & Concessionary services) Based on Slovenian Water Act and its sub-legislations

Last revisions to the Water Act (Official Gazette of the Republic of Slovenia, No. 57/08),

1. Rules on the methodology for determining areas threatened by floods and their associated inland waterways and sea erosion and on the method of land classification in the threat classes (Official Gazette of the Republic of Slovenia, No. 60/07),
- Decree on the Conditions and Restrictions for the Implementation of Activities and Interventions in the Area in the Areas Affected by Floods and Related Erosion of Inland Water and Sea (Official Gazette of the Republic of Slovenia, No. 89/08 - hereinafter: the Flood Regulations) and
- Decree on the content and method of preparing a more detailed flood risk reduction plan (Official Gazette of the Republic of Slovenia, No. 7/10).

5 Best-practice examples

Many good best-practice examples could be collected during the conference „Flood protection through protection forests in the Alpine Region“ which was held during the German EUSALP-presidency from 23./24.10.2017 in Bad Reichenhall. Other examples were brought in by the members of the working group on mountain forests of the Alpine Convention.

Integral risk management on torrent in Bavaria

In the 100 years since establishment of torrent control major changes happened in land use: residence area and infrastructure grew substantially and forest cover also increased significantly. The old control works need to be maintained often replaced.
An Integral Risk Management Concept was developed considering:

- check of flood-risk: land use, actual vegetation cover's and soil's conditions and existing technical works; water discharge, bedload and trees transported during floods are considered.
- analysis of alternative strategies (considering original objective and actual conditions)
- definition and management of rest-risk, communication and monitoring.

Integral torrent development plan in Bavaria (Rimböck, 2017).

Integral torrent development plan in Bavaria are aimed to design an optimal management of torrent catchment areas. It consists of a circle of risk analysis, risk assessment and risk management. The projects consider technical works as well as the improvement of the forest in order to reduce the flood risks.
The following main objects have been defined:

- improving flowing conditions and creating bedload and water storage
- replacing and completing still necessary control works and abandoning those not needed anymore
- creation of a stable, mixed forest, capable of natural regeneration (forest measures and planting)
- change in hunting and grazing to allow good regeneration

Relevant stakeholders were involved in the project that considered all form of land use in the area. The project was carried out by water management agencies with the participation of forest agencies.

Integral Risk management plan Ahr valley catchment (South Tyrol, Italy) (Unterthiner, 2017)

The plan is carried out by municipalities with the cooperation of the torrent control and the forest services. The analysis for the plan considered

- land use: actual, changes, conflicts, potential conditions
- natural risks,
- water use, river and land ecology
- forestry:
  - protection function, actual condition and potential.
  - risk of trees in the river causing obstructions.

Special attention was given to the involvement of the community and stakeholders through communication, information and participation procedures have been put in place

Protection forest management by Bavarian State Forests (BaySF) (Müller, 2017)

BaySF are a major actor in the Bavarian alpine region, with a large land- and forest-ownership: 189.000 ha land; 159.000 ha forests (106.000 ha protection forests, 48.000 in production). As BaySF are in public ownership special attention to ecosystem services (particularly regulating ones) is given in the definition of management objectives.
In order of priority the management of the forests have to

1. maintain/improve protection function
2. sustainable wood production
3. other functions (particularly nature conservation and recreation) must be maintained
4. management of areas out of production
5. hunting must be compatible with previous objectives

Special measures help to maintain and restore the multi-layered structure of the forests and the needed tree-species. Special attention is given to maintain natural regeneration. The permanent forest cover and the natural regeneration help reducing the impact of extreme events (humus depletion, difficult regeneration).

Torrent monitoring in Tyrol (Fuchs, 2017)

Austrian Forest Law prescribe Municipalities to check **torrents (2.700 km in Austria) at least once yearly** to control possible obstacles to regular flow and monitor the stand of existing control works. 80% of the torrents are checked, only in particular conditions the monitoring is carried out in longer periods. Reports are checked by the federal technical service for torrent control. 50% of alerts are linked to trees (driftwood deposited by floods, large and unstable, trees in dangerous areas).

Torrent protection forests in Switzerland

The practice has already been described in the report 2015-2916 of the WG, but it is useful to be reminded in this context. Torrent protection forests are the larger part of protection forests in Switzerland (80% of the area) and are defined as forests that can directly influence torrent activity through landslides, bedload or large trees reaching the torrent flow.
Public subsidies for forest management are linked to protection functions and to the goal of more stability, improved positive effect on storage and soil protection and avoiding negative effects. Management objectives and forest measures must be detailed in the management plan and subsidy proceeding.

Switzerland has important projects on protective forests, with guidelines and specific training for foresters on the management of protection forests, where the primary objective is to improve stability and resilience of the forest

- silvaProtect.ch (http://www.bafu.admin.ch/naturgefahren)
- NAIS (Sustainability in Protective Forests)

River Contracts in Lombardy region

The bad quality of water in many watercourses, the urgency to govern complex basins, the need to answer to the increasing demands for territorial quality and direct participation of citizens, lead Lombardy Region to identify a governance tool able to meet the requirements and at the same time to effectively impact on territorial transformations. River Contracts are processes based on different funding (European funds, national and regional funds, calls of Foundations). They encourage to identify projects and funding in an integrated way.

The River Contracts experience in Italy begins 2004 with the Lambro-Seveso-Olona riverbasin: it is a process without a definitive deadline, with objectives and action plans to be renewed over time, without a closing date.
Today (2018) in Italy many experiences are starting and a dozen consolidated; among these, the most mature are in Lombardy and Piedmont Region.

In Lombardy they derive from the need to effectively manage the integration of Flood Risk Planning (PGRA), water quality protection (PTUA) and basin spatial planning. These are in fact planning issues traditionally handled in a sectoral way, to be integrated in a common strategy.

The Lombardy River Contracts focused **to foster resilient river communities, fixing and mitigating the impacts due to decades of heavy urban development and improper land and water use,** even in mountain areas.

The objective is to activate a "voluntary tool of strategic and negotiated planning pursuing basins conservation, good water resources management and river areas valorization, together with risk flood protection, contributing to local development (article 68bis of Environment Code Law 152/2006 update 2015).

River Contracts in Lombardy are promoted and coordinated both from Lombardy Region Government, both from local bodies as Parks and Mountain Communities.

Three River Contract characteristics are relevant:

1. The **focus** of concerted actions is **geographical and social**: a river basin cuts across any border, which puts emphasis on the common needs to support biodiversity and the shared cultural origins of settled human communities;
2. Negotiations and concerted action plans **involve territorial stakeholders**, from the public authorities at various levels (project, authorisation and infrastructure investments) to service providers operating in the area (water management companies), from scientific experts to NGOs and citizen groups, to businesses (such as farmers, fisheries, food industries etc.);
3. The River Contract measures are usually based on **research studies and diagnoses/prognoses on the best ways to recover, improve and preserve the river ecosystem**, but are defined in concrete terms and prioritized as per costs and benefits through a participative process.

Basins involved in River Contracts are Olona-Bozzente-Lura-Lambro Meridionale, Seveso, Lambro Settentrionale and Mincio. The basins with in-progress River Contracts are: Adda Valtellinese, Toscolano , Bardello (these entirely in mountain areas), Oglio, Mella. Olona, Seveso and Lambro Settentrionale River converge towards the Metropolitan Area of Milano.

The River Contract is the outcome of a process of negotiated multi-level governance, implying a multiplicity of concurrent initiatives, multi-sectoral and multi-actor, aimed at restoring the eco-landscape of an existing river basin. *The 2000 World Water Forum has characterized the River Contract as enabling "the implementation of a system of rules in which the criteria of public utility, economic profitability, social value and environmental awareness are equally involved in the search for effective solutions".* River Contracts identify strategic areas in which it is necessary to intervene: • water pollution management and reduction; • water risk management and reduction; • sustainable protection and enhancement of hydrographic systems and landscape; • urban renewal and environmental improvement along river corridors. Lombardy Region, supported by the ERSAF technical-scientific Team, is more and more assuming a coordination role and reference helping the Contract processes. In particular, the effort of coordinators aims to improve synergies among regional River Contracts and foster the integrated approach to several issues (flood risk, ecologic networks, ecosystem services, cultural heritage,...). The **Strategic River basin Project** is the instrument to implement actions; it assumes in its measures the river as the core of the process and decision-making, relating water quality, flood risk and ecosystem services. It implies to switch from a traditional sectoral and restrictive approach to the concept that constraints are opportunity to re-think the river and basin areas.
Each Contract details actions aiming to reach the identified objectives in the Action Plan. The action plan also provides an impact assessment framework dealing with: • water quality improvement targets; • river banks recovery, protection and maintenance investments; • hydraulic risk reduction and flood prevention measures, including Sustainable Drainage Solutions (SUDS); • better exploitation of water resources by the local service providers; • improved water management according to the different uses; • river ecosystem and biodiversity support and enhancement; • awareness raising, communication and dissemination.
Actions in Action Plan are targeted on the short-medium term and are updated every three/four years. The long term is considered in the Contract vision (strategic documents) with the main objectives.
Actions have different size and costs: from about thousands euro for training and awareness initiatives to action of millions euro for important structural interventions, such as flood retention basin or plants revamping.
Technical-Scientific Team of River Contracts cdf@ersaf.lombardia.it 0039 02 67404217
www.contrattidifiume.it
Since 08.03.2018 the national coordination requested by Environment Ministry has became operational through the institution of National Observatory of River Contracts (reference: http://www.minambiente.it/pagina/wp2-gestione-integrata-e-partecipata-dei-bacinisottobacini-idrografici)
http://www.contrattidifiume.it/export/sites/default/it/doc/Azioni/progetti_collegati/Mappa_CDF-lombardi_20180322.pdf

Good practices and current situation in Slovenia:

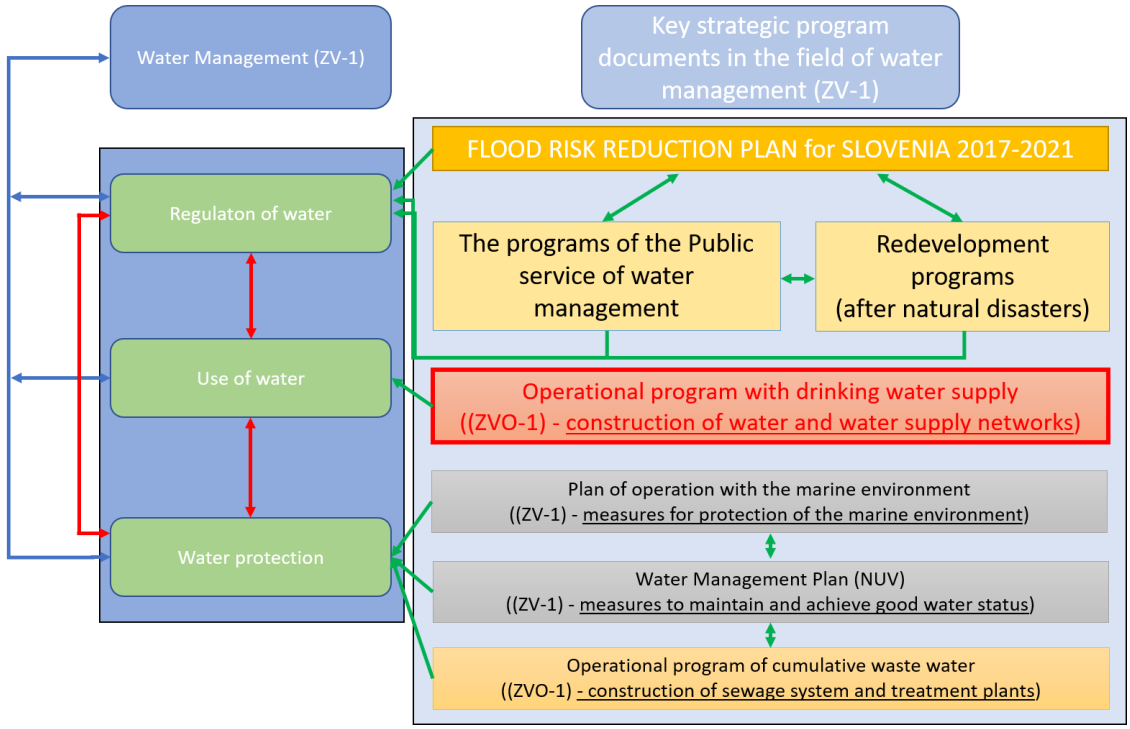

Fig. 4 *Water management (regulation, use and protection of waters) in relation to strategic program documents in the field of water management (2017), Flood risk reduction plan for Slovenia 2017-2021, Slovenian Ministry of the Environment and Spatial Planning, p. 262.*

Slovenia has been coping with enormous flood related damages in the last 10 years (approx. 150 mio EUR of damages per year). Trobec (2017) states that in Slovenia flash floods occur with varying frequency during different times of the year due to specific climatic conditions with a variety of seasonally dependent weather processes that generate heavy and intense precipitation that cause flash floods.

In recent times lots of structural and non-structural flood reduction measures have started. All of these activities have been integrated in the Flood Risk Management Plan 2017 - 2021 that has addressed and determined flood risks at the areas of potentially significant flood risk (61 such areas were identified in Slovenia). The basic task of the state is to ensure the comprehensive implementation of measures to reduce the harmful effects of water through the use of spatial and water planning, informing, educating and raising awareness of people and alarming events.

Because of above mentioned facts Slovenia adopted some important documents, namely **EU Floods Directive implementation:**

1. Preliminary Flood Risk Assessment – done (22.12.2011), published (22.12.2011) and reported to EC (22.03.2012);

2. Areas with Potential Significant Flood Risk – 61 APSFRs identified (14.02.2013) and reported to EC (21.03.2013);

3. Flood Hazard and Flood Risk Maps – reported to EC (20.03.2014);

4. Flood Risk Management Plan 2017 – 2021

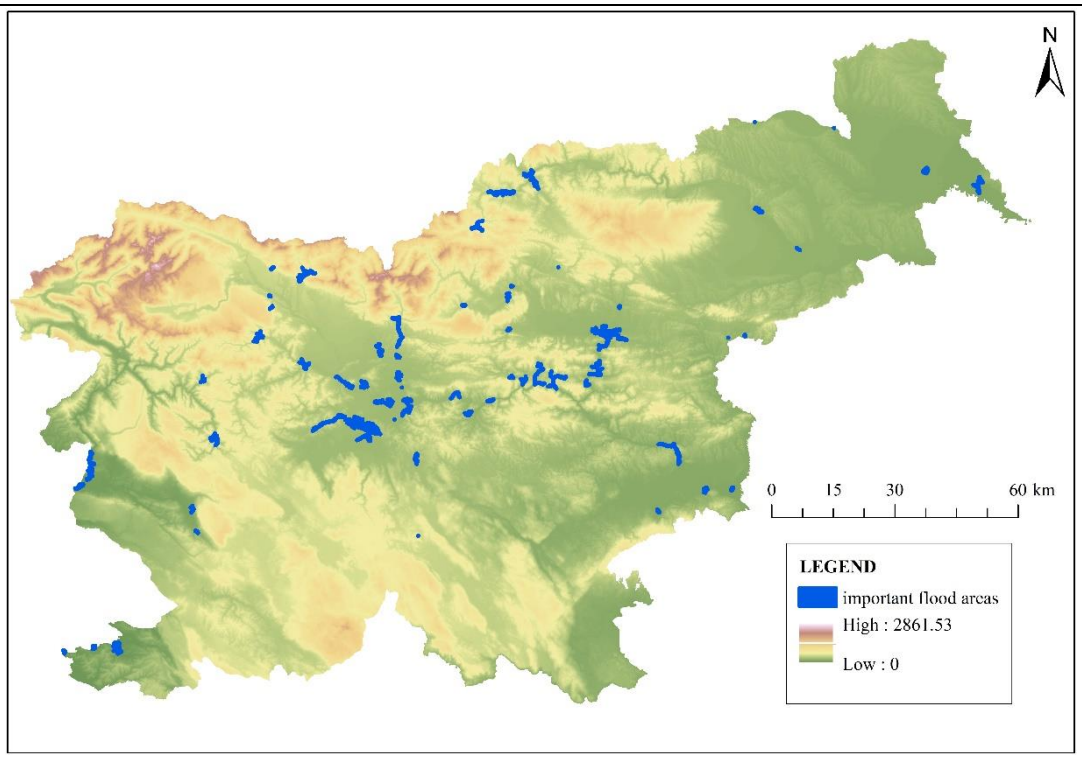

Fig. 5 *Map showing important flood areas in Slovenia. Source: Institute for Water of the Republic of Slovenia, Sector for Fresh Waters, 27.07.2018.*

Torrent protection forests in Slovenia

Horvat et al. (2008) recommend that damage inflicted by natural disasters can only be mitigated through systematic, long-term, integral and sustainable measures. In practice this means a set of appropriate measures within an integral system of managing dangers and risks, coupled with the participation of all relevant players. One should be aware that the issue of providing safety fro erosion and torrents is not limited solely to physical safety of the population in the affected areas, but rather has broader economic and demographic perspectives. In a country where nearly half of the territory is represented by areas potentially endangered by erosion, ensuring safety from erosion and torrents is also an important political issue. The price of preventing is significantly lower than the price of rehabilitation.

According to Papež (2011) reducing the occurrence of woody floats in torrential streams could be provided with the following measures:

1. planning and cultivation of forests: nurture the appropriate structure of the forest, adapted to the protective function; it is particularly important to remove unsuitable old trees in time, which can cause clogging of the riverbed;

2. planning, implementation and control of forestry work: exploitation of forest should be adapted in the torrent influence areas, anti-erosion measures, with consistent preventive behaviour, reducing possibility of introducing wooden floats (logs, stalls, branches, wood, etc.);

3. control role of foresters in the forest: identifying and documenting the extent and intensity of torrential and erosion processes and critical points (storage logging, logs, etc. in inaccessible places, etc.) providing necessary input data for an appropriate hazard assessment, timely planning and implementation of preventive measures (removal of wood from the riverbed, etc.).

Alpine Space project GreenRisk4ALPs (GR4A)

Goal is the development of ecosystem-based risk governance concepts with respect to natural hazards and climate impacts – from ecosystem-based solutions to integrated risk assessment. Especially in the Alpine Space (AS) forests and mountain ecosystems are outstandingly important and are increasingly considered on-par with technical measures or other prevention concepts: forests efficiently protect against avalanches, torrents, landslides or rock-fall. Without an adequate implementation of mountain ecosystems services (incl. forests) in a risk mitigation strategy, sustainable development in the AS will be hard to achieve, balancing green, technical and preventive risk strategies. To overcome conflicts and resistances all relevant actors are involved with science-based communication support.

The project foundation are five pilot action regions (PAR) from SLO/ITA/FRA/GER/AUT, which are fully involved.

Slovenia's CURRENT and FUTURE state regarding the flood protection

The current set of measures and projects for the period 2017-2021 is valued at approximately EUR 540 million. Potential sources of funding for the preparation, development and implementation of measures and projects are European and national funds and municipal budgets.

Two important research works are currently running on driftwood under the mentorship of doc. dr. Milan Kobal (Department of Forestry and Renewable Forest Resources, BF UL, Slovenia).

1. Estimation of the amount of woody debris and driftwood in torrents on the basis of multispectral analysis. The positive function of the wooden float in providing ecosystem services and the negative influence of the excessive amounts during floods is considered. A balance can be achieved through preventive measures in the wider area of watercourses and by appropriate monitoring of the **wooden debris and driftwood**. Multispectral imagery has proven to be a useful tool in the manual way of recognizing it and estimating their volume [Gregor Senegacnik].

2. The influence of the forest structure on the quantity and amount and distribution of wooden debris and driftwood in selected watercourses in Slovenia.

The research was carried out in the area of six watercourses in three different regions in Slovenia. The fieldwork included measurements of the location of the wooden debris and driftwood (x and y coordinates) and the estimation of the quantity (number) of the wooden debris and driftwood, the description of the building structure (the development phase, the tree structure) and the calculation of the distance of each piece from the road (roads and trains) [Avgustin Leskovec].

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