PART 3

WATERSHED RESEARCH IN EUROPE

CHAPTER 8
NEGLECTED ASPECTS OF WATERSHED MANAGEMENT

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INTRODUCTION

Integrated watershed management should not only deal with water balance or focus on the needs of stakeholders, land use and forestry but should also integrate aspects such as water and sediment sources, slope stability and sediment transport, especially in young, active mountain belts.

This paper will concentrate on:
- high alpine regions in the United States, Germany, Switzerland, Austria, France and Italy;
- stakeholders, mainly from forest services, small farms, alpine clubs, villages and small towns downstream;
- the treatment of watershed management as a comprehensive problem covering issues that range from precipitation to runoff, from ecology to evapotranspiration and from slope instability to sediment transport.

STATEMENT 1: WATER BUDGET AND EVAPOTRANSPIRATION

Water budget

In mountain watersheds, there is little sense in carrying out water balance studies in the traditional manner of calculating evaporation losses from the deficit between precipitation and discharge because precipitation is too inaccurate a factor to act as the main determinant. Instead, an alternative approach is suggested in which regional precipitation is back-calculated from the sum of the losses incurred by discharge and evaporation (Figure 1; de Jong, List and Ergenzinger, 2002; Schädler and Weingartner, 2002). This is more accurate than determining the regional precipitation with standard extrapolation procedures from few point stations. Because the losses by evapotranspiration in high mountains are relatively small, the relative error of accuracy of evapotranspiration models can also be kept minimal. Accordingly, integrated watershed management in high alpine regions should pay far more attention to the determination of evapotranspiration in forested zones and in those covered by alpine meadows and shrubs. Due to its ecological importance and potential for change in the near future as a consequence of climatic perturbations, the zone above the tree line, which interacts with alpine meadows, shrubs and the forest border, should no longer be neglected by hydrologists.

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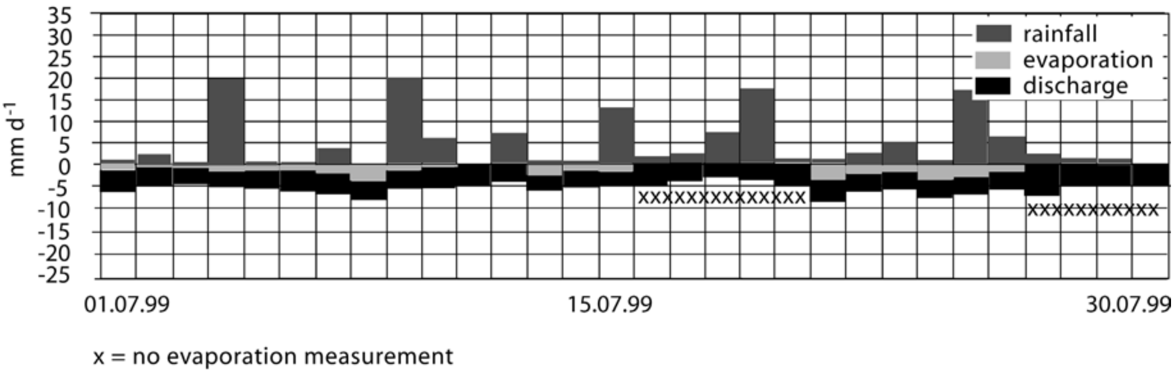
Another factor that is often neglected in watershed management in mountains is the hydrological role of avalanches within the water cycle. Avalanches are agents for the internal water movement within a basin and should therefore be investigated. Snow transfer into the lower valley zones near water route ways causes faster melt at different temporal and regional scales owing to higher temperatures. If snow melt occurs more rapidly and at an earlier stage seasonally, local soil moisture conditions can be influenced and water discharge into the streams is accelerated, so water can be transported away more quickly, and discharge increases. Any change in the frequency of avalanches through changes in climate or vegetation cover will be reflected in these hydrological processes.

FIGURE 1

Measured evaporation (from evaporation pans), discharge and rainfall in the Dischma valley for the wet month of August 1999.



Evapotranspiration

The regionalization of evapotranspiration requires a suitable description of the physical characteristics of the watershed. It is suggested that the regional differentiation of temperature as detected by remote sensing, e.g. from light aircraft or satellite, is the most appropriate approach for validating evapotranspiration model results in mountain terrain. Because there is no simple evapotranspiration approach that can be transferred from the lowlands to the alps, well-known meteorological functions that have been developed for flat terrain and non-turbulent conditions, such as the Penman or Bowen ratio, are not applicable (de Jong, Collins and Ranzi, 2005). On the other hand, the Priestley-Taylor function has proven to be a robust approach.

A profound knowledge of evapotranspiration processes of single trees and tree stands in alpine areas already exists from long-term experimental studies such as those carried out by the WSL Birmensdorf in Davos, Switzerland (Häsler, 1982). In contrast, little is known on evapotranspiration of the high alpine belt above the tree line, especially those areas covered by pasture and dwarf shrubs. The hydrological interactions between this zone and the lower-lying alpine meadow zone in relation to its role as meadow or pasture for milk production has been largely neglected. In alpine catchments, the amount of evapotranspiration increases significantly from the colder, windier meadow on the valley floor to the sheltered, highly insulated shrub zone on the lower valley slopes (de Jong, Migala and Mundelius, 2005). It is these zones that are most highly frequented by grazing cattle. Should they undergo strong land-use change, this will not only have important impacts on the water balance in terms of ecology and biology; for example, once alpine meadow is abandoned, a rich and valuable deposit of fertilizer is developed locally (Körner, Hoflacher and Wieser, 1978). As a result of this extensive organic cover and the limited weathering capacity of the parent material, soil development is modified over many decades. No natural soil development will be possible for a long time, and any soil development that does occur will be strongly dependent on antecedent land-use conditions. Such modifications of the soil and vegetation cover influence the storage capacity of the soil and the amount of evapotranspiration.

STATEMENT 2: SEDIMENT BUDGETS AND RIVER BED STABILITY

During the International Year of Mountains 2002, the principal focus in natural sciences was narrowed down to problems of the hydrological cycle in mountains. However, in these extreme regions, watershed management has to be far more comprehensive and should include new focal points such as:

- river bed stability;
- general aspects of flooding;
- sediment transport.

River bed stability has an important causal relationship with the floodplain zones where land use and infrastructure are intensive. It is therefore important to understand and predict potential destructive changes in terms of erosion and deposition by flood flows in these zones (Dunne, 2000). During and after floods, large woody debris and coarse sediment play a dominant role in restructuring river beds, and this can have disastrous effects on areas with traditional land use. The stakeholders concerned include farmers with property in riparian river zones and administrators, especially of forest roads that are prone to erosion during floods. Locally, the hydraulic conditions and the river morphology are quite often altered by the impact of eroded trees and/or log jams (de Jong and Ergenzinger, 1995). Wood-induced river bed formations are common in mountain torrents and – apart from step-pool systems –are responsible for major habitat diversity. In contrast to hard check dam structures, these natural breaks in the longitudinal development of a stream enable far higher connectivity of the fluvial system (Figure 2).

It is commonly assumed that the probability of floods changes with land use, especially in relation to forested and agricultural land. However, during extreme thunderstorms with high intensity rainfall, the influence of land use on flood discharge rapidly loses significance. Forests, for example, can reduce average flood flows, but where extreme precipitation occurs during single precipitation events with magnitudes of 40 to 80 mm per day, extreme floods will develop independent of the vegetation cover. Liniger and Weingartner (1998) indicate that the influence of forest ceases as soon as soil is saturated, as was the case in the extreme rainfall–flood events in Switzerland in the last century. Naef, Sherrer and Weiler (2002) describe how storm runoff cannot be significantly reduced by land-use changes, unless they occur in the runoff generation areas where runoff is rapidly produced. Thus, for hazard assessment of extreme floods the question of whether catchments are forested or not is not nearly as important as how much water can be stored and transmitted in rapid runoff production areas such as slopes, scree fields or river beds. Good geomorphological and hydrogeological maps that coherently describe the sub-surface conditions are therefore necessary, in addition to land-use maps. From a hydrological point of view, predictive tools will fail if prognoses rely only on forest cover maps.

It is often overlooked that the hazard potential of floods is not merely a function of the amount of peak flow but also of the amount of sediment mobilized (de Jong, 1997). Large-sized sediments are usually only set into motion during floods, and will then cause considerable river bed changes (de Jong, 1994). Such changes can have long-lasting effects on forests and other types of land use along the valley floor. This is especially true for Mediterranean mountain areas, where farmland and fruit orchards are closely tied to riparian areas. The danger of river bed change increases significantly in zones of slope instability. During extreme events, there is a high potential for slope degradation by mass movements; slope degradation, in turn, generates very large sediment point sources. Mass movements that block river courses can even create temporary lakes and act as source areas of coarse sediments for a considerable time after an event, thereby temporarily elevating the river bed (Ergenzinger, 1992). It can take decades for former valley conditions to be restored after disruption by fluvial erosion.

In order to obtain a comprehensive understanding of the dynamics of mountain torrent beds, appropriate observation systems should be applied. Apart from standard geodetic cross-sections or longitudinal surveys, remote sensing from tethered balloons or via helicopter using digital cameras or video systems is suggested for streams in the order of 5 to 10 m width

FIGURE 2

Damaged and sedimented check dams in the Bavarian Alps, Lainbach River after the 1990 extreme event.

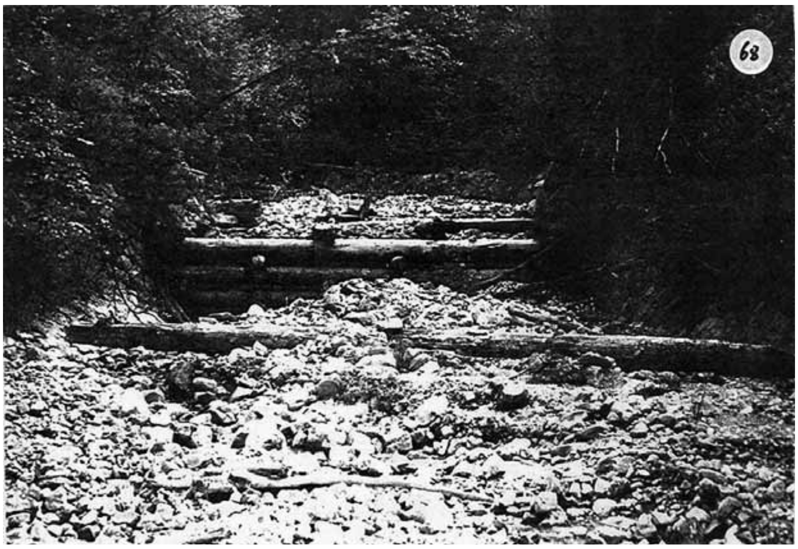


Photo: Thilo Schmalfeld.

(Ergenzinger and de Jong, 2003). For larger rivers (> 200 m in width), river bed changes can be determined with the help of drones or light aircraft and scanning stereo techniques (Figure 3), such as the HRSC system (Bucher and Lehmann, 2000). In addition, the velocity of representative bed particles during bedload transport can be measured with radio tracers (Figure 4) (Ergenzinger and Conrady, 1982) or magnetic tracers (Ergenzinger, de Jong and Christaller, 1994).

FIGURE 3

New possibilities of investigating morphological changes of river beds with HRSC scanner from light aircraft. Example of the Rissbach 400 m above its confluence with the Isar River, Upper Bavaria in 2000. The 3-D resolution of the river bed is 15 cm.

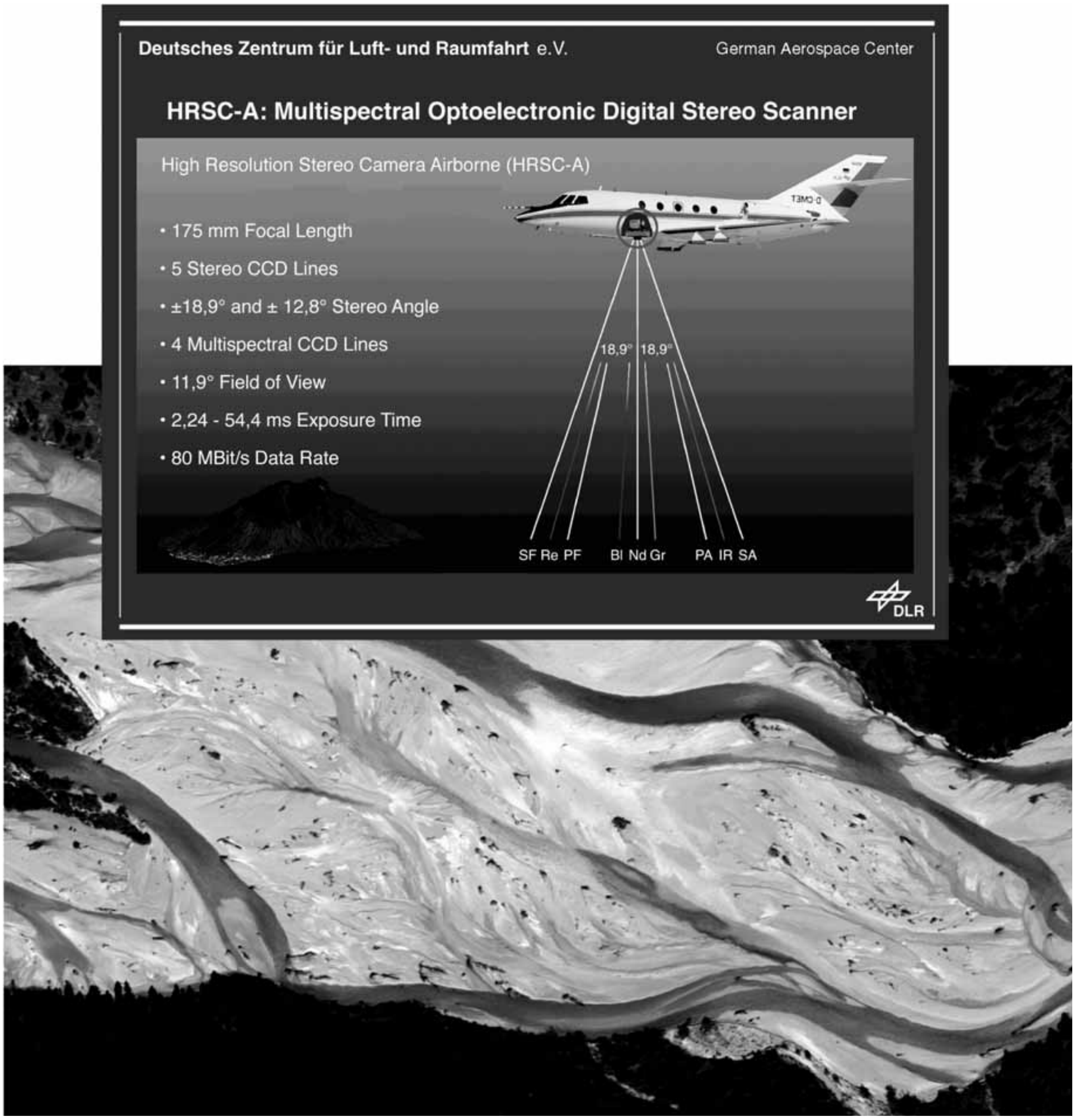
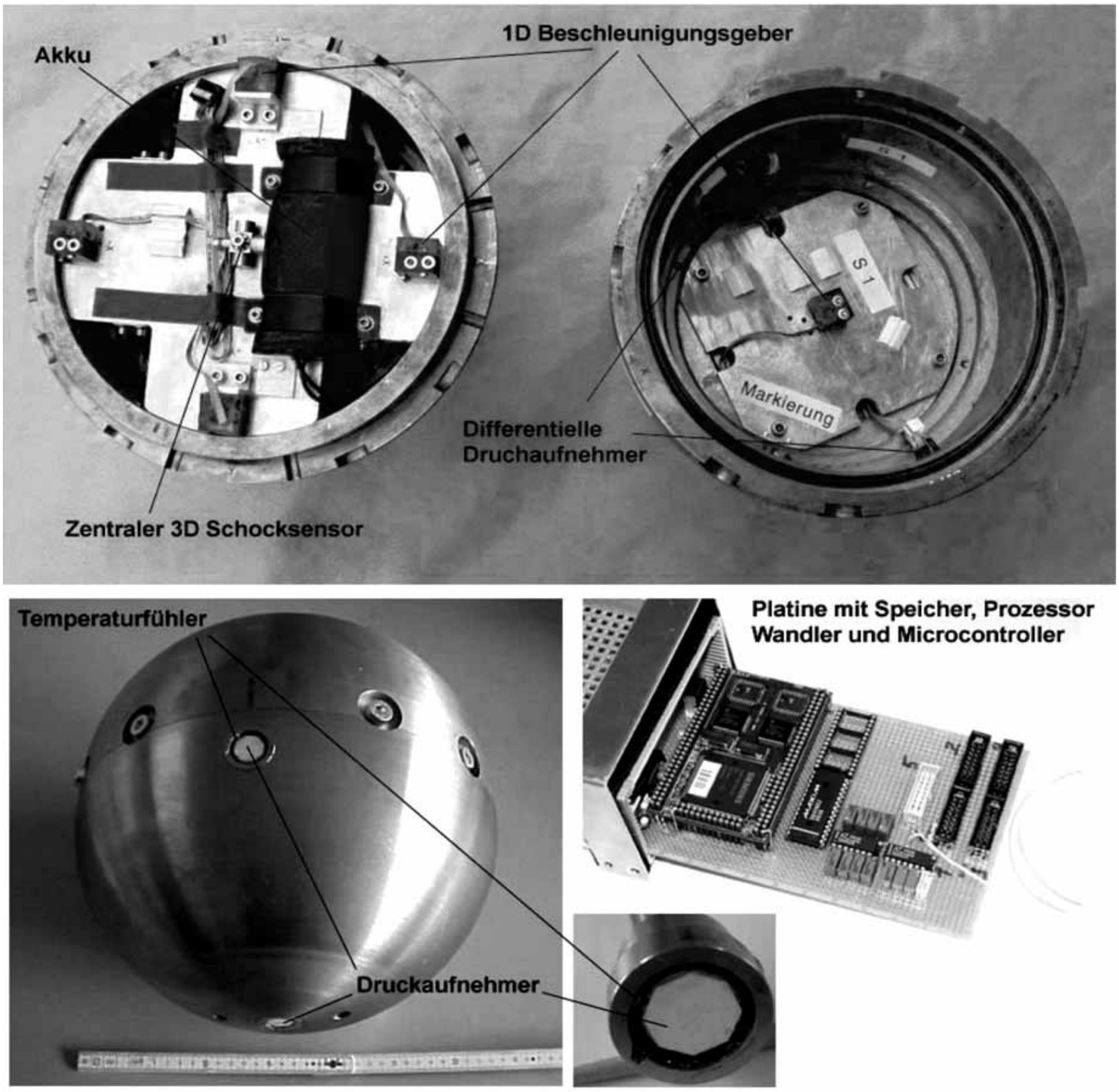


FIGURE 4

Instrumented mobile measuring probe for quantifiying pressure differences and velocity of sediment transport during natural debris flows and floods in high mountain streams. The probe is fitted with pressure transducers and memory module (developed by J. Hanisch, BGR Hannover and P. Ergenzinger, FU Berlin 2001)



STATEMENT 3: SEDIMENT RETENTION STRUCTURES AND SUSTAINABILITY

Over the past 150 years, special problems caused by human intervention have arisen in alpine catchments (Habersack and Piégay, in press). Modifications in the sediment source areas of catchments have had considerable impact on river channel dynamics. Considerable effort was undertaken to retain sediment in the source areas, on the one hand through slope stabilization (reforestation and technical measures) and on the other by torrent control work (Wildbachverbauung). As a result, sediment delivery was strongly altered, and new protective measures were required in the downstream areas, e.g. to counteract excessive channel incision resulting from sediment deficit further downstream (Liébault and Piégay, 2002).

One procedure for sediment retention in the nineteenth and early twentieth centuries was the construction of small check dams, mostly of wood, in high density along the upper river reaches (Bravard and Peiry, 1993; Habersack and Nachtnebel, 1995). The check dams store sediment until they are full, when the surplus is conveyed over the sill. Although the concept of check dams is to reduce the longitudinal river profile and associated sediment transport, the dams have proximal as well as distal effects. Small check dams in river channels are potentially dangerous nowadays because they have stored large quantities of sediment over long time periods and are weakening owing to a shortage of maintenance budgets (Figure 2). Disaster in terms of excessive sediment release and the consequent destruction of human-made structures downstream can result from the so-called "check-dam domino" effect (i.e. sudden failure of one check dam after the other resulting from the impact of sudden sediment release from the upper check dams). Whereas the sudden failure of check dams has strong local effects, long-term sediment retention in check dams alters the river dynamics over longer distances (hundreds of kilometres) by causing continual channel deepening. As a result of decreasing sediment supply over many years, it is possible that the active channel width decreases and the channel narrows. In the Rhone catchment, 70 percent of braided reaches have disappeared owing to the combination of torrent regulation, sediment trapping upstream and gravel mining (Bourdin, 2004). The financial costs of the effects of such measures are considerable (Bravard, Kondolf and Piégay, 1999).

The widespread claim that forests act as protectors against such sediment-dominated disasters is often a myth. The protective role of the forest is dependent on the soil porosity, slope gradient and rainfall intensity. Where flatter slopes dominate, runoff does not concentrate as much as it does on steep slopes, and in these zones the forest can reduce the impacts of sediment transport or the passage of debris flows. However, such conditions are rare in steep alpine areas, and forests cannot protect against the concentration of runoff during storm flow. In highly porous areas, such as steep debris flow cones within the forest, infiltration capacity is higher than rainfall intensity during storm events. Surface runoff does not occur except where the rapidly rising groundwater table reaches the surface and initiates small debris flows. Forests may dampen the effects of extreme events during the first 15 mm/hour of effective rainfall (without interception), but for rainfall exceeding 80 mm/hour, surface runoff dominates and sediment stored over decades on the forest floor is rapidly transported into the river. Thus, the capacity of the forest as a sediment trap is limited. This is also true for the occurrence of debris flows (Figure 5). Debris flows can either be generated above the tree-line or as a result of bank failure of streams within the forest, and their tracks can directly traverse the forest downslope. Again, the forest cannot help in protecting the passage of the debris flows. An example was the flood/debris flow disaster in the Lainbach valley in 1990 (de Jong, 1994) in which small, zero-order streams in the forest were rapidly enlarged to transport large debris flows. After this event small, turned-over grass patches provided evidence that groundwater had surfaced locally under high pressure in hollows, reactivating channels in the source areas. All these processes should have a significant impact on the way in which hazards are assessed in mountain catchments with major transport infrastructure and villages below forested slopes.

FIGURE 5

Multiple debris flows traversing dense forests at Piz Madlain in Prätigau (Lower Engadin) Switzerland.

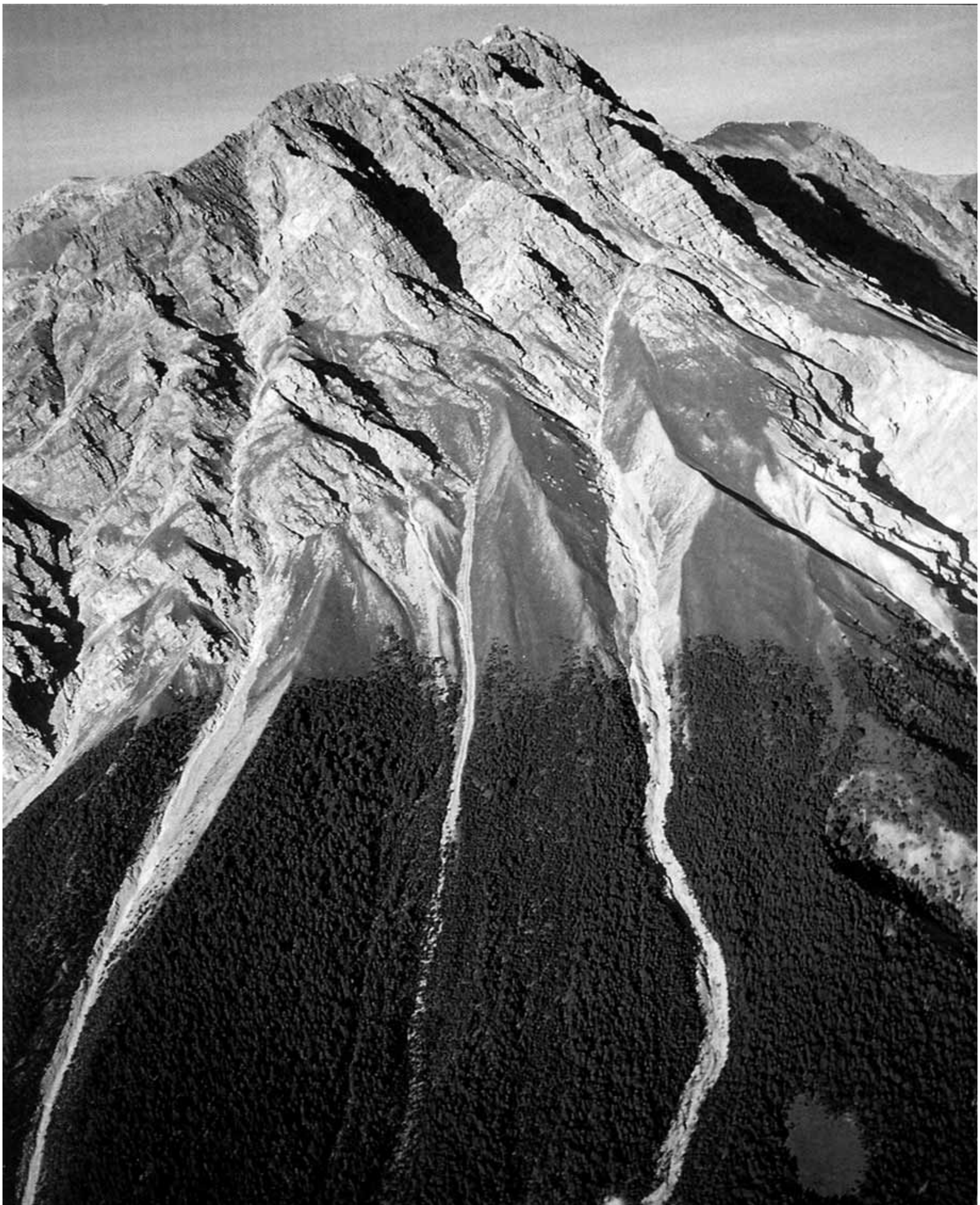


Photo: Donatsch and Pult in Ikarus über Graubünden, 1995.

Other problems are the unwanted side-effects of sediment retention of large dams or dammed catchments (Kondolf and Swanson, 1993). Because the majority of sediment cannot be removed from the dam reservoir (Verstraeten and Poesen, 2000), sedimentation behind dams, whether minor or major, can be compared to a time bomb. However, the number of new dams being built in high mountain catchments is still increasing, and the sedimentary problems associated with them are largely ignored. By reducing flood magnitude, dams decrease or eliminate bedload transport and cause major ecological change downstream. Minimum discharge released from dams is not well regulated from an ecological viewpoint, and can completely extinguish ecosystems that depend on a certain flow velocity and river bed morphology. Not only is the limited life expectancy of all technical solutions to nature a challenge for us in the near future, we are already being confronted with the problem of how to react to large quantities of – at times, polluted – sediments that have been stored within dammed basins over many decades and centuries.

CONCLUSION

This paper has shown that there is no single solution that is suitable for mountain watershed management. It is therefore not advisable to discuss only the procedures of hydrological top-down or bottom-up strategies or of combinations of the two methodologies. Problems cannot be solved by applying single-discipline approaches, but require profound inputs from hydrology, meteorology, biology, geomorphology and related sciences. The neglected aspects of watershed management will remain neglected if there are no interdisciplinary means for controlling the success or failure of watershed programmes. In order to enable more sustainable solutions for the future, further technical developments, possibly from cross-cutting disciplines, are necessary to substantiate our understanding of the dynamics of high mountain basins.

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CHAPTER 9
INTEGRATED WATERSHED MANAGEMENT ON A LARGE-SCALE BASE

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INTRODUCTION

The control of natural hazards is part of watershed management and the main aim of the Forest Technical Service in Erosion, Torrent and Avalanche Control of Austria.

Natural hazards can only be controlled by integrated risk management. On the one hand, an interdisciplinary cooperation of authorities concerning management of the habitat and the basins of a region is essential, and on the other hand a proper control technique has to be implemented in each sub-catchment of a region. Naturally, the problems of watersheds vary from case to case and can only be answered individually. Therefore, again and again the question arises as to what kind of risk management should be applied to level down natural hazards to an incalculable risk.

First of all, risk has to be analysed and assessed by regional survey. Through the results of a regional survey, proper risk management has to be derived and implemented.

METHODOLOGY

Risk management can be derived by applying the risk concept method.

Risk is defined as: "Qualitative and quantitative characterization and analysis of a hazard due to its probability and consequences" (BUWAL, 1998: S.12).

Regional survey

A regional survey has to analyse the environmental situation of a region and its land use and contents, including:

- the boundaries of the area of survey;
- the communities, catchments and areas of natural risk concerned;
- data regarding the planning of measures;
- land use, forestry, settlements, infrastructure, etc.;
- basic investigations;
- geology, morphology, hydrology, etc.

A regional survey is a combination of risk analysis and risk assessment.

TABLE 1
Regional survey

Risk analysis Definition of risk Analysis of consequences Analysis of exposition Analysis of risk	Characterization and/or quantification of a disaster according to its probability and consequences
Risk assessment	Socio-political answering of the question: Which risk will be accepted by the claimants?

Results of the regional survey: The regional survey makes it possible to project hazard maps and hazard zone maps; the reach of risks from outside the dedicated area can also be selected. Furthermore, the results of the regional survey define the necessities of integrated watershed management.

Risk management – planning of measures

The control concept is a combination of measures that have to be integrated in a way reaches the target of control optimally and efficiently. Measures are hazard zone maps, regulations and rules, as well as structures and biological measures.

Measures are classified by their functions and divided into two categories, as shown in Table 2.

Planning of the measures depends on:
- the type of disaster: flood, bed load disaster, debris flow.
- the aim of control: settlement, infrastructure.

TABLE 2
Classification of functions

Damage causing area	Impacted area
Consolidation Drainage Biological measures	Bed load dosing and sizing Debris flow breaker Retention of floods Hazard zone maps

Control technique

A so-called "function chain" is applied as a control technique in Salzburg, Austria.

"A function chain is a unit of function carriers with interdependency. If one necessary function is not occupied, the whole control technique has to be questioned" (Kettl, 1994: S. 43).

The following are definitions of functions (Fiebiger, 1988):

- *Stabilization:* Fixation of debris flow channels at a desired level to stop and/or prevent depth erosion.
- *Consolidation:* Elevation of debris flow bed to support and/or prevent slides and slopes and lateral erosion.
- *Sorting and sizing:* Filtration and/or storage of undesirable debris flow components during debris flow.
- *Debris flow sizing:* Filtration and storage of large pieces of bed load during an event or debris flow.
- *Wood grading:* Filtration of undesirable wood during a debris flow.
- *Retaining:* Storage and deposition of debris flow until the retention capacity is increased.
- *Dosing:* Separation of a large mass of debris flow into small amounts.
- *Debris flow dosing:* Quantitatively dosing the transport of intermediate stored debris flow and bed load by decreasing flood and mean waters.
- *Breaking of debris flow:* Decreasing the high energy level of a debris flow to a lower level under particular energy change.

SYSTEMATIC CONTROL SYSTEM IN INTEGRATED WATERSHED MANAGEMENT

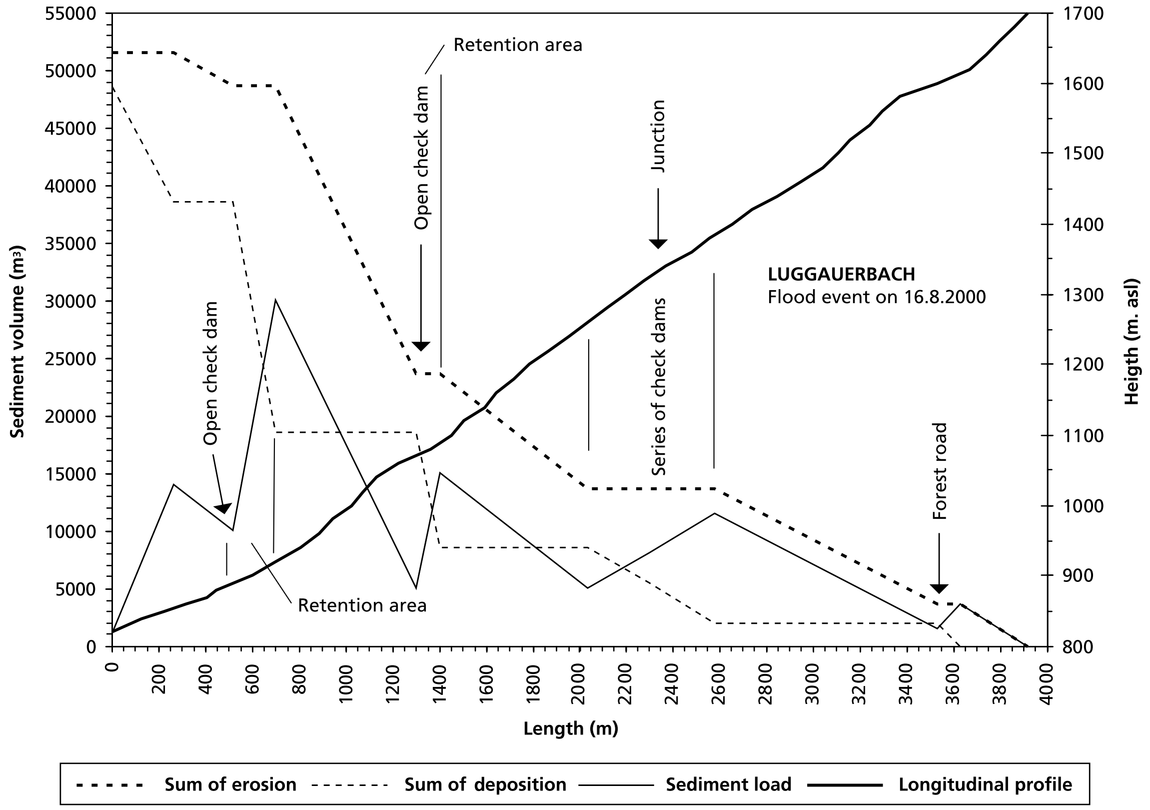
A method for deducing an effective control system is first to define the objectives of treatment and the necessary functions of the measures.

Hazard zone map

The technical method of preparing hazard zone maps is through aerial mapping of the level of danger at sites from torrents and avalanches – red and yellow hazard zones – as well as reference (brown) and reservation (blue) areas. The hazard zone map is the basis for projecting and implementing measures and surveying work. A method for hazard zone mapping is, for example, investigation of bed load balance from disaster documentation (Figure 1).

FIGURE 1

Bed load balance



TYPES OF STRUCTURE OF SALZBURG'S FOREST TECHNICAL SERVICE

Several structures with different functions combine to form the function chain and make it possible to treat torrent problems individually.

CONCLUSIONS

In managing natural hazards, an integrated view of the habitat and the basins is essential in order to be able to define the problem properly. Deducing an effective control system demands the interdisciplinary cooperation of authorities concerning the problems of a specific region.

The necessary measures derived from the regional survey have to be combined with local measures (each sub-catchment has to be treated individually). For example, the hazard zone maps should be taken into account in land-use planning.

Coordination of regional and local necessities in planning control systems would implement an integrated sustainable watershed management.

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CHAPTER 10
LAND USE AS LAND PROTECTION

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INTRODUCTION

The research project Land Use as Land Protection is being carried out by an interdisciplinary working team, under the supervision of Prof. Giuliano Cannata and in close cooperation with the technical staff of the Volturno Basin National Authority.

Started in July 2000, and now near to conclusion, it is focused on the most appropriate land uses for land protection against floods or landslides.

Giving priority to agriculture and wooded land, it aims to find the way to encourage those land management practices that are expected to be most effective in the prevention of such “natural” disasters, and to discourage those that are not.

In order to provide scientifically sound, as well as relevant to land planners, figures at the basin scale, three Italian case studies, which are well representative of a variety of land-use patterns, environmental concerns and human pressures, are analysed. A simulation model (Topkapi) has been set up to simulate the rainfall–runoff transformation process; a physically based grid cell scale modelling of the hydrological processes allows detailed understanding of the influence of land cover changes on stream flow, by depicting alternative land-use scenarios.

Existing policy tools, legal and institutional constraints and opportunities are analysed in depth at both the European and the national levels; special focus is reserved for those Regional Operative Programme measures that address EU Structural Funds in Objective 1 Regions for land protection, forest management and rural development.

THE PROJECT FRAMEWORK

Assuming the basin scale as the basic unit both for understanding the close connection between land use and water management and for implementing effective land management measures, the major topics addressed are:

- the influence of land-use changes on land protection, and the potential role of some vegetation covers in preventing/mitigating floods or landslides;
- the social and economic feasibility of such actions;
- the multifunctional perspectives of rural development in the framework of the EU Common Agricultural Policy (CAP) reform (Agenda 2000).

According to the last EU communication on Intermediate CAP Revision (COM 394/2002 def.), which aims to consolidate the decoupling processes of rural development by applying the cross-compliance principle, rural and wooded areas' multifunctional role is expected to become increasingly important in meeting broader environmental targets.

In this context, land-use changes at the basin scale have to be taken into account as a "structural" environmental issue, and should be considered as a strategic tool of watershed integrated management and planning policies.

It is worth noticing that in order to pursue this objective, CAP cross-compliance measures will be reoriented in the framework of Agenda 2000 Intermediate Revision, in order to avoid current subsidy distortions, and the expected reform of Forestry Directive (EC)2158/92 will integrate the key concept of land use as land protection.

In risk-prone areas above all, productive needs and revenues from both forestry and agriculture have to be evaluated and compared with the social benefits arising from risk prevention improvements.

In a preventive, long-term approach, the quality of the vegetation coverage that is faced by erosion agents plays a crucial role. There is an increasing scientific awareness of the high performance of mixed and multi-layered forests in soil protection and surface runoff control. The favourable influence of permanent minimum vegetation coverage and riparian natural areas or parcels scattered among cultivated crops has also been broadly recorded.

Despite its limited, or rather difficult to quantify, role during extreme events, such as flash floods or mudflows, land-use management should address land protection, as it provides alternative solutions to more complex (and often more expensive) restoration measures. Furthermore, it can reduce the recurrence rate of moderate events, as well as prove beneficial to citizen warning systems, by delaying peak flow occurrences.

Disadvantaged rural areas show a clear economic feasibility for the implementation of reforestation and set-aside programmes. In these areas, a closer engagement of farmers in sustainable practices, specifically oriented to land protection, will not only reinforce the community's sense of the interrelations between upstream and downstream settlements, but can also provide alternative incomes, from both the higher environmental value of the landscape and the higher professional qualifications needed to look after renaturation processes.

In these terms, the EU rural development multifunctional perspective can lead to an innovative approach to social cohesion concerns.

THE CASE STUDIES

In order to consolidate and spread scientific knowledge on land-use management as land protection, and to demonstrate the socio-economic feasibility of changes in agricultural and forestry patterns, the following case studies have been selected:

- a flood-prone area, the Dora Baltea Basin, located in northern Italy, in the Piedmont and Valle d'Aosta regions;

- the Bussento Basin, located in southern Italy, and included in the Cilento National Park;
- the Vernotico Basin, located a few kilometres north in the same region of Campania, and affected by landslide phenomena specific to volcanic areas (mudflows).

The *Dora Baltea* valley is a flood-prone area, its headwaters encompassing the highest Alpine peaks of Italy, before flowing into the Po River. In this area, geomorphology, hydraulics and hydrogeology are seriously threatened by both heavy river training works and numerous water abstractions for minor hydropower generation.

In the last decade, two extreme flood events occurred, very heavily damaging settlements, crops and infrastructure and causing casualties. Subsequent structural restoration works have invariably proved inadequate to face the next flood.

We use the term "river training" to refer to all structural engineering works such as levees, weirs, channel straightening, lining, etc.

The alleged purpose is the protection of areas considered vulnerable owing to the human activities that take place on them. One major frequent drawback is the shifting of risk: where floodplains are withdrawn from the river's overflows, floods will become more destructive downstream, owing to the increase in water discharge, energy and speed.

The case study is focused on trying to demonstrate that the recent floods can partly be ascribed to river training, which has artificialized a good deal of the channels, bringing about a change in the basin's hydrologic response to rainfall.

Towards this goal, six major flooding events of the Dora Baltea have been studied relative to contexts both pre- and post-1980s river training works.

The analysis of frequency and examination of the available hydrologic parameters (peak discharge and corresponding rainfall) seem to show that the basin now reacts with a more severe runoff response to precipitation. Some confirmation of these findings has come through the use of a preliminary version of the distributed rainfall–runoff model.

In the framework of a watershed integrated management programme, embankment decommissioning should be better considered, together with the relocation of infrastructure and settlements on floodplains, in order to restore river divagation areas, wherever feasible.

The *Bussento Basin* is characterized by very low population density (a mean of 40 inhabitants per square kilometre) as a result of the emigration processes that occurred in the last century. Associated with a large extent of permanent set-aside crops, the last period of emigration, dated 1950 to 1960, was followed by a broad spontaneous landscape renaturation. Now, 80 percent of land is covered by forests either at, or in spontaneous evolution to, a natural stage, which achieves high performance in land protection.

In 1994, the area was included in the Cilento National Park, to protect and improve its increasing biodiversity. The Cilento Park plan specifically recognized forests' land protection functions as one of its major concerns. Residual wine and oil production must be submitted to sustainable good practice, in line with EU agriculture measures (Cilento olive oil has recently been certified).

Tourism and scientific research plans (a rich endemic entomofauna is present) are now the first source of income for the local population.

The *Vernotico Basin* represents the opposite of Bussento, as it is subject to heavy urban expansion and intensive agricultural production.

Although covering more than 50 percent of the area, forests appear damaged because of intensive forestry (especially logging at too short time spans of 12 to 15 years) and fires. Land protection capabilities are consequently poor. The area is widely affected by landslides, such as the well-known mudflows of Sarno.

The Vernotico Basin is located at the core of national chestnut and hazelnut production areas: owing to its volcanic soils, yields per hectare are ten times the national average values.

In wooded areas, any residual biodiversity is lost. Where current industrial systems of harvesting have taken place, brushes and spontaneous vegetation are continually eradicated. Where traditional harvesting practices are still in use, these are often associated with wood production, which implies abrupt drops in canopy coverage rates. The same occurs with fires: most are located in or close to productive parcels and they appear very frequently. Both phenomena can cause abnormal rises in soil moisture and speed up erosion processes, thus increasing local landslide hazards.

In spite of the national ranking in hazelnut production, the related incomes remain economically marginal for local farmers. A few figures summarize the economic dimension of the actual conflict between current productive practices and revenues, and risk prevention's potential benefits. Farms extend on average for about 1.2 ha each, 80 percent being less than 1 ha and only 1 percent more than 10 ha. Hazelnut production gives an annual income of about €2 500 per hectare. Local forestry incomes are evaluated at about €290/hectare/year: just the same as set-aside EU subsidies.

None of these practices, which spoil forests' and soil profiles' resistance to erosion, is subject to control. Only properties of more than 10 ha are including by the regional Forestry Act in Forestry Assessment Plans. National legislation does not include hazel trees among forest resources. Local planning tools do not consider specific crops the defining features of agricultural areas.

With the support of our project research team, the local basin authority, together with the region of Campania and the Volturno National Basin Authority (based in Naples), are now cooperating to identify the most effective legal and institutional framework to improve the conditions of the area's resistance to landslide hazards.

The aim is to reorient the Regional Operative Programme financial resources towards risk prevention instead of restoration, and to assess beneficial land-use changes on the basis of existing hazard maps.

At the local level, the so called "Consulta", an experimental committee on the model of the United States' Watershed Partnerships, has also been set up. It is formed by stakeholders, representatives of both public and private parties, that are potentially interested (inasmuch as they are present on the territory) in being involved in the new wide-scope and integrated approach to land management, as promoted by the project.

LESSONS LEARNED AND RECOMMENDATIONS

The following statements have been confirmed through the simulations performed so far with the rainfall-runoff model:

- Forests can play a crucial role in flood and landslide prevention (in the Vernotico, a 60 percent rise in annual peak flow is expected in the case of removal of forest coverage).
- Natural and abandoned agricultural areas disseminated in productive agricultural land can increase the risk mitigation capacity, especially when appropriate land management schemes are followed (e.g. buffer strips along watercourses).
- Diffuse non-structural measures such as appropriate land-use management should be preferred to point engineering works along river networks or on hill slopes.

Except for protected areas, all case studies show a very poor degree of integration among different existing policy tools suitable for risk prevention and land protection.

Despite a national Land Protection Act, dated 1989, which puts the integrated management of water and land use at the basin scale under the control of river basin authorities, land protection is still considered a sectoral goal.

There is a lack of integration at the spatial scale among land-use planning tools. There is a lack of coordination regarding the various land uses and sectoral policies implemented, namely agriculture, forestry and water resources management. There is a lack of data at the basin scale to provide geocoded maps of risk hazards, river networks and land use in order to support decision-making. There is also a broader lack of cooperation among institutional levels. Related policy targets often appear to be in conflict, and this must be seen as a reason for land protection policies' poor effectiveness, if not failure, in the face of increasingly frequent "natural" disasters.

Because of their influence on the evolution of national and local legislation, international agreements and EU directives should assume specific land protection targets, and strengthen risk prevention purposes at the basin scale. Watershed integrated management's key concept has to be put into practice as an effective interdisciplinary approach, sharing risk prevention and land protection concerns among different policy fields and encouraging land-use changes towards potential, innovative multifunctional roles.

CHAPTER 11
WATERSHED MANAGEMENT IN MOUNTAIN REGIONS IN BOSNIA AND HERZEGOVINA – A GENERAL OVERVIEW

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HISTORICAL REVIEW

Watershed management has not been completely defined and properly examined in Bosnia and Herzegovina. The greatest lack of information dates back to the Middle Ages period, but the Turkish administration period has not been described and studied attentively either. Some information about water management starts to emerge from the Austria-Hungary administration period. There is much evidence and documentation from this period up until the beginning of the war in Bosnia and Herzegovina in 1992.

Using the time interval development methodology for watershed management (of A. Trumic A. Mikulec), in which both technical praxis and scientific research are considered, watershed management development can be separated into three historical development periods:
- the period until the end of nineteenth century – development and formation based on empirical experience and tradition for each region separately;
- the period until the beginning of the Second World War – new technology application based on scientific approaches, especially from technical science;
- the period beginning at the end of the Second World War – multidisciplinary approaches to concrete technical problems considering the full cooperation of experts from different fields.

None of these periods has particular focus on mountain regions. For each historical development period there exist management elements from mountain regions, but these are part of general management and use concepts. User, organizational and management elements of watershed activities in mountain regions can be separated by detailed expertise.

The first two historical development periods were characterized by intensive activities in a wide range of watershed problems related to multipurpose uses.

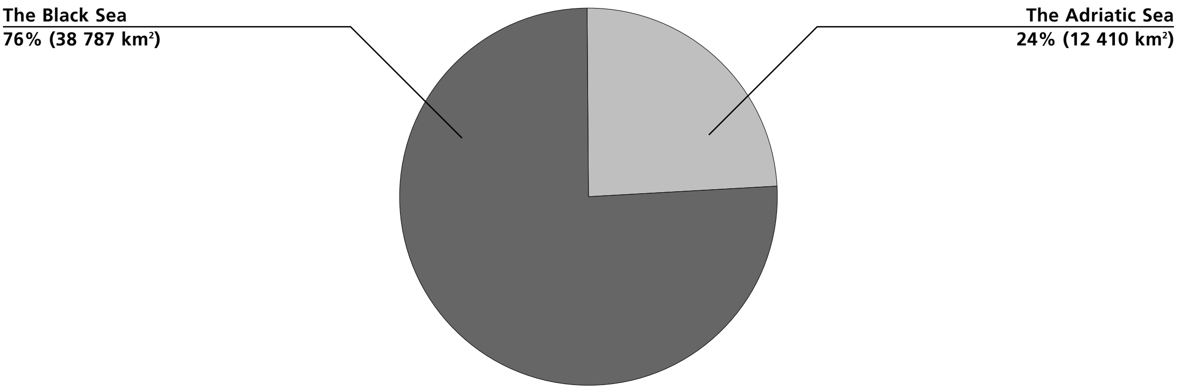
The last three decades have been characterized by scientific research with the main focus on a definition of wastewater and an evaluation of research carried out on rocky soil and karst. The water protection plan was completed in the last decade of the twentieth century.

GENERAL CHARACTERISTICS OF BOSNIA AND HERZEGOVINA

Bosnia and Herzegovina is located between 42° 26' and 45° 15' latitude north and 15° 45' and 19° 41' longitude east. Geomorphologically it is a complex of mountain and hilly areas with Perpanonic planes. It is a southeastern European country in the Mediterranean region and included in the Balkan Peninsula. Hydrological river basins (watersheds) in Bosnia and Herzegovina belong in the Black Sea and the Adriatic Sea watersheds.

FIGURE 1

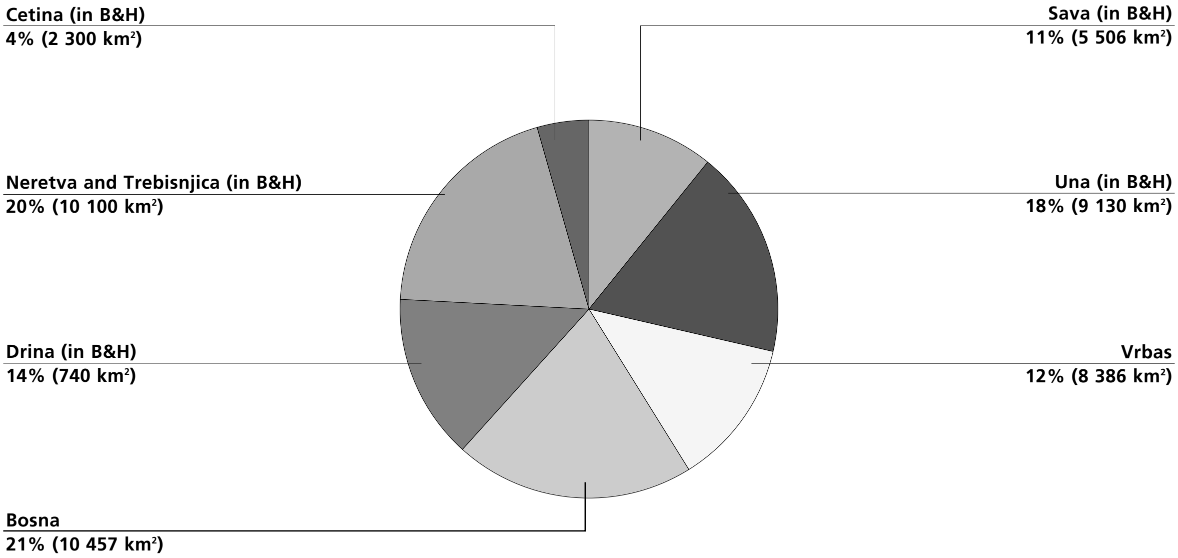
Bosnia and Herzegovina's watersheds



The total area of Bosnia and Herzegovina is 51 197 km^2, with 51 percent in mountain regions. The mountain regions range from 700 to 2 386 m in altitude. Of the total area of Bosnia and Herzegovina, about 38 790 km^2 (75.76 percent) belongs to the Black Sea watershed and about 12 410 km^2 (24.24 percent) to the Adriatic Sea watershed (Figure 1).

The total area of Bosnia and Herzegovina is separated into eight river basins (Figure 2):
the Sava river basin, the Una with the Korana and the Glina river basin, the Vrbas river basin, the Bosna river basin, the Drina river basin, the Neretva river basin, the Trebisnjica river basin, the Cetina river basin.

FIGURE 2
Bosnia and Herzegovina's main river basins



The Neretva and Trebisnjica river basins are usually considered and presented together.

The important characteristic of the water system in Bosnia and Herzegovina is that huge parts of watershed belong to the international watershed category. These parts mainly represent the country's borderlines. Only the Vrbas, the Bosna and the Ukrina river basins belong entirely to the Bosnia and Herzegovina area (43 percent of total area).

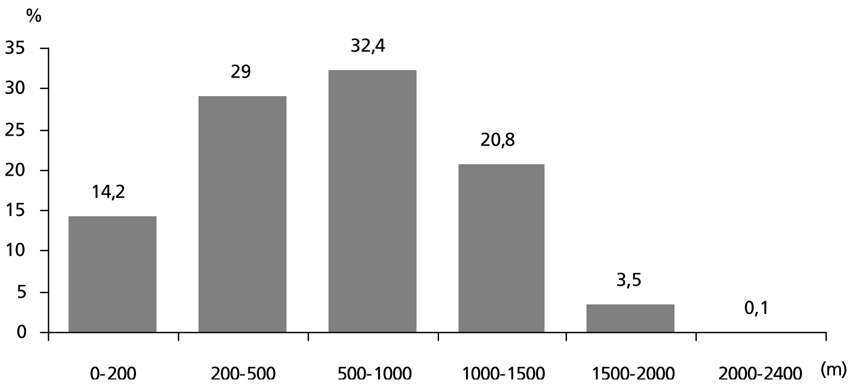
The hydrologic regime in Bosnia and Herzegovina is defined according to geological, topographical, orographic, climatic and other factors, such as water basin area, water basin shape and the type and conditions of vegetation. Some other factors are permanent, such as morphology and hydrogeology. Water basins are also influenced by some periodical events causing important deviation from expected hydrology regime characteristics. It could be concluded that in Bosnia and Herzegovina the hydrologic regime is influenced by complex factors expressing variety and differences in space and time.

The mountainous region, especially its specific form and character, evolved under morphological and hydrological conditions. The present form of this region is modelled mostly by erosion. The high mountain zones are almost exclusively of limestone-dolomite formation. The northern and internal parts of the Dynaride system consist of very split and different, low and medium-height mountain formations with upper altitudes of about 1 500 m. Upper belts of the middle mountains (1 000 to 1 500 m) present the most important forest resource zone with the most attractive landscape. The central and the Mediterranean parts, such as the southeastern external part of the Dynaride system, consists of high limestone-dolomite sediment mountains (1 500 to 2 386 m) modelled predominantly by tectonic movements and water erosion. They are closely connected, and mountains are separated only by river courses. Vertical differentiation in the mountain region is at its greatest around the

Black Sea and the Adriatic Sea watershed lines, while horizontal differentiation is least in limestone-dolomite massifs. The rocky mass character causes extreme inclination in crags and crossing between karst areas and high reefs. The mountain massifs' position and their entangled geological character are influenced by very diverse climate elements, which cause a wide spectrum of natural phenomena. This is the zone with the greatest natural diversity. In the south and Mediterranean parts of Bosnia and Herzegovina there are karst zones, which represent a specific zone in mountain regions of this part of southeastern Europe.

Bosnia and Herzegovina has altitudes ranging from sea level to more than 2 386 m. Most of the territory lies in areas of 500 to 1 000 m altitude. The height ranges are shown in Figure 3.

FIGURE 3
Height categories of mountains in Bosnia and Herzegovina



Relief development, geologic structure, pedologic structure, plant cover, land uses and climate conditions are a base for flood and erosion focuses. Extreme erosion processes appear on steep south and southwest expositions, where temperature differences are the greatest and ksero-termical conditions lead to the weakest soil protection. In these conditions, especially in the summer, surface flow is about 60 percent of total precipitation. Erosion processes cover about 45 574 km^2 (89 percent) of the total area of Bosnia and Herzegovina. Erosion processes caused by water and wind are more intensive then those caused by geological erosion. Recently, 935 floods have been registered on a surface area of 12 969 km^2 (25.4 percent) of Bosnia and Herzegovina. The annual production of erosion alluvium is about 16 518 030 m^3 or 323 m^3/km^2.

Hydrological status in Bosnia and Herzegovina is based on geomorphologic and hydrogeologic elements. Position and altitude relations, the Dynaride system barrier (and the Alps' influence) influence wet air mass circulation from the Mediterranean and the Atlantic. The south and southwest part of the country is characterized by specific karst hydrology and huge underground retention hydrology potential. This zone is a major part of the high mountain massifs of Bosnia and Herzegovina.

Total forested area in Bosnia and Herzegovina is 2 708 507 ha, with a mountain forest area of about 70 percent (1 895 955 ha). The most important and most present species are native, mixed, uneven-aged high beech, fire and spruce forests. Forest category structure is given in Table 1.

TABLE 1
Forest category structure

Category	Area structure (%)
High forests	47. 4
Low forests and brushes	34.0
Forest terrain	14.6
Non productive	4.0
Total	**100. 0**

This situation, including border contacts with hydrogeologic insulators, is the most important source of rivers.

HYDROLOGIC CHARACTERISTICS

The Black Sea watershed

The Sava river basin. The whole Sava river basin is in the Black Sea watershed. Homogeneous drain out is identified on a large area of this river basin.

Exceptions are the karst areas belonging to the Una, the Sava, the Pliva, the Vrbas and some small river basins. The figures for surface areas and percentage of karst areas in the Black Sea watershed are presented in Table 2.

TABLE 2
The karst area distribution

River basin	Area (km^2)	Karst (%)
Una	9 368	24.4
Vrbas	6 386	17.4
Bosna	10 457	0.8
Drina	19 946	4.2

The Una River basin. The headwater of the Una River consists of many karst sources in mountain regions located in the Sator mountain and south of Martin Brod town. The Una has a characteristic snow–rainwater regime. It has high spring and autumn flows, with frequent high winter flows as well. The summer is characterized by low water flow.

The Vrbas river basin. The source of the Vrbas River is located in a mountain massif named the Vranica in the central part of Bosnia and Herzegovina. The Vrbas water basin is mainly in the west part of Bosnia (the central part of the Dynaride system). The river drains mountain massifs up to Krupa town. South and west parts of the water basin are located in karst zones. The Vrbas River has a pluvial–snow water regime. It is characterized by high spring and autumn flows. Winter and summer water flows are low.

The Bosnia river basin. The headwater of the Bosna River is a strong karst source in the foothills of Igman mountain. The Bosna water basin includes central parts of Bosnia. The course of the Bosna River is directed northwards, following the decreasing altitude of medium-height Bosnian mountains. The Bosna River has a pluvial–winter water regime. It has high water flow levels in spring and lower water flow in autumn. It is characterized by low flow levels in summer and winter.

The Drina river basin. The Drina River consists of two smaller streams, the Piva and the Tara, appearing at the border with Montenegro. The Drina water basin surrounds central parts of the Dynaride system. It has a pluvial–snow regime. It has important high spring water flows caused by snow melting, and high autumn water flows caused by autumn rains. Summer and winter water flows are low.

The Adriatic Sea watershed

This is an area with strong karst character, but important surface watercourses originate here. Two water basins are dominant: the Neretva river, with the Trebisnjica river basin; and the Cetina river, with the Krka river karst water basin.

Underground water flows in karst zones differ from those in other geological substrata. It is difficult to define underground water flow principles precisely, but significant differences can be noticed in relation to some hydrologic parameters between karst and non-karst water basins.

The Neretva river basin. The Neretva River has its headwater in the Zelengora mountain. The Neretva River drains out a karst area of almost 250 km total length. This is the greatest water reach of any river in a karst zone in Bosnia and Herzegovina. It is connected to the Trebisnjica River by underground flows from a surrounding surface area of about 1 250 km^2.

The Trebisnjica river basin. A strong karst spring near Bileca town forms the source of the Trebisnjica River. This is a typical karst river, whose surface water disappears in karst underground gradually. West of the karst field Popovo polje, the Trebisnjica River sinks underground completely.

The Neretva and Trebisnjica river basins have the most important hydroenergy capacities in Bosnia and Herzegovina.

The Cetina and Krka river basins. Water basin parts of the Cetina and Krka rivers belonging to Bosnia and Herzegovina are located in west Bosnia karst fields (Kupresko, Glamocko, Duvanjsko and Livanjsko) positioned in a mountain region zone of between 700 and 1 300 m altitude.

CLIMATE CHARACTERISTICS

As part of southeastern Europe, Bosnia and Herzegovina has dynamic changes of climate elements in a geographically small area. The annual air temperature course is characterized by warm summer and cold winter periods. The annual precipitation course is characterized by a strong influence from the Azores and Atlantic cyclone fields.

According to geographical specifics, climate conditions are separated into three distinct types:
- south and southwest part – modified Mediterranean climate with maritime influences (Mediterranean part);
- central parts and mountain zones – continental and mountain climate with sub-alpine elements in the highest mountain parts (mountain and sub-Alps part);
- north Bosnia and Perpanonic plane – temperate zone and middle European climate, with cannoning climate influences (north Bosnia and the Perpanonic plane part).

The Mediterranean part

The Mediterranean part surrounds the south and southwest part of the karst and mountain zones. Mid-January temperatures reach up to 4.8 °C and mid-July temperatures exceed 24.0 °C. Annual precipitation is in the range of 1 000 to 1 500 l/m^2. The lowest level of precipitation is in August, with about 30 l/m^2, and the highest is in the periods September to December and February to April, with about 150 l/m^2. The main maximum is in December, with more then 160 l/m^2.

The mountain and sub-Alps part

The mountain and sub-Alps part includes the central part, with altitudes from 700 to more than 2 000 m. It is characterized by a modified continental climate, with strong influences of mountain and sub-Alps climates. The main characteristics of this climate type are sharp winters with January temperature of -3.4 °C and hot summers with maximum July temperature of 36 °C. The minimum average temperature in January is about -6.8 °C, and maximum average temperature in July is about 18.7 °C. The annual average precipitation is about 1 200 l/m^2, with an average maximum of 94 l/m^2 in November and an average minimum of 67 l/m^2 in February. Snow precipitation is very abundant in mountain regions of this climate zone.

The north Bosnia and Perpanonic plane part

The north Bosnia and Perpanonic part includes north and northeastern Bosnia and Herzegovina. Here there is a temperate continental climate with strong influence from the Pannonian climate. The main characteristics are warm summers and mild winters. Winter and summer temperatures rise from west to east. Average minimums in January are below zero, decreasing to -7.4 °C. The northeastern part is the warmest, with average maximum in July of about 21 7 °C. This area has the lowest average annual rainfall with a maximum of 800 l/m^2.

WATER DISTRIBUTION

The annual rainfall in Bosnia and Herzegovina is about 1 250 l/m^2. This is about 64 x 10^9 m^3 (2 030 l/s) water for the whole area. About 1 155 m^3/s, or on average 57 percent of total rainfall is delivered from Bosnia and Herzegovina. Water quantities are not distributed uniformly in time and space (Table 3).

TABLE 3
Rainfall distribution

Water area	Area (km^2)	Length of water flow longer than 10 km	Number of inhabitants (1991)	Average flow (m^3/s)	Biological minimum (m^3/s)
Sava river basin	5 574	1 693.2	635 353	63	1.5
Una river basin	9 130	1 480.7	620 373	240	41.9
Vrbas river basin	6 386	1 096.3	514 038	132	26.3
Bosna river basin	10 457	2 321.9	1 820 080	163	24.2
Drina river basin	7 240	1 355.6	422 422	124	24.1
Black Sea watershed	38 787	7 947.7	4 012 266	722	118.0
Neretva and Trebišnjica river basins	10 110	886.8	436 271	402	56.5
Cetina river basin	2 300	177.0	79 089	31	1.8
Adriatic Sea watershed	12 410	1 063.8	515 360	433	58.3
Bosnia and Herzegovina	**51 129**	**9 011.5**	**4 527 626**	**1 155**	**176.3**

Water from about 76 percent of the total area of Bosnia and Herzegovina flows off into the Black Sea watershed. The rest, about 24 percent, flows off into the Adriatic Sea watershed. The Sava river basin delivers about 62.5 percent (722 m^3/s) of total water, and 37.5 percent (or 433 m^3/s) of total water flows off in the Adriatic Sea watershed. The Neretva and Trebisnjica rivers have the highest water quantity. The lowest water quantity is from the Sava river basin.

Considering water supply and number of inhabitants, the most difficult situation is in the Bosna river basin. The Bosna river basin covers about 20.4 percent of the total area of Bosnia and Herzegovina, but about 40.2 percent of the country's total inhabitants live here. In this region, water flows are about 14.1 percent of total water quantity. Some small negative differences appear in the Sava direct river basin.

The situation is completely different in the Neretva and Trebisnjica river basin. The Neretva and Trebisnjica river basin covers about 19.8 percent of the total area of Bosnia and Herzegovina, but has only about 9.6 percent of total inhabitants. Water flows are about 34.8 percent of total water quantity.

In the other river basins, these relations are more or less equal, especially in the Vrbas river basin. The data regarding water supply are presented in Table 4.

As well as river basins there are also many natural lakes of different types and hydrological importance. These lakes can be categorized as permanent or temporary. Permanent lakes are river and mountain lakes. The temporary lake category contains hydroenergy and economic potential lakes.

TABLE 4
Relative water supply

Water area	Average specific flow		Biological specific minimum	
	From area Qaver./A (l/s/km2)	**From inhabitant Qaver/inhab.** (l/s/inhab.)	**From area Qbm/A** (l/s/km2)	**From inhabitant Qbm/inhab.** (l/s/inhab.)
Sava river basin	11.44	0.099	0.272	0.002
Una river basin	26.29	0.387	4.589	0.067
Vrbas river basin	20.67	0.257	4.118	0.051
Bosna river basin	15.59	0.089	2.314	0.013
Drina river basin	17.13	0.293	3.329	0.057
Black Sea watershed	18.65	0.180	3.048	0.029
Neretva and Trebišnjica river basin	39.76	0.921	5.588	0.129
Cetina river basin	13.48	0.392	0.782	0.023
Adriatic Sea watershed	34.89	0.840	4.698	0.113
Bosnia and Herzegovina	**22.59**	**0.255**	**3.448**	**0.039**

Water balance

Climate parameters of evaporation and evapotranspiration have been registered at a small number of meteorological stations in Bosnia and Herzegovina. Table 5 shows potential evapotranspiration (PET), real evapotranspiration (RET) and evaporation (E) figures from different meteorology stations.

TABLE 5

Climate parameters from different meteorology station

No.	Meteorology station	River	Rainfall (mm)	PET(T) (mm)	RET(T) (mm)	E from water surface (mm)
1	Sarajevo	Bosna	913	553	470	691
2	Zenica	Bosna	776	576	490	720
3	Doboj	Bosna	870	588	500	735
4	Tuzla	Bosna	895	571	485	714
5	Modrića	Bosna	795	585	497	731
6	Derventa	Sava	906	569	488	711
7	Orašje	Sava	720	615	523	769
8	Foča	Drina	938	572	486	715
9	Goražde	Drina	798	557	473	696
10	Višegrad	Drina	732	588	500	735
11	Zvornik	Drina	912	588	500	735
12	Bihač	Una-Sana	1 306	584	796	730
13	Prijedor	Una-Sana	913	591	502	739
14	Sanski most	Una-Sana	1 024	584	496	730
15	Ključ	Una-Sana	1 069	581	494	726
16	Bugojno	Vrbas	828	534	454	688
17	Jajce	Vrbas	914	570	485	713
18	Banja luka	Vrbas	1 026	582	495	728
19	Konjic	Neretva	1 509	611	519	764
20	Jablanica	Neretva	2 012	618	525	773
21	Mostar	Neretva	1 513	718	610	898
22	Livno	Cetina	1 143	536	456	670
23	Glamoč	Cetina	1 413	493	419	616
24	Kupres	Cetina	1 204	465	395	581
25	Čemerno	Trebišnjica	1 817	455	387	569
26	Gacko	Trebišnjica	1 720	516	439	645
27	Bileća	Trebišnjica	1 633	632	537	790
28	Trebinje	Trebišnjica	1 837	688	585	860

Owing to the low number of available data, these parameters are determined using the Thorntweith method. For climate conditions in Bosnia and Herzegovina the following relation between real evapotranspiration and potential evapotranspiration is used:

$$RET = 0.85 \times PET$$

Considering this relation, RET values are about 85 percent of PET. So, evaporation from free water surface is higher than PET by about 25 percent:

E = 1.25 x PET

PET ranges from 387 mm (the Cemerno meteorology station) to 610 mm (the Mostar meteorology station).

Water quality

In Bosnia and Herzegovina there are hard and very hard water types. Water quality decreases significantly during the summer period, with minimal water flows on one side and increasing water needs and quality on the other.

Water quality has been determined for 58 profiles. In the last five years, water quality has been in the expected range in almost all profiles. The worst results were registered in the Bosna river basin, the Vrbas river basin near cities Jajce and Banja Luka, the Sana empty, and downstream of the Sana empty. The Una has the highest hardness and alkalinity.

WATER REGIME EVALUATION LEVEL

Globally, the present status of the water regime evaluation could be considered as satisfactory. Serious problems were caused during the war in 1992 to 1995, which destroyed basic hydrological documentation and the results of basic hydrological analyses.

Now, one of the priorities is reconstructing the destroyed documentation and hydrological observations. In addition, more studies need to be conducted to determine:

- balance and water regimes for small and medium-sized river basins (watersheds);
- balance and water regimes in mountain regions and planes;
- extreme flows;
- in and out water quantity distribution for each year and periodically;
- underground water regimes, underground water zones, underground water communications (especially in karst);
- comparative analyses of hydrologic events in the most important river basins (watersheds) in the Black Sea and Adriatic Sea watersheds.