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Water-retention potential of Europe's forests

A European overview to support natural water-retention measures

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Summary

One third of European territory is covered by forests (210 million ha). Approximately 296 million European inhabitants live in — or close to — forests. European forests are also closely connected to much of the hydrological network, and serve large groundwater bodies and many river sources. Forests provide more than 4 km^3 of water annually to European citizens by hosting 870 000 km of rivers (the total length of European rivers is about 3.5 million km), and almost 33% (or 92 000 km^2) of 71 000 lakes are located in forested catchments.

Natural water-retention measures are measures implemented to prevent extreme hydrological events. Among the major ecosystem types, forests have a large potential for water retention. Forests retain excess rainwater, and help to moderate run-off patterns, preventing extreme run-offs. This in turn reduces damage from flooding, and also helps to mitigate the effects of droughts. It is also vital to understand these functionalities in the context of the broader discussion of ecosystem services, which includes the MAES project (Mapping and Assessment of Ecosystem Services), a project that was identified in the European Union (EU) Biodiversity Strategy to 2020.

This report provides for the first time a European overview of the role of forests in water retention, based on the Water Accounts Production Database developed at the EEA. The results represent 287 sub-basins hosting more than 65 000 catchments across Europe. As the data are not available at the same level of detail across Europe the results are highly aggregated and restricted to some key parameters. The impact of forests on water retention is measured according to three parameters/characteristics: forest cover (measured in hectares), forest types (coniferous, broad-leaved, mixed), and the degree of management of the forests ('protected' versus unprotected/commercial forests). The estimation of the water-retention potential is derived from the relationships between input (rainfall) and output (water run-off into rivers and lakes) as affected by these three forest characteristics.

Data interpretation is difficult due to the complexities of forest hydrology, which are still the subject of scientific debates on issues such as water yield and water quality. Nevertheless, the first preliminary results confirm the importance of forest cover on water retention. In water-basins where the forest cover is 30%, water retention is 25% higher than in basins where the forest cover is only 10%. In basins where the forest cover is 70%, water retention is 50% higher than in basins where the forest cover is only 10%. The results in this report also confirm that water retention in any sub-basin (whether it has 80% forest cover, 50% forest cover, or 30% forest cover) is typically about 25 % greater in summer time than in winter time. The findings also reveal the role of the types of trees in the forests in determining the degree of water retention. Coniferous forests in general retain 10% more water than broadleaved forests or mixed forests. It is more difficult to draw any conclusions about the impacts of forest-management practices on the water-retention potential of forests. Some contradictory results have been obtained when comparing protected forests against non-protected forests.

In general, forests in Alpine and Continental regions provide the highest water-retention potentials, while Atlantic and Mediterranean regions register lower water-retention potentials. Due to insufficient data coverage in the Mediterranean region, water retention could not be clearly linked to forest cover. This relationship needs further investigation with the involvement of additional data.

This shows that water retention cannot be promoted by a one-size-fits-all solution of encouraging forest cover across Europe. Instead, water retention needs to be considered on a case-by-case basis according to local and regional ecological and hydrological conditions, as proposed in the natural water-retention measures catalogue of the European Commission.

The European Environment Agency is continuously improving the European Water Accounts Production Database by means of reported data from its member countries under different data flows such as SoE and WFD. These data combined with Corine 2012 and the high resolution of forest layers of the Copernicus programme will enable the EEA to further develop analyses of water-forest interactions from the ecosystem services perspective. This will also provide more robust results on the role of forests on water retention.

1 Introduction

Forests in Europe are essential for human well-being and for the delivery of a wide range of ecosystem services to society (European Commission and Directorate-General for the Environment 2013). Forest land covers more than one third of Europe (¹) (Box 1.1). In six European countries, forests cover more land surface than any other land cover types. Finland and Sweden have almost 80% forest cover, with high coverage also found in Slovenia at 60% and around 55% in Estonia, Spain and Latvia.

Forests play an important role in the hydrological cycle and its components, having a major influence on the amount of water flowing to groundwater, streams and other water bodies. Forests have a crucial impact on the amount of surface water as well as soil and groundwater. Only a portion of rainfall will reach the soil surface in the forests as some of it will be retained by tree canopies; and evaporation and transpiration will take place from the trees. The larger the forest cover, the more water is retained. This again lowers the amount of water flowing as surface run-off and as run-off at the outlets of the catchments. Run-off refers to the amount of water coming from rainfall running over the land surface or through the soil to groundwater and streamflow.

Around 25% of all European rivers flow through forested areas (870 000 km out of 3.5 million km of European rivers). Almost 33% of 71 000 lakes are located in the forested catchments of Europe. The annual average volume of water outflowing from Europe's forested catchments is estimated at about 4.30 km^3, which is more than 4% of total renewable water resources in Europe.

Water retention is defined in this report as the water absorbed or used by forests. The volume of water retained by forests depends on forest characteristics such as forest cover area, leaf area index, the length of vegetation growing season, tree composition, and tree density. However, it also depends on other stand factors such as age and the number of layers of vegetation cover. Water retention has an influence on the amount of — and timing of — water delivery to streams and groundwater by increasing and maintaining infiltration and storage capacity of the soil. Forests can soak up excess rainwater, preventing run-offs and damage from flooding. By releasing water in the dry season, forests can help to provide clean water and mitigate the effects of droughts. We can create better policies to tackle the effects of climate change and extreme weather events by better understanding this role of forests in retaining water,

Approximately 296 million European inhabitants live in or in the neighbourhood of forests (²) and are dependent on the ecosystem services provided by forests. The relationship between forests and water is a critical issue that must be accorded high priority.

Overexploitation and misuse of forest resources may threaten the overall availability and quality of water in Europe as well as the provision of forest ecosystem

Box 1.1 Forests as a percentage of land cover in Europe

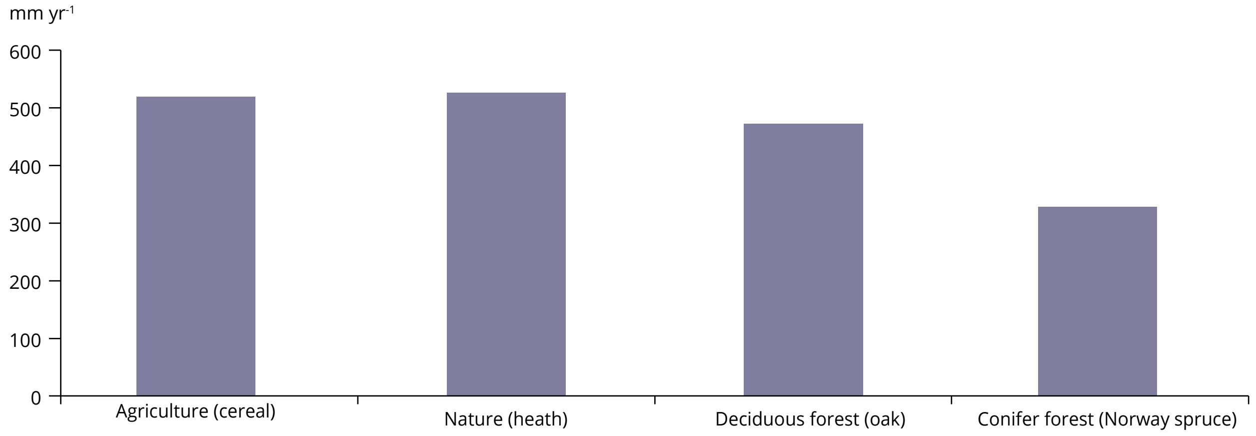
Forests are defined as land spanning more than 0.5 ha with trees higher than 5m, and a canopy cover of more than 10%, or trees able to reach these thresholds in situ. They do not include land that is predominantly under agricultural or urban land use (FAO 2010).

Based on this definition, approximately 32% of total territory in Europe (~ 211 million ha) is covered by forests (UNECE/FAO 2011).

(¹) In this report, Europe covers the EEA region with 39 countries: EU-28 plus Iceland, Norway, Switzerland, Lichtenstein, Turkey, and the EEA cooperating countries in the west Balkans.

(²) Based on an intersection of Urban Morphological Zone 2000 with the Corine 2006 forest layers.

Figure 1.1 Impact of different land uses on groundwater recharge expressing the different capacity of water retention



Source: Bastrup-Birk et al., 2004.

Photo 1.1: Harz Selke River in Germany © Andre Keunzelmann (UFZ), 2014.

services. Forests supply clean drinking water because fertilisers and chemicals (such as pesticides, insecticides and herbicides) are not used in forests (or are only used in exceptional circumstances). Deforestation such as conversion of forests to agricultural tillage, pastures or lawns results in deterioration of water quality as chemicals and fertilisers are used on these land types (Birot and Gracia, 2011).

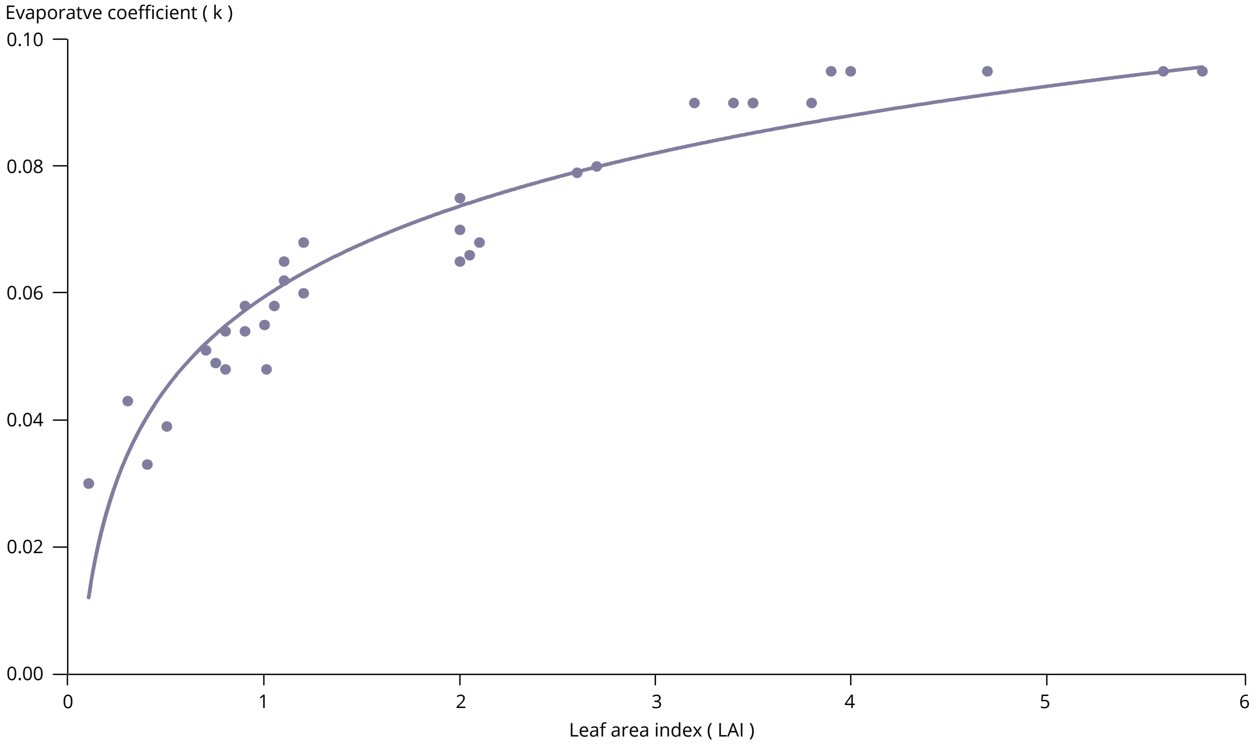
1.1 The importance of the relationship between water and forests in Europe

The distribution of forests is largely controlled by the interactions between climate, biology, soil, population growth, and forest management. The hydrological and meteorological role of forests has attracted considerable attention over the last two centuries (Andréassian, 2004; Blumenfeld et al., 2009; Calder, 2007; Hamilton, 2008). In general, forest ecosystems use more water than other types of vegetation (see Figure 1.1) (Bastrup-Birk and Gundersen, 2004; Calder et al., 2003). Higher amounts of water are lost from tree canopies and soil by interception and evapotranspiration. Surface run-off is uncommon in forest ecosystems, and subsurface flow (base flow) is usually slower in forests.

Water consumption by forests varies among tree species. It also varies according to seasonal changes in the relative extractable water, radiation, and vapour pressure deficit (Aranda et al., 2012; Bastrup-Birk et al., 2004; Kumagai et al., 2011). Both water consumption for tree growth and increasing evapotranspiration from forests by comparatively higher interception and percolation, have consequences on the generation of run-off from precipitation in terms of time and magnitude.

Forest management can have a large impact on water retention capacity depending on the size of the harvested area. Forest-management operations result in changes in vegetation composition and in the structure of the forest stands, such as diameter, height and age of the trees (Blumenfeld et al., 2009). Past studies suggest that water yield is the most obvious and immediate response of a watershed to a forest-management activity due to changes in evapotranspiration from the forests (Zhang et al., 1999, 2001; Riekerk, 1989) (Figure 1.2).

Figure 1.2 **Relationship between leaf area index of the overstorey of mature climax plant communities and the evaporative coefficient**



Source: Zhang et al., 1999.

1.2 Natural water-retention measures and related policies

Especially during the last decade there has been increased recognition of the importance of water retention in Europe. A number of European and international policy instruments have proposed measures for water retention. Natural Water-Retention Measures (NWRMs) are defined as 'measures to protect and manage water resources and to address water-related challenges by restoring or maintaining ecosystems, natural features and characteristics of water bodies using natural means and processes' (European Commission and Directorate-General for the Environment 2014). NWRMs include actions such as growing forests, restoring wetlands and lakes, removing dams, and reducing tillage in agriculture. The main focus is to enhance and preserve the water retention capacity of aquifers, soil and ecosystems and improve their status. Water retention is a regulatory ecosystem service. Water stays in the environment and is available for human well-being and for other ecosystems for a longer time. This helps to improve the capacity of other ecosystems to provide ecosystem services.

The 'Blueprint to Safeguard Europe's Water Resources' refers to the potential capacity of green infrastructure and NWRMs that use natural processes to moderate extreme disturbances such as floods, droughts, desertification or soil salination ([3]). The Blueprint mentions the restoration of floodplains and wetlands to improve the retention of water in periods of excessive rainfall for use in periods of scarcity ([4]). The EU Biodiversity Strategy to 2020 emphasises the importance of NWRMs to ensure the provision of ecosystem services (Europäische Kommission 2011). The EU Forest Strategy encourages NWRMs,

Photo 1.2: Flood plain forest © Andre Keunzelmann (UFZ), 2014.

([3]) See http://ec.europa.eu/environment/water/adaptation/ecosystemstorage.htm.

([4]) See http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52012DC0673&from=EN.

and recommends that forest cover is maintained and increased to protect soils, and to regulate the quality and quantity of water (European Commission, 2013). The Strategy also recommends that sustainable forest management practices are to be integrated into Rural Development Programmes and the Programmes of Measures (5).

A specific study conducted by Stella Consulting produced guidance at local level for three NWRMs for forests: i) continuous cover forestry (CCF); ii) maintenance and development of riparian forests, and iii) afforestation of agricultural land (Stella Consulting 2012). Furthermore, the European Commission (EC) has developed the study of NWRMs by collecting case studies across Europe and by developing a catalogue of measures for more than 50 different types of measures in 2014 (6) (Box 1.2).

The present study will not aim to include additional types of measures beyond what has been proposed by the European Commission, but rather will give an overview of the relationships between forests and water retention at European scale. This report explores the possibility of classifying water-retention potentials from forests in Europe by assessing the influence of forest characteristics on forest-water interactions.

Of course, a detailed analysis of water–forest interactions would require experiments carried out at catchment level to reveal the impacts of land cover and land-use changes on water yield and water regime. This is not feasible at European level as such data are not available. But the existing information can be used to validate and help the interpretation of the large-scale results. The present report uses a simplified approach and presents highly aggregated results.

Box 1.2 Natural Water Retention Measures (http://www.nwrm.eu)

The Commission's study on Natural Water Retention Measures classifies 53 different NWRMs suggested for implementation in four different areas: agriculture, forests, urban areas, and hydromorphology. There are 14 different types of forest-related measures:

- F01 Forest riparian buffers
- F02 Maintenance of forest covers in headwater areas
- F03 Afforestation of reservoir catchments
- F04 Targeted planting for 'catching' precipitation
- F05 Land-use conversion
- F06 Continuous cover forestry
- F07 'Water sensitive' driving
- F08 Appropriate design of roads and stream crossings
- F09 Sediment capture ponds
- F10 Coarse woody debris
- F11 Urban forest parks
- F12 Trees in urban areas
- F13 Peak flow-control structures
- F14 Overland flow areas in peat-land forests

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(5) A management tool that is part of the River Basin Management Plans of the Water Framework Directive.

(6) www.nwrm.eu.

2 Study area, data and methodology

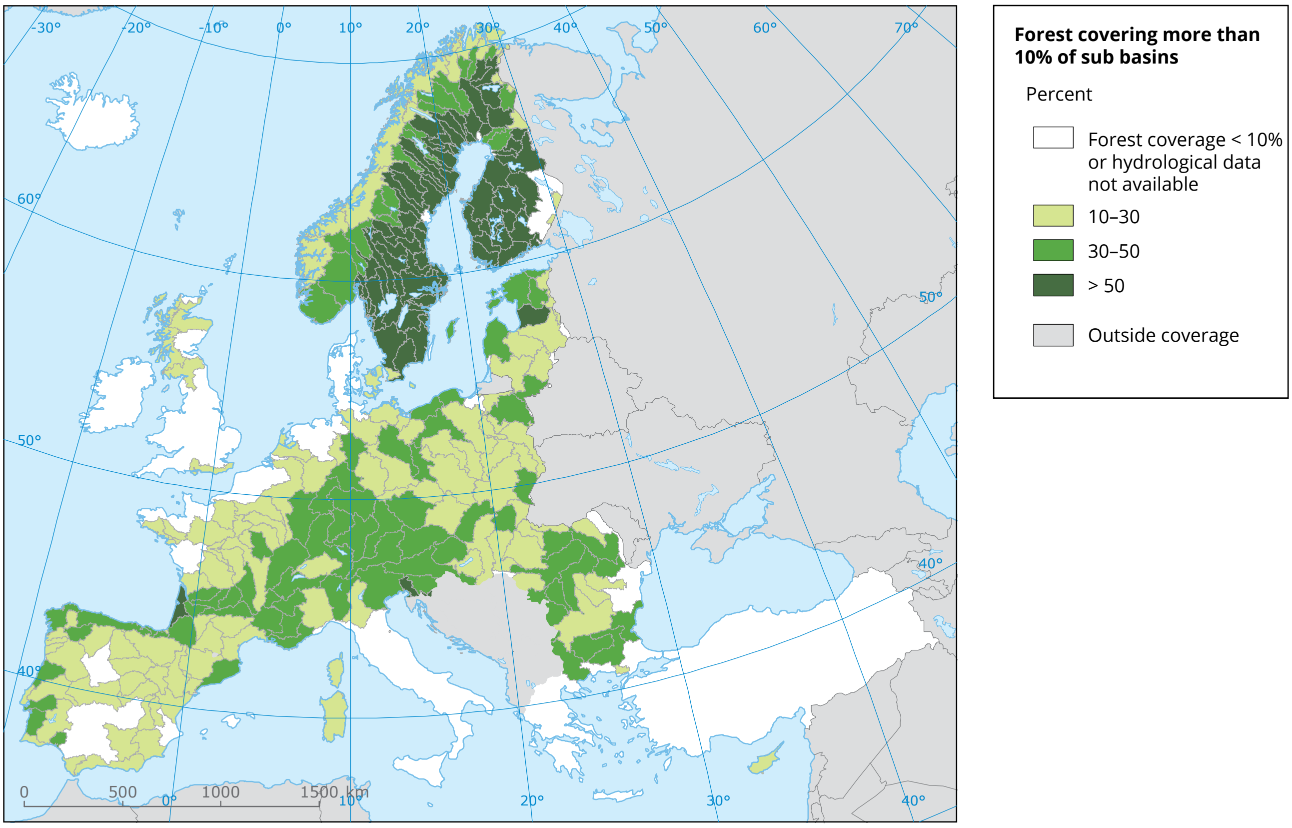
2.1 Study area

The spatial extent of this study is defined by two major delimiters: delineation of hydrological unit and percentage of forest cover in the defined hydrological unit.

The Ecrins (European Catchments and Rivers Network System) (EEA, 2012) sub-basin delineation is the reference hydrological unit used in the whole analysis of this report. The Ecrins sub-basin delineation is quite close to the Water Framework Directive sub-unit delineation, except for those crossing country boundaries. In addition, this report covers only those forested sub-basins where forest cover exceeds 10% of total area. This threshold is consistent with the FAO forest definition (FAO 2010) and with the approach taken by previous studies (Burek et al., 2012; Hamilton, 2008; National Research Council (US), 2008). Assessing the impact of forest cover of less than 10% in a given hydrological unit requires detailed hydrological analyses for which sufficient data is not available on the European scale.

There are 334 sub-basins out of 425 sub-basins across Europe where forest covers more than 10% of the total area (Map 2.1). The availability of hydrological data further narrows down the number of sub-basins from 334 to the 287 involved in this report. The selected forested sub-basins host more than 65 000 catchments and represent major parts of Alpine, Atlantic, Boreal, Continental and Pannonian biogeographical regions.

Map 2.1 Spatial cover of the present study



65% of Mediterranean forests are also presented in the study. Due to the lack of water-related data, the Black Sea and Macaronesian regions had to be excluded.

Temporal coverage of the study was selected according to the availability of forest land-cover spatial data in Corine (namely, 2000 and 2006) and in the EEA Water Accounts database (2002–2012). Based on the available spatial and temporal data sets, this study covers the years 2002–2012.

2.2 Data sources

Spatial data on forest cover were extracted from the Corine land cover maps (7). Forests are classified in three forest types in Corine: 311 coniferous forests, 312 broadleaved forests and 313 mixed forests. Forest cover was assigned for every biogeographical region: Boreal (BOR), Atlantic (ATL), Continental (CON), Alpine (ALP), Mediterranean (MED), Pannonian (PAN), and Steppic (STE). Changes in forest cover were estimated by comparing the Corine maps of 2000 and 2006. A simple linear regression was used to produce yearly forest cover by forest types and by biogeographical region. The area of protected forests was extracted from the Common Database on Designated Areas (CDDA).

The availability of hydrological data at catchment scale varies across Europe, in particular for run-off data. Therefore, a more compact hydrological unit than the catchment unit had to be chosen in order to avoid a high level of uncertainty. This more compact unit is the Ecrins sub-basin.

The hydrological data sets were extracted from the European Environment Agency (EEA) Water Accounts Production Database (8). The datasets involve the following variables: external inflow, outflow and surface run-off.

Climatic data were obtained from the EEA Climatic Database developed based on the ENSEMBLES Observation Dataset (Haylock et al., 2008). The surface run-off data used in this study were calculated from this database by the EEA (Kurnik et al., 2014). Surface run-off is taken as water generated by rainfall and flooding on the surface to join natural water courses. All maps use the LAEA1989 projection. Corine maps a resolution of 25 ha.

2.3 Methodology

The study analyses water retention from forests at two consecutive steps. The first part of the analysis included the estimate of water retention by forests at sub-basin level. For this purpose, selected indicators of forests and water retention are implemented in estimating the run-off generation from precipitation and the regulatory roles of forests on the run-off regime (Figure 2.1). The second part of the analysis explores the classification of the water retention potential of forests. The basic assumption is that the relationships between rainfall and run-off in forested sub-basins are highly correlated with forest characteristics (Andréassian, 2004; Calder, 2007).

2.3.1 Estimating water retention potentials from forests

Forest indicators

The selected forest characteristics are forest cover, forest type, and degree of management expressed as protected and unprotected forests in sub-basins with a forest cover greater than 10%. Soil factors are not addressed in the present study.

Total forest cover is assessed as the sum of the Corine forest layers. The forest types were classified according to the three Corine forest layers. Sub-basins are large hydrological units with several forest types. The dominant forest type in the sub-basins was assigned to the forest type with the highest relative forest area. For instance, the forest type of a sub-basin with a share of 34% coniferous, 33% broadleaved and 33% mixed forest area has been characterised as coniferous. This approach is somewhat simplified but quite easy to apply.

A proxy for forest management activities was developed based on information from the Corine and CDDA databases. In general, protected forests registered in CDDA are considered to be managed less intensively for timber production than other forests. Protected forests have been developed primarily for

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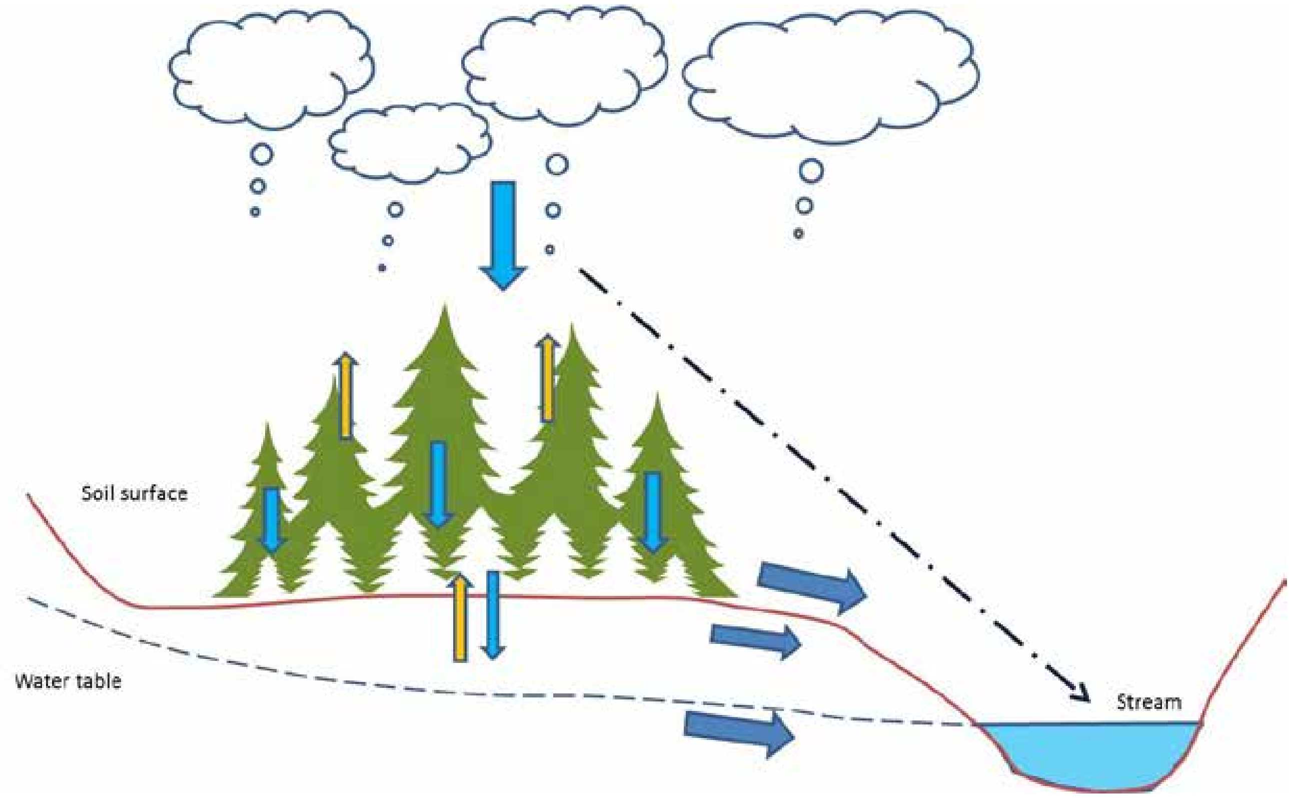
(7) http://www.eea.europa.eu/data-and-maps/data/clc-2006-vector-data-version-3.

(8) The EEA Water Accounts Production Database is a subset of different datasets involving both reported and external data on various climatic and hydrological parameters in assessing physical water balance. This database is mainly used in producing information on European water assets accounts and the Water Exploitation Index.

Figure 2.1 **Conceptual model of analysing the relationship between precipitation (input) and run-off (output)**



Note: This figure has been slightly adapted from the original structure and content.

Source: National Research Council (US), 2008.

biodiversity conservation. Thus, it is assumed that the primary objectives of silvicultural implementations and forest management plans in the 'protected forests' are not directly for timber production, while 'unprotected forests' are primarily used for timber harvesting under different implementation methods, e.g. from selective thinning to clear-cut. Clear-cut areas have been excluded from the analyses (Corine land cover type 244) in order to avoid confusion between fully forested areas and forest regeneration in areas after clear-cutting.

Water retention indicators

Water retention is estimated in this study as the time and proportional difference between rainfall and run-off in sub-basins associated with forest characteristics. For this purpose, four hydrological indicators were selected. The first two indicators (run-off coefficient and surface run-off coefficient) are applied to assess the run-off generation (water yield) from rainfall in forested sub-basins, while the 'run-off irregularity' coefficient (the third hydrological indicator) aimed at exploring the regulatory role of forests over the water regime. One supplementary indicator, the flushing ratio, was applied to validate the results obtained from the other indicators.

Run-off coefficient

The run-off coefficient is used to directly compare run-off with rainfall in the given territory and time:

$$\mathrm{K} = \frac{Run\text{−}off\ (mm)}{Rainfall\ (mm)} \quad (1)$$

The coefficient is dimensionless and looks simple. Nevertheless, the rainfall–run-off relationship may be more complex. For example, input to the catchment comes not only from rainfall but also from eventual groundwater and from upstream catchment. In addition to that, human intervention for water abstraction and water use impacts the water cycle, which in the end impacts the run-off. Therefore, a minor modification of the above equation is made to estimate possible extents of the net run-off from the sub-basins to the following:

$$K = \frac{Q - Qi}{P} \quad (2)$$

Where:
Q = Run-off (hm^3)
Qi = External inflow (hm^3)
P = Rainfall (hm^3)

As assessing net run-off from sub-basins is quite a complex issue due to the relationship between upstream and downstream, two assumptions have been applied in evaluating the inflow–outflow relationship according to the location of sub-basins. In the case of a sub-basin where the outlet is the upstream of another downstream sub-basin, the external inflow coming from upstream to the downstream is subtracted. In the case where there are multiple output points to the sea (Figure 2.2), outflow to the sea was summed up as compound outflow.

Surface run-off coefficient

Surface run-off refers to water from rainfall and flooding that flows on the surface to join natural water courses (see for further clarification Kurnik et al., 2014). The surface run-off coefficient is estimated by comparing total monthly volumes of rainfall with the total monthly volumes of surface run-off in the given territory.

$$SC = \frac{SrF}{P} \quad (3)$$

Where:
SC = Surface run-off coefficient
P = Rainfall
SrF = Surface run-off.

Run-off irregularity coefficient

The indicator has been used to analyse the amplitude of extreme run-off conditions throughout the year. It aims to quantify the impact of forests on the hydrological regime. An increased water retention by forests regulates the maximum flow of water in the sub-basins.

The run-off irregularity coefficient can be calculated according to Tyszka (Tyszka, 2009; Tyszka, and Stolarek, 2013) as:

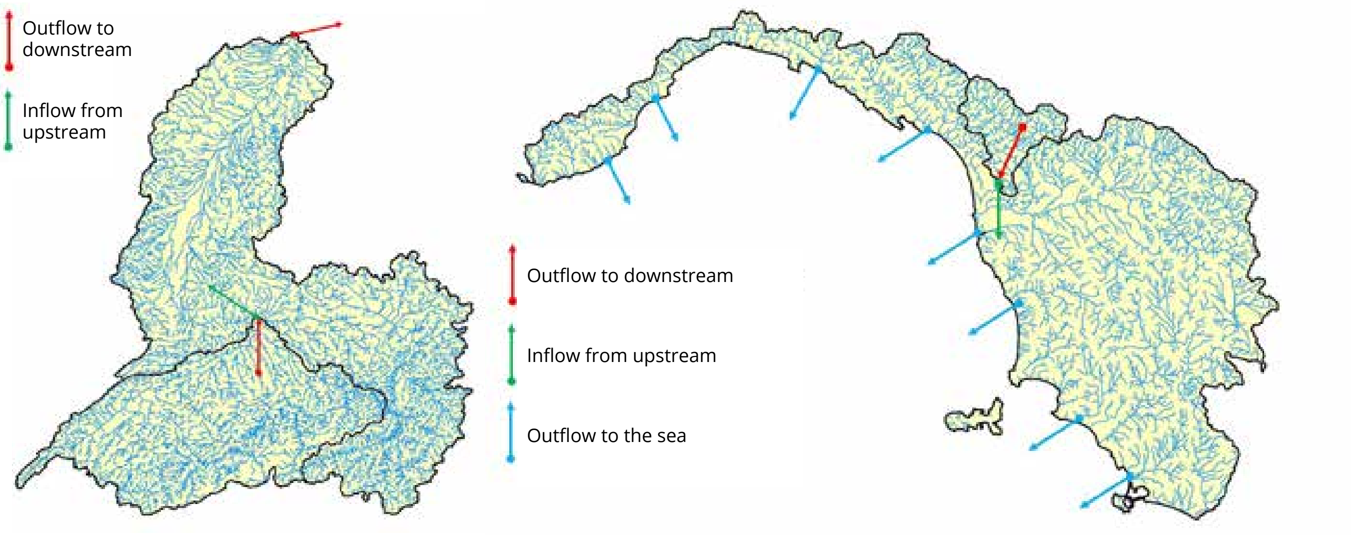
$$k_d = \frac{Q_{max}}{Q_{min}} \quad (4)$$

Where:
k_d = Run-off irregularity coefficient
Q_{max} = Maximum run-off observed in the given time period (i.e. throughout the year)
Q_{min} = Minimum run-off observed in the given time period (i.e. throughout the year)

The value of k_d ranges between 1 and ∞. 1 means constant regularity in run-off.

In the present study, the approach by Tyszka has been slightly modified by excluding the temperature

Figure 2.2 Case of total outflow to downstream areas (left) and total outflow to the sea (right)



dimension from the analysis to ensure the compatibility of run-off irregularity results with the other indicators. Furthermore, the definition of seasonality has been modified. The winter period includes December, January and February whereas summer includes the months of June, July and August.

Flushing ratio

The flushing ratio estimates the residence time between rainfall and run-off. The flushing ratio was used as a supplementary indicator to check with the results obtained from the other indicators. The indicator depends on a number of different variables and not necessarily on forest characteristics. For example, catchment characteristics (such as catchment size, topography, slope, soil properties) and climatic variables (type of precipitation, temperature, evaporation) as well as land cover type (forests, agriculture, etc.) have impacts on the flushing ratio.

The flushing ratio itself is a rough indication of the time that effective rainfall stays in the environment (residence time). The estimation precision of the flushing ratio depends on the scale of the hydrological unit. Smaller hydrological units would be more appropriate for sound estimation. Multiplying days of a month with the flushing ratio would provide an approximate number of days needed to flush out all the water received from the rainfall of that respective month. If the flushing ratio would be multiplied with the number of days in a year, this would estimate the residence time for a year.

The residence time for rivers has been estimated to vary from 2 weeks to up to 6 months (Worrall et al., 2014). The flushing ratio (τ) is defined as the relative time that water remains within a given territory (9):

$$\tau = \frac{V}{q} \quad (5)$$

Where:
τ = Flushing ratio
V = Input (rainfall) into the hydrological unit
q = Flow (run-off) from the hydrological unit.

2.3.2 Statistical method

The rainfall/run-off relation was analysed as a function of the water retention potential of forests and selected forest characteristics: forest cover, forest types and degree of management (protected/unprotected). Linear relationships between the quantitative variables were explored. The Pearson correlation coefficient was used to assess the strength of the linear relationship between the hydrological variables and the forest characteristics (Montgomery and Runger, 2003).

The correlation of forest cover of an area (x) with selected indicators (y) i.e. run-off, surface run-off, and run-off irregularity is expected to provide negative linear regression, while flushing-ratio results are expected to be positive. In the case of increasing forest cover, the more water is intercepted, percolated or consumed by forests, the higher the flushing ratio, which means that residence time is prolonged.

Sub-basin comparisons were conducted across grouped sub-basins located within the same biogeographical region and even within the same river basin where data are available. The purpose is to avoid climatic interference and inter-basin variability and to reduce the uncertainties.

2.3.3 Classifying water retention potentials

The water-retention potential (WRP) is an index that unifies the three main indicators: run-off, surface run-off, and run-off-irregularity coefficients. The flushing ratio was not included in the final classification of the water-retention potentials due to the different nature of its characteristics.

The WRP aimed to quantify the water-retention capacity of forests: the ability of a forest to retain, store and yield water. The WRP in a given sub-basin was classified in three classes: low, medium or high. As shown in (Figure 2.3), the selected hydrological indicators are distributed in quartile ranges.

The first quartile indicated high retention; the third quartile presented low retention potential; and the median showed the medium level of water retention potential. In this study, the three coefficients have been equally weighted. A weighting of the WRP should be carried out in future analysis to check for internal correlations and for their sensitivity to the degree of forest cover. This may enhance the support for environmental protection actions related to NWRMs.

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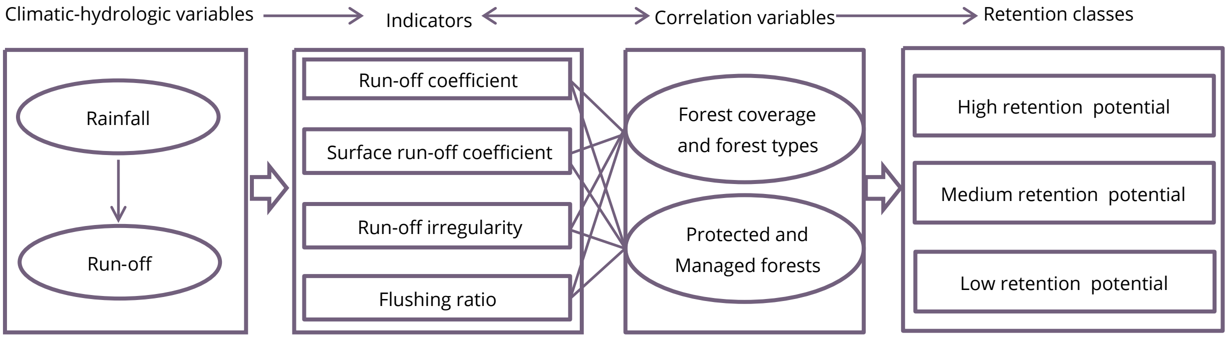
(9) See http://www.belgradelakes.org/Watershed%20Wisdom_12_11_Residence%20Time.pdf.

Figure 2.3 **Conceptual approach for analysing run-off regulation of forests and classification of water-retention potentials**



2.4 Uncertainties

As already addressed in this report, the conceptual model had the approach 'environmental input — hydrological areas boundaries — forest areas (and forest type) assigned with > 10% coverage — environmental output'. This approach was adopted in order to provide an overview of forest impact on the hydrological regime across Europe. This approach of course does not take into account details such as soil types, slope, seasonal snow coverage etc. but it aggregates all this information into a general forest profile based only on forest coverage in the study area. In order to reduce the uncertainty of the results, a separate analysis per forest type was conducted to justify the general results over the whole forest area. In the future, more detailed forest-oriented information will be collected and analysed, and will possibly be united with hydrological and land-cover data to fill this 'gap' in the model. The results presented in this report should be interpreted as highly aggregated and generic aiming at only providing a European overview. Therefore, the report does not aim to suggest a set of measures that can be directly implemented at the local scale.

3 Water retention from forests

3.1 Forest cover and water retention

The analysis of the Corine forest layers shows, not surprisingly, that forest resources are largest in the Boreal and Alpine biogeographical regions. These two regions account for around 65% of total forest resources in Europe (Figure 3.1).

Comparisons of forest cover in the period 2000–2006 highlight that the forest cover across Europe has not changed significantly. The largest changes occurred in sub-basins smaller than 20 000 km². These sub-basins comprise two thirds of the sub-basins selected for this study (Figure 3.2). No clear effects of changes in forest cover on run-off could be detected within individual sub-basins. The results obtained in this study provide information mainly on inter sub-basin conditions.

3.1.1 Decrease of run-off by forest cover

The water balance calculations estimated that approximately one third of rainfall contributes to run-off in Europe. The present analysis reveals the large seasonal variations in run-off (Map 3.1). In winter, high run-off conditions are mainly characteristic of the mountain areas, in particular on the Apennines and west Alps. The lowlands of central Europe, western France and Spain are characterised by medium and/or low run-off compared to rainfall conditions.

During summer, low run-off conditions prevail in the western and central part of Europe, while high run-off conditions are restricted to northern Scandinavia and the upstream sub-basins of the Rhone (western part of the Alpine region).

Figure 3.1 Forests and other land-cover types in biogeographical regions

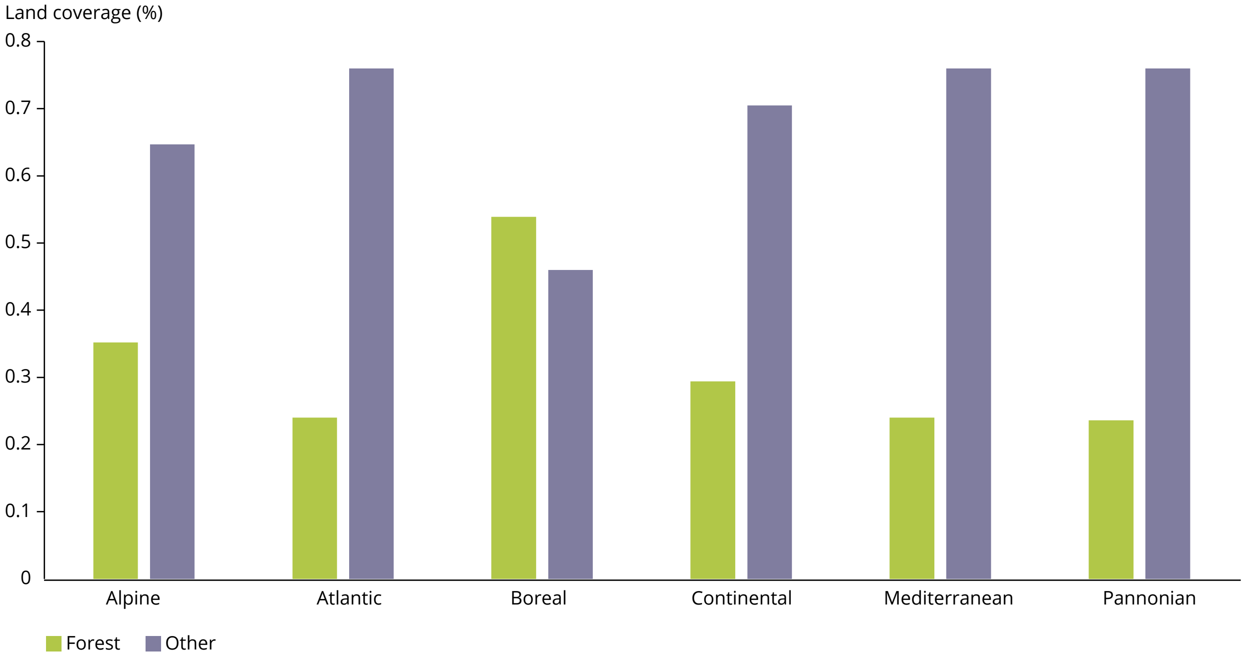
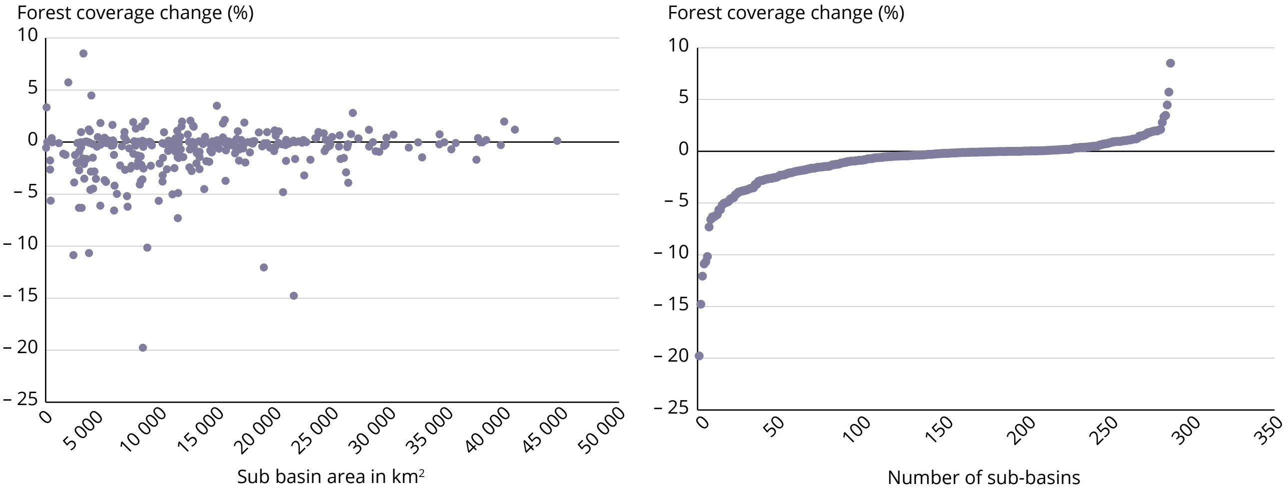


Figure 3.2 **Forest cover change**



Note: Left — sub-basin area (km²); right — total number of the sub-basin population.

A comparison of the run-off with forest cover indicates that once forest cover exceeds 30% of the area of the sub-basin, forests impact run-off conditions regardless of seasonality (Figure 3.3). Each additional increase of 10% in forest cover decreases run-off by 2–5%, and thus increases water retention by forests. In addition, when forest cover exceeds 70% of the sub-basin's area, forests retain 50% more water than sub-basins where forest cover is only 10%.

Forests decrease run-off by almost 25% more in summer than in winter.

Figure 3.4 shows the strong relationships between forest cover and run-off across biogeographical regions. Even small changes in the forest cover of sub-basins resulted in reduced run-off in most biogeographical regions.

Significantly, the Mediterranean sub-basins demonstrate another pattern. The forest and run-off relationship under the dry conditions of this region differs from other regions in that run-off *increases* with increasing forest cover. In all other regions, run-off decreases with increasing forest cover. It has to be underlined that this overview strongly indicates the dominance of local factors, i.e. soil conditions in the Mediterranean playing a more significant role on run-off conditions compared to forests in other regions. As a matter of fact, the role of soil conditions in run-off generation in forested catchments has been reported in the scientific literature from the Mediterranean region (Cosandey et al., 2005; Rana-Renault et al., 2012). These conditions are explained in local cases (Latron and Gallart, 2008; Mena-Martinez et al., 1998) as the influences of soil genesis in forested catchments reducing the permeability and retention capacity (Box 3.1).

Map 3.1 **Seasonal run-off coefficients in winter (top) and summer (bottom)**

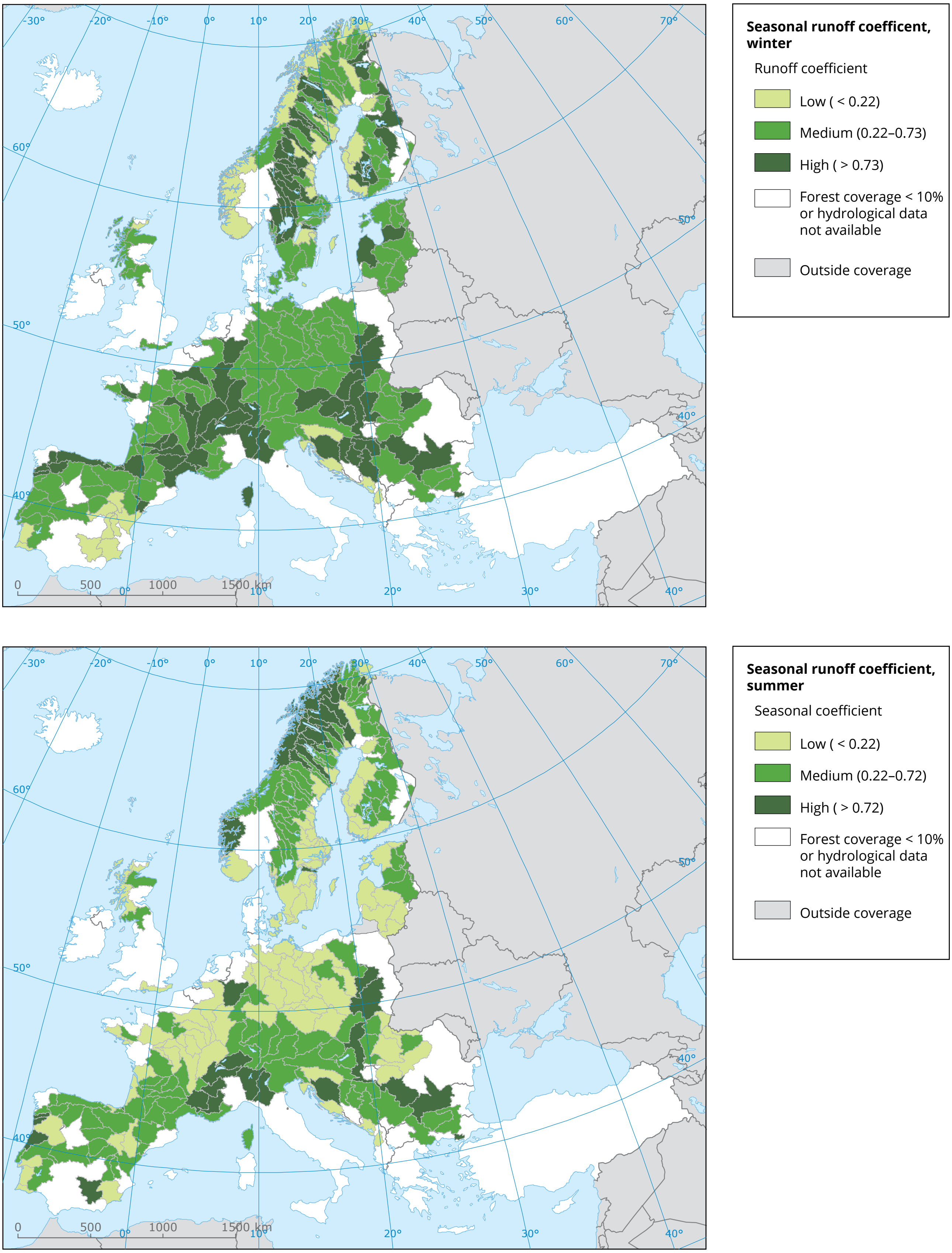
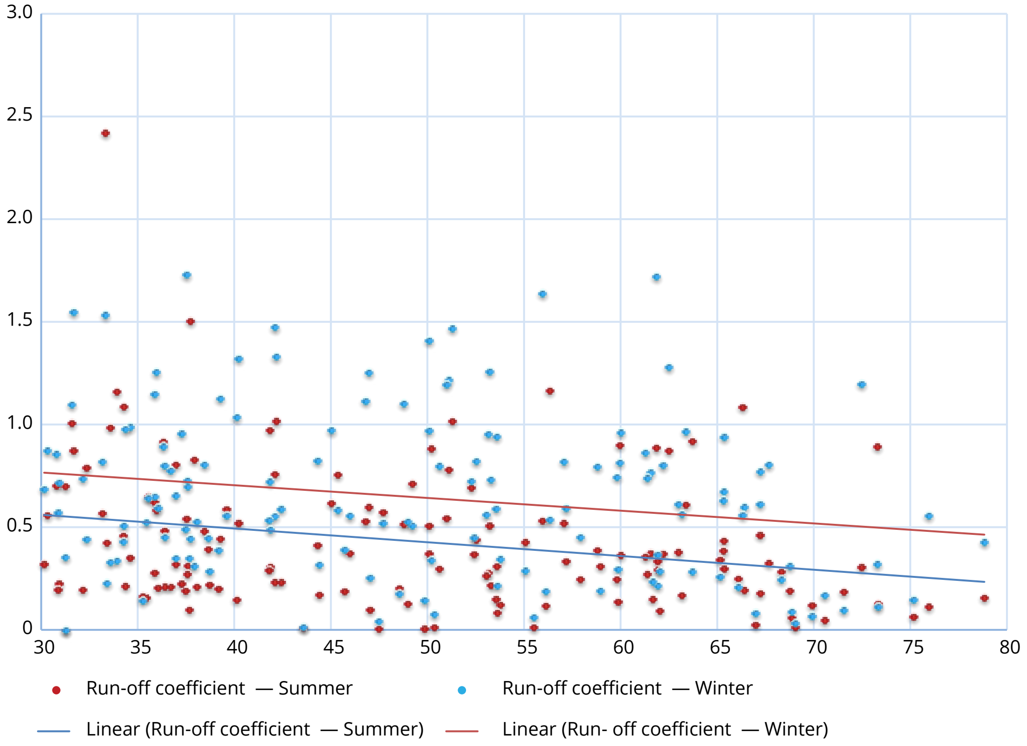


Figure 3.3 Seasonal run-off coefficient as a function of forest cover larger than 30%



Box 3.1 Run-off generation in the Mediterranean region

Draix, Digne and other Lozère basins (France)

This catchment experiment in Mediterranean France was designed to analyse the hydrology of the catchment as a function of forest cover changes under wet conditions. The study covers three basins; Draix, Digne and the Réal Collobrier basin. While Draix is 87% covered by woodland (plantation, 100–120 years old) the others are mostly covered maquis and other land cover types. The study reports higher floods in forested catchments compared to other non-forested catchments. The results are explained by local climatic conditions and low soil permeability.

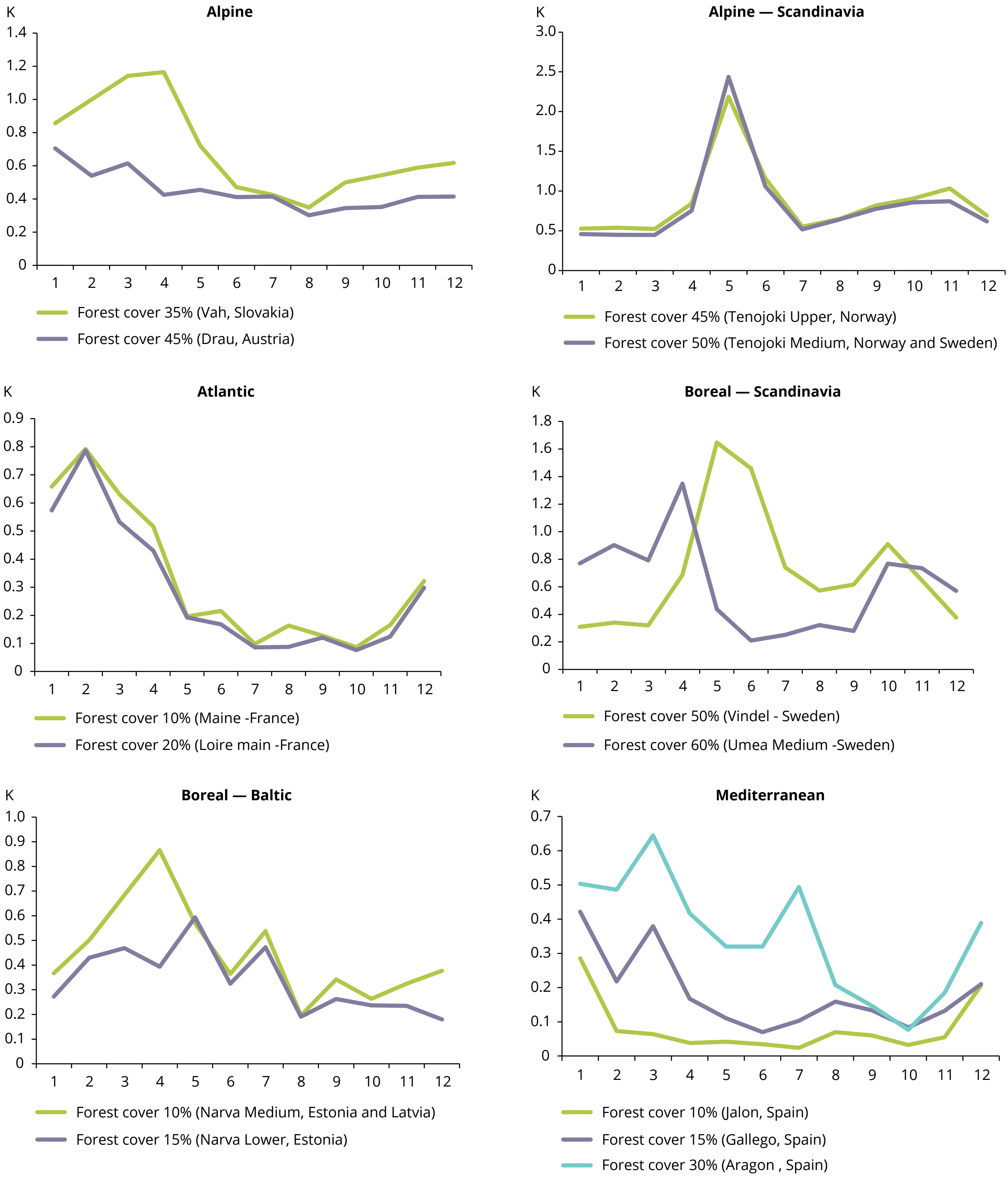
Source: Cosandey et al., 2005.

Aragón River (Spain)

In this study, the hydrological response of two neighbouring catchments in the central Spanish Pyrenees with similar lithology and topography but different land use was compared. One catchment (2.84 km^2) was extensively cultivated in the past and the other (0.92 km^2) is covered by dense natural forest. Differences in run-off were strongly related to catchment wetness conditions and showed a marked seasonality: under dry conditions run-off tended to be greater in the former agricultural catchment, whereas under wet conditions it tended to be greater in the forested catchment. One explanation for this switching behaviour could be an increase in the hydrological connectivity within the slopes of the forested catchment as it becomes wetter, which favours the release of large amounts of subsurface flow. Differences in land use (vegetation and soil properties) dictate the contrasting dominant run-off generation processes operating in each catchment, and consequently the differences between their hydrological responses. In February, April and May, run-off was higher in the forested catchment, although the relative differences were not as large as during dry conditions. Under wet conditions, both saturated excess run-off and subsurface flow were the dominant run-off processes in the former agricultural catchment. In the forested catchment, saturated areas were never observed. The slow response and longer recession limbs for most of the hydrographs, together with the strong correlation of the streamflow response and the water table fluctuations, indicate a significant contribution of subsurface flow in this catchment. One explanation for the higher run-off observed in the forested catchment under wet conditions could be the existence of a moisture threshold above which the hydrological connectivity within the slopes of the catchment increases abruptly, such that all or a very large part of the system contributes to run-off.

Source: Rana-Renault et al., 2012.

Figure 3.4 Examples from sub-basins on the relation between forest cover and run-off by biogeographical region



Source: Cerdà and Doerr, 2007.

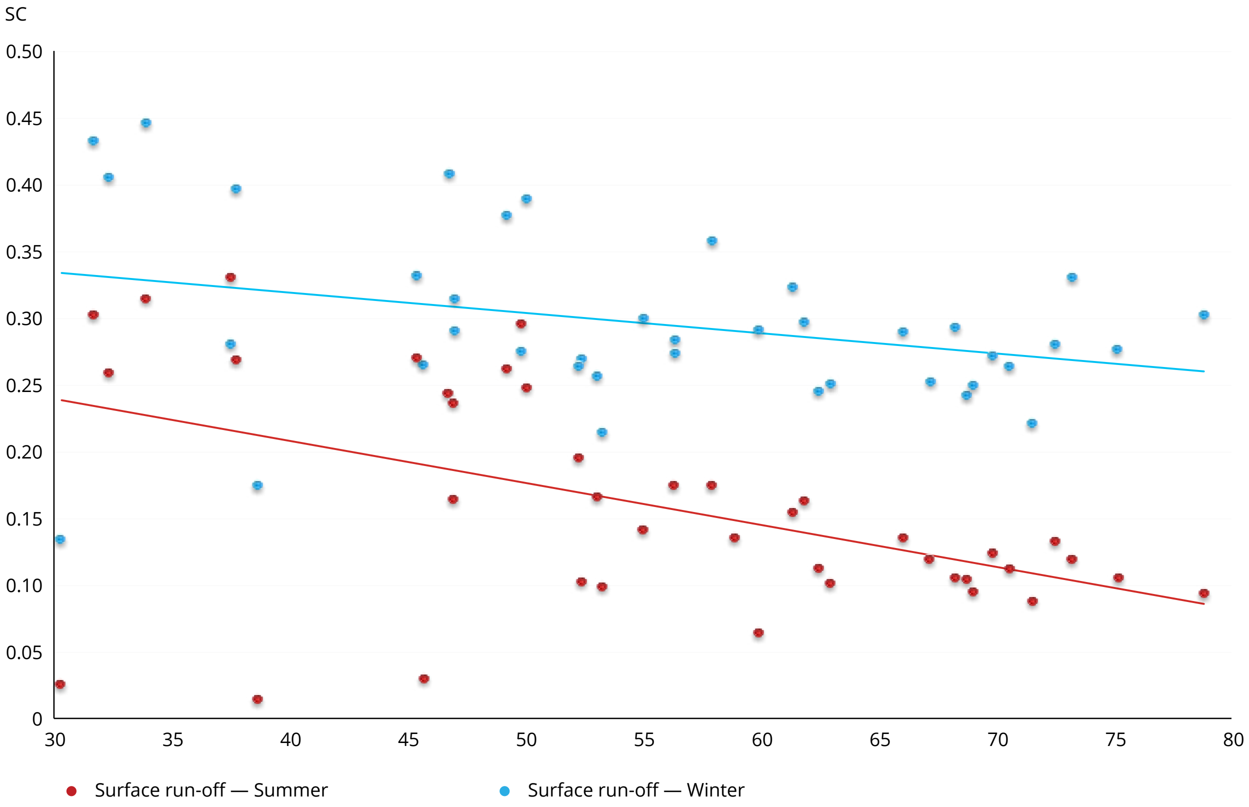
3.1.2 *Surface run-off reduction by forest cover*

Similarly with run-off decrease by forests, the impact of forests over the reduction of surface run-off can only be observed once the forest cover exceeds 30% in small sub-basins (Figure 3.5). The findings show that surface run-off decreases with increasing forest cover.

The surface run-off coefficient was mapped across Europe. Large seasonal variations appear between winter and summer (Map 3.2). The values of surface run-off coefficient are high in both summer and winter in the Alpine region. In the rest of Europe, the summer period is characterised by low surface run-off coefficient in forested sub-basins.

Comparisons at biogeographical level reveal that increase in forest cover will lead to a decrease in the surface run-off in the forested sub-basins, with the exception of the Mediterranean region (Figure 3.6).

Figure 3.5 **Seasonal surface run-off and forest cover for all biogeographical regions (forest cover > 30% and small sub-basins)**



Map 3.2 **Seasonal distribution of surface run-off coefficients in winter (top) and summer (bottom)**

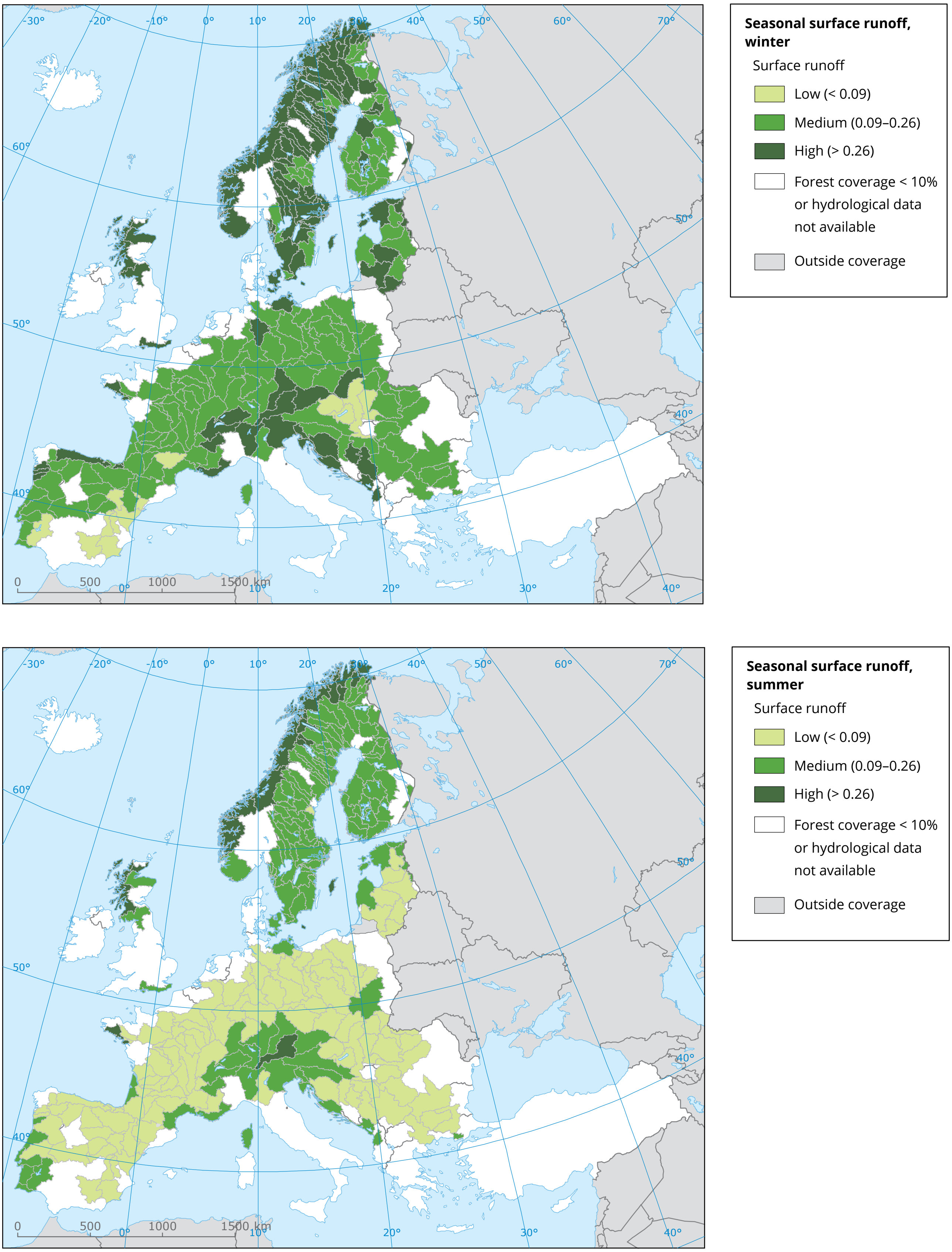
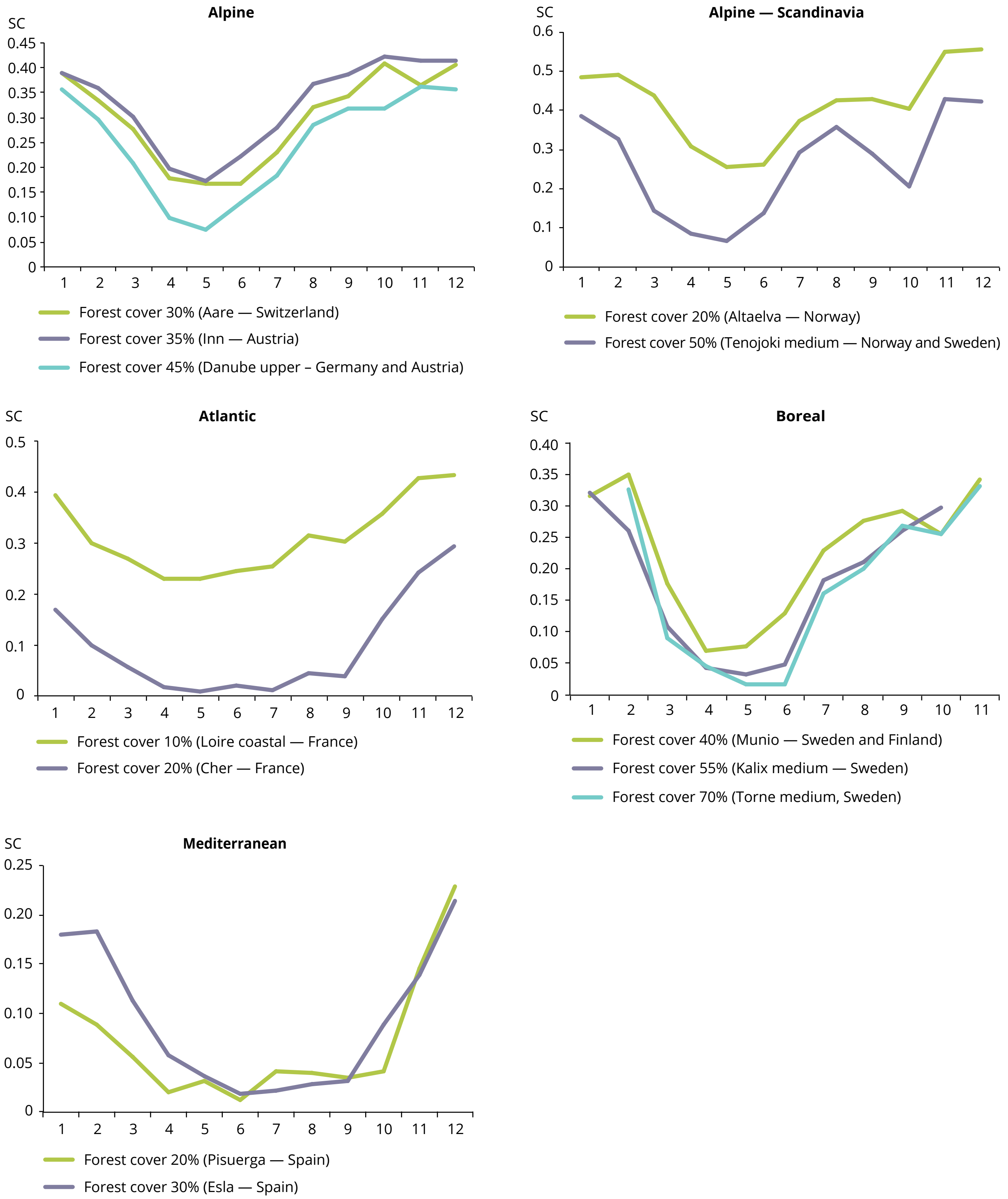


Figure 3.6 Examples of sub-basins on surface run-off coefficient per biogeographical region



Changes in forest cover in some sub-basins in the time period 2000 to 2006 resulted in some impact on run-off. Examples of such relationships have been observed e.g. in the Garonne sub-basin (France) during the period 2000–2012 after severe storm damages in that period. In that case, the forest cover decreased by about 20%. Figure 3.7 (left diagram) illustrates the impact of these changes on both run-off and surface run-off. Forest cover decreased by almost 15% in the west Aegean sub-basin of Greece (Figure 3.7, right diagram). In both cases, forest cover changes show a large impact on run-off coefficient but almost no impact on surface run-off.

Results obtained from both run-off and surface run-off provide evidence that the forest cover at the sub-basin scale must exceed 30% to have an impact on decreasing run-off and surface run-off. Forests retain 25% more surface water when the forest cover increases from 30% to 70%. Similarly almost 10% more water is retained in the summer months compared to the winter months.

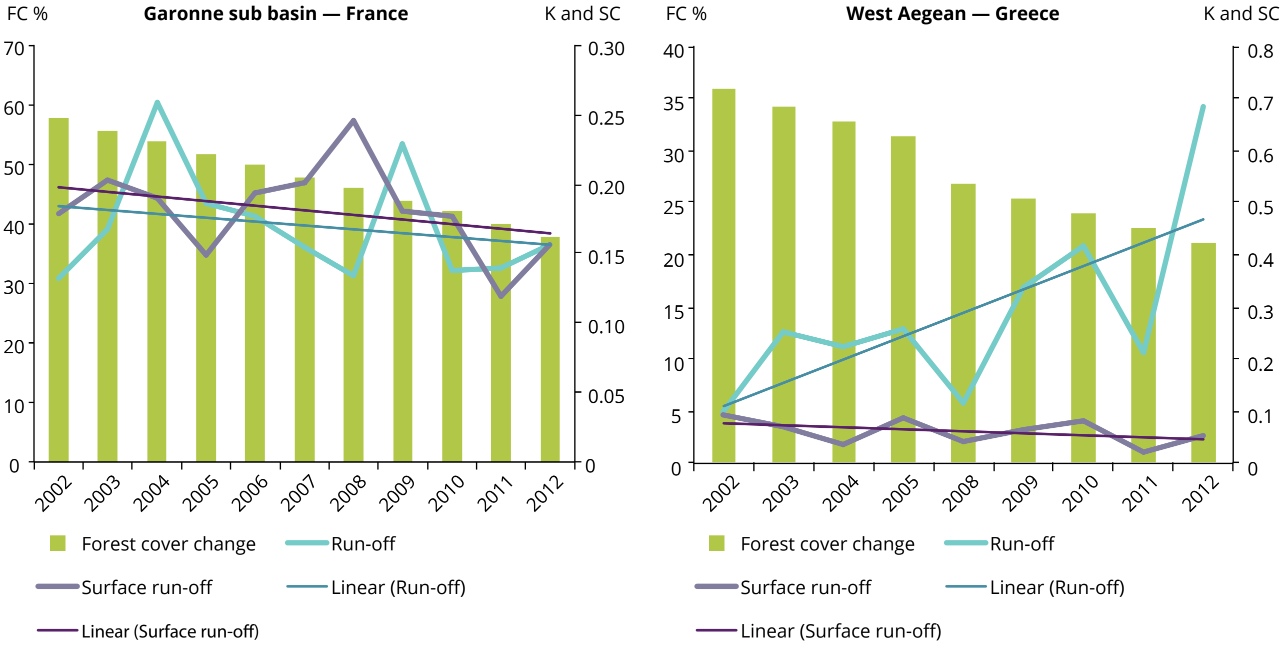
Among the biogeographical regions, the highest rate of run-off generation from rainfall was estimated for the Alpine region. Due to snow accumulation in winter, and the resulting melting during spring and summer (particularly over Scandinavia), the Alpine region and the Scandinavian part of Alpine region experience the highest contribution of rainfall to run-off generation (about 80% of total rainfall). In other biogeographical regions, the contribution of rainfall to run-off generation is about 50%.

3.1.3 Run-off regulation by forest cover

Forests play a particularly strong role in regulating run-off in upstream small sub-basins where forest covers more than 50% of the total sub-basin area.

Generally, high run-off irregularity conditions are experienced on mountainous areas in summer and in lowlands in winter (Map 3.3). Normalised distribution of irregularity magnitudes (10) show that in the Alpine region forests smooth more than 30% of run-off irregularity where forest is the dominant land cover type (i.e. where forest cover is greater than 50%). In Boreal and in Continental regions, forests only smooth approximately 10% of run-off irregularity. In the Mediterranean, run-off irregularity increases with increasing forest cover.

Figure 3.7 Impacts of decreasing forest cover on run-off and surface run-off



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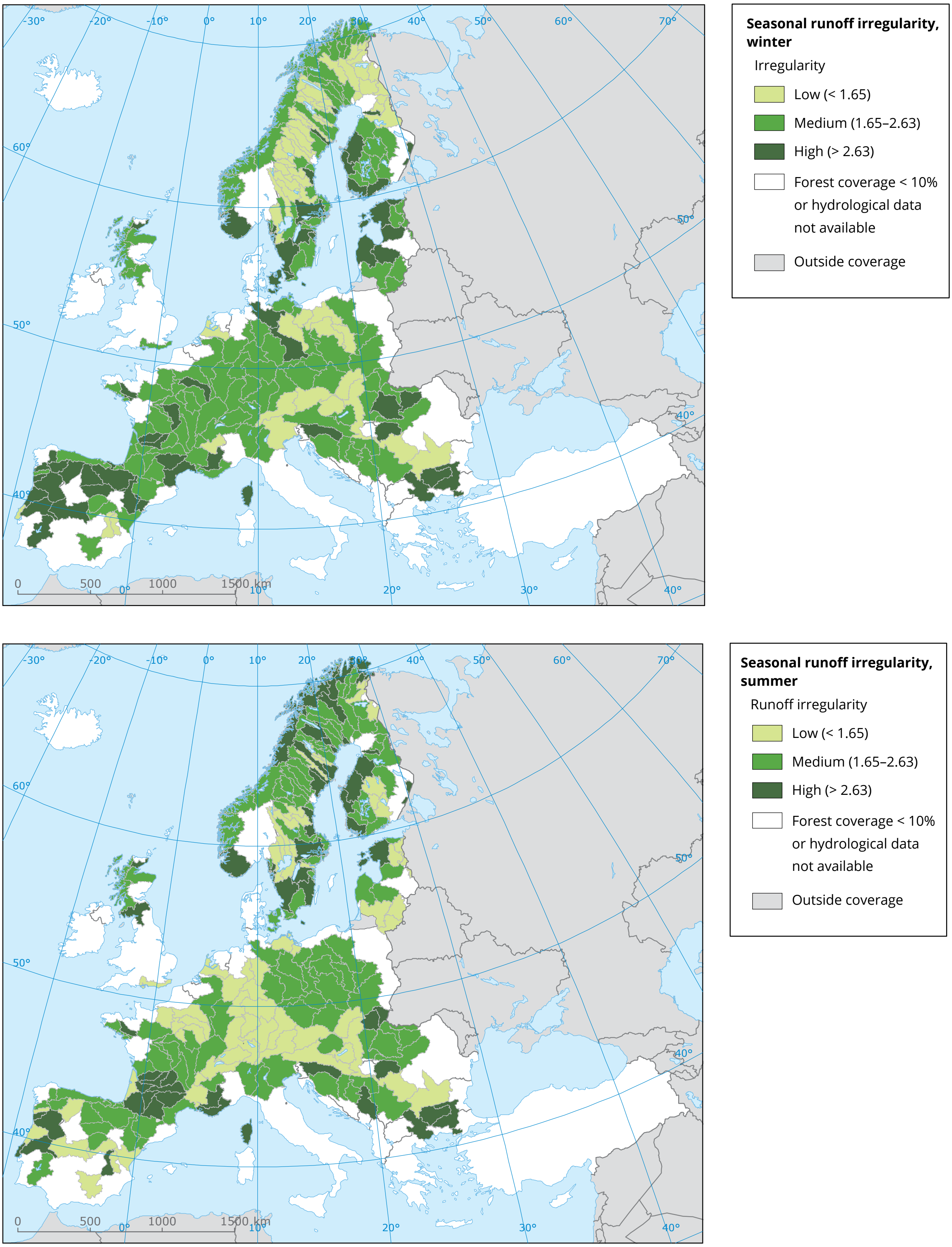
(10) Normalisation has been done by adopting the run-off irregularity coefficient greater than 100 as an extreme event.

Map 3.3 Seasonal run-off irregularity across Europe (based on estimation)in winter (top) and summer (bottom)



The Mediterranean region experiences the highest annual run-off irregularity coefficient throughout the year (k_d=13.5). This is explained by the special rainfall regime in the Mediterranean. The Alpine and Atlantic regions followed with k_d=10 and k_d=8, respectively. Continental and Boreal regions had kd values of 8 and 6, respectively. The lowest run-off irregularity coefficient is estimated for the Pannonian region (k_d=3).

Due to snowfall during the winter months, most mountainous areas in the Alpine region show comparatively low irregularity conditions. During the winter, lowland areas, particularly in Scandinavia and the Mediterranean region (for instance the north of Portugal and north-west of Spain) have highly unstable run-off conditions.

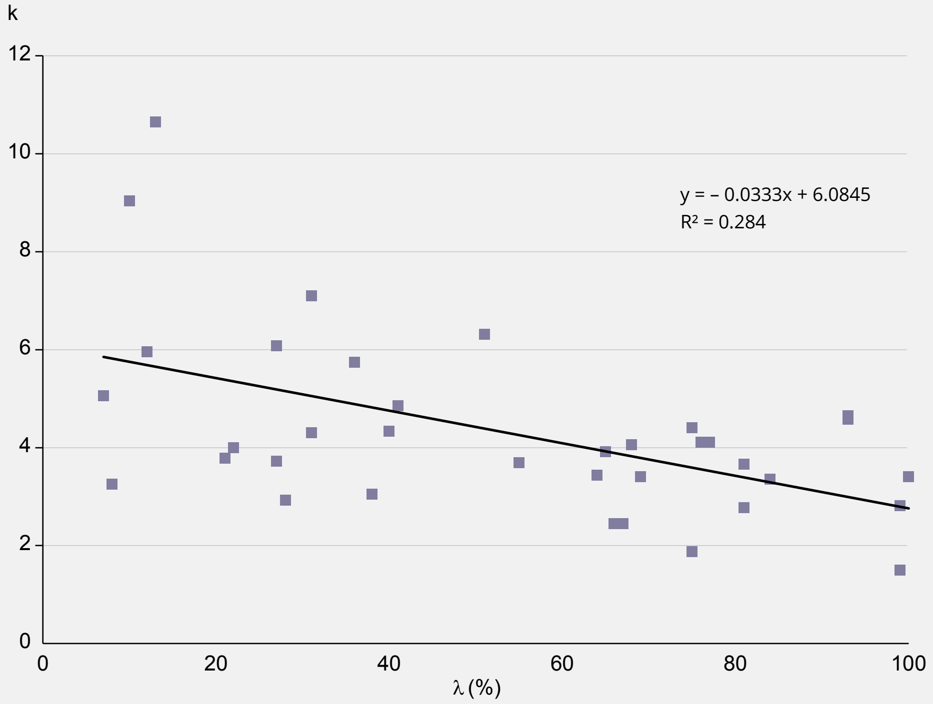
The results show that forest cover has a significant impact in reducing the magnitude of run-off irregularity throughout the year. For instance, Tyszka and Stolarek (Tyszka, 2009; Tyszka and Stolarek, 2013) applied the run-off irregularity coefficient to compare natural forest retention capacities with long-term mean annual run-off in 40 small Polish lowland catchments and in Białowieża Primeval Forest. Their analysis indicates quite high correlation between forest cover and water retention. This study reached similar conclusions for some selected sub-basins across Europe (Box 3.1)

Box 3.1 Run-off-regulating capacity of forests

Polish lowland catchments (Tyszka, 2009)

Several studies in Poland have used the run-off irregularity coefficient to compare natural forest water retention capacities with long-term mean annual run-off in Polish lowlands and in the forested catchments of the Great Valley Region. An increase of forest cover from 0 to 100% resulted in a decrease of the annual run-off irregularities (Figure 3.8). Seasonal variations of run-off were also examined, revealing increases of outflow during the water deficit months (April to June). This study also demonstrated how forests stabilized the climate, increased species diversity, and provided other essential ecosystem services. The study demonstrated the importance of efficient water retention activities as well as the importance of integrated water-resources management practices to balance the water demands of tree stands with the needs of external users.

Figure 3.8 **The effect of percentage of forest cover (λ) on the coefficient of irregularity on annual run-offs (HR max/HR min)**



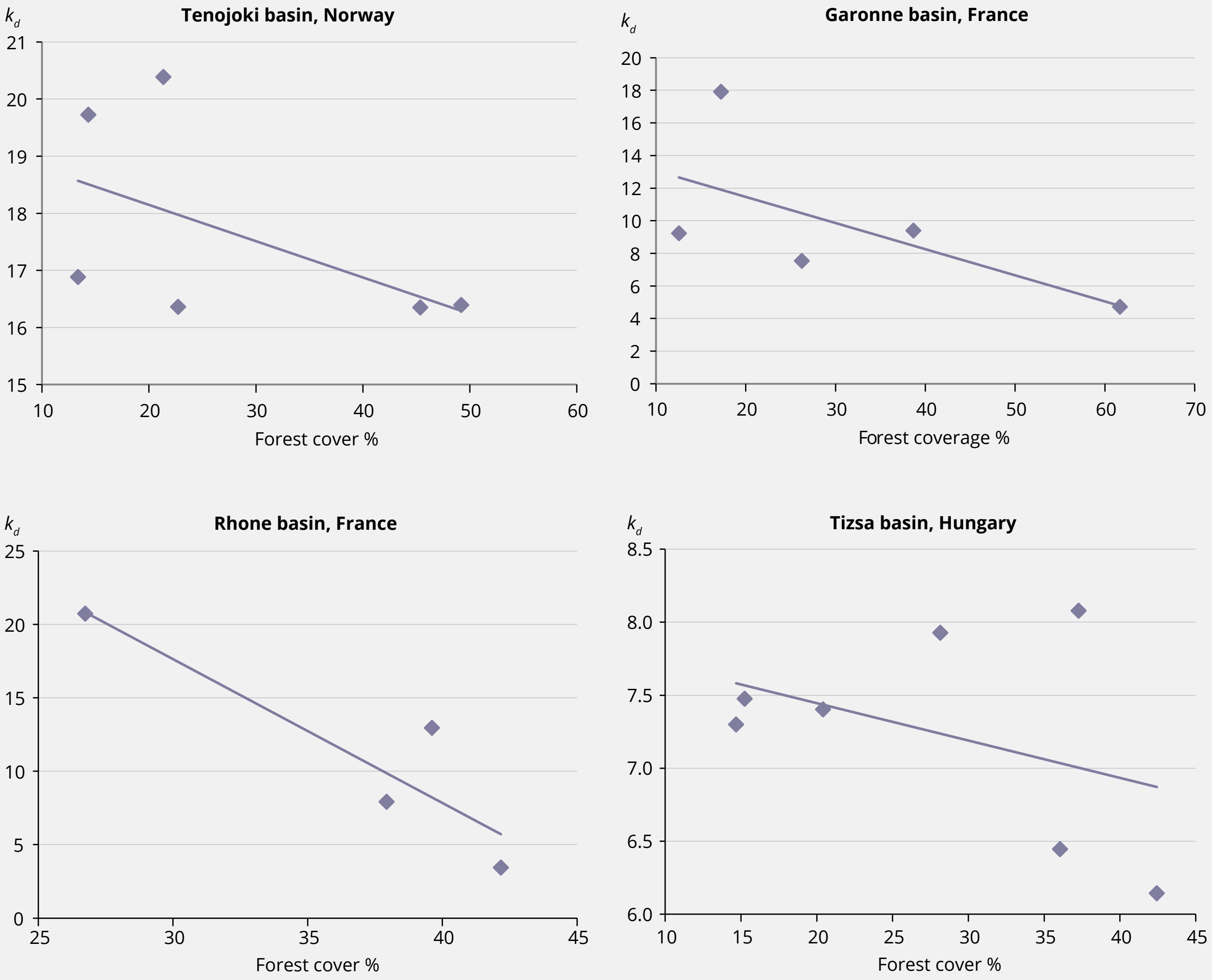
Source: Tyszka, 2009.

Box 3.1 Run-off-regulating capacity of forests (continued)

Selected sub-basins across Europe

Four different river basins were selected across Europe by this study (Figure 3.9). The sub-basins represent various forest cover ratios starting from 10% up to 60%. All selected sub-basins provide quite strong correlations, indicating the regulatory role of forests over run-off regime.

Figure 3.9 Relation between forest cover and run-off irregularity in selected sub-basins



3.1.4 *Increasing residence time by forest cover*

Our estimation revealed that residence time (11) is longer in large sub-basins compared to small sub-basins. This linear relationship can also be observed in Figure 3.10. Normally, residence time is a function of the spatial extent of the hydrological unit together with the density of rainfall. But some local conditions such as soil, vegetation type, land cover, and degree of human intervention also influence the prolongation or shortening of the time to flush all effective rainfall out from the sub-basins. An important question is whether forests influence the prolongation of residence time. Analyses revealed that under

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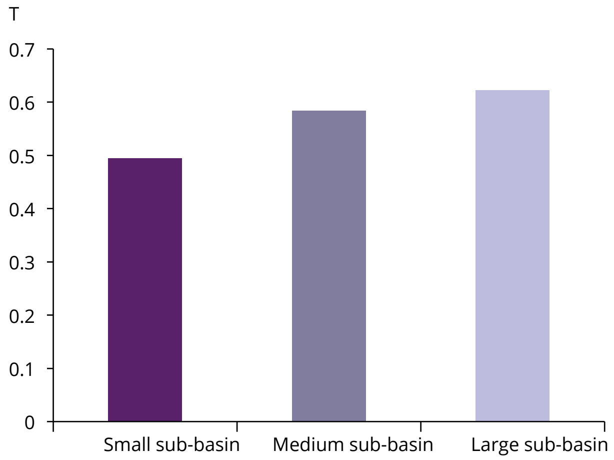
(11) In this study, it was assumed that the surface water cycle is completed within one month at the sub-basin scale; this means that the flushing ratio cannot exceed '1'.

Figure 3.10 Estimated flushing ratio in small, medium and large sub-basins



comparable sub-basin conditions the impact of forests on prolonging residence time are detectable where forest cover is greater than 30%.

Moreover, the residence time is prolonged by almost 15% in medium sized sub-basins and by 35% in large sub-basins where the forest covers more than half of the territory (Figure 3.11).

The lowest residence time was estimated in the Mediterranean region. The Alpine and Boreal regions had the highest residence time.

3.2 Influence of forest types over water retention

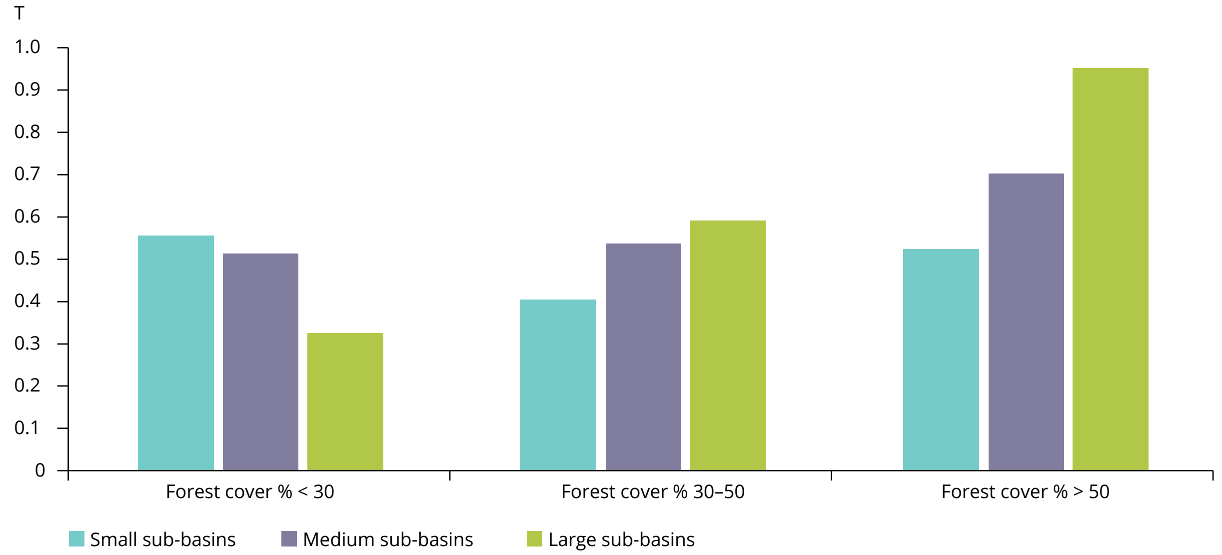
Forests in Europe were classified according to Corine into three main forest types: broadleaved, coniferous and mixed. Coniferous forests are dominant in Europe (accounting for 44% of all forests), followed by broadleaved forests (34%). The Boreal and Continental regions are covered mainly by coniferous forests, while other regions are mainly represented by broadleaved forests.

A typical range of annual evaporation losses (mm) for different land covers was applied to the water-balance calculations by Nisbet (2005) to assess the influence of forest types on the water balance. It has been found that depending on the composition of forest tree species, the layer structure of forests, and the location of forests, coniferous forests usually consume more water compared to broadleaved forests due to higher interception and transpiration values (Table 3.1).

The average run-off coefficient by forest type was estimated for the period from 2002 to 2012. The results of this report generally support the findings of Nisbet (2005). The analysis revealed that coniferous forests retain 10% more water compared to broadleaved forests (Figure 3.12).

The results vary in the respective biogeographical regions. Coniferous forests in the Alpine, Boreal and

Figure 3.11 Estimated flushing ratio under different forest cover per sub-basin size



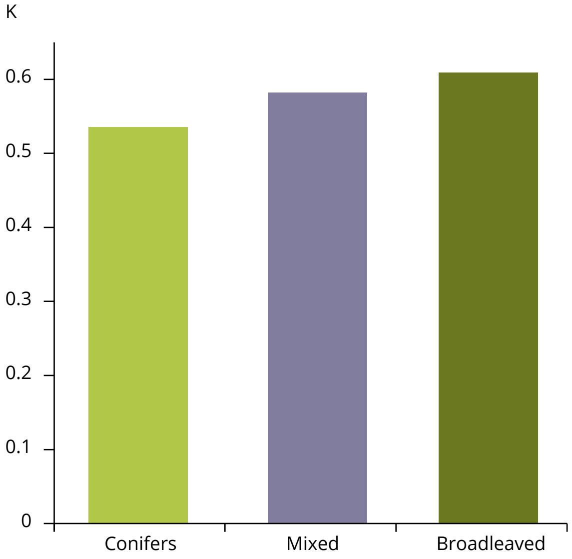
Note: SB = Sub-basin.

Table 3.1 Typical range of annual evaporation losses (mm) for different land covers receiving 1 000 mm annual rainfall

Land cover	Transpiration	Interception	Total evaporation
Coniferous	300–350	250–450	550–800
Broadleaved	300–390	100–250	400–640
Grass	400–600	–	400–600
Heather	200–420	160–190	360–610

Source: Nisbet, 2005.

Figure 3.12 Average run-off coefficient per forest type in Europe, 2002–2012



Mediterranean regions retain more water than the European average. Broadleaved and coniferous forests in the Atlantic region retain about the same amount of water. In the Continental region, mixed forests retain water more than other forest types (Figure 3.13).

These biogeographical comparisons do not explain the entire relationship between forest types and water retention. Seasonality is important in forest ecosystems, and in particular in the context of water consumption and retention. Comparing winter and summer hydrological behaviours in different forest types reveals large seasonal differences across Europe. Usually, and as indicated earlier, the summer months are represented by lower run-off conditions than the winter months (Figure 3.14). Vegetation periods and their impacts on hydrology are mainly controlled by the amount of water being intercepted and transpired from forests. Water consumption by trees over the year depends on the size of tree and the canopy expressed as the leaf area index.

Figure 3.13 Run-off coefficient and forest types by biogeographical region

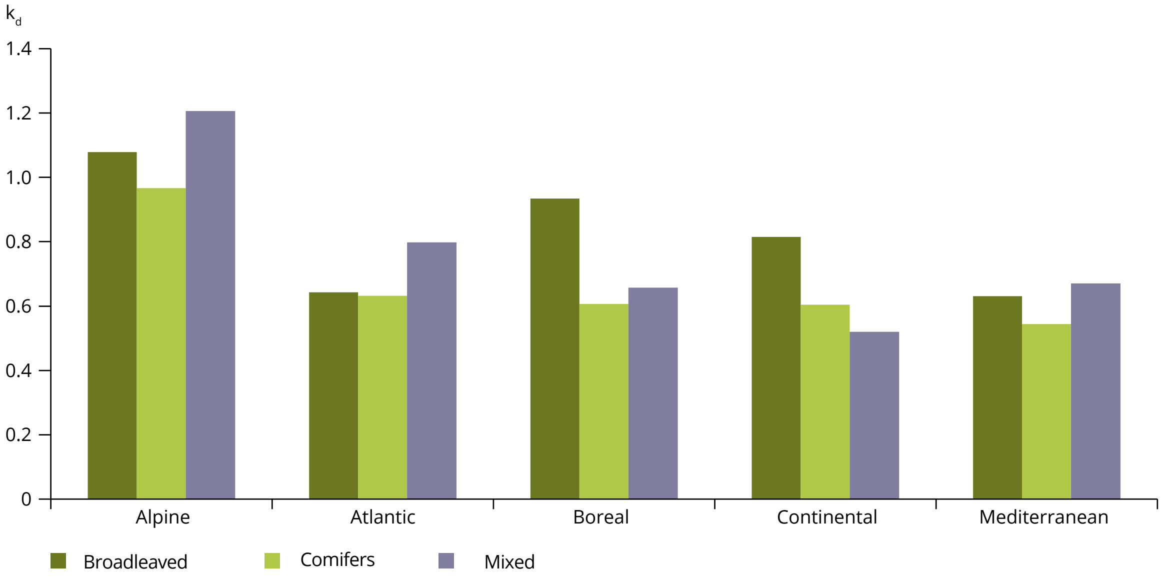
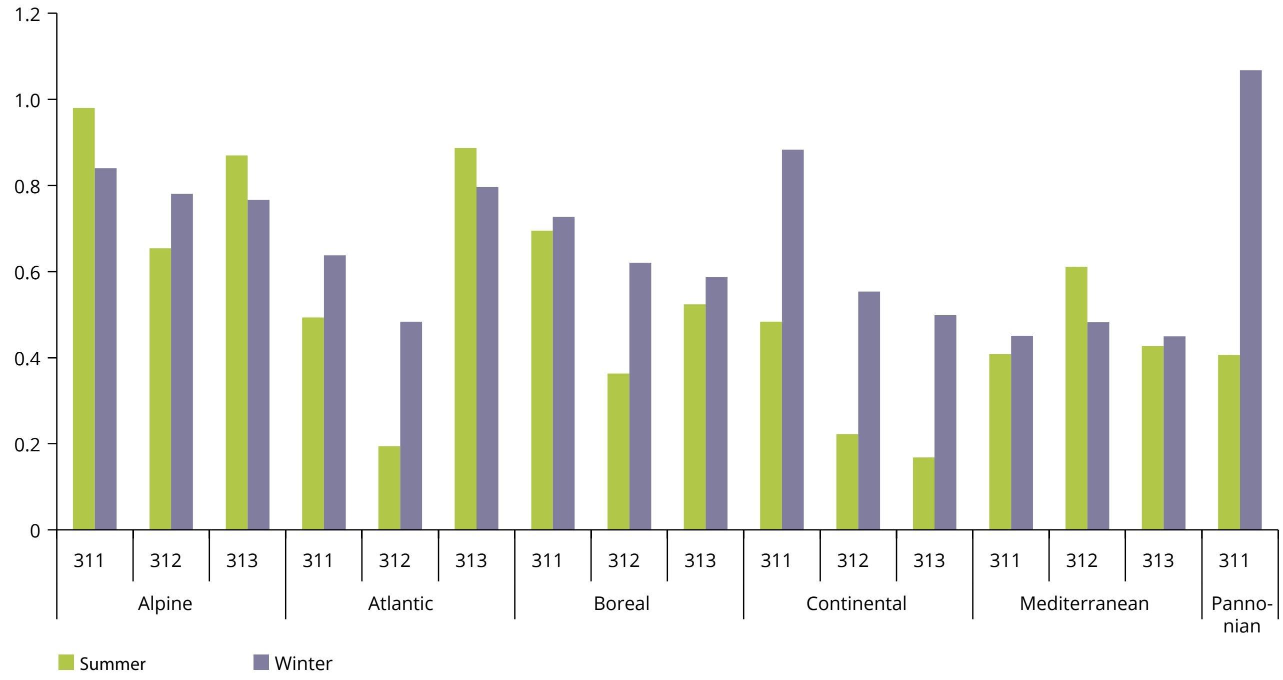


Figure 3.14 Seasonal run-off coefficient vs. forest types by biogeographical region



During the summer period, coniferous forests have a significant role in reducing run-off, particularly in the Alpine, Atlantic, Boreal and Continental regions. In the Mediterranean and Pannonian regions, broadleaved forests provide lower run-off than coniferous forests. This regional pattern can also be observed during the winter time. One significant difference is observed in the Continental and Mediterranean regions with mixed forests that provide lower run-off coefficient values.

The analysis of the impact of forest types on run-off irregularity confirms that coniferous forests overall regulate run-off by 10% more than broadleaved forests in Europe (Figure 3.15).

Despite this general trend, there are large variations in the biogeographical regions. The results at the sub-basin scale are sometimes different from this overview pattern. However, the general trend remains constant across Europe (Figure 3.16).

Regarding seasonal variations in terms of forests' regulatory role on run-off, no significant differences have been detected between winter and summer. Nevertheless, the influence of conifers on the regulation of run-off depends on seasonal climatic conditions and vegetation periods. Broadleaved forests also affect the run-off regime, particularly in summer months in some biogeographical regions, for instance in the Atlantic and Continental regions where broadleaved forest cover dominates.

As for the residence time, in general, it is higher in the summer period compared to winter months.

Figure 3.15 Average of run-off irregularity coefficients by forest type, 2002–2012

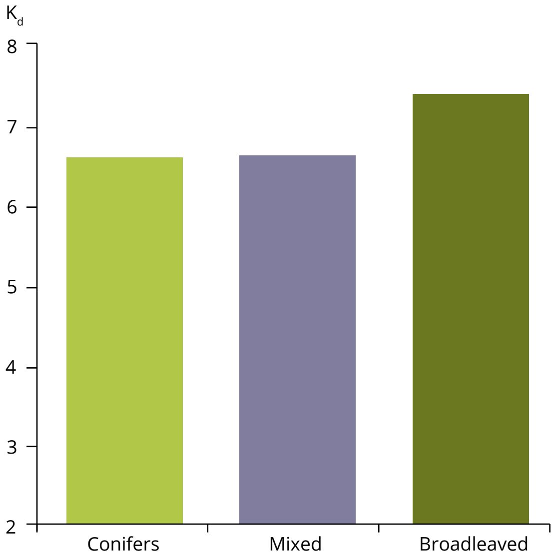
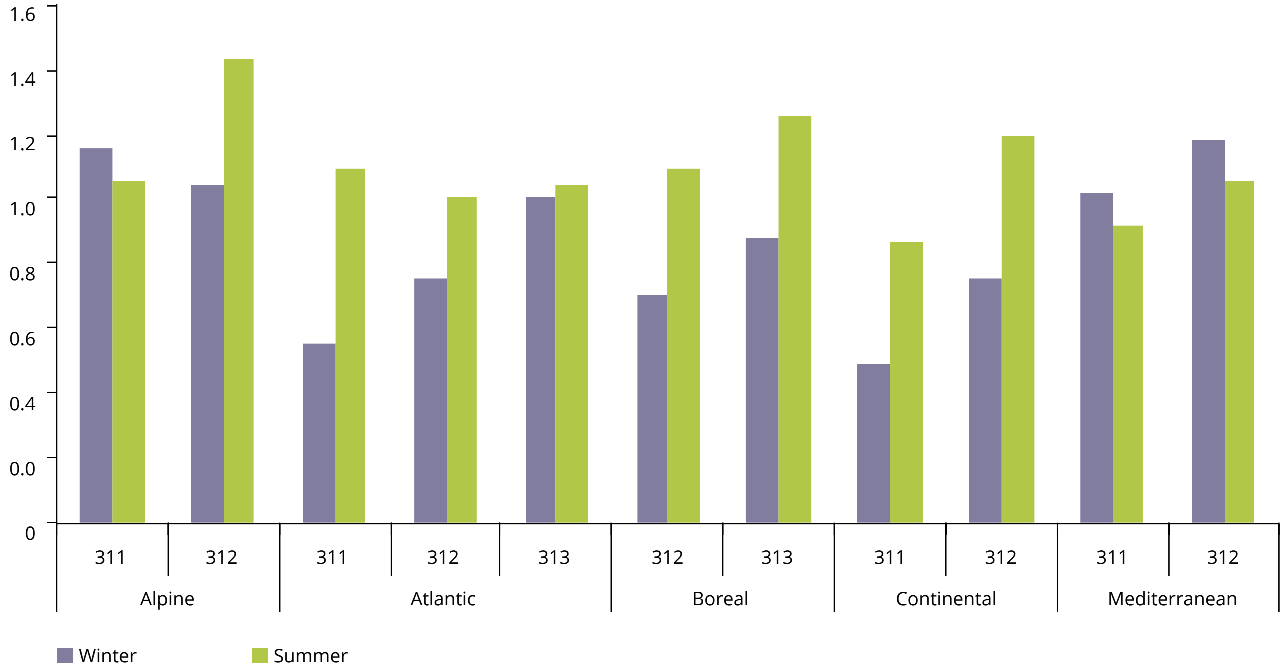


Figure 3.16 Seasonal run-off irregularity coefficients by forest type and by biogeographical region



3.3 Forest management and water retention

This study confirms that for all biogeographical regions except the Mediterranean region, an increase in forest cover reduces and regulates run-off. Differences between full forest cover and clear-cut have already been well-identified and the impacts of silvicultural practices on run-off conditions have also been examined in the previous study (Riekerk, 1989).

Approximately 28% of the forested areas included in this study are registered in the CDDA and considered as protected forests under extensive management.

In general, the percentage of protected forests is highest in the Alpine and Continental regions (Figure 3.17). Regarding the forest types, coniferous forests have the highest proportion of protection (with over 30% of the coniferous forests in this study falling under protected status), followed by broadleaved (29%) and mixed forests (22%).

A comparison of run-off coefficients between protected and managed forests — without considering the percentage of forest cover in the respective sub-basins — indicates contradictory results from different locations regarding the impacts of the management practices over the runoff conditions.

Some local examples from Sweden and Finland (located in the Boreal region) suggest an inverse relationship between the degree to which a forest is protected and the degree of water retention (12) (see Table 3.2). In the selected local examples, the forest cover in all sub-basins is higher than 50%, except for the Torne Upby sub-basins where forest cover is approximately 34%. Forest cover is significantly different in protected and unprotected forests.

Several calculations in this study suggest that 10% changes in forest cover results in a moderation of the run-off. The above values do not give any possibility for further investigation of that question. On the other hand, some other cases provided opposing results and indicate higher retention potential for protected forests and lower values for managed forests. Due to an insufficient number of sub-basins meeting the preconditions (See footnote 10), such results could not be presented here. These preliminary results need further examination before a European conclusion is drawn. The impacts of forest management practices on the run-off are very site specific and could provide

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(12) In order to avoid possible high uncertainties around this finding, the examples from sub-basins have been selected under some strong conditions. For example, sub-basins should be located within the same biogeographical region, in the same river basin, having upstream–downstream relation and similar sub-basin size and also roughly similar forest cover. The current database enables few examples to be compared from protected and unprotected forests under such preconditions.

Figure 3.17 **Relative distributions of protected and managed forests by biogeographical region**

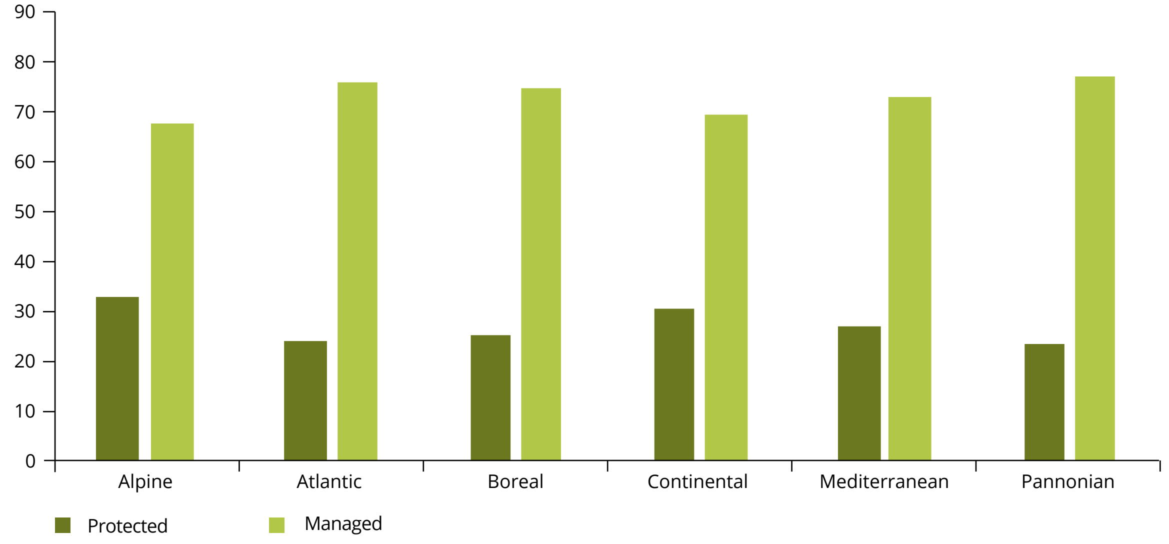


Table 3.2 **Examples of estimated run-off coefficient for protected and unprotected forests in selected sub-basins**

Sub-basin name	Protected forest (%)	Total forest cover (%)	Run-off coefficient
Angerman main — Lower - Faxa		53	0.98
Angerman main — Medium		57	0.62
Angerman main — Upby	13	51	0.91
Dal main — Lower		67	0.59
Dal main — Medium - Vasterdal		61	0.70
Dal main — Upby	14	60	0.75
Ljusnan main — Lower		69	0.42
Ljusnan main — Medium		59	0.70
Ljusnan main — Upby	36	50	0.89
Kalix main — Lower	11	66	0.83
Kalix main — Medium		55	0.56
Kalix main — Upby	51	38	0.99
Torne main — Lower		64	0.63
Torne main — Medium		73	0.67
Torne main — Upby - Lainio	42	34	0.74

contradictory evidence for both protected and managed forest categories. For example, removing trees from the riparian areas would have more impact on buffering water than the removal of mountainous forests. Moreover, young generations of forest trees use more water compared to old generations, and so on. In addition, logging paths and hauling are often reported as reasons for increases in run-off rather than the composition of forests themselves. But on the other hand, it has also been reported that a mosaic cycle in close-to-nature silviculture management with horizontally and vertically structured forest stands using site-adapted tree species increases water retention (Schüler, 2006). Nevertheless, the results obtained in this study on water retention by protected and non-protected forests remain debatable, but provide a first estimate of the relationships between forest management and water retention.

4 Classifying water retention potential of Europe's forests

This report conducted an analysis of the relationships between forest and water retention for the whole of Europe. It is based on available data at European level from the EEA Water Accounts Production Database, as well as on information on forest land use and cover from forest statistics and Corine. The selected indicators did not always provide the same level of signals for the same territory due to different soil, climatic or forest stand reasons, as well as because of data precision issues. Therefore, the classification method focuses on computing an index by summing-up the results obtained from three main indicators: run off coefficient, surface run-off coefficient and run off irregularity coefficient. This classification should be interpreted as an attempt to quantify the water retention potential of forests in a very generalised way. However, such a classification is helpful to provide an overview at European level of the influence of forests on water retention.

The study resulted in a classification of European forests into those with high, medium and low water retention potentials. Water retention is a time-dependent process. Seasonality is very important where water retention of forests is concerned. Therefore, the water retention potentials of European forests have been estimated separately for winter and summer months rather than providing annual averages that might be misleading when making conclusions. Water retention potential across Europe varies significantly between winter and summer (Map 4.1). The analysis revealed few forest areas in winter that had high retention potential, due to the different rainfall regime. The rest of Europe presented mainly medium or low levels of water retention during the winter. In contrast, forests play a significant role in retaining water during summer months, thus expanding high water retention potentials across Europe. High water retention potentials occur mostly in the lowlands of the Atlantic, Continental, and Boreal regions and in the Alpine region.

Another conclusion that can be drawn from this report is that the impact of forests on water retention is particularly noticeable in small sub-basins. This might be explained by the fact that the influence of forest cover on the run-off dynamics is easier to delineate and observe in small-sized sub-basins compared to large sub-basins (Figure 4.1).

No significant changes have been observed in forest cover within the individual sub-basins. However, a simple statistical analysis indicates that a 10–15% decline in forest cover increases the run-off (Figure 4.2).

Forest cover greater than 30% results in higher water retention potentials. Regarding forest types, coniferous forests have the largest impact on run-off across Europe with some local exceptions, for instance mixed forests in the Alpine region and broadleaved forests in the Continental region (Figure 4.3). Medium water-retention areas are mostly represented by coniferous and mixed forests, except for the Mediterranean region. In the Mediterranean region, broadleaved forests are dominant in the medium retention areas. Regarding low water retention, apparently no explicit relationship could be detected with forest stands in these areas. It is assumed that other soil factors like regional topographic or climatic conditions and sub-basin size could also play a role in addition to forest stands in those areas.

Map 4.1 **Seasonal water retention potentials (based on estimation) in winter (top) and summer (bottom)**

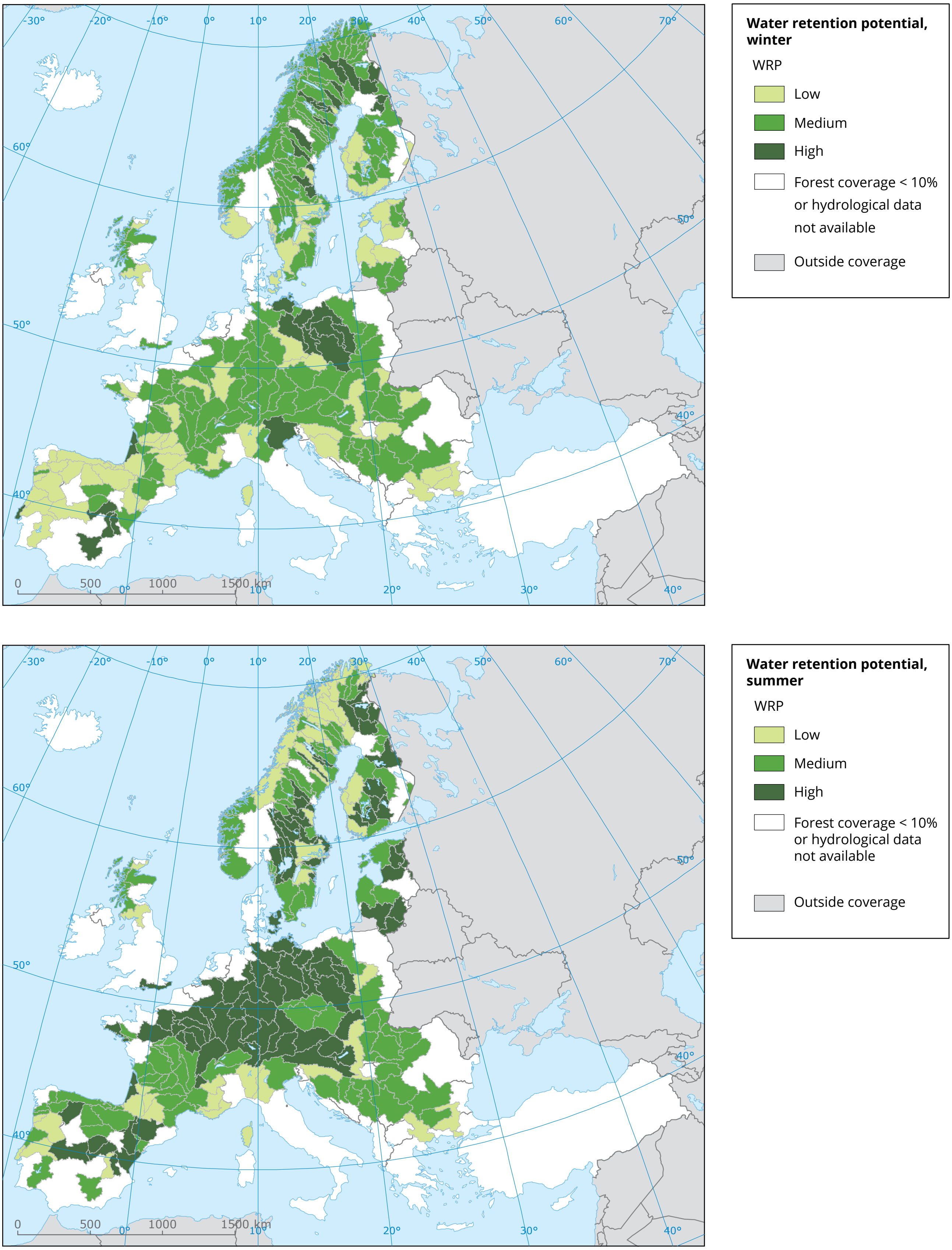


Figure 4.1 Water retention potential vs. sub-basin area (in km²)

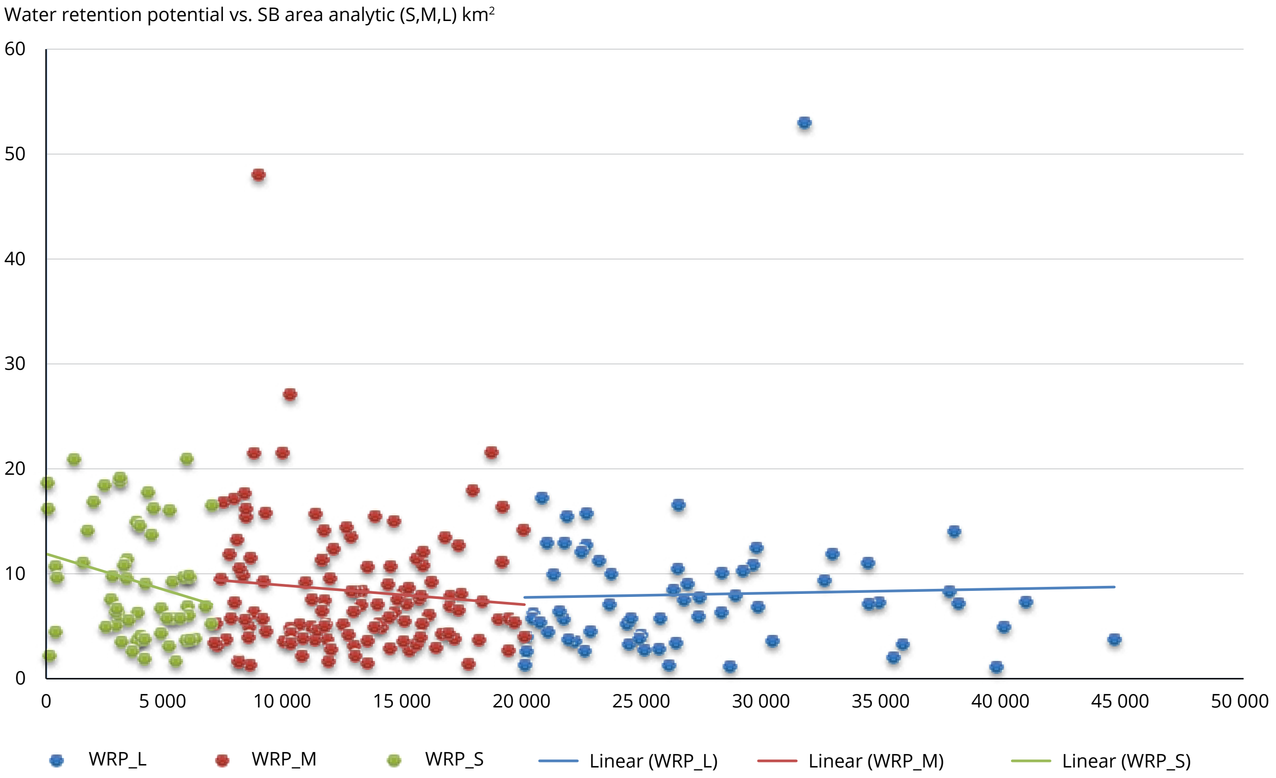


Figure 4.2 Water retention potential vs. forest cover change (%)

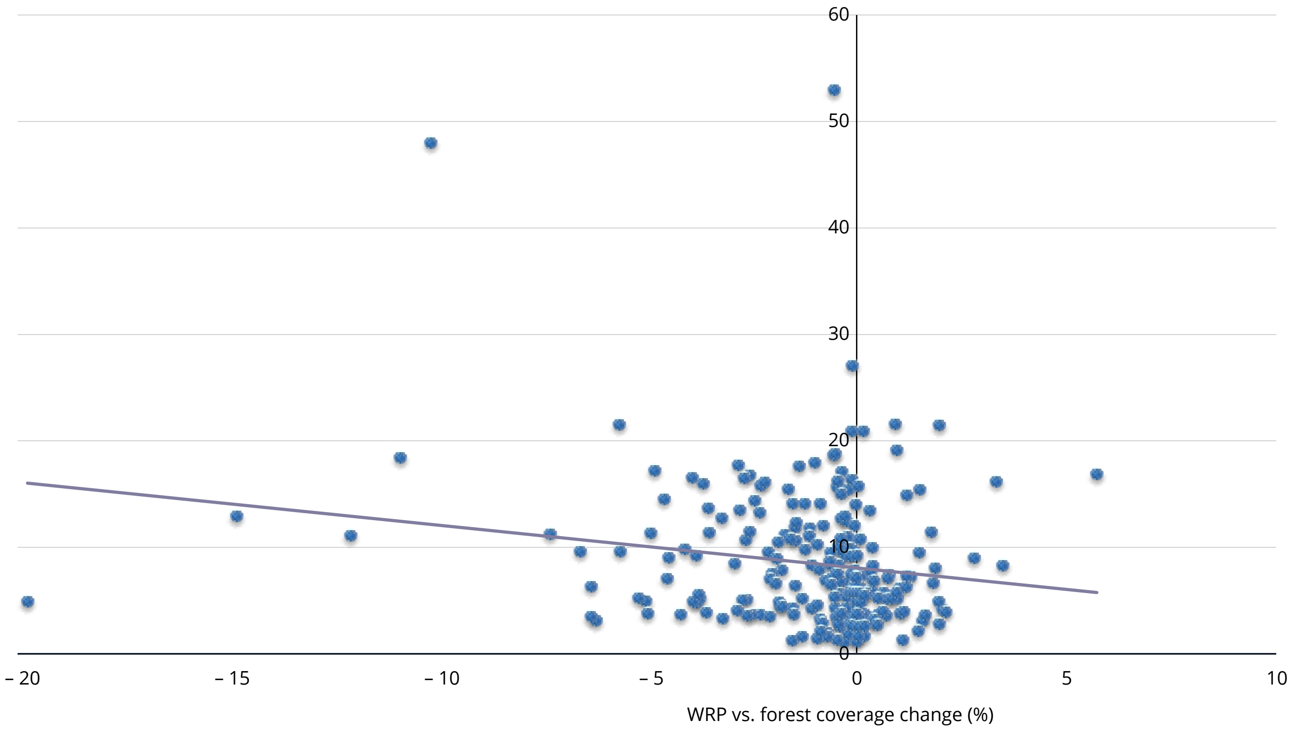
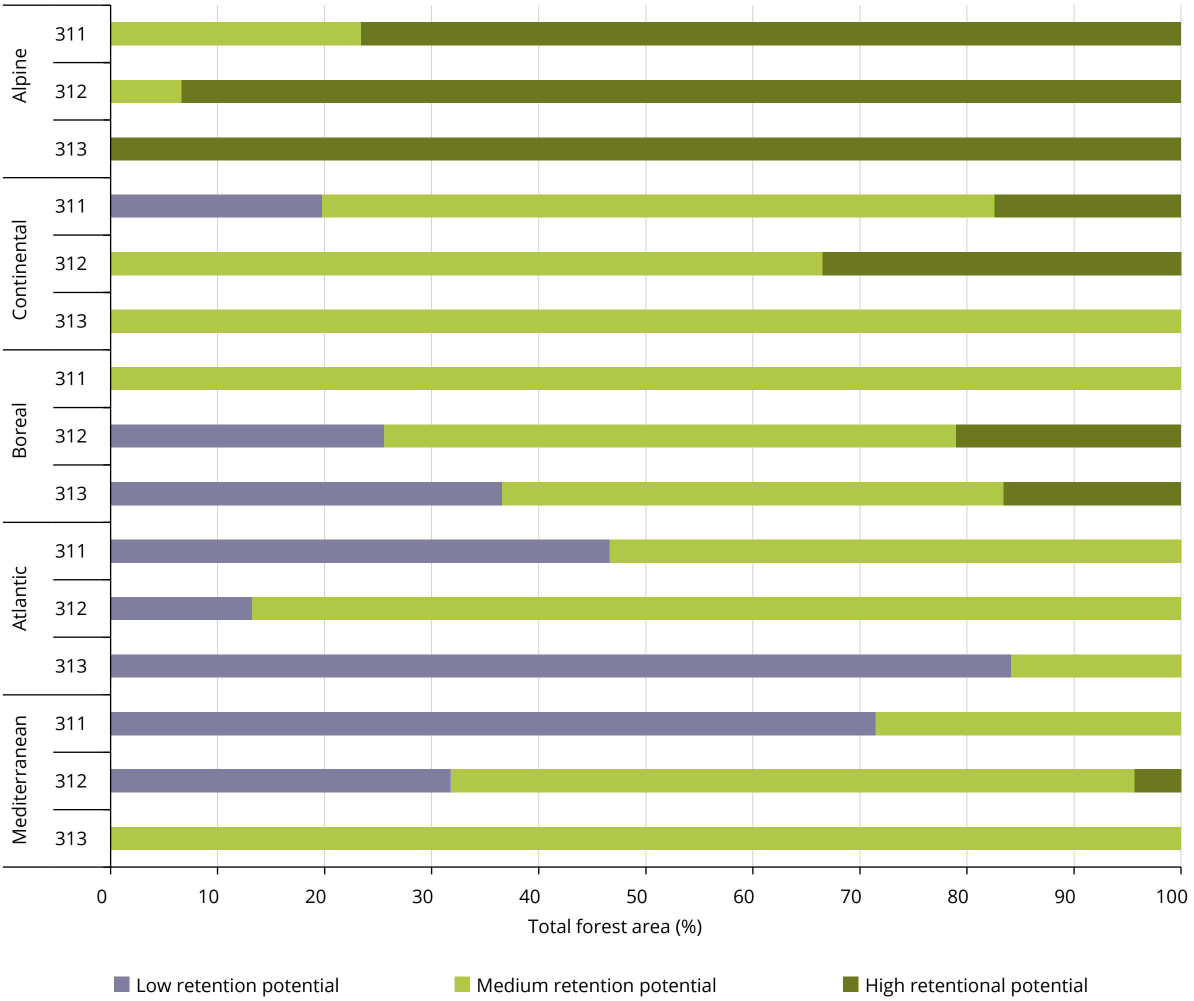


Figure 4.3 Water retention potential and percentage of forest cover and types by biogeographical region



In practice, the term water retention implies taking measures (structural or natural) for prolonging the residence time of water in the environment before it joins run-off and finally goes out to sea. This exposes an important question in the context of natural water retention measures: is the objective of water retention to keep the same volume of water in the environment during a given time period? Or rather is the objection of water retention to increase water consumption by ecosystems — i.e. forests?

Based on the assessments of this study as well as evidence from previous scientific studies, an increase in forest cover regulates the run-off. Coniferous forests in particular consume more water than other forest types. However, water retention is obviously not the only ecosystem function forests have. Forests that have kept or retained a good part of their natural flora and fauna also help to safeguard biodiversity. The Biodiversity Strategy 2020 lists as one of its six targets the aim of encouraging forest managers to protect and enhance forest biodiversity and to integrate biodiversity measures in forest management plans. Therefore there is a need to balance the different possible ecosystem services forests can provide. It is also necessary to find relevant solutions at regional and local scale that support each of the possible services and targets.

These issues underline the fact that Natural Water Retention Measures need to be site-specific and target-oriented. Any environmental impact assessment including water retention measures should be conducted at local scale before implementation in forests.

4.1 Future directions

Forest hydrology is a complex issue, which has been the subject of scientific debates for decades on how forests affect water yield and water quality. Further improvements in the understanding of such a complex system would require empirical analysis to be conducted at a smaller scale than the European continental scale. Nevertheless, the general overview from the analysis at continental scale is helpful to evaluate the main trends in hydrological processes.

The assessment made in this study is highly aggregated. This aggregation exposes a number of uncertainties around the obtained results. Therefore, not surprisingly, a number of local cases would contradict the results assessed in this study. However, spatial coverage of this study involves a significant number of catchments (65 000 catchments across Europe) aggregated to 287 sub-basins, which makes it possible to carry out a European-scale comparison.

Some aspects of forest hydrology are purely site specific. Nevertheless, forest hydrology has a wider relation to climatic conditions and the overall hydrological cycle at the regional or continental scale. This means that the results of forest hydrology on a European scale need to be interpreted carefully.

In the coming years, improvements in spatial and temporal coverage of relevant data mean that catchment-scale studies would be able to provide more robust and sound results at the European scale. For instance, a high resolution layer of forests combined with the EEA Water Accounts production database could have promising results. This possibility will tremendously increase the EEA's capacity in analysing any subject on forest-water interactions.

In this respect, European overview assessments are highly valuable in that they can be integrated with European-scale ecosystem assessments. Such an integration would be able to provide the background for more detailed analysis on regional and local scale. This analysis will always build on the regional and local knowledge provided by experts on national level. The implementation of ecosystem assessments conducted and supported by Member State experts is also the core of the broader discussion of ecosystem assessments and services, such as in the MAES project (Mapping of Ecosystem Services), which was identified in the European Union (EU) Biodiversity Strategy to 2020.

List of acronyms

CDDA	Common Database on Designated Areas
CCF	Continuous Cover Forestry
EC	European Commission
ECRINS	European Catchments and Rivers Network System
EEA	European Environment Agency
FAO	Food and Agriculture Organization
NWRMs	Natural Water-Retention Measures
WFD	Water Framework Directive
WRP	Water Retention Potential

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