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Non-invasive Environmental Monitoring of the Coniferous Forests Using Statistical Analysis and Data Modelling

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ABSTRACT

Climate plays a pivotal role in construction of relationships between coniferous forest health and water balance for efficient biosynthesis under changing meteorological variables. Here we identify that the age of the forest (young <30 years old, and old >200 years old) confers an improved ecophysiology for the maintenance of water balance through the response of trees to weather conditions (precipitation, temperature and water balance in different seasons). Global climate change, of the rise in temperatures, has an impact on the environment of mountain ecosystems in the Alps. Subalpine forests enhance partitioning precipitation inputs, with interception processes in the tree canopy determining the stability of the proportion of water reaching the ground and its quantity in the form of evaporation. These processes support global improvements in forest ecosystems at the catchment scale, as interception is influenced by the structure and density of the tree canopy and the presence of epiphytes. This study revealed that coniferous forests (spruce, fir and pine) have a significant influence on how much water is retained and discharged in the soil and plants. Interception in dense subalpine forests can account for a significant proportion of precipitation. Data analysis using Python-based modeling revealed that forest age increases biosynthesis by enhancing water fluxes. This study highlights the significance of uncovering hidden climate-environment determinants leading to improved forest hydrology and ecophysiology to enhance the biosynthesis and water balance in coniferous forests of the Alps.

1. Introduction

Environmental monitoring has been used for many years to evaluate forest health (Klaučo et al., 2013, 2017; Tanovski et al., 2022; Stajić et al., 2023; Yu et al., 2025). The specific aim of silviculture is forest hydrology which is the sum of a great variety of highly coordinated climate-environmental variables. Many studies investigated the physiology of leaves to evaluate the water balance as a vast array of biophysical components (Lemenkova, 2021a, 2023; Feng et al., 2025; Liu et al., 2025). The sustainability of forest ecosystems depends on sufficient water. Therefore, water balance is crucial for normal functioning of forest ecosystems and health of trees. Water sources encompass diverse types (fog, rain, snow) and intensity of balance between precipitation and evapotranspiration which significantly impact water interception by trees and vegetation coverage

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(Lemenkova, 2021b, 2022a; Li and Rex, 2025; Wang et al., 2025a).

In recent years, the environmental monitoring surveys have witnessed a concerning rise in global warming and changes in land cover, causing considerable disruptions across multiple landscapes worldwide (Menzel, 2000; Liu et al., 2023; Vázquez-Luna et al., 2025; Kustura et al., 2025; Wang et al., 2025b). The Tyrolean habitats in the Alps have also experienced consequences of global climate change, affecting vegetation, energy supplies, and health of mountainous forests (Schermer et al., 2018). These included, for instance, disruption of fragile ecosystem due to the current climate changes, decline in richness of natural resources, the decrease in the diversity of the fauna and climatic vulnerabilities (Cattivelli, 2021; Cattivelli, 2023). Specifically, coniferous forests have been notably impacted by changing meteorological parameters (variations in temperature and precipitation), encountering difficulties in water balance maintenance and resource supplies (Swidrak et al., 2013; Brunner et al., 2015).

As forests regions contend with these challenges, particularly those arising from climate change (rise in temperatures, lack of precipitation) and responses of soil (dryness), the ecological crisis holds the potential to pave the way for environmental monitoring using integrated system of fieldwork data collection and modelling (Ranković et al., 2016; Ratknić et al., 2019; Lemenkova, 2024a, Lemenkova, 2024b). This development could strengthen and expand climate-ecological ties between different components of ecosystems (soil, water, and vegetation), a major global controllers of climate and sustainability (Studer et al., 2007; Lemenkova 2022b; Akkala et al., 2025). As these connections grow, a more pronounced environmental monitoring in subalpine forests is anticipated, underscored by extensive and strategic ecological surveys that include climate, biological and meteorological observations and data modelling for sustainable development of protected areas in the Alps (Los et al., 2000).

Firstly, the canopy of trees functions as a dynamic permeability barrier, adjusting water balance to coordinate solute transport and drought stress resistance (Beswick et al., 1991; Chandel et al., 2025). In this way, they sustain nutrient and moisture availability in leaves. Heavy rainfall can exceed canopy storage capacity, leading to quicker through-fall and reduced interception efficiency (Caldwell et al., 2016; Scavotto et al., 2025). Conversely, lighter rain and fog events are more easily captured and retained by the canopy cellular structure, cell growth, stress response (Klemm and Wrzesinsky, 2007; Uehara and Kume, 2012). These factors are tightly linked to and thus grip all aspects of metabolic processes and water interception in leaves.

Water balance in forests has been systematically studied and progressively enhanced over the past years (Nikić et al., 2012; Węgrzyn et al., 2021; Zhang et al., 2025; Li et al., 2025). In these studies, strategies are primarily focused on the increasing of our understanding of how water is being regulated in old and young trees, and what role plays fog in water interception. Considering that key meteorological parameters (temperature, humidity, precipitation, pressure, and wind speed) are embedded within modelling and dataset networks, many potential determinants could unexpectedly enhance integrated effects of their synthesis (Los et al., 2001; Kupec et al., 2021). This is possible through diverse modelling techniques and approaches using statistical libraries of Python or R (Kulshreshtha et al., 2018; Lemenkova, 2019c; White and Powell, 2019). Modelling of these factors helps to reveal the unknown regulatory interactions between the climate, hydrological and environmental determinants.

In previous similar studies, diverse approaches were combined with statistical analysis to identify factors that influence water balance in forests (Thorne and Arain, 2015; Karinou et al., 2025; Gerula and Gąbka, 2025). In this study, Eddy covariance techniques were applied for meteorological data collection to gather information in methodical pathways to improve models. Afterwards, the Python-based modelling was conducted using tabular data and variables processed individually using diverse libraries (van Rossum, 1995). A limited dataset of the period of 2015-2019 was modelled using Python libraries of statistical analysis. To identify potential linkages between climate and environmental factors that influence water balance in trees hidden within the ecosystem network, the climate and environmental variables were modelled in the statistical analyses. The target area included South Tyrol, north Italy.

2. Objectives and goals

To understand wide landscape dynamics and responses of forest to changing climate processes, it is necessary to monitor, collect and model the data regarding water balance and responses of forest canopy. To this end, monitoring observation system was performed from 2015 to 2019 with the aim to observe major climatic variables in the Italian Alps: precipitation, temperature, evapotranspiration and water pressure deficit. These variables were collected using Eddy covariance technique and then processed using Python-based statistical analysis for graphical visualization. Eddy covariance is a robust approach in environmental modelling which enables to measure micrometeorological parameters such as carbon dioxide (CO_2), water vapor, and energy. Using Eddy covariance supports data analysis for understanding climate-environment processes and their relationships in the Earth's surface and the atmosphere, as demonstrated in existing relevant studies (Evrendilek et al., 2011; Chen et al., 2014). Among others, this technique measures the turbulent fluxes of the climate-environment quantities, which are employed to quantify the net exchange of carbon, water, and energy between the surface and the atmosphere.

Previous studies touched upon a small fraction of the problem of the climatic-environmental monitoring of coniferous forests with specific question of water balance. To continue existing works on climate-hydrological variations in coniferous forests, this study extends the scope of targeted trees (spruce and pine) to the entire ecosystem through a statistical analysis. As such, we identified a beneficial factors that improve water balance (age of trees), positive role of epithytes (lichens) and target precipitation level and temperature optimal for health of forest canopy, contributing to those in the available previous studies (Breuer et al., 2003; Dohnal et al., 2014; Chen et al., 2018; Skalova et al., 2022). In the end, our goal is to create a better understanding of relationships between biophysical properties of forest (canopy and age of trees) and water balance (regulation of precipitation and humidity) by analyzing environmental climate datasets.

That is why it is important that selected parameters and features of exploited characteristics can be inserted in statistical analysis as variables to realize their links in the studied dataset (evapotranspiration, temperature, water pressure deficit, temperature). By integrating these data on coniferous forests with different age (<30 y. o. and >200 y. o.), we are able to create better models on how age of trees affect water balance, and what is the role of additional factors (lichens and density of canopy).

3. Materials and Methods

This paper adopts a secondary methodology within the domain of climate-environmental interactions in the Italian Alps, Figure 1.

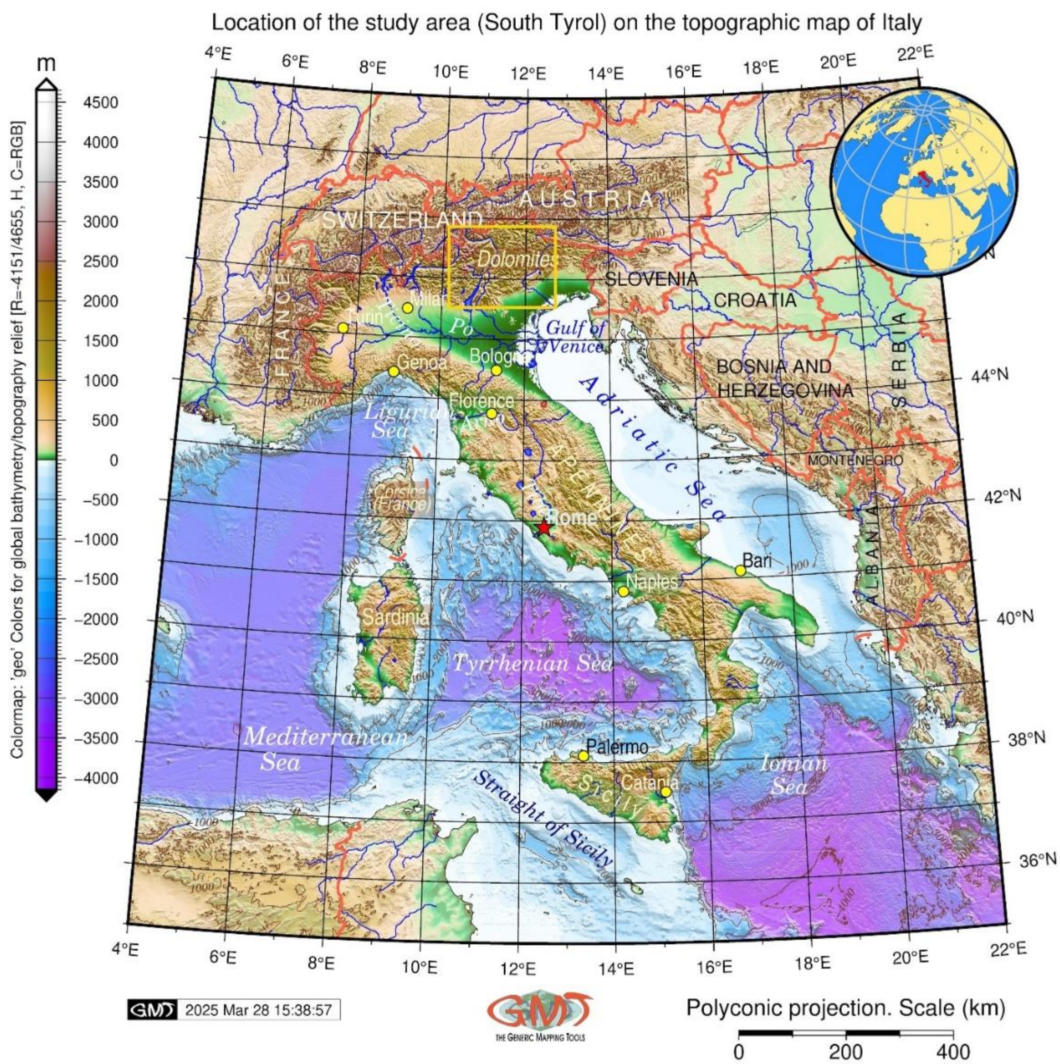

Figure 1. Study area: coniferous forests in Dolomites, the Italian Alps. Maps source: author

The methodology is utilizing data from geospatial GMT-based mapping, previously published researches, fieldwork measurements by Eddy covariance techniques, and Python-based modelling distribution. To this end, water components were measured from 2019-5-30 (DOY 150) until 2019-11-07 (DOY 311) at canopy level of forests. The environmental measurements were based on daily observation data divided into dry and precipitation periods. The stem flow was measured at each tree of the old and young stands. Water running downwards around the tree trunk was collected into a funnel, and measured with a tipping bucket pluviometer (Table 1). The measured volume of stem flow was divided with the projected crown area of the trees to convert the data into mm. Missing values owing to logger failure were added via linear correlations with automatic through-fall measurements (R^2 = 0.81 for the old forest and 0.55 for the young forest). The precipitation was measured inside and outside the forest (minor amount of precipitation during "dry" period because periods were defined based on the outside climate station alone), through-fall and stem flow measured with automatic tipping gauges, storage/interception calculated as P - Tf – St, Table 1.

The soil water content was measured continuously within the study site and the change of soil water content was calculated as the difference between the start and end of the measuring period and the hydrologic year, respectively.

Water discharge at the catchment scale was measured using a combination of a water stage sensor and flow velocity measurements. The water stage sensor was placed at the lowest spot of the catchment, just above an artificial water basin.

After measurements, the data were systematically summarized as a dataset in tabular format to address the following two research questions:

1. what is the most significant contribution of forests that regulate water balance (temperature, precipitation and evapotranspiration)
2. what is the role of forest age (old trees >200 years old and young trees <30 years old) in regulating water balance?

These questions are answered using measurements and modelling in the context of climate changes (because observations were taken in different periods). This approach seeks to construct a comprehensive and nuanced representation of the climate-environment challenges in mountainous forest landscapes of Alps. The techniques included data examination, graphical modelling using libraries of Python and data analysis.

Such integrating approach offers insights that align with the theoretical research and practical needs of the environmental monitoring and sustainable development in protected regions of Europe.

Table 1
Water components at canopy level in the coniferous forests of young (<30 years old) and old (> 200 yeasr old) trees. The data are based on daily data divided into dry and precipitation periods

Period	Nr of days	P	ET	Throughfall	Stemflow	Interception
			young forest			
dry	78	1.3 ± 1.8	350	2.6 ± 3.3	0.0	-1.3 ± 3.3
fog	8	0.1 ± 0.2	26	0.2 ± 0.0	0.0	-0.0 ± 0.2
mixed fog+P	42	460 ± 35	110	292 ± 26	1.0	167 ± 36
rain/snow only	34	132 ± 21	147	47 ± 11	0.1	85 ± 19
			old forest			
dry	78	1.3 ± 1.8	350	0.6 ± 0.2	0.0	0.7 ± 1.4
fog	8	0.1 ± 0.2	26	0.1 ± 0.0	0.0	0.1 ± 0.2
mixed fog+P	42	460 ± 35	110	216. ± 11	0.8	242 ± 29
rain/snow only	34	132 ± 21	147	36 ± 3	0.2	97 ± 16

Table 2
Water components at canopy level divided into months according to dates of the manual through-fall gauges

Days with mixed precipitation	young forest	old forest
P measured	460 ± 35	460 ± 35
Total Tf measured (mm)	292 ± 26	216 ± 11
Tf estimated from rain only events (mm)	243 ± 7	184 ± 8
Fog contribution in mixed events (mm)	70 ± 15	53 ± 5
Measured Tf/P (%)	64	47
Estimated rain-only Tf/P (%)	53	40
Estimated fog Tf/P (%)	15	12
Rain contribution to Tf (%)	83	84
Fog contribution to Tf (%)	24	24

To ensure the effective acquisition of environmental and climate data, three principal strategies were employed. The first involved exploring Eddy covariance platforms specifically tailored to micrometeorological observation technique. Using Eddy instruments, the following climate variables were directly measured using methods reported in existing studies: turbulent fluxes of heat (Zhang et al., 2015), biophysical parameters (Zhu et al., 2016), water vapor and water balance between the surface and the atmosphere (Kandel and Bhattacharjee, 2024). These data were then analyzed high-frequency wind and scalar data. Here, Table 2 shows observations of water components are summarized using data observation for 5 months from 2019-5-30 (DOY 150) until 2019-11-07 at canopy level roughly divided into months according to sampling dates of the manual through-fall gauges. The technique of field measurements was the following. Fog contribution was estimated daily for all single through-fall gauges and negative estimations were set to zero, thus the sum of estimated fog and rain contribution was higher than measured through-fall, Table 3. The measured values were logged at 10 min intervals and then scaled to the tree level by multiplying them with stem circumference (minus the bark and phloem thickness measured during sensor installation) and integrated them to 30 min and daily sums per tree (L day-1). When a sensor was installed for more than a year, the data were checked whether accumulation of resin led to a decrease in sap flow by comparing the 95th percentile of 30 min sap flow rates for 2019 and the previous years. For the two smallest trees, we found a considerable decrease in the P95 sap flow and consequently corrected sap flow for 2019 by multiplying it with the ratio of P95. Minor data gaps caused by power outages or temporary sensor malfunction were filled by using a linear correlation of the respective tree's sap flow with eddy covariance evapotranspiration (R^2 = 0.57 to 0.66 at a 30-min resolution). The second step of methodology involved review of scientific literature regarding forest hydrology, climate and environmental interactions and modelling techniques, enabling access to peer-reviewed journals and scholarly articles that provide in-depth analysis and credibility. The second strategy utilized Python based modelling to statistically analyze the essential correlation between the variables and reveal environmental trends.

This approach is widely used in environmental research (Weng et al., 2023; Alnmr et al., 2024, Lemenkova, 2025a, Lemenkova, 2025b). A crucial aspect of this process was the application of advanced data modelling techniques that were able to do using Python's libraries Matplotlib, Numpy, Pandas (Lemenkova, 2019a; Lemenkova, 2019b; She et al., 2019). Such techniques include the use of the specific syntax of Python and filters to datasets, to secure that data have relevant formats, and are transparent and precise. Such data control enables to minimize the potential for bias in data analysis of the environmental dynamics. As shown in Table 3, the data variables were collected to analyze the estimated fog contribution to through-fall in mixed precipitation events in the young and old forest stand (mean ± standard deviation for absolute amounts).

Additionally, a diverse array of research methodologies regarding the effects of fog on forest hydrology, climate-vegetation interrelation and analysis was employed. Such methodologies aim at augmenting the depth and analytical rigor of the environmental studies. Moreover, these methodologies encompass the methods of data analysis, data integration and synthesis, data comparison through statistical analysis achieved by Python. Using integrated approach of data processing, the deductive-inductive approach in environmental analysis was achieved.

Table 3
Fog contribution to through-fall in mixed precipitation events in the young and old forest stand

Days with mixed precipitation	Young forest	Old forest
P measured (mm)	460 ± 35	460 ± 35
Total Tf measured (mm)	292 ± 26	216 ± 11
Tf estimated from rain only events (mm)	243 ± 7	184 ± 8
Fog contribution in mixed events (mm)	70 ± 15	53 ± 5
Measured Tf/P (%)	64	47
Estimated rain-only Tf/P (%)	53	40
Estimated fog Tf/P (%)	15	12
Rain contribution to Tf (%)	83	84
Fog contribution to Tf (%)	24	24

4. Results

The projected crown area of the sampled tree was about 19.6 m^2 (average radius of the canopy 2.5 m), and the amount of water held by the tree was 0.63 kg m^{-2} or 0.63 mm. Notably, this amount of water can be refilled by each rain and fog event and is consequently evaporated without stomatal control dependent on VPD. This is known as the function of the forest to respond to radiative forcing by increasing the emission of latent heat instead of sensible heat. Part of this water and fog can be directly absorbed by the plant through its leaves. Hence, the results confirm the positive feedback loop involving hydrological and vegetation components, which were particularly effective in the old stand due to its higher capacity to store water in its canopy. The tree age (>200 years old is better than young trees <30 y. o.) in the coniferous trees confers improved hydrology for water balance in the subalpine coniferous forests. In addition, the epiphytes survive where humid conditions which are more favorable in old-stand forest (with trees over 200 y. old). Therefore, fog links the positive feedback loop between the presence of lichens in old-growth forests and cool and humid meteorological conditions.

Table 4 shows the average air temperature (T), air relative humidity (RH), and vapor pressure deficit (VPD) from 30 min data outside and at two heights inside the canopy for the measuring period (15m and 23m at the top of the canopy) during the measuring period from 25 May to 7 November 2019.

Table 4
Meteorological-climate parameters: Average air temperature (T), air relative humidity (RH), and vapor pressure deficit (VPD) from 30 min data outside and at two heights inside the canopy (Lemenkova, 2025c)

sensor position	T (°C)	RH (%)	VPD (hPa)
outside	11.0 ± 4.8	77.5 ± 16.6	3.5 ± 3.3
15 m	11.5 ± 5.3	89.1 ± 14.2	2.0 ± 3.3
23 m	12.4 ± 6.2	82.7 ± 17.5	3.6 ± 5.1

The results of the environmental analysis presented processed data and visualized in graphs in Figure 2 to 5. The data represent the findings from the instrumental in deconstructing complex concepts applied into simpler environment-climatic investigations. The presented graphs enable to achieve more understandable environmental components showing the relationships between forest characteristics and meteorological setting. The data analysis allows for clearer interpretation and better engagement with the subject matter on forest ecology and hydrology.

Although leaf physiology is highly complex, statistical technique and data modelling underscore the significance of identifying environmental and climate determinants for forest engineering and silviculture. Thus, Figure 2 shows that the amount of water intercepted by the forest canopy varies with its age, structure and leaf type. Besides, it also shows that additional features such as mosses and epiphytes may intercept high amounts of water. Thus, they store water inside the forest, sustain evapotranspiration, decrease the Bowen ratio, and increase the air humidity. In this way, coniferous forests maintain water pressure deficit conditions and pose little water stress to leaves, and particularly to epiphytes. This could also be the case for temperate mountain forests, where needles can live for years and epiphytes develop on boles and branches of old trees. In aged forests, lichens continue to grow on old plants and increase interception capacity, when the stand leaf area index has already reached its maximum.

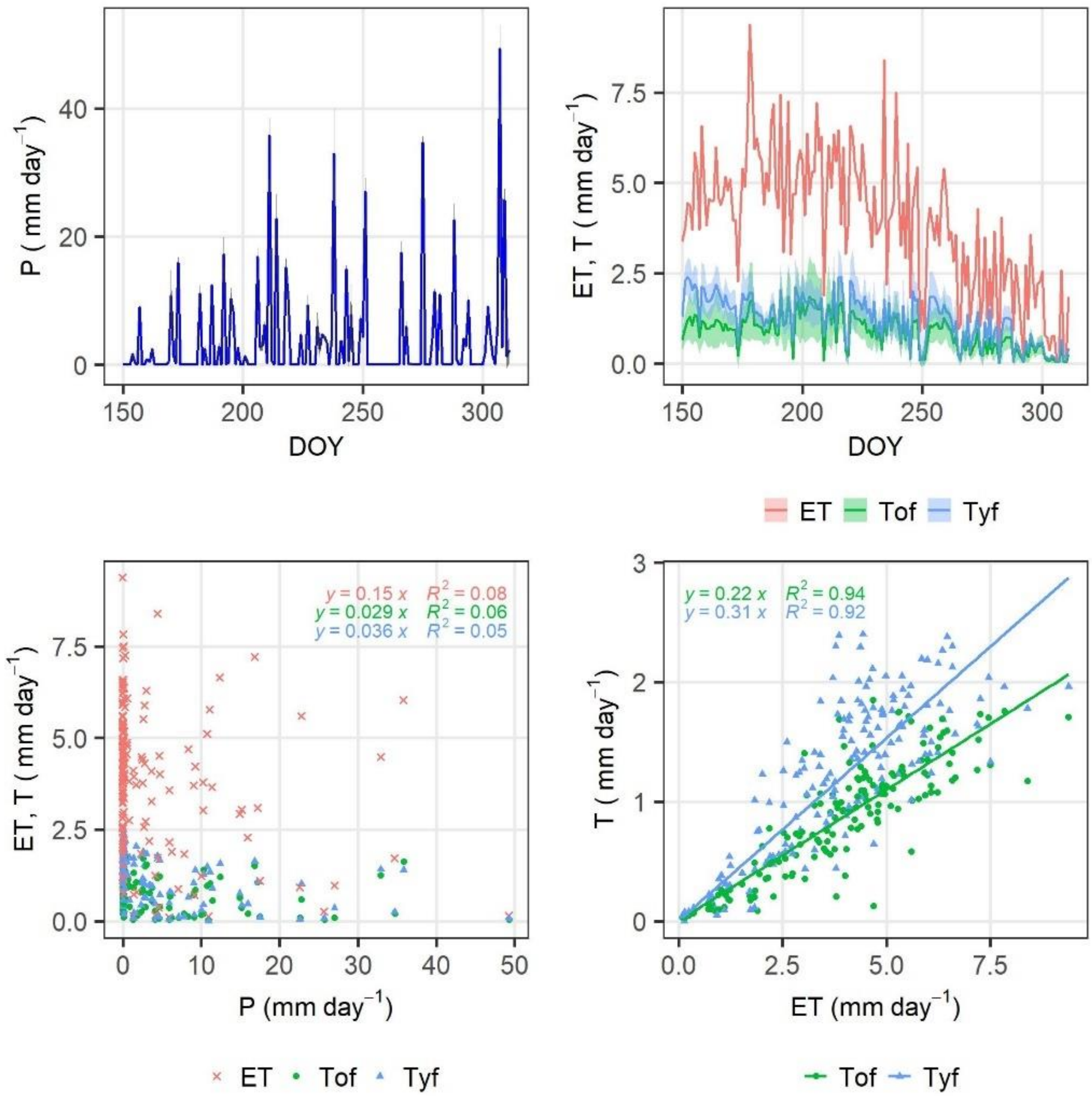

Figure 2. Meteorological parameters (precipitation, evapotranspiration, transpiration, and sap flow) measured using eddy covariance techniques

Figure 3 shows the results of the modelling of through-fall in old forest (of) and young forest (yf) stand versus precipitation accumulated to sampling dates of the manual gauges measured with manual gauges (top left), automatic gauges (top middle) and all gauges (top right). Through-fall was much higher during days with mixed fog and rain precipitation (Figure 2), conversely interception rates (I/P) were lower during rain-only days. This surplus in Tf (Tf/P = 0.28 for the young stand and Tf/P = 0.27 for the old stand), was attributed to fog.

Besides, it also demonstrates the correlation of through-fall of old (of, x-axis) versus young (yf, y-axis) stand measured with manual gauges (bottom left), automatic gauges (bottom middle), and all gauges (bottom right).

The error bars show the standard deviation between gauges of each stand in all plots.

Hence, the synthesis method of environment-climate data analysis combines these simplified elements into a cohesive and meaningful structure of correlation. This enables to create a framework that facilitates comprehensive understanding of climate effects on forest health and response of canopy to water balance (different precipitation and fluctuations in temperature). Together, these methods not only enhance the robustness of the environmental research specifically to forest hydrology but also ensure that it addresses the intricacies of the topic of mountain landscapes and sustainability of subalpine coniferous stands in a structured and systematic way.

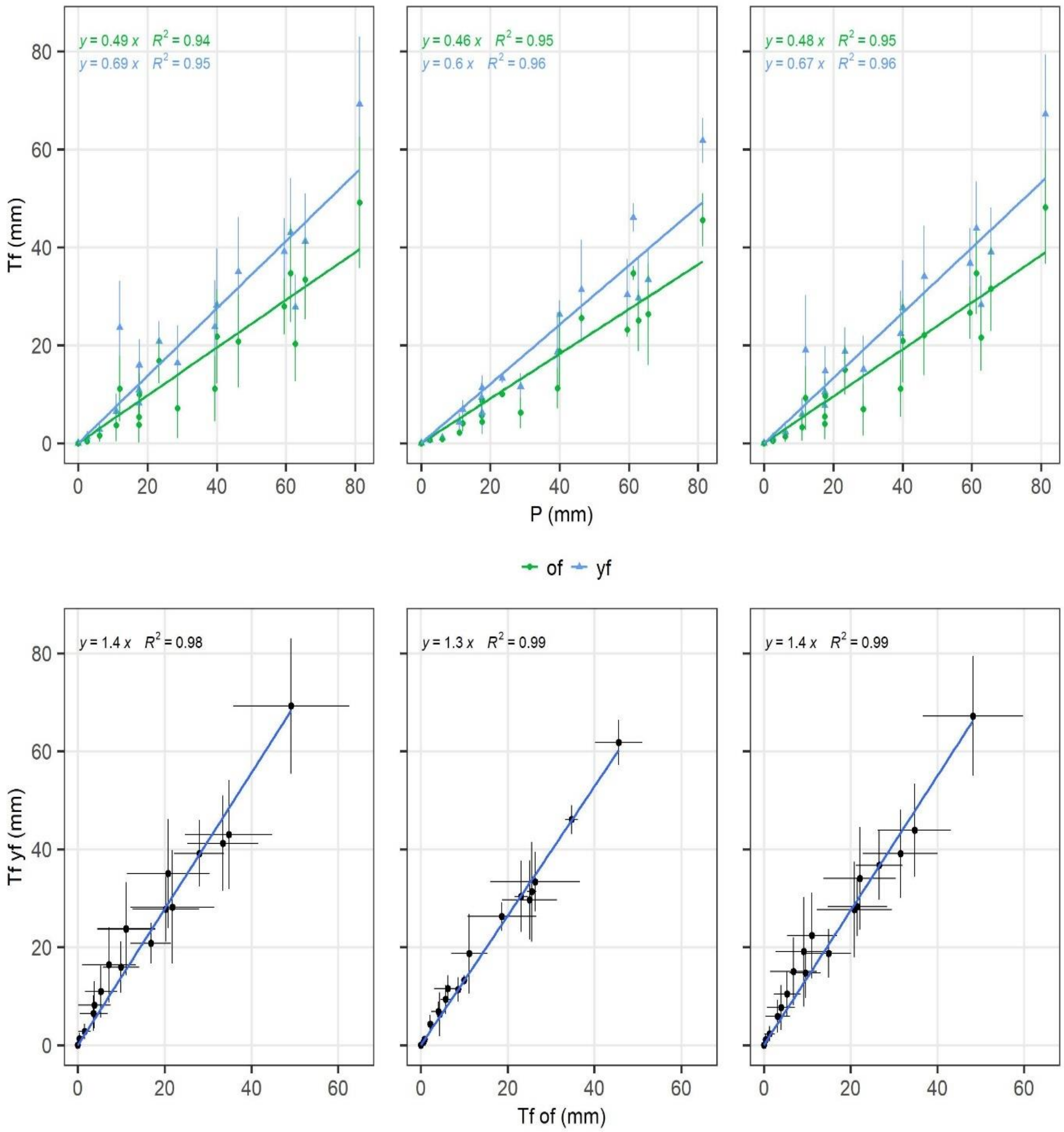

Figure 3. Climatic variables for old forest (>200 years old, of) and young forest (<30 years old, yf) throughfall in coniferous stand versus precipitation

Thus, Figure 4 shows time course of daily precipitation (P, top left in continuous line for clarity) as well as daily evapotranspiration measured with eddy covariance (ET) and daily transpiration for the old (Tof) and young (Tyf) forest upscaled from sap flow measurements (top right) and (below) correlation of daily ET, Tof, and Tyf with daily P (bottom left) and correlation of daily Tof and Tyf with daily ET (Lemenkova, 2025d). Figure 5 shows the results of modelling using Stankey plot in Python that shows water partitioning for the young forest (left) and the old forest (right) for the 5 months measuring period from 2019-5-30 until 2019-11-07. Total precipitation was split into rainfall (P), mixed precipitation (Mixed fog + P) according to fog observations. Interception (I) was calculated as the residual of measured P + mixed fog+P – through-fall (Tf) – stem flow (Sf). Evapotranspiration of soil and understory (Esu) was calculated as the residual of evapotranspiration (ET) measured with eddy covariance for the whole forest minus interception (I) and tree transpiration (T) measured as sap flow. Discharge (DC) and change of soil moisture (dSWC) were also measured for the whole forest, deep percolation was not quantified for the measuring period as ET + DC + dSWC was greater than total precipitation.

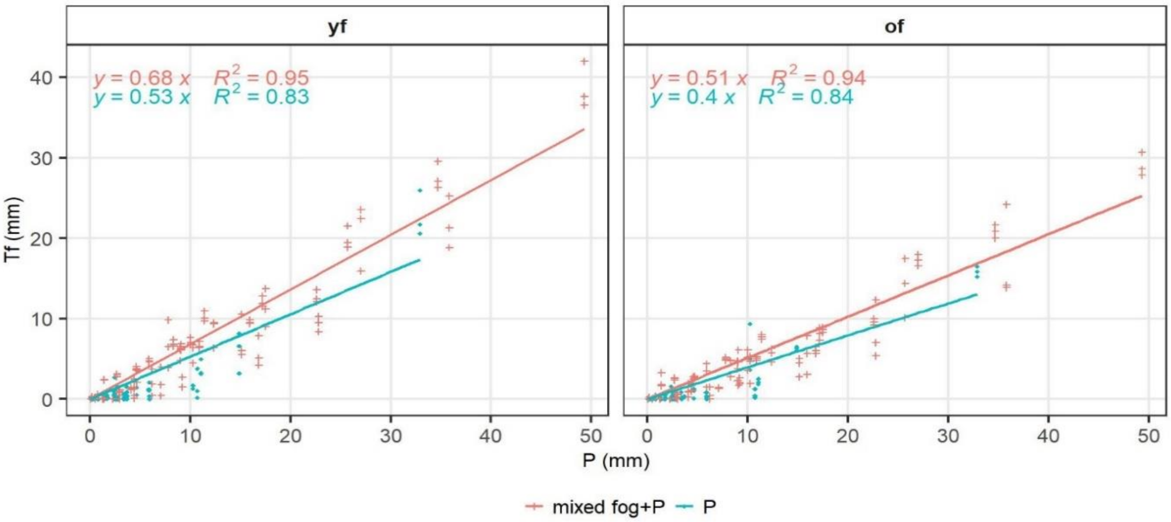

Figure 4. Through-fall versus precipitation during mixed precipitation (mixed fog+P) and rain-only (P) events in the young (yf) and old (of) forest (Lemenkova, 2025c)

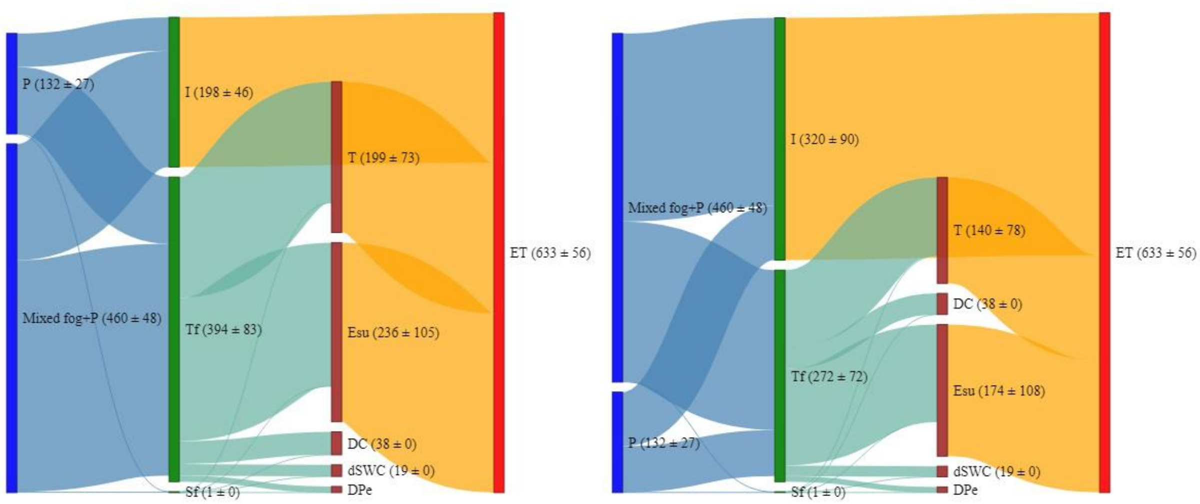

Figure 5. Through-fall versus precipitation during mixed precipitation (mixed fog+P) and rain-only (P) events in the young (yf) and old (of) forest

5. Discussion

Climate-oriented environmental engineering plays a pivotal role in improving the biosynthesis of coniferous trees and water balance in ecosystem due to its intrinsic and profound effects on meteorological variables, metabolism and hydrology. However, the complexity of climate-ecological and hydrological variations severely hinders effective environmental modelling of the coniferous forests. In our work, we leveraged a Python library Matplotlib combining diverse ecological parameters (through-fall, precipitation, temperature, evaporation) in the coniferous forests of various age to systematically identify environmental determinants that confer water balance in the subalpine ecosystems of north Italy. This catchment-scale modelling and high-through screening of ecological variables allowed us to map the potential determinants within the coniferous stands for water balance maintenance and also to integrate insights with ecophysiological functionalities for silviculture.

Due to its effectiveness and flexibility of Python-based modelling, identification of the correlation between variables has been applied to the dataset with other contexts, such as presence of lichens. In this way, statistical analysis employed in environmental studies has promoting effects on the sustainable development of coniferous forests. This study represents such application of eco-hydrological modelling of the selected parameters in the coniferous forests for environmental monitoring. This study contributes to the sustainable development goals in European Alps and allows for exploring the complex target networking in forest ecosystems for enhanced data observation in forest massifs.

One of the key successes of our study was identifying that tree age (<30 y. o. and >200 y. o.) confers ecophysiological benefits for water balance in coniferous forest. Recent studies have also associated that older trees maintain more water interception with improved leaves phenotypes and presence of epiphytes. For example, tolerance toward meteorological variations in temperature and precipitation, measured in rainy of foggy days was enhanced upon presence of lichens. These findings underscore the substantial potential of lichens for environmental engineering and water balance for biotechnological traits of interest.

However, how lichens and fog modulate integrated effects on water balance to adapt to such enhanced leave phenotypes remains unclear, impeding a deeper understanding of the climate-environment connections and tis recommended for further development in studies. Here we demonstrated how tree ages and health of canopy confers water balance through systematic analyses of the regulation of meteorological and hydrological parameters (precipitation P, temperature T, evapotranspiration ET).

6. Conclusions

In summary, the presented results demonstrated that several factors affect the water balance and drive water interception and discharge in subalpine forests. This was demonstrated in particular in the South Tyrol region where the forests have complex precipitation patterns and different vegetation structures. The study revealed that the age of the forest, the structure and density of the canopy, the meteorological conditions, the type and intensity of participation, and the presence of epiphytes (lichens) are among the most important factors. These parameters affect humidity and temperature in forest massifs. Although trees physiology is highly complex, our Python-based modelling screen highlights the significance of identifying beneficial environmental and hydrological determinants for forest engineering and silviculture. We can envision that forest engineering should also use modeling techniques to investigate the water balance in similar regions.

In terms of regulating ecosystem health in mountain conifer forest, we verified that Python-based modelling improves the analyzes of datasets by reducing potential bias and errors and increasing the accuracy of computation and precision of data visualization. As for regulation of forest hydrology, the integrated system is involved in field observation for dataset collection and Eddy covariance which is recognized as the most efficient acid resistance system for obtaining meteorological and hydrological data. We determined that data analysis using such an approach improved our understanding of importance of canopy interception in subalpine ecosystems due to the unique climate patterns revealed during modelling, thereby endowing improved understanding of functioning of Alpine ecosystems with a case study of the Italian Alps. To conclude, our findings provide valuable insights into silviculture engineering for enhanced environmental tolerance to climate effects and biosynthetic efficiency of old and young trees.

Specifically, further studies may investigate the effects of wind speed, humidity, and temperature that directly impact interception and evaporation of trees. Besides, there is still to analyse how higher wind speeds can facilitate evaporation from intercepted water, increasing water loss before it reaches the soil. Similarly, we hypothesize that humidity affects how quickly water evaporates from the canopy surface; lower humidity typically accelerates this process. In this way, our study contributes to the eco-hydrologiclal investigations ecohydrological studies of coniferous forests in the subalpine forests of northern Italy.

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Neinvazivno ekološko praćenje četinarskih šuma primenom statističke analize i modelovanja podataka

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I Z V O D

Klima ima ključnu ulogu u uspostavljanju odnosa između zdravlja četinarskih šuma i vodnog bilansa, što je od suštinskog značaja za efikasnu biosintezu u uslovima promenljivih meteoroloških faktora. U ovom radu se ističe da starost šume (mlade šume <30 godina i stare šume >200 godina) doprinosi poboljšanoj ekofiziologiji u održavanju vodnog bilansa kroz odgovor drveća na vremenske uslove (padavine, temperatura i vodni bilans u različitim sezonama). Globalne klimatske promene, pre svega porast temperatura, imaju značajan uticaj na životnu sredinu planinskih ekosistema Alpa. Subalpske šume poboljšavaju raspodelu padavina, pri čemu procesi presretanja u krošnjama stabala određuju stabilnost udela vode koja dospeva do tla, kao i količinu vode koja isparava. Ovi procesi doprinose globalnom unapređenju šumskih ekosistema na nivou slivova, jer na presretanje utiču struktura i gustina krošnji stabala, kao i prisustvo epifita. Istraživanje je pokazalo da četinarske šume (jela, smrča i bor) značajno utiču na količinu vode koja se zadržava i otpušta u zemljištu i biljkama. Presretanje u gustim subalpskim šumama može predstavljati značajan deo ukupnih padavina. Analiza podataka korišćenjem modelovanja zasnovanog na Python-u pokazala je da starost šume doprinosi povećanoj biosintezi putem unapređenja protoka vode. Ova studija naglašava značaj otkrivanja skrivenih klimatsko-ekoloških činilaca koji vode ka unapređenju šumske hidrologije i ekofiziologije, sa ciljem poboljšanja biosinteze i vodnog bilansa u četinarskim šumama Alpa.