



DENUCHANGE

FIELD TEST SITE CATALOGUE



DENUCHANGE Field Test Site Catalogue

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INTRODUCTION

The working group on Denudation and Environmental Changes in Different Morphoclimatic Zones (DENUCHANGE, <http://www.geomorph.org/denuchange-working-group>) was approved as a new working group of the International Association of Geomorphologists (IAG) during the 9th International Conference on Geomorphology, 6-11 November 2017, New Delhi, India.

The key question of DENUCHANGE is:

What are the contemporary chemical and mechanical denudation rates in different morphoclimatic zones on the Earth?

Denudation, including both chemical and mechanical processes, is of high relevance for Earth surface and landscape development and the transfer of solutes and sediments from headwater systems through main stem of drainage basin systems to the world oceans. Denudation is controlled by a range of environmental drivers and can be significantly affected by anthropogenic activities.

The better understanding of possible effects of ongoing and accelerated environmental changes on present-day denudation requires systematic and quantitative studies (environmental monitoring) on the actual drivers of denudational processes. Only if we have an improved knowledge of drivers and quantitative rates of contemporary denudational hillslope and fluvial processes as well as of the (dis)connectivity in landscapes and between hillslope and fluvial systems across a range of different selected climatic environments, possible effects of global environmental changes on denudation can be better assessed. Special focus is given to selected morphoclimatic zones that are expected to react particularly sensitively to ongoing and accelerated environmental changes, and the key focus of DENUCHANGE is therefore on (i) cold regions (including glacierized, glaciated and unglaciated cold climate environments), (ii) temperate regions, (iii) arid/semi-arid regions and (iv) tropical regions. The different morphoclimatic zones are defined by morphometric characteristics/signatures detected in the various zones.



INTRODUCTION

DENUCHANGE

- Provides a detailed compilation and comparison of contemporary chemical and mechanical (drainage-basin wide) denudation rates in selected and clearly defined drainage basin systems in selected cold regions, temperate regions, arid/semi-arid regions and tropical regions worldwide;
- Provides a process-oriented, coordinated and integrated analysis and compilation of the respective key drivers of contemporary denudation occurring under the different present-day morphoclimates;
- Addresses the key question how environmental changes are affecting contemporary denudation rates in different morphoclimates. This also includes human activities in different morphoclimatic zones, in the context of environmental changes in the Anthropocene.

This DENUCHANGE field test site catalogue has been prepared as an interactive PDF-file including short and well illustrated presentations of 22 accepted DENUCHANGE field test sites which are currently in operation within the DENUCHANGE network. Each presented field test site is linked to an interactive map. Key information on each field test site includes short descriptions of the field sites and the methods and techniques applied, and key meteorological and hydrological data. Both, field test sites with available longer data records and newly established field sites are included in the catalogue.



February 2022
Achim A. Beylich
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Dongfeng Li



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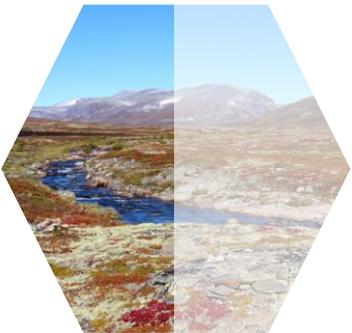
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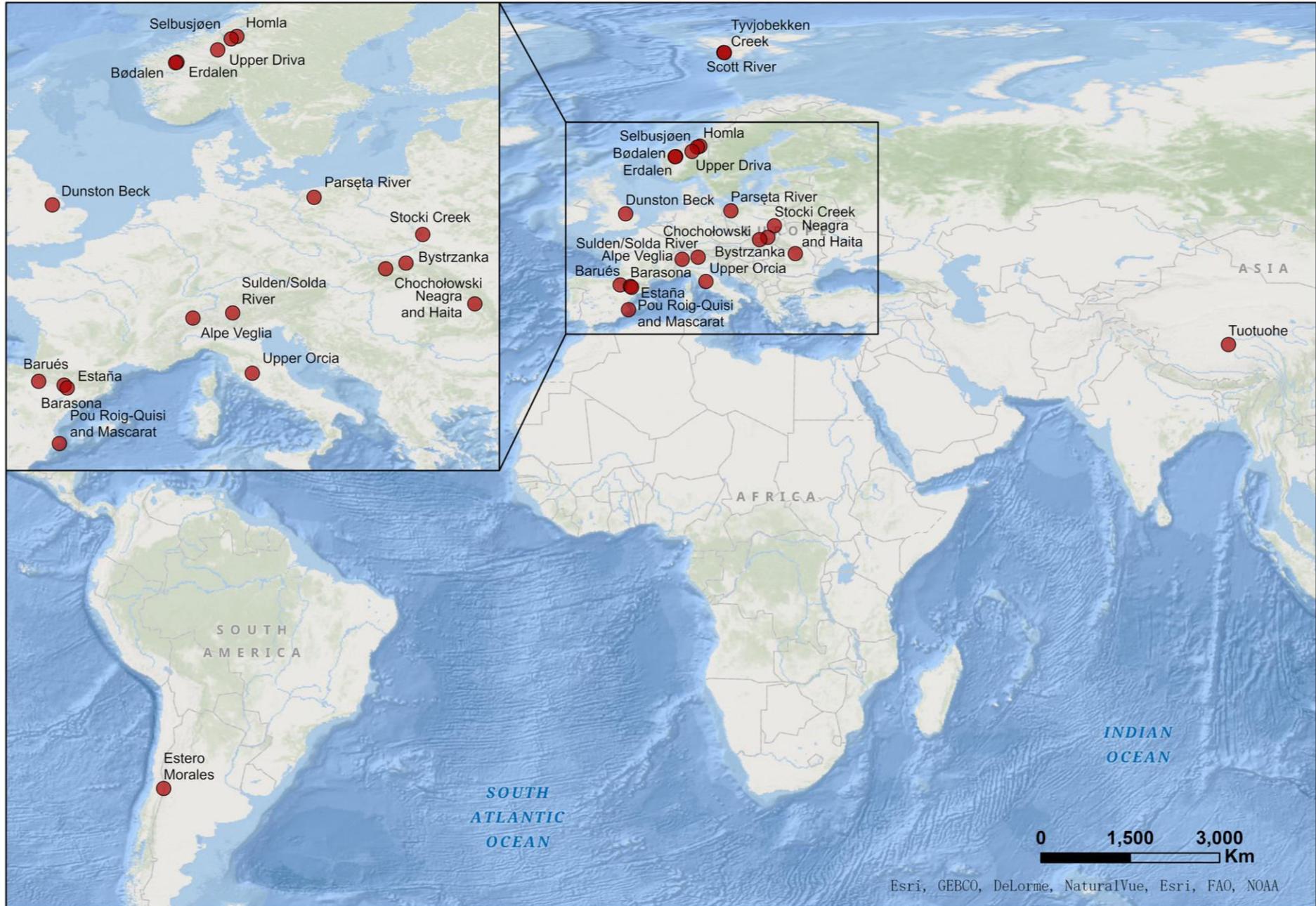
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WORLD MAP

An interactive version of this map can be found under this [link](#).



FIELD TEST SITES

Scott River

Site overview

The gravel-bed Scott River is located in the NW part of the Wedel-Jarlsberg Land (SW Svalbard). The glacial-nival alimention regime catchment area (~10 km²) is in 40% covered by the valley-type Scott Glacier. The glacier reaches up to 502 m a.s.l., and the glacier snout is located at 85 m a.s.l. The length of the glacier is ~3.1 km, and its width varies between 1.1 and 1.8 km. The lithology is varied from diamictites shales and phyllites, sandstones and conglomerates (upper part), Paleogene deposits covered by Quaternary sea gravels (central part) to Quaternary glacial, fluvio-glacial and fluvial deposits (lower part). The glacier-free part of the catchment has a maximum elevation of 92.5 m a.s.l. The average elevation of the catchment is 267 m a.s.l. and the average slope is 0.1 m m⁻¹. The morphology of the 3.3 km section of the glacier-free valley floor includes two narrowings: the upper gorge (through the terminal moraine rampart) and the lower gorge (cutting through the elevated marine terrace). Between the gorges, in a central - wider part of the valley, the Scott River develops an extensive multiple-channel system fed by small tributaries. In the lower part the valley bottom is narrower, and the river passes the lower gorge cut into the marine terrace at 17-25 m a.s.l. At the mouth to the fjord the Scott River develops an alluvial fan with a system of distribution channels. Above the lower gorge, the Scott River is fed by its largest right-bank tributary - Reindeer Creek. The valley drains the area of Calypsostranda dissecting the surfaces of five elevated marine terraces (from 25 to 85 m a.s.l.). The Reindeer Creek has a catchment area of 1.3 km².

Selected key publications

- Lehmann-Konera S, Kociuba W, Chmiel S, Franczak Ł, Polkowska Ż. 2021. Effects of biotransport and hydro-meteorological conditions on transport of trace elements in the Scott River (Bellsund, Spitsbergen). PeerJ 9:e11477 DOI 10.7717/peerj.11477. <https://peerj.com/articles/11477/>
- Kociuba, W., Gajek, G., Franczak, Ł., 2021. A Short-Time Repeat TLS Survey to Estimate Rates of Glacier Retreat and Patterns of Forefield Development (Case Study: Scottbreen, SW Svalbard). Resources 10, 2. <https://doi.org/10.3390/resources10010002>
- Lehmann-Konera S., Kociuba W., Chmiel S., Franczak L., Polkowska Z., 2019. Concentrations and loads of DOC, phenols and aldehydes in a proglacial Arctic river in relation to hydro-meteorological conditions. A case study from the southern margin of the Bellsund Fjord – SW Spitsbergen, Catena 174, 117–129. <https://doi.org/10.1016/j.catena.2018.10.049>
- Kociuba, W., 2017. Assessment of sediment sources throughout the proglacial area of a small Arctic catchment based on high-resolution digital elevation models, Geomorphology 287, 73-89. <https://doi.org/10.1016/j.geomorph.2016.09.011>

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Site views



Site key facts

Country: Norway (Svalbard)
 Geographical coordinates: 77°34' N, 14°26' E
 Climate: Polar, Arctic
 Lithology: Paleogene and Quaternary deposits
 Catchment area: 10.1 km²
 Elevation range: 0 – 502 m a.s.l.

Methods for analysis of denudation

Fieldwork included field measurements and analysis of bedload transport rates and its relation to the dissolved and suspended load. Bedload flux was measured by means of multi-module sets of River Bedload Traps (RBT). Moreover, the daily cycle of water sampling was collected for the determination of dissolved and suspended load. Water physicochemical parameters (velocity, condition, temperature, condensation, salinity, TDS) were studied using sensors: AV Flowmeter Module 2150 TELEDYNE ISCO; Acoustic Digital Current Meter OTT ADC; YSI 600XL V2; CTD-Diver and MiniDiver Schlumberger Water Services. The assessment of sediment supply to a proglacial river was performed by Leica Scan Station C10 terrestrial laser scanner (TLS) and RTK-GNSS Hipper II EPP TOPCON survey systems.

Site key annual data

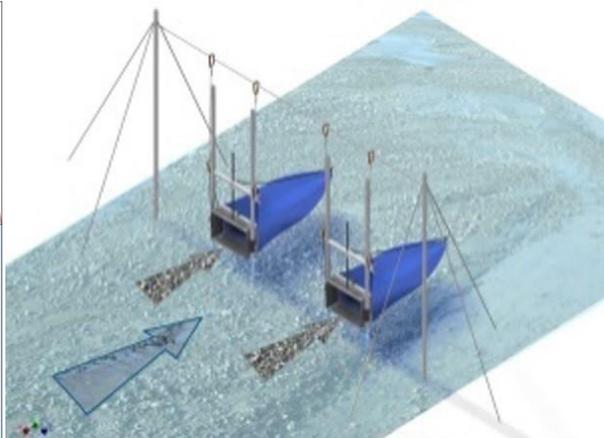
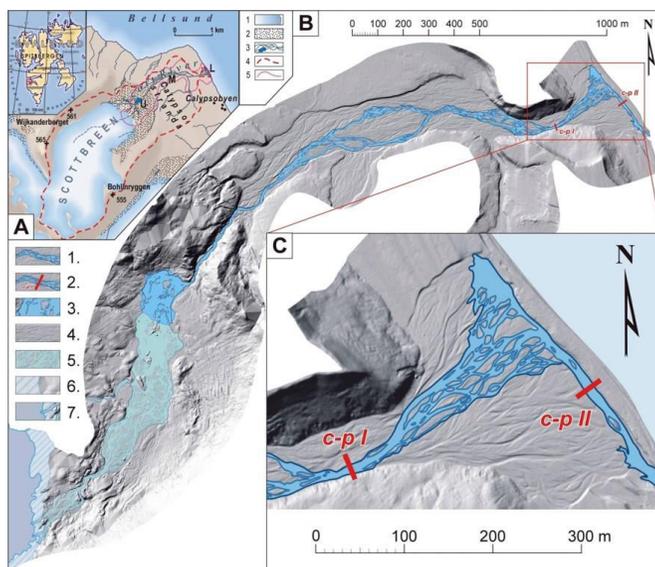
Measuring period	2013-
Meteorological and hydrological data	
Air temperature (°C)	5.7
Precipitation (mm)	47.8
Runoff (mm)	671
Drainage basin wide denudation rates	
Solute yield* (t km ⁻² yr ⁻¹)	32
Suspended sediment yield (t km ⁻² yr ⁻¹)	178
Bedload yield (t km ⁻² yr ⁻¹)	0.3

*atmospherically corrected

Views of instrumentation and methods



Location of fluvial transport measurement sites in the Scott River valley



Tyvjobekken Creek

Site overview

The Tyvjobekken Creek drains the eastern foreland of the Renard Glacier and the slopes of the Bohlinryggen massif. The catchment area is 1.3 km². The Tyvjobekken Creek valley is oriented from the WSW to the ENE for about 1.2 km with an average gradient of about 4.1%. The lithology is dominated by Paleogene deposits (metadiamictite, sandstone, silicite with fossils and loose sandstones, as well as hard coal) covered by Quaternary sea gravels in Calypsostranda (upper and middle section) to Quaternary glacial, fluvio-glacial, and fluvial deposits (lower section). The upper section has the character of an extensive, poorly developed basin-like depression, extending between the moraine zone of the northeastern foreland of the Renard Glacier and the eastern slopes of the Bohlinryggen massif. The middle section has a permanent drainage and receives the largest tributary with a length of 350 m. The stream forms a gorge up to 25 m deep, dissecting the elevated marine terraces for 0.8 km. The narrow erosional valley is shaped by a stream system. The stream bed covers the entire valley bottom. In the lower section, below the gorge, the creek forms a mouth alluvial fan. The cone surface cutting-through shallow dry channels. Strong sea currents overcoming the shoreline rampart and the relatively low discharge of Tyvjobekken Creek result in the formation of a micro-lagoon to which the waters of the creek are mostly discharged.

Selected key publications

Lehmann-Konera S., Franczak L., Kociuba W., Szumińska D., Chmiel S., Polkowska Z., 2018. Comparison of hydrochemistry and organic compound transport in two non-glaciated high Arctic catchments with a permafrost regime (Bellsund Fjord, Spitsbergen), *Sci. Total Environ.*, 613-614, 1037-1047.
<https://doi.org/10.1016/j.scitotenv.2017.09.064>

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Site views



Site key facts

Country: Norway (Svalbard)
 Geographical coordinates: 77°33' N, 14°31' E
 Climate: Polar, Arctic
 Lithology: Paleogene and Quaternary deposits
 Catchment area: 1.3 km²
 Elevation range: 0 – 315 m a.s.l.

Methods for analysis of denudation

Fieldwork included field measurements and analysis of bedload transport rates and its relation to the dissolved and suspended load. Bedload flux was measured by means of multi-module sets of River Bedload Traps (RBT). Moreover, the daily cycle of water sampling was collected for the determination of dissolved and suspended load. Water physicochemical parameters (velocity, condition, temperature, condensation, salinity, TDS) were studied using sensors: AV Flowmeter Module 2150 TELEDYNE ISCO; Acoustic Digital Current Meter OTT ADC; YSI 600XL V2; CTD-Diver and MiniDiver Schlumberger Water Services. The assessment of sediment supply to a proglacial river was performed by Leica Scan Station C10 terrestrial laser scanner (TLS) and RTK-GNSS Hipper II EPP TOPCON survey systems.

Site key annual data

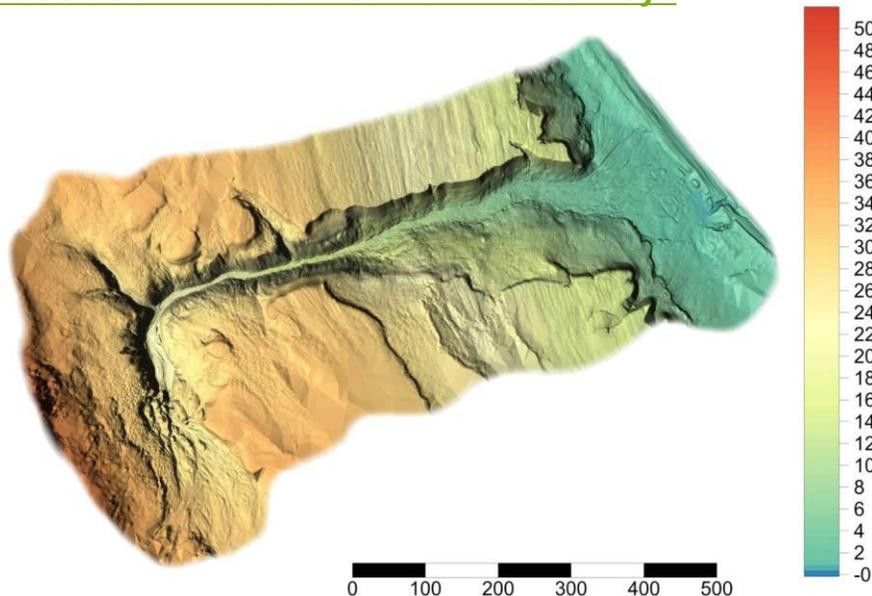
Measuring period	2013-
Meteorological and hydrological data	
Air temperature (°C)	5.7
Precipitation (mm)	47.8
Runoff (mm)	143
Drainage basin wide denudation rates	
Solute yield* (t km ⁻² yr ⁻¹)	i.p.
Suspended sediment yield (t km ⁻² yr ⁻¹)	i.p.
Bedload yield (t km ⁻² yr ⁻¹)	n.a.

*atmospherically corrected
i.p. = in progress
n.a. = not available

Views of instrumentation and methods



High-resolution DTM derived from TLS surveys



Homla drainage basin

Site overview

The Homla drainage basin is located in a boreal-oceanic mountain environment and drains to the north into the Trondheim fjord in central Norway. The lithology is dominated by greenstone and amphibolites, green-grey phyllite and greywacke with locally found rhyolite-tuff. Quaternary glaciations created a morphology that is characterized by rather flat to hilly areas between 200 and 400 m a.s.l. with single peaks reaching maximum elevations of above 600 m a.s.l. and a well-defined and deeply incised main valley in the lower part of the drainage basin. Quaternary deposits and covers include larger areas with till and ice-marginal moraines, peat and humus in combination with areas of bare bedrock in elevations above 200 m a.s.l. and mostly glacio-marine deposits along the main river in the lower part of the drainage basin. The largely closed and continuous vegetation cover is dominated by large areas with boreal forests and bogs in combination with areas of bare bedrock in elevations above 200 m a.s.l. and grassland areas with agricultural use along the main river in the lower part of the drainage basin. Geomorphological processes include chemical weathering and fluvial solute transport, mechanical weathering, local rock falls, slides and mud/debris flows, surface wash, fluvial erosion and down-cutting, stream bank erosion, and fluvial suspended sediment and bedload transport.

Selected key publications

- Beylich, A.A., Laute, K., 2021. Fluvial processes and contemporary fluvial denudation in different mountain landscapes in western and central Norway. In: Beylich, A.A. (Ed.), Landscapes and Landforms of Norway. Springer. <https://www.springer.com/gp/book/9783030525620>
- Beylich, A.A., Laute, K., 2018. Morphoclimatic controls of contemporary chemical and mechanical denudation in a boreal-oceanic drainage basin system in central Norway (Homla drainage basin, Trøndelag). Geografiska Annaler: Series A, Physical Geography. <https://doi.org/10.1080/04353676.2017.1407219>

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Site views



Site key facts

Country: Norway
 Geographical coordinates: 63°24' N, 10°48' E
 Climate: Boreal oceanic
 Lithology: Greenstone, amphibolite, greywacke
 Catchment area: 156.3 km²
 Elevation range: 0 – 697.1 m a.s.l.

Methods for analysis of denudation

The research on drivers of chemical and mechanical denudation is based on extended statistical analyses of high-resolution meteorological data, detailed field and remotely sensed mapping, computing of morphometric catchment parameters, and year-round process geomorphological field work. Geomorphological field work includes detailed field observations, repeated photographic documentations of selected stream channel stretches and hillslope surface areas, and field monitoring and frequent measurements with snow, rain water, stream-water and bedload samplings for the analysis of solute and suspended sediment concentrations and the study of atmospheric solute inputs, and the quantification of fluvial solute and sediment transport.

Site key annual data

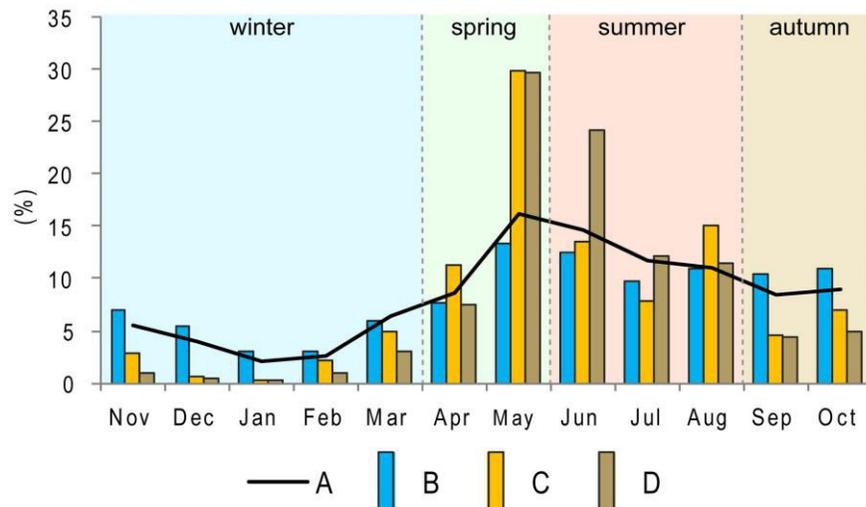
Measuring period	2011-2016
Meteorological and hydrological data	
Air temperature (°C)	6.6
Precipitation (mm)	769
Runoff (mm)	593.2
Drainage basin wide denudation rates	
Solute yield* (t km ⁻² yr ⁻¹)	12.1
Suspended sediment yield (t km ⁻² yr ⁻¹)	3.3
Bedload yield (t km ⁻² yr ⁻¹)	0.3

*atmospherically corrected

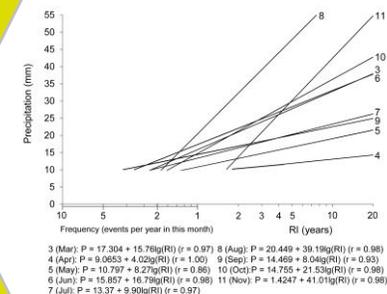
Views of instrumentation and methods



Mean monthly shares of mean annual runoff (A), mean annual solute yield (B), mean annual suspended sediment yield (C) and mean annual bedload yield (D)



From Beylich and Laute (2021)



Selbusjøen drainage basin

Site overview

In the boreal mountain environment of central Norway the regulated lake Selbusjøen, situated at ca. 160 m a.s.l. with an area of 58 km² and connecting the upstream main mountain river Nea and the downstream main river Nidelva, forms a significant sink for sediments being transferred from its drainage basin area of in total 2876 km². At Selbu (171 m a.s.l.) the annual air temperature is 5.3°C and annual precipitation reaches 771 mm. The annual runoff in the area amounts to 684 mm. The selected sub-catchment and drainage area systems within the Selbusjøen drainage basin are all characterized by high shares of surface areas with a nearly closed and continuous vegetation cover mostly composed of boreal forests and bogs, and represent a range of different catchment sizes, catchment morphometries, orientations/aspects, and sediment sources and sediment availabilities. Different types and intensities of anthropogenic impact like, e.g., agriculture, forestry and modifications of natural stream channels (e.g., dams, steps, stream bank protection) and channel discharge for water power purposes are found in various catchments. Runoff is occurring year-round and the natural runoff regime is clearly nival. Most fluvial transport is occurring during peak-runoff events generated by snowmelt, rainfall events or combinations of snowmelt and rainfall. Altogether, chemical denudation is moderate but dominates over mechanical fluvial denudation. Agriculture and forestry are generally increasing mechanical fluvial denudation rates whereas anthropogenic stream channel and channel discharge modifications are leading to reduced fluvial bedload transport rates into Selbusjøen.

First publications

Beylich, A.A. , Laute, K., 2022. Contemporary denudation rates in undisturbed and anthropogenically modified surface areas of the boreal mountain basin of a regulated lake system in central Norway. Geophysical Research Abstracts, EGU22-1766.

Beylich, A.A., Laute, K., 2021. Natural and anthropogenic drivers of denudation and sedimentary source-to-sink fluxes in the boreal mountain basin of lake Selbusjøen in central Norway. EGU21-729, 2021.

<https://meetingorganizer.copernicus.org/EGU21/EGU21-729.html>

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Site views



Site key facts

Country: Norway
 Geographical coordinates: 63°15' N, 10°27' E
 Climate: Boreal oceanic
 Lithology: Phyllites, greenstones, greenschists
 Catchment area: 2876 km²
 Elevation range: 160 – ca. 1200 m a.s.l.

Methods for analysis of denudation

This ongoing GFL research is based on statistical analyses of high-resolution meteorological data, detailed field and remotely sensed mapping, computing of morphometric catchment parameters, and year-round process geomorphological field work. Geomorphological field work includes detailed field observations, repeated photographic documentations of selected stream channel stretches and hillslope surface areas, and field monitoring and frequent measurements with snow, rain water, stream-water and bedload samplings for the analysis of solute and suspended sediment concentrations and the study of atmospheric solute inputs, and the quantification of fluvial solute and sediment transport. Field work is carried out in 25 defined catchments and drainage areas draining into the lake Selbusjøen.

Site key annual data

Measuring period	2020-
Meteorological and hydrological data	
Air temperature (°C)	5.3
Precipitation (mm)	771
Runoff (mm)	684
Drainage basin wide denudation rates	
Solute yield* (t km ⁻² yr ⁻¹)	i.p.
Suspended sediment yield (t km ⁻² yr ⁻¹)	i.p.
Bedload yield (t km ⁻² yr ⁻¹)	i.p.

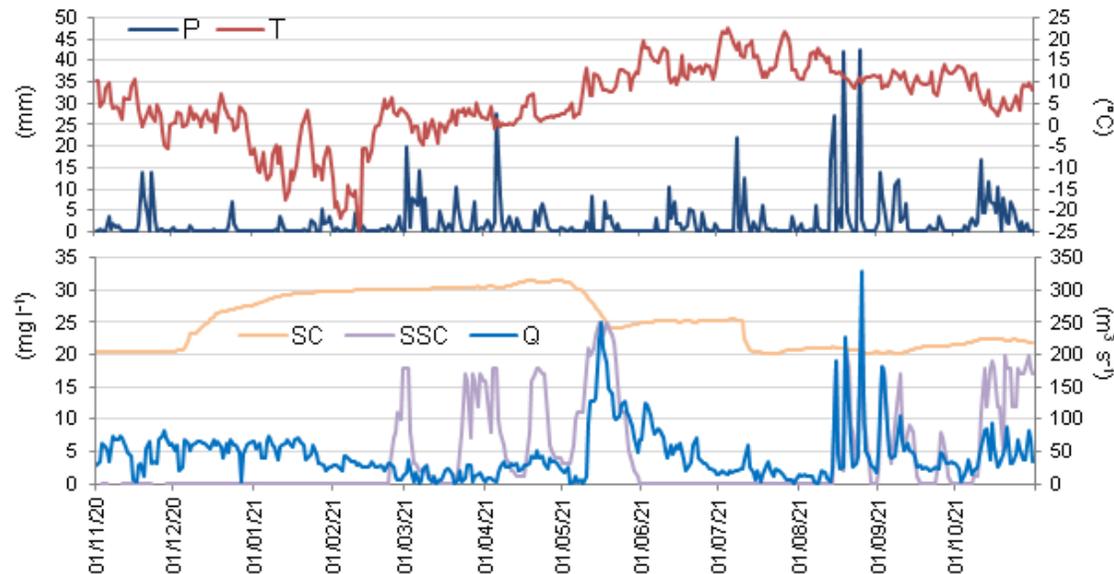
*atmospherically corrected
i.p. = in progress

Views of instrumentation and methods



Meteorological and hydrological time series for the hydrological year 2021

Time series of daily precipitation sums (P in mm) and daily mean air temperatures (T in °C) at Selbu, daily discharge (Q in m³ s⁻¹) and daily suspended sediment concentrations (SSC in mg l⁻¹) in the regulated Nea river, and daily solute concentrations (SC in mg l⁻¹) in lake Selbusjøen.



Upper Driva drainage basin

Site overview

The upper Driva drainage basin in central Norway (Oppdal) is situated in a cold climate and mountainous environment and ranges with a total drainage basin area of 1630 km² from 220 to 2286 m a.s.l. Discharge occurs year-round with a nival runoff regime, and the temporal variability of sediment transfers, runoff and fluvial transport are largely controlled by thermally and/or pluvially determined events. The mean annual air temperature at Oppdal (545 m a.s.l.) is 4.3°C, and mean annual precipitation at Oppdal amounts to 532 mm. The mean annual runoff in the upper Driva drainage basin is 576 mm. The lithology in the drainage basin is complex and varied, and is clearly dominated by metamorphic rocks (mostly gneisses and schists). Vegetation cover varies between tundra vegetation in the high and rather flat areas of the uppermost drainage basin area, situated at elevations around 900-1200 m a.s.l., tree vegetation (mostly birch and pine) in the lower parts of the incised tributary valleys of the Driva main river and grasslands in the agriculturally used areas close to the lower sections of main river Driva. Relevant geomorphological processes include chemical and mechanical weathering, rockfalls, snow avalanches, debris flows, slides, wash processes, fluvial erosion, fluvial streambank erosion and down-cutting, and fluvial solute, suspended sediment and bedload transport. Special focus is on six selected tributary valleys (the catchments of the tributary rivers Svone, Kaldvella, Stølaa, Tronda, Vinstra, Ålma) displaying different lithologies, valley morphometries and sediment availabilities

First publications

Beylich, A.A., Laute, K., 2019. Morphoclimate and contemporary denudation in the upper Driva drainage basin in central Norway.

[GFL Geomorphological Field Laboratory Publication Series, Number 1, September 2019: 12](#)

Beylich, A.A., Laute, K., 2019. Denudational processes, source-to-sink fluxes and sedimentary budgets under changing climate and anthropogenic impacts in selected drainage basin systems in central Norway and eastern Spain. Geophysical Research Abstracts, Vol. 21, EGU2019-1969, 2019.

<https://meetingorganizer.copernicus.org/EGU2019/EGU2019-1969.pdf>

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Site views



Site key facts

Country: Norway
 Geographical coordinates: 62°35' N, 09°38' E
 Climate: cold temperate to subarctic
 Lithology: Metamorphic rocks (gneisses, schists)
 Catchment area: 1630 km²
 Elevation range: 220 – 2286 m a.s.l.

Methods for analysis of denudation

This ongoing GFL research includes detailed field and remotely sensed geomorphological mapping, permafrost mapping, and computing of morphometric catchment parameters combined with the detailed statistical analysis of high-resolution meteorological and ground temperature data, and the continuous observation and year-round monitoring of sediment transfers, runoff and fluvial solute and sediment transport using a range of different techniques. Specific focus is on six selected tributary systems (Svone, Kaldvella, Stølaa, Tronda, Vinstra, Ålma) of the upper Driva drainage basin system. Stationary hydrological stations are monitoring continuously and year-round runoff, fluvial solute and suspended sediment transport. The analysis of fluvial bedload transport includes the application of different tracer techniques together with underwater video filming and Helley-Smith and impact sensor measurements.

Site key annual data

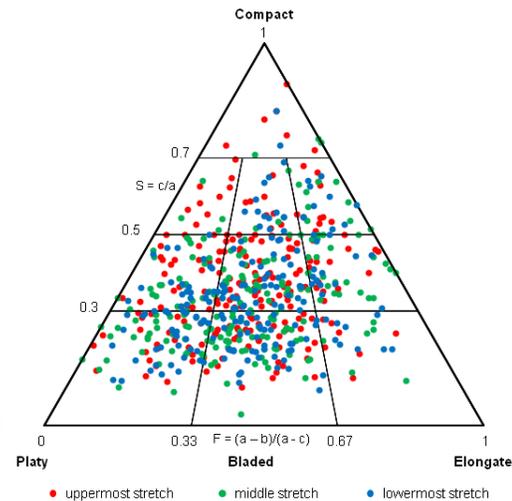
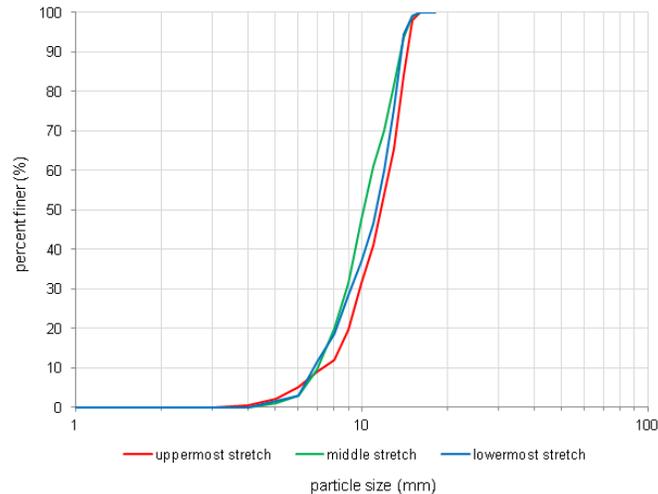
Measuring period	2012-
Meteorological and hydrological data	
Air temperature (°C)	4.3
Precipitation (mm)	532
Runoff (mm)	576
Drainage basin wide denudation rates	
Solute yield* (t km ⁻² yr ⁻¹)	i.p.
Suspended sediment yield (t km ⁻² yr ⁻¹)	i.p.
Bedload yield (t km ⁻² yr ⁻¹)	i.p.

*atmospherically corrected
i.p. = in progress

Views of instrumentation and methods



Particle grain size and shape distribution at different stretches along the Driva main river



Erdalen drainage basin

Site overview

Erdalen is a steep and parabolic-shaped valley system in the fjord landscape of western Norway (inner Nordfjord). The Erdalen drainage basin is connected to the Jostedalsgreen ice cap through defined outlet glaciers. The lithology is primarily composed of Precambrian granitic orthogneisses. In 2010 surface area percentages displayed the highest share for bedrock with 45%. Only 32% of the drainage basin surface area was covered by slope sedimentary deposits/regolith whereas glaciers covered 18% and valley bottom infill occupied 5%.

Mean annual air temperature is 5.7°C with January and February being the coldest months. Highest monthly precipitation values are found in the autumn and winter periods with an annual precipitation sum of 1500 mm yr⁻¹. Relevant denudational hillslope processes in Erdalen include rock and boulder falls, snow avalanches, slush flows, creep processes, debris flows, and wash/fluvial denudation. Runoff occurs year-round and fluvial transport includes solute, suspended sediment and bedload transport. Sedimentary slope covers, outlet glaciers and stream channel banks represent the most important sediment sources. Relevant storage elements are proglacial lakes, valley infill and slope talus cones. Human impact occurs through grass cropping, animal husbandry and limited hiking tourism. Environmental changes are recognizable through active glacier retreat and general vegetation succession.

Selected key publications

- Beylich, A.A., Laute, K., 2021. Fluvial processes and contemporary fluvial denudation in different mountain landscapes in western and central Norway. In: Beylich, A.A. (Ed.), *Landscapes and Landforms of Norway*. Springer. <https://www.springer.com/gp/book/9783030525620>
- Beylich, A.A., Laute, K., Storms, J.E.A., 2017. Contemporary suspended sediment dynamics within two partly glacierized mountain drainage basins in western Norway (Erdalen and Bødalen, inner Nordfjord). *Geomorphology* 287, 126-143
- Beylich, A.A., Laute, K., 2015. Sediment sources, spatiotemporal variability and rates of fluvial bedload transport in glacier-connected steep mountain valleys in western Norway (Erdalen and Bødalen drainage basins). *Geomorphology* 228, 552-567
- Laute, K., Beylich, A.A., 2014. Environmental controls, rates and mass transfers of contemporary hillslope processes in the headwaters of two glacier-connected drainage basins in western Norway. *Geomorphology* 216, 93-113

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Site views



Site key facts

Country: Norway
 Geographical coordinates: 61°50' N, 07°10' E
 Climate: cool temperate, oceanic
 Lithology: Precambrian granitic orthogneiss
 Catchment area: 79.5 km²
 Elevation range: 29 – 1888 m a.s.l.

Methods for analysis of denudation

Contemporary and drainage basin-wide chemical and mechanical fluvial denudation rates were measured in the partly glacierized Erdalen drainage basin. Year-round and continuous field monitoring included meteorological parameters, atmospheric solute inputs, runoff, and solute and suspended sediment concentrations. Continuous monitoring of water level, electric conductivity and turbidity in selected stream channels was combined with frequent discharge measurements and water samplings. Detailed analysis of bedload transport was conducted using impact sensors and Helley-Smith samplings. Based on the obtained dataset, annual atmospheric solute inputs, annual solute gross yields and the associated annual chemical denudation rates were calculated together with annual suspended sediment and bedload yields.

Site key annual data

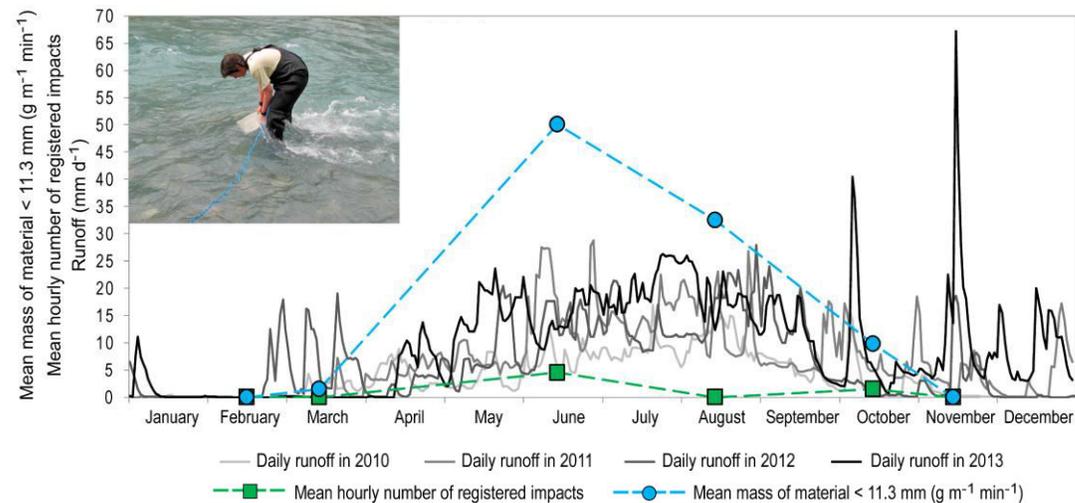
Measuring period	2004-
Meteorological and hydrological data	
Air temperature (°C)	5.7
Precipitation (mm)	1500
Runoff (mm)	1398
Drainage basin wide denudation rates 2004-2013	
Solute yield* (t km ⁻² yr ⁻¹)	6
Suspended sediment yield (t km ⁻² yr ⁻¹)	16.4
Bedload yield (t km ⁻² yr ⁻¹)	2.4

*atmospherically corrected

Views of instrumentation and methods



Fluvial bedload transport measured with Helley-Smith sampler and impact sensors



Modified after Fig. 7.7 in Beylich and Laute (2021)

Bødalen drainage basin

Site overview

Bødalen is a steep and parabolic-shaped valley system in the fjord landscape of western Norway (inner Nordfjord). The Bødalen drainage basin is connected to the Jostedalsgreen ice cap through defined outlet glaciers. The lithology is primary composed of Precambrian granitic orthogneisses. In 2010 surface area percentages displayed the highest share for bedrock with 43%. Only 16% of the drainage basin surface area was covered by slope sedimentary deposits/regolith whereas glaciers covered 38% and valley bottom infill occupied 2%.

Mean annual air temperature is 5.7°C with January and February being the coldest months. Highest monthly precipitation values are found in the autumn and winter periods with an annual precipitation sum of 1500 mm yr⁻¹. Relevant denudational hillslope processes in Bødalen include rock and boulder falls, snow avalanches, slush flows, creep processes, debris flows, and wash/fluvial denudation. Runoff occurs year-round and fluvial transport includes solute, suspended sediment and bedload transport. Sedimentary slope covers, outlet glaciers and stream channel banks represent the most important sediment sources. Relevant storage elements are proglacial lakes, valley infill and slope talus cones. Human impact occurs through animal husbandry and limited hiking tourism. Environmental changes are recognizable through active glacier retreat and general vegetation succession.

Selected key publications

- Beylich, A.A., Laute, K., 2021. Fluvial processes and contemporary fluvial denudation in different mountain landscapes in western and central Norway. In: Beylich, A.A. (Ed.), *Landscapes and Landforms of Norway*. Springer. <https://www.springer.com/gp/book/9783030525620>
- Beylich, A.A., Laute, K., Storms, J.E.A., 2017. Contemporary suspended sediment dynamics within two partly glacierized mountain drainage basins in western Norway (Erdalen and Bødalen, inner Nordfjord). *Geomorphology* 287, 126-143
- Beylich, A.A., Laute, K., 2015. Sediment sources, spatiotemporal variability and rates of fluvial bedload transport in glacier-connected steep mountain valleys in western Norway (Erdalen and Bødalen drainage basins). *Geomorphology* 228, 552-567
- Laute, K., Beylich, A.A., 2018. Potential effects of climate change on future snow avalanche activity in western Norway deduced from meteorological data. *Geografiska Annaler*, 100A (2): 163-184. <http://dx.doi.org/10.1080/04353676.2018.1425622>

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Site views



Site key facts

Country: Norway
 Geographical coordinates: 61°48' N, 07°05' E
 Climate: cool temperate, oceanic
 Lithology: Precambrian granitic orthogneiss
 Catchment area: 60.1 km²
 Elevation range: 52 – 2083 m a.s.l.

Methods for analysis of denudation

Contemporary and drainage basin-wide chemical and mechanical fluvial denudation rates were measured in the partly glacierized Bødalen drainage basin. Year-round and continuous field monitoring included meteorological parameters, atmospheric solute inputs, runoff, and solute and suspended sediment concentrations. Continuous monitoring of water level, electric conductivity and turbidity in selected stream channels was combined with frequent discharge measurements and water samplings. Detailed analysis of bedload transport was conducted using impact sensors and Helley-Smith samplings. Based on the obtained dataset, annual atmospheric solute inputs, annual solute gross yields and the associated annual chemical denudation rates were calculated together with annual suspended sediment and bedload yields.

Site key annual data

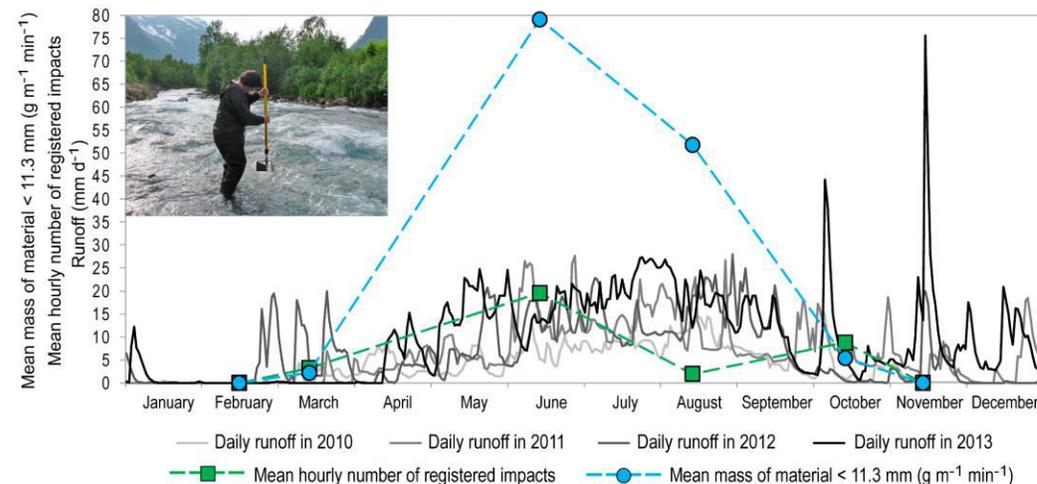
Measuring period	2008-
Meteorological and hydrological data	
Air temperature (°C)	5.7
Precipitation (mm)	1500
Runoff (mm)	1411
Drainage basin wide denudation rates 2008-2013	
Solute yield* (t km ⁻² yr ⁻¹)	2.8
Suspended sediment yield (t km ⁻² yr ⁻¹)	31.3
Bedload yield (t km ⁻² yr ⁻¹)	13.3

*atmospherically corrected

Views of instrumentation and methods



Fluvial bedload transport measured with Helley-Smith sampler and impact sensors



Modified after Fig. 7.7 in Beylich and Laute (2021)

Parsęta River

Site overview

The Parsęta drainage basin drains directly into the Baltic Sea. The total basin area is 3,067 km² and the river is 142.8 km long. The catchment represents a lowland geocosystem in a temperate climatic zone. The representativeness of the Parsęta River basin is determined by its location in the range of glacial forms of the Pomeranian Phase of the Weichselian Glaciation and by mosaic pattern of lithology, soil types, land cover and land use. A characteristic feature of the Parsęta valley is the inclusion into one system of polygenetic elements (marginal valleys, melt-out basins and river gaps through terminal moraines) of different ages, with a varied gradient and erosive or accumulation tendencies. The last 200 years have been a period of a rapid increase in human interference in the river systems. Agricultural land (52%) and forests (44%) are the dominant land cover and land use types in the Parsęta catchment. The catchment has an even pluvial runoff regime, being fed by groundwater, rain and snow with the occurrence of spring floods and low outflow variability in a year. A unique feature of the Parsęta catchment are rare lakes, which cover only 0.5% of the catchment. Contemporary denudation processes include slope wash, tillage erosion, gully erosion, channel processes, and only locally: earth slide, creep, earthflow, solifluction and seepage erosion. The most important sediment sources are the wetted perimeter of the river channels, the floodplain, biogenic and man-made supply. Relevant storage elements are valley infill, floodplain, kettle holes, natural or artificial lakes. Dissolved substances come mostly from processes of chemical weathering and leaching of glacial and biogenic sediment rich in calcium carbonate, and also from atmosphere and the biological cycle.

Selected key publications

- Kostrzewski A., Mazurek M., Zwoliński Z., 1997. Sources of material supply and nature of fluvial transport in post-glacial agricultural-forested catchment (the upper Parsęta river, Poland). *Landform Analysis*, Vol. 1, 19-31.
- Stach A., Kostrzewski A., Mazurek M., Michalska G., Zwoliński Zb., 2003. Spatial patterns of stream alimentionation in lowland areas of NW Poland. A hydrochemical and geostatistical analysis. *J. Hydrol. Hydromech.*, 51, 3: 221-240.
- Szpirowska G., 2009. Spatial differences in the intensity of leaching in the geocosystem of a post-glacial catchment (Chwalimski Potok, upper Parsęta). *Questiones Geographicae, Special Issue*; 28A/1, 75-82.
- Szpirowski J., Szpirowska G., 2018. Hydromorphological and physicochemical conditions of the Parsęta River. *Bulletin of Geography. Physical Series*, 15(1): 53-62. <https://doi.org/10.2478/bgeo-2018-0015>
- Zwoliński Zb., 1993. Dynamics of bed load transport in the Parsęta River channel, Poland. In: M. Marzo, C.Puigdefábregas (eds.), *Alluvial Sedimentation, Spec. Pubs Internat. Assoc. Sediment.*, 17: 77-87.

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Site views



Site key facts

Country: Poland
 Geographical coordinates: 53°37' N, 15°29' E
 Climate: transitional temperate
 Lithology: glacial tills, glacial/fluvioglacial sands
 Catchment area: 2866 km² (Bardy)
 Elevation range: 6 – 230 m a.s.l.

Methods for analysis of denudation

Chemical and mechanical fluvial denudation rates have been measured in the Parsęta drainage basin and in three subcatchments: the upper Parsęta catchment and the Młyński Brook since 1987, the Chwalimski Brook for the period 2000-2003. The Chwalimski Brook (length 200 m, catchment area 0.05 km² (topographic), runoff 300 mm) is a headwater feeding the Młyński Brook (2.1 km, 4.05 km², 163 mm), and then the upper Parsęta River. The upper Parsęta catchment is closed by the hydrometric profile in Storkowo (13 km, 74,3 km², 180 mm). The whole Parsęta drainage is closed by the hydrometric profile in Bardy (123 km).

Continuous monitoring includes meteorological parameters, precipitation chemistry, runoff, solute and suspended sediment concentrations. Daily stream stage records and water sampling are performed in the hydrometric profiles in Storkowo (for the upper Parsęta and Młyński Brook). The hydrometric method has determined the annual solute gross yields and the chemical denudation rates have been based on electric conductivity and concentrations of dissolved components, taking into account the atmospheric solute inputs. The annual suspended sediment and the mechanical denudation rates have been calculated using the weight method based on the amount of suspension in the water samples. In Bardy daily water level records were carried out. Water outflow from the whole catchment area was calculated from the formula for rating curve. Chemical and mechanical denudation was determined by the SWAT modelling method.

The rate and composition of the dissolved load in the upper Parsęta catchment in 1994-2015

From Szpikowski et al.
2018

Site key annual data

Bardy

Measuring period	1951-2020
Meteorological and hydrological data	1951-2020
Air temperature (°C)	8
Precipitation (mm)	671
Runoff (mm)	300
Drainage basin wide denudation rates	1997-2019
Solute yield* (t km ⁻² yr ⁻¹)	89.7
Suspended sediment yield (t km ⁻² yr ⁻¹)	6.4
Bedload yield (t km ⁻² yr ⁻¹)	4.3

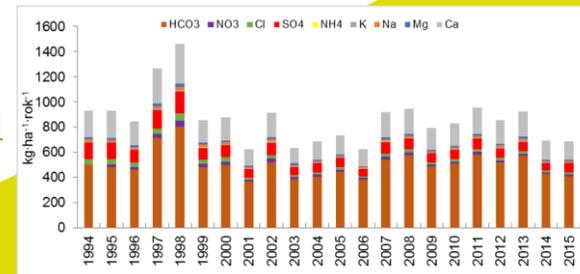
*atmospherically corrected

Upper Parsęta catchment

Measuring period	1987-2019
Meteorological and hydrological data	
Air temperature (°C)	8
Precipitation (mm)	700
Runoff (mm)	180
Drainage basin wide denudation rates	
Solute yield* (t km ⁻² yr ⁻¹)	86.5
Suspended sediment yield (t km ⁻² yr ⁻¹)	2.9
Bedload yield (t km ⁻² yr ⁻¹)	n.a.

*atmospherically corrected

n.a. = not available



Views of instrumentation and methods



Dunston Beck

Site overview

The Dunston Beck is a narrow gravel-bedded stream in Lincolnshire (East Midlands in the UK), 15 km south from the city of Lincoln. The geology is dominated by limestone formations, and the mean annual rainfall in the area is about 730 mm. The stream is spring-fed, but fast responses to precipitation events are frequent in late winter. The stream is generally narrow and incised, and the study reach has been restored in January 2021 with a design that includes ponds, gravel augmentation, and the creation of new riffles and secondary channels. The stream is relevant from an ecological point of view as there are modern depositions of tufa, which is a solid precipitation of calcium carbonate that creates stable staircase-like sequences of barrages.

First publications

Coming soon.

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Site views



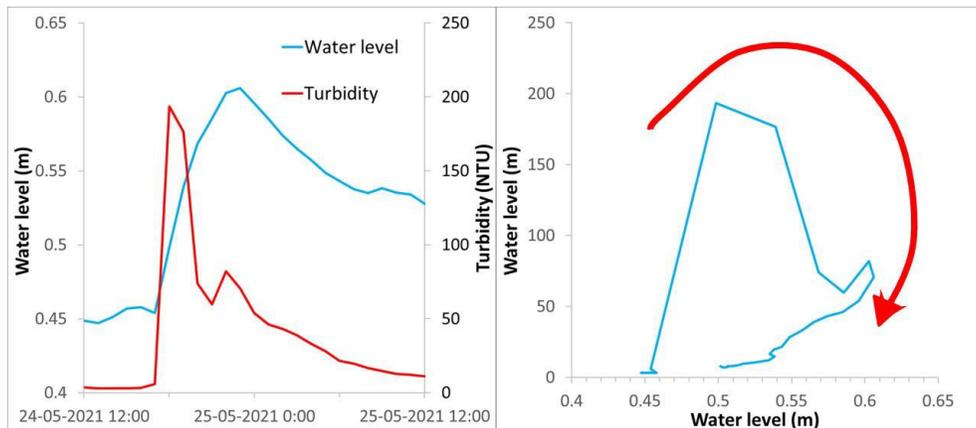
Site key facts

Country: UK
Geographical coordinates: 53°09' N, 0°23' W
Climate: temperate (no dry season)
Lithology: limestone
Catchment area: 37 km²
Elevation range: 15 – 77 m a.s.l.

Methods for analysis of denudation

A bedload acoustic pipe has been recently installed at the upstream end of the restored reach, and in the same cross-section the water depth, turbidity, electrical conductivity and temperature are monitored continuously by a multiprobe sonde installed by the Environment Agency in 2021. The bedload acoustic pipe is connected to a datalogger that stores impulse data generated by the impact of gravel on the pipe, lying in the center of the monitored cross-section. The mobility and displacement length of single sediments will be soon monitored using natural clasts equipped with 23-mm-long Radio Frequency Identification Passive Integrated Transponder (RFID-PIT) tags. PIT tags are transmitters without batteries that emit an identification code, which is detected and recorded by a mobile RFID antenna device, used to determine the position of PIT tags after floods.

Example of the suspended sediment transport during a flood generated by a rainfall event.



The hysteresis of the event (clockwise) suggests a ready availability of fine sediments.

Site key annual data

Measuring period	2021-
Meteorological and hydrological data	1984-2022
Air temperature (°C)	13
Precipitation (mm)	370
Runoff (mm)	180
Drainage basin wide denudation rates	
Solute yield* (t km ⁻² yr ⁻¹)	i.p.
Suspended sediment yield (t km ⁻² yr ⁻¹)	i.p.
Bedload yield (t km ⁻² yr ⁻¹)	i.p.

*atmospherically corrected
i.p. = in progress

Views of instrumentation and methods



Funds for the monitoring devices and activities are provided by the local Environment Agency. This work was supported by a British Society for Geomorphology grant (BSG-2021-11), awarded to Dr. Luca Mao.

Stocki Creek

Site overview

The Stocki Creek catchment with an area of 17 km² is located in the western part of the Nałęczów Plateau (Lublin Upland, SE Poland). This region has a loess relief which is distinguished by a dense network of dry valleys and gullies. In this part of the Nałęczów Plateau, elevation differences exceed 100 m, and its relief is unique in Europe by its unusually dense network of gullies that span up to 10 km/km². The Stocki Creek catchment which is located in the southern part of this area joins the Bystra River valley. This right-bank tributary of the Vistula River is the morphological axis of the studied part of the Nałęczów Plateau. The relatively wide and flat bottom of the Bystra River valley is deeply indented (60-80 m). The convex slopes of the valley which are 20-300 m long, reach a slope of 20-30°. The Bystra River valley, once overgrown with alder and ash-elm riparian forests, is now occupied by grasslands (fresh and moist meadows). Small forest areas, which are mainly found within the gullies, are covered by sub-continental oak-hornbeam woods.

Selected key publications

Rodzic J., Furtak T., Zgłobicki W., 2009. The impact of snowmelt and heavy rainfall runoff on the erosion rates in a gully system (Lublin Upland, Poland). *Earth Surf. Process. Landforms* 34, 14, pp. 1938–1950.

<https://onlinelibrary.wiley.com/doi/10.1002/esp.1882>

Kociuba W., Janicki G., Rodzik J., Stępniewski K., 2015. Comparison of volumetric and remote sensing methods (TLS) for assessing the development of a permanent forested loess gully. *Natural Hazards*, 79 (1), 139–158. <https://link.springer.com/article/10.1007/s11069-015-1807-6>

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Site views



Site key facts

Country: Poland
Geographical coordinates: 51°21' N, 22°04' E
Climate: transitional temperate
Lithology: loess and colluvium
Catchment area: 17 km²
Elevation range: 136 – 225 m a.s.l.

Methods for analysis of denudation

The field study in Stocki Creek included: precipitation recording (digital Pluviograph TPG-023 A-STER; with a span record 0.1 mm), water outflow control (limnigraph Thalimedes OTT), monitoring of suspended sediment concentrations (field sampling of water during surface run-off; Thomson Triangular Transfer located in the outlet of the gully), monitoring of the effects of erosive episodes in the gully sub-catchment, periodical (half year span from autumn 2012) Leica Scan Station C10 TLS surveys.

Site key annual data

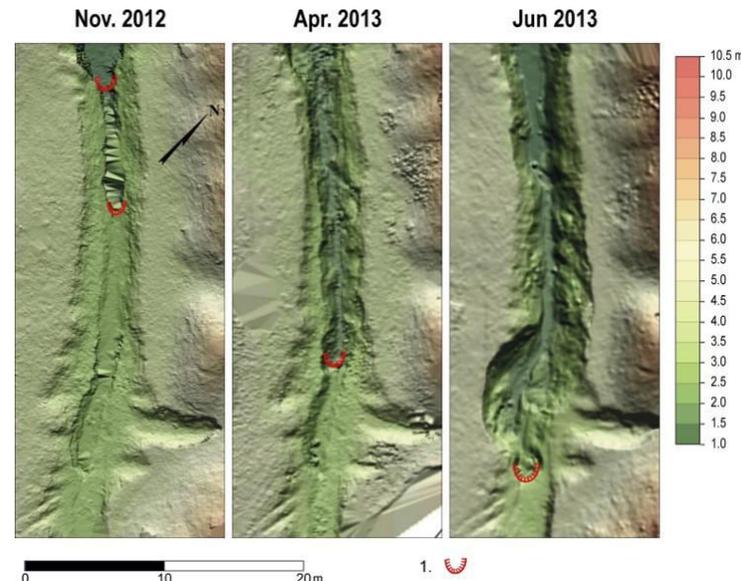
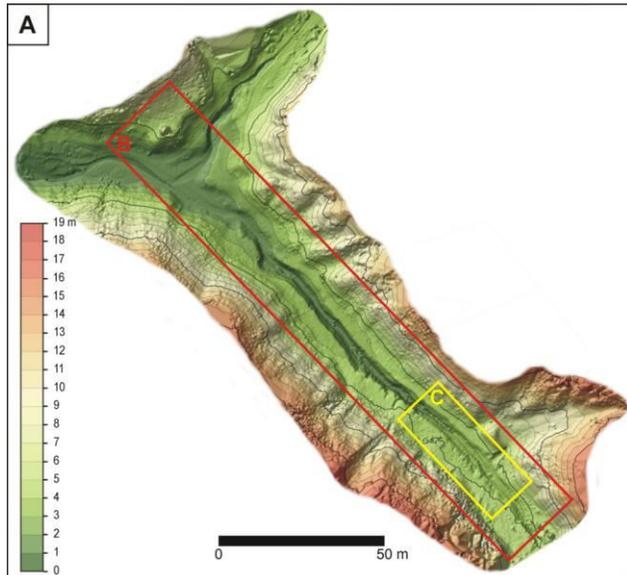
Measuring period	2011-2012
Meteorological and hydrological data	
Air temperature (°C)	8.0
Precipitation (mm)	595
Runoff (mm)	19.1
Drainage basin wide denudation rates	
Solute yield* (t km ⁻² yr ⁻¹)	i.p.
Suspended sediment yield (t km ⁻² yr ⁻¹)	171
Bedload yield (t km ⁻² yr ⁻¹)	n.a.

*atmospherically corrected
i.p. = in progress
n.a. = not available

Views of instrumentation and methods



High-resolution DTM derived from TLS surveys



Bystrzanka catchment

Site overview

Bystrzanka catchment is located in the Western Flysch Carpathians. Alternate sandstone and shale layers of varying thickness underlie the catchment. Slope inclinations in the catchment range from 0° to 40° with a dominant contribution in the 5° to 10° range (47% of the catchment). The lithological conditions, the energy of relief, and the erosive activity of the streams as well as precipitation make the study area susceptible to landslides, which cover 27% of the catchment. Approximately 40% of the landslide areas have direct connections with the river network. Mean annual temperature is 8.1°C and mean annual precipitation is 837 mm (1970–2020). Approximately 68% of the annual precipitation falls between May and October. The mean annual discharge and a mean specific runoff are 0.164 m³s⁻¹ and 0.012 m³s⁻¹ km⁻², respectively. The mean annual runoff is 402 mm and varied from 117 to 898 mm. The hydrological regime is characterised by two flood seasons: in spring connected with snowmelt and in summer connected with heavy rainfall. In the Bystrzanka catchment, LULC changes led to a significant decrease of cultivated land and increase of grassland and forest area, which reduced soil erosion on slope. Fluvial transport includes solute, suspended sediment and bedload transport. The main source of sediment are channel, landslide and human activity (eg. construction works).

Selected key publications

Bryndal, T., Krocak, R., Kijowska-Strugała, M., Bochenek, W. (2020). How human interference changes the drainage network operating during heavy rainfalls in a medium-high relief flysch mountain catchment? The case study of the Bystrzanka catchment (Outer Carpathians, Poland). *Catena*, 194, 104662.

<https://doi.org/10.1016/j.catena.2020.104662>

Kijowska-Strugała, M. (2019). Sediment variability in a small catchment of the Polish Western Carpathians during transition from centrally planned to free-market economics. *Geomorphology*, 325, 119-129.

<https://doi.org/10.1016/j.geomorph.2018.10.008>

Kijowska-Strugała, M., Kiszka, K. (2018). Environmental factors affecting splash erosion in the mountain area (the Western Polish Carpathians). *Landform Analysis*, 36. <https://doi.org/10.12657/landfana.036.009>

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Site views



Site key facts

Country: Poland
Geographical coordinates: 49°37' N, 21°03' E
Climate: continental, warm, humid
Lithology: flysch, sandstone and shale layers
Catchment area: 13 km²
Elevation range: 300 – 753 m a.s.l.

Methods for analysis of denudation

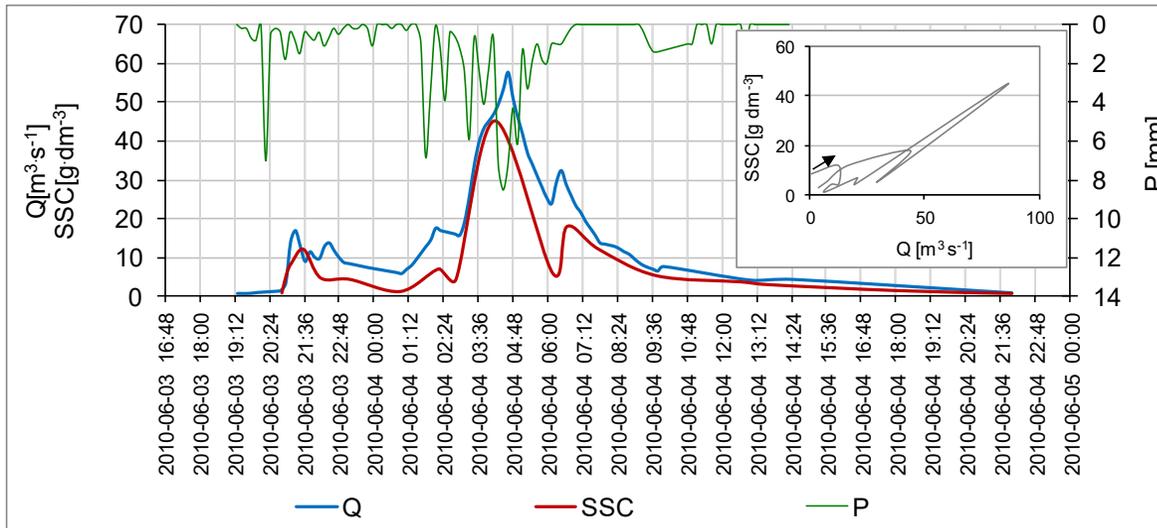
The Bystrzanka catchment has continuous field monitoring including meteorological parameters (since 1970), atmospheric solute inputs (since 1994), solute (since 1994) and suspended sediment concentrations (since 1970). Continuous water level is recorded using a limnigraph (KB2) installed at the outlet of the Bystrzanka Stream to the Ropa River (since 1970). As part of the ongoing stream monitoring, water samplings are collected manually (every day at 6 a.m. UTC). During floods, water samples are taken at a frequency ranging from 15 min to 2 h, depending on the rate of water increase in the stream. Solute and suspended sediment analyses are conducted in the laboratory at the Research Station in Szymbark.

Site key annual data

Measuring period	1968-
Meteorological and hydrological data	
Air temperature (°C)	8.1
Precipitation (mm)	837.4
Runoff (mm)	402
Drainage basin wide denudation rates	
Solute yield* (t km ⁻² yr ⁻¹)	39
Suspended sediment yield (t km ⁻² yr ⁻¹)	310
Bedload yield (t km ⁻² yr ⁻¹)	n.a.

*atmospherically corrected
n.a. = not available

Suspended sediment concentration in Bystrzanka stream during flood in 2010 (Q-discharge, SSC-suspended sediment concentration, P-precipitation)



Views of instrumentation and methods



Chochołowski Stream catchment

Site overview

The Chochołowski Stream catchment is a small (34.8 km²) formerly glaciated fluvial system located in the western part of the Tatra Mountains (Inner Carpathians). About 56% of the catchment area is composed of gneiss, metamorphic schists and granitoids, while 44% is occupied by limestones, dolomites and marls. About 27% of the catchment area is covered with glacial deposits produced by mountain glacier in the Pleistocene. Spruce forests cover 61% of the study area and occur as high as approx. 1500 m a.s.l. The forested part of the catchment is being transformed mainly by mass movements. Slopes above the upper tree line are being transformed mainly by debris flows, nivation and snow avalanches. Mean annual temperature ranges from 0°C at peak elevations to 4°C in the lower parts of the catchment. Precipitation reaches about 1700 mm yr⁻¹ with the highest amounts noted from May to September. Snow cover in most parts of the studied catchment is present from late October to late April (about 140 days). Since 1955 the Chochołowski Stream catchment has been part of Tatra National Park. Human impact is now limited to tourist foot traffic, heritage sheep grazing, and forest management works at lower elevations. The strong foehn wind in 2013 resulted in 16% reduction of forest cover in the catchment.

Selected key publications

Płaczowska, E., Krzemień, K., Gorczyca, E., Bojarczuk, A., Żelazny, M., 2020. Disturbances in coarse bedload transport in a high-mountain stream channel system (Western Tatras, Poland). *Geomorphology* 371, 107428. <https://doi.org/10.1016/j.geomorph.2020.107428>

Płaczowska, E., Krzemień, K., 2018. Natural conditions of coarse bedload transport in headwater catchments (Western Tatras, Poland). *Geografiska Annaler* 100 A (4), 370-387. <https://doi.org/10.1080/04353676.2018.1522957>

Krzemień, K., 1992. The high mountain fluvial system the Western Tatra perspective. *Geographica Polonica* 60, 51-66. http://rcin.org.pl/igipz/Content/4197/WA51_13392_r1992-t60_Geogr-Polonica.pdf#page=53

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Site views



Site key facts

Country: Poland
Geographical coordinates: 49°16' N, 19°49' E
Climate: subarctic (Dfc)
Lithology: gneiss, schists, limestones, dolomites
Catchment area: 34.8 km²
Elevation range: 926 – 2176 m a.s.l.

Methods for analysis of denudation

Mechanical and chemical denudation rates, including solute, suspended sediment and bedload yields, were measured in the Chochołowski Stream catchment and in two subcatchments (Upper Chochołowski Stream and Starorobocianski Stream). Since 1975 a continuous field monitoring including precipitation and runoff has been conducted. Additionally, bedload transport was being measured in the entire stream channel network (including headwaters) using painted tracers. Ongoing measurements of meteorological data, runoff, suspended sediment concentration and bedload transport will be used to repeat the calculations of mechanical denudation rate. It is assumed that after the formation of large windthrow areas in 2013 and the resulting attempt to remove damaged trees, the rate of mechanical denudation increased.

Site key annual data

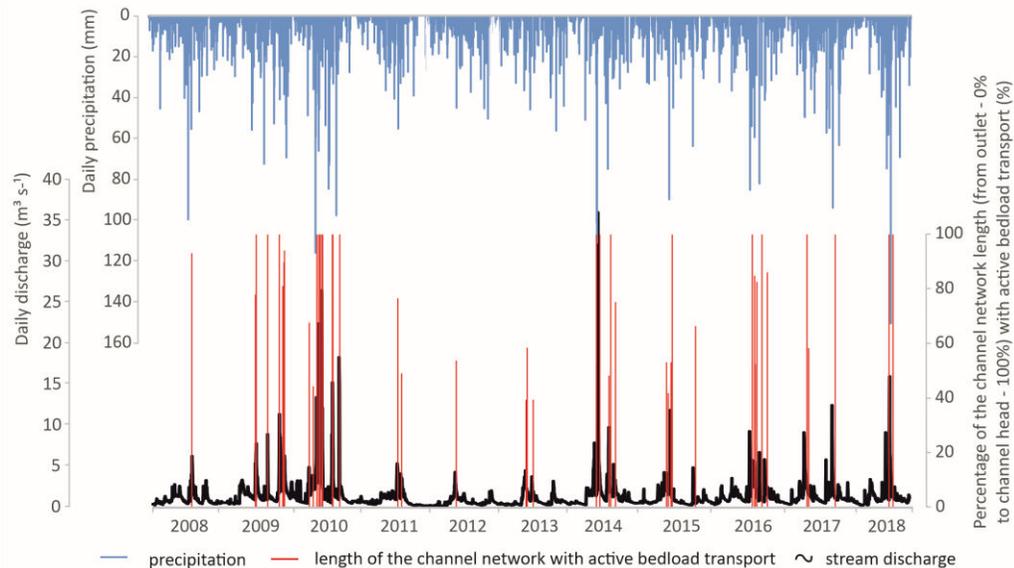
Measuring period	1983-1987
Meteorological and hydrological data	
Air temperature (°C)	4.0
Precipitation (mm)	1378
Runoff (mm)	1150
Drainage basin wide denudation rates	
Solute yield* (t km ⁻² yr ⁻¹)	82.8
Suspended sediment yield (t km ⁻² yr ⁻¹)	6.0
Bedload yield (t km ⁻² yr ⁻¹)	0.2

*atmospherically corrected

Views of instrumentation and methods



Bedload transport activity in the channel system



Neagra and Haita drainage basins

Site overview

The Călimani Mountains (2100 m a.s.l.) are part of the extinct volcanic chain in the Eastern Carpathians (Romania). Volcanic activity extended between 11.3 Ma and 6.9 Ma (Seghedi et al., 2005) being responsible for the creation of various volcanic structures, e.g. stratovolcanoes, caldera, lava domes, lava and pyroclastic plateaus and intrusive bodies. Pleistocene glaciers shaped the preexisting volcanic morphology in the highest altitudes. The Neagra and Haita rivers and their tributaries drain the volcano caldera. Since the second half of the twentieth century, the mining activities for sulfur-rich ore extraction and processing caused significant morphological changes and consequently an accelerated sediment transfer across the Neagra drainage basin. In the adjacent Haita drainage basin, the human impact is related to forest harvesting, tourism, and pastoral activities. The temperature and precipitation data are recorded at the weather station (2023 m a.s.l.) located in the southernmost part of the two drainage basins. Mean annual air temperature is negative (-0.2°C). The highest monthly precipitation values are in July (122 mm), with an average amount of annual precipitation of 875 mm yr⁻¹. Contemporary denudational processes include cryonival processes, rockfalls and rockslides, debris flows, snow avalanches, aeolian transport and deposition processes. Fluvial sediment transport occurs along Neagra and Haita streams. The main sources of sediments are the slope deposits, alluvial deposits, and anthropogenic deposits. Temporary sediment storage occurs along the stream channels, channel banks, talus cones, as well as the sediment retention reservoirs constructed along Neagra stream.

Selected key publications

- Tichavský, R., Pop, O.T., Mihaljevič, M., Šilhán, K., Vondrovicová, L., 2021. Tree ring archives of debris flow contamination in a post-mined area: Combined dendroecological research. *Catena* 207: 105595.
<https://doi.org/10.1016/j.catena.2021.105595>
- Pop, O.T., Germain, D., Meseșan, F., Gavrilă, I.G., Alexe, M., Buzilă, L., Holobăcă, I., Irimuş, I.A., 2019. Dendrogeomorphic assessment and sediment transfer of natural vs. mining-induced debris-flow activity in Călimani Mountains, Eastern Carpathians, Romania. *Geomorphology* 327: 188-200.
<https://doi.org/10.1016/j.geomorph.2018.10.028>
- Seghedi I, Szakács A, Pécskay Z, Mason PRD, 2005. Eruptive history and age of magmatic processes in the Călimani volcanic structure (Romania). *Geologica Carpathica* 56 (1): 67-75.
<http://www.geologicacarthica.com/browse-journal/volumes/56-1/article-298>

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Site views



Site key facts

Country: Romania
 Geographical coordinates: 47°08' N, 25°13' E
 Climate: temperate continental, mountain climate
 Lithology: andesite, monzodiorite
 Catchment area: Neagra: 49 km², Haita: 41 km²
 Elevation range: 1050 – 2100 m a.s.l.

Methods for analysis of denudation

Dendrogeomorphic investigations and topographic surveys were carried out to document the history of hydrogeomorphic activity, the volume of material stored behind the sediment retention dams, and the rate of sediment accumulation in the sediment retention reservoirs.

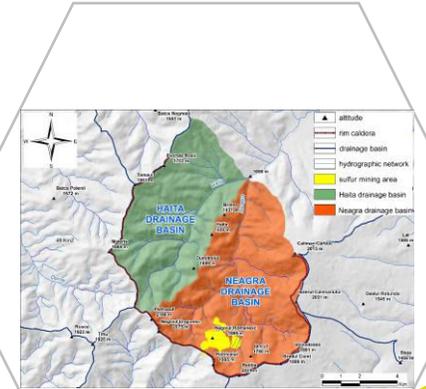
A field monitoring in the outlet area of both drainage basins, including records of meteorological parameters, fluvial transport (suspended sediments, solutes) is planned to be started in the future.

Site key annual data

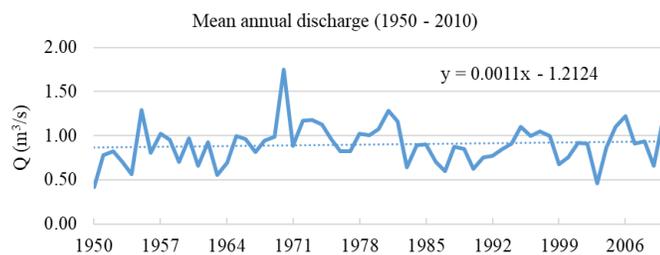
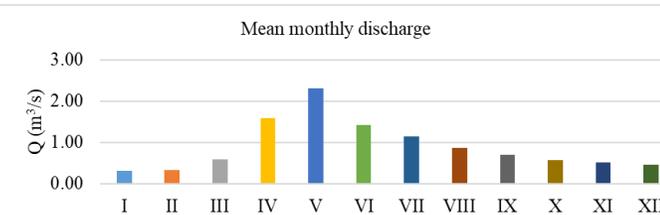
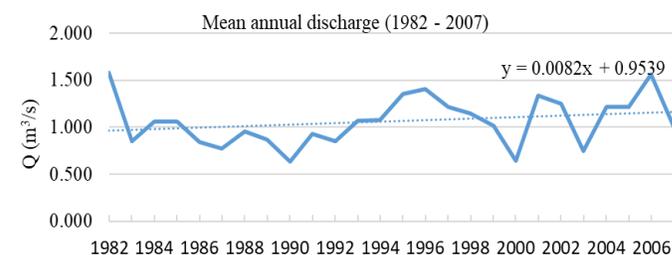
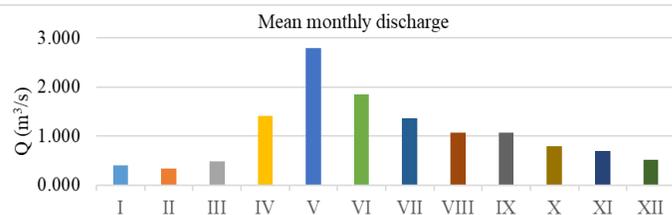
Measuring period	2008-
Meteorological and hydrological data	
Air temperature (°C)	-0.2
Precipitation (mm)	875
Runoff (mm) Neagra/Haita	692/686
Drainage basin wide denudation rates	
Solute yield* (t km ⁻² yr ⁻¹)	n.a.
Suspended sediment yield (t km ⁻² yr ⁻¹)	n.a.
Bedload yield (t km ⁻² yr ⁻¹)	n.a.

*atmospherically corrected
n.a. = not available

Views of instrumentation and methods



Mean monthly and annual discharge Neagra and Haita basin



Sulden/Solda River

Site overview

The Sulden/Solda river basin is located in the Eastern Italian Alps. The basin is about 130 km² in drainage area and is composed of two major portions: the actual Sulden (77.5 km²) and the Trafoi (52.6 km²) (Fig. 1). The basin is characterized by large elevation differences, from 1100 m a.s.l. to 3905 m a.s.l. (Ortler/Ortles peak). The basin is highly glacierized (about 14% of the basin area), with the presence of both debris-covered (Fig. 2) and clean ice bodies (Fig. 3).

The bedrock geology includes metamorphic rocks and Permo-Triassic carbonate rocks. Forests are mostly composed of conifers and extend up to about 2000 m a.s.l. The presence of glaciers, of periglacial and proglacial landforms contributes to very complex sediment pathways (Buter et al., 2020; Savi et al., 2021).

Hydrologically, the Sulden River has a nivo-glacial regime (Engel et al., 2019). For the period 1981–2010, mean annual air temperature (MAAT) at the Sulden/Solda village (1907 m a.s.l.) was 2.8°C, whereas mean annual precipitation (MAP) was 835 mm (Savi et al., 2021). A marked warming is evident in the last decades during all seasons, while mean annual precipitation do not show any clear trend (Fig. 4 on next page).

Selected key publications

Buter, A., Spitzer, A., Comiti, F., & Heckmann, T. (2020). Geomorphology of the Sulden River basin (Italian Alps) with a focus on sediment connectivity. *Journal of Maps*, 16(2), 890–901.

<https://doi.org/10.1080/17445647.2020.1841036>

Engel, M., Penna, D., Bertoldi, G., Vignoli, G., Tirlir, W., & Comiti, F. (2019). Controls on spatial and temporal variability in streamflow and hydrochemistry in a glacierized catchment. *Hydrology and Earth System Sciences*, 23(4), 2041–2063. <https://doi.org/10.5194/hess-23-2041-2019>

Savi, S., Comiti, F., & Strecker, M. R. (2021). Pronounced increase in slope instability linked to global warming: A case study from the eastern European Alps. *Earth Surface Processes and Landforms*, 46, 1328–1347.

<https://doi.org/10.1002/esp.5100>

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Site views



Fig. 2

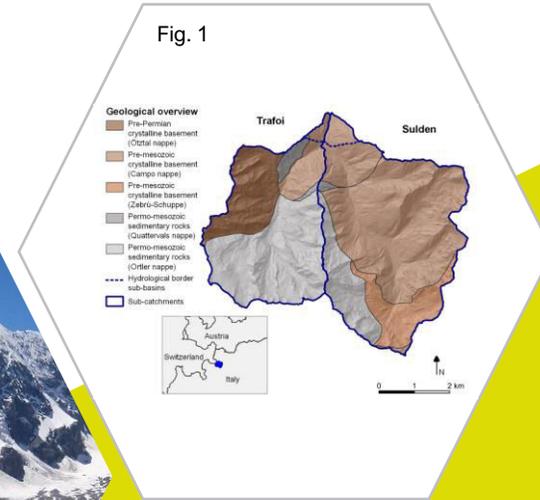


Fig. 1



Fig. 3

Site key facts

Country: Italy

Geographical coordinates: 46°35' N, 10°33' E

Climate: Eastern Alps

Lithology: phyllites, ortho-/paragneiss, dolomites

Catchment area: 130 km²

Elevation range: 1100 – 3905 m a.s.l.

Methods for analysis of denudation

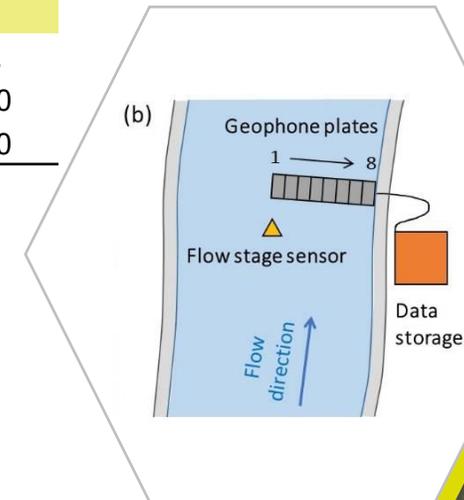
The Sulden River monitoring station at Stilfserbrücke – Ponte Stelvio started operating in May 2014 and was the result of the cooperation between public institutions (Universities and local agencies) and private companies (see www.aquased.net). From 2014 to 2020, suspended sediment transport has been measured by a turbidimeter and by an automatic pumping sampler. Bedload transport has been indirectly monitored by 8 geophone plates installed on a check dam (Fig. 5a, b). Direct bedload samples have been taken by a portable bedload trap supported by truck-operated crane (Fig. 5c). Water discharge has been monitored by water level measurements combined to salt-dilution flow measurements.

Site key annual data

Measuring period	2014-
Meteorological and hydrological data	
Air temperature (°C)	2.8
Precipitation (mm)	835
Runoff (mm)	1430
Drainage basin wide denudation rates	
Solute yield* (t km ⁻² yr ⁻¹)	n.a.
Suspended sediment yield (t km ⁻² yr ⁻¹)	~700
Bedload yield (t km ⁻² yr ⁻¹)	~350

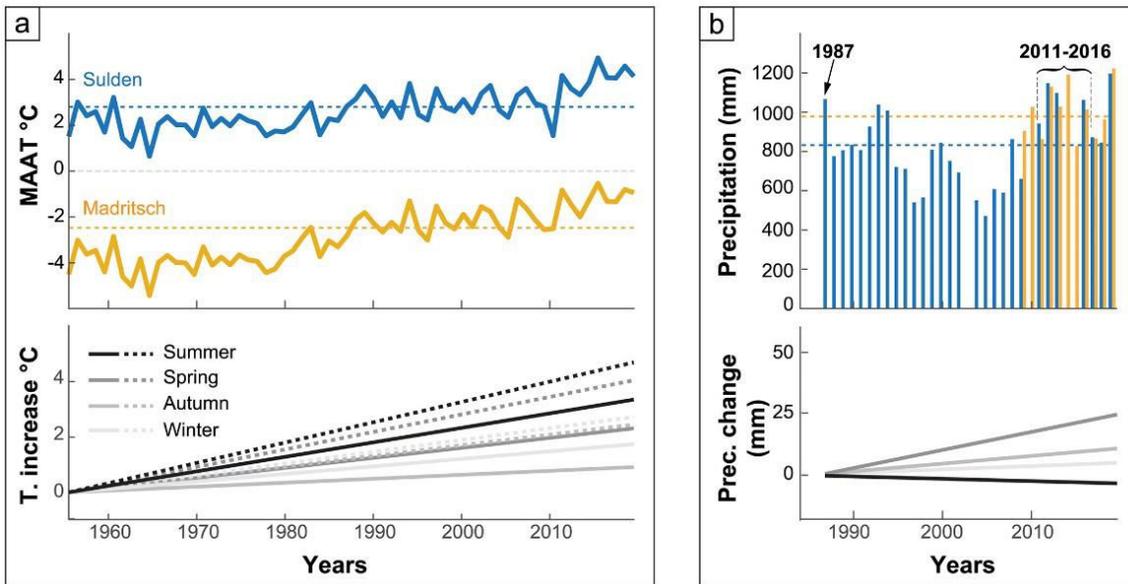
*atmospherically corrected
n.a. = not available

Views of instrumentation and methods



Temperature (a) and precipitation (b) within the Sulden basin at annual and seasonal scale

Fig. 4



Alpe Veglia

Site overview

The Alpe Veglia lies in the Cairasca river basin and covers about 29 km², comprising the Aurona, Frua and Mottiscia watercourses, joining the Cairasca River at its southern limit. The Alpe Veglia is part of the protected area “Veglia-Devero Natural Park”. The main lithologies outcropping in the area are gneisses, calcschists and carbonatic rocks, with local mafic outcrops. The most important geomorphic processes at play within the catchment are rockfalls, debris flows, fluvial erosion, and snow avalanches, while active glacial processes are restricted to specific portions of the catchment. The most important sediment sources for debris flow and fluvial transport are glacial sediments and talus deposits. Two sectors, bordering the Alpe Veglia structural hollows, can be identified (Fig.1 on next page): i) the Frua and Mottiscia eastern sector (16 km²) has a negligible glacial cover (0.41%), mostly characterised by large rock glaciers (Fig.2), peat bogs, talus slopes, and Pleistocene moraines; ii) the Aurona western sector (13 km²) hosts two glaciers (Leone and Aurona) covering 5.5%, and Pleistocene and Little Ice Age moraines are well preserved; they border proglacial plains (Fig.3) where an historical, now infilled, proglacial lake was identified in 1950’s (Fig.4), and permafrost related landforms are very peculiar. Human influence is limited to cattle grazing, mainly in the Alpe Veglia plain, and to hiking, from late spring to early autumn.

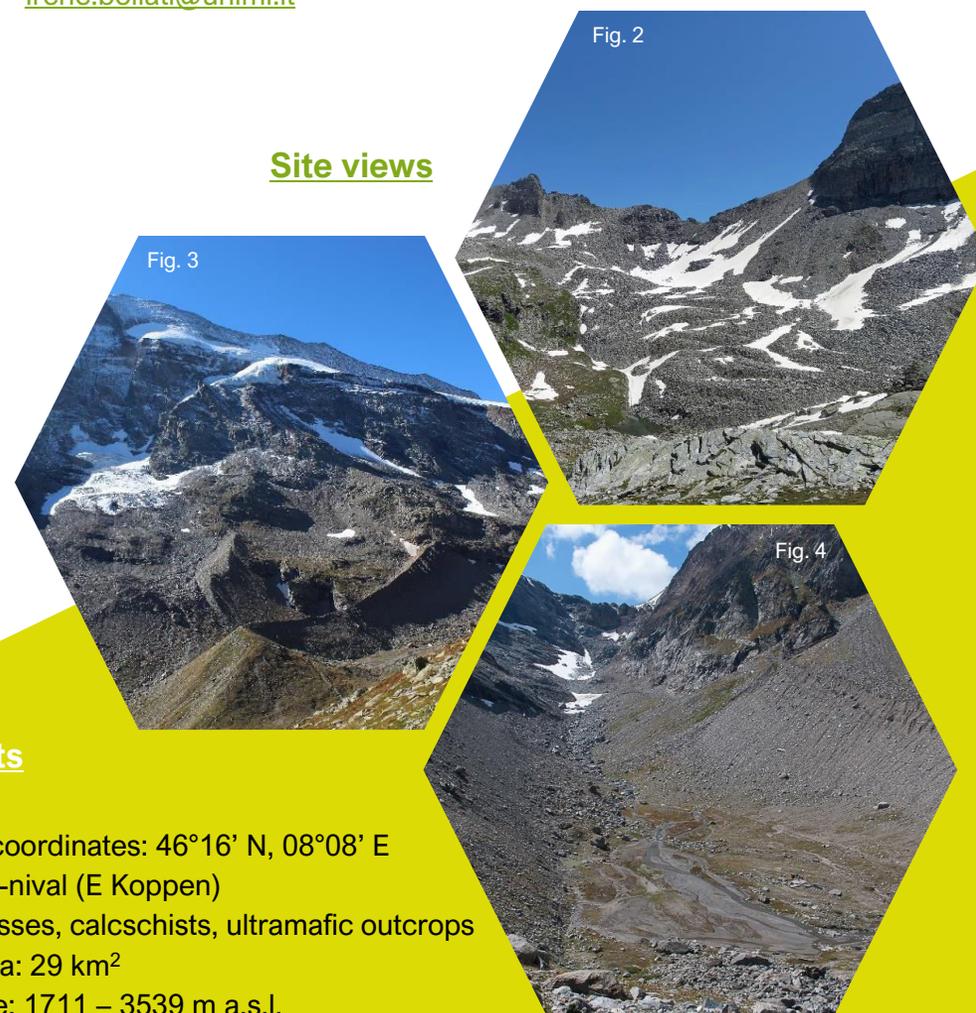
First publications

Tronti G., Bollati I.M., Comiti F., Perotti L., Testa B., Viani C., Pelfini M. After the Ice: geomorphological evolution of the Leone and Aurona proglacial areas (Lepontine Alps) in relation to geodiversity, BeGeo Scientists 2021, Naples Napoli, 3-6 June 2021. <https://unimibox.unimi.it/index.php/s/EdnswpGx4NbxDfk>

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Site views



Site key facts

Country: Italy
 Geographical coordinates: 46°16' N, 08°08' E
 Climate: glacio-nival (E Koppen)
 Lithology: gneisses, calcschists, ultramafic outcrops
 Catchment area: 29 km²
 Elevation range: 1711 – 3539 m a.s.l.

Methods for analysis of denudation

The monitoring of sediment fluxes, water runoff and electrical conductivity, has been taking place since 2021 in the Aurona catchment through a multiparametric probe located in the Alpe Veglia plain (Fig.5). The station, (installed by University of Milan, the Free University of Bozen-Bolzano and the CNR IGAG in Milan, Italy), records at 5 min intervals water stage (by a pressure transducer), electrical conductivity (Fig.6), temperature, and turbidity (up to 3000 NTU). Flow rating curve of the station are performed through water discharge measurements by the salt dilution technique. Water samples are taken at proglacial plain and near the turbidimeter, these latter to derive the relationship between turbidity and suspended sediment concentration. Occasional bedload transport measurements are carried out by means of portable traps (Fig.7). A hydro-morphometric approach was also adopted, to evaluate the stream behaviour influences on the riverbed evolution through GPS hydro-morphological surveys (Fig.8) along the Aurona river.

Site key annual data

Measuring period	2017-
Meteorological and hydrological data	2017-2021
Air temperature (°C)	4.5
Precipitation (mm)	1473
Runoff (mm)	i.p.
Drainage basin wide denudation rates	2021-
Solute yield* (t km ⁻² yr ⁻¹)	i.p.
Suspended sediment yield (t km ⁻² yr ⁻¹)	i.p.
Bedload yield (t km ⁻² yr ⁻¹)	i.p.

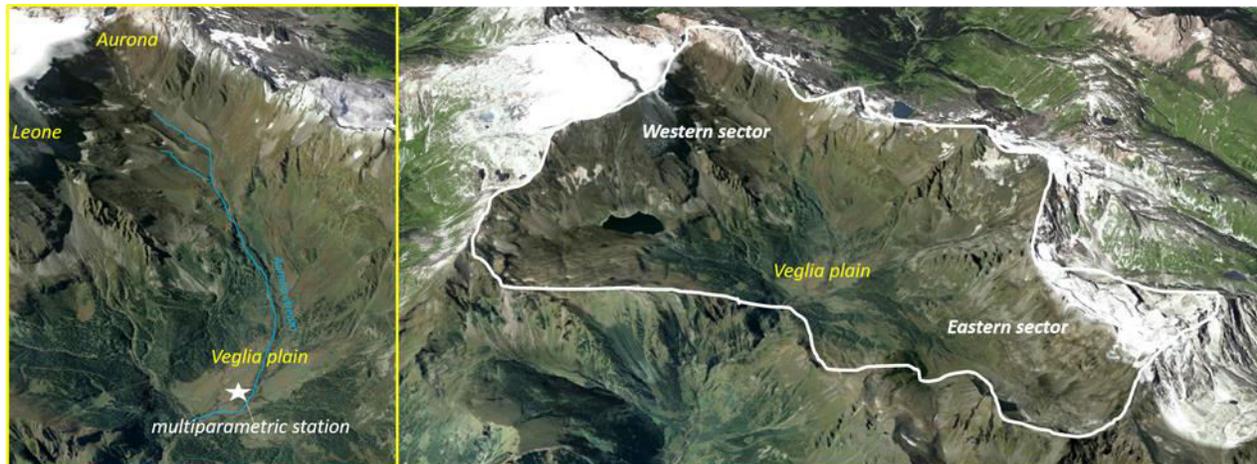
*atmospherically corrected
i.p. = in progress

Views of instrumentation and methods



Aurona proglacial area (on the left) and Cairasca river catchment (on the right)

Fig. 1



Upper Orcia Valley

Site overview

The Upper Orcia Valley is the easternmost portion of the Ombrone River basin. The area is located in the Tuscan Pre-Apennines, close to Siena, at an altitude of about 600 m a.s.l., where Plio-Pleistocene marine deposits, filling NW–SE elongated sedimentary basins, have been uplifted during the Quaternary, due to volcanic activity, up to several hundreds of meters above present sea level. These deposits consist of lithological units particularly prone to denudation. Mean annual rainfall is 700–800 mm (varying from 500 to 1,100mm), although its values during the time-spans are discontinuous, as typical for Mediterranean regions. The convergence of soft rock outcropping, wetting-drying cycles typical of the Mediterranean climate and widespread steep hillslopes has caused pervasive water erosion processes, leading to the formation of typical badlands, with calanchi, on the steeper clayey slopes, and biancane landforms, on the gentler ones. About the 70% of biancane landforms have disappeared, being remolded for agricultural purposes during the last decades. Ephemeral or permanent gullies, often recognizable in croplands, grow rapidly as a consequence of concentrated rainfall and mass movements contribute to slope denudation along with water erosion. Considering the off-site effects of denudation, the estimated values of mean annual suspended sediment load for the major catchments increases exponentially with the ratio of badlands area to the whole catchments.

Selected key publications

- Neugirg F, Stark M, Kaiser A, Vlacilova M, Della Seta M, Vergari F, Schmidt J, Becht M, Haas F. 2016. Erosion processes in calanchi in the Upper Orcia Valley, Southern Tuscany, Italy based on multitemporal high-resolution terrestrial LiDAR and UAV surveys. *Geomorphology* 269: 8–22. <https://doi.org/10.1016/j.geomorph.2016.06.027>
- Aucelli P.P.C., Conforti M., Della Seta M., Del Monte M., D'uva L., Roskopf C.M., Vergari F. 2016. Multi-temporal digital photogrammetric analysis for quantitative assessment of soil erosion rates in the Landola catchment of the Upper Orcia Valley (Tuscany, Italy). *Land Development & Degradation*, 27: 1075–1092. DOI: 10.1002/ldr.2324
- Vergari, F., Della Seta, M., Del Monte, M., Barbieri, M. 2013. Badlands denudation “hot spots”: the role of parent material properties on geomorphic processes in 20-years monitored sites of Southern Tuscany (Italy). *Catena*, 106, 31–41. [doi:10.1016/j.catena.2012.02.007](https://doi.org/10.1016/j.catena.2012.02.007)
- Della Seta M, Del Monte M, Fredi P, Lupia Palmieri E. 2009. Spacetime variability of denudation rates at the catchment and hillslope scales on the Tyrrhenian side of central Italy. *Geomorphology* 107: 161–177. <https://doi.org/10.1016/j.geomorph.2008.12.004>

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SAPIENZA
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Site views



Site key facts

Country: Italy
Geographical coordinates: 42°55' N, 11°44' E
Climate: Mediterranean
Lithology: clays, sandy clays, alluvial deposits
Catchment area: -
Elevation range: 300 – 650 m a.s.l.

Methods for analysis of denudation

Long-lasting field activities have been aimed at evaluating hillslope denudation rates, by applying different techniques, from the more traditional (like erosion pins), the dendrogeomorphology, until the application of more innovative technologies: to quantify and monitor erosion, volumetric analyses were performed after Difference of Difference (DoD) calculated using multitemporal aerial photographs, seasonal surveys with UAV and TLS, D-GPS surveys. At this scale, the SSY can exceed $1000 \text{ t km}^{-2} \text{ yr}^{-1}$. The analysis of the parent material properties of the badland slopes have also been carried out. Instant suspended load measures have been performed and instrumented catchment for recording hydrological and suspended sediment yield is planned.

Site key annual data

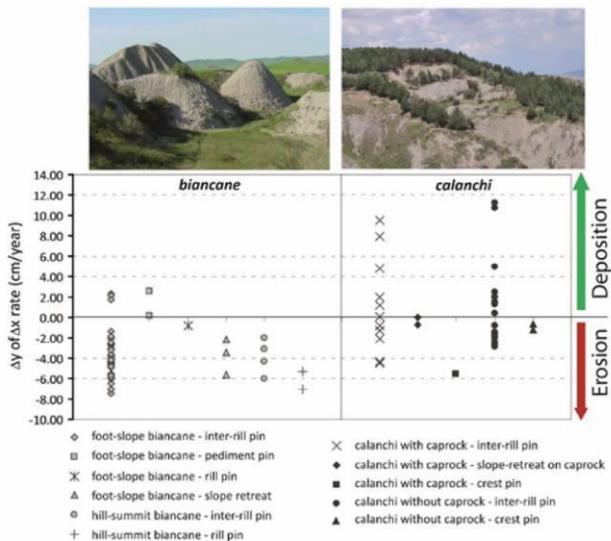
Measuring period	1976-
Meteorological and hydrological data	
Air temperature (°C)	14
Precipitation (mm)	700
Runoff (mm)	n.a.
Drainage basin wide denudation rates	
Solute yield* ($\text{t km}^{-2} \text{ yr}^{-1}$)	n.a.
Suspended sediment yield ($\text{t km}^{-2} \text{ yr}^{-1}$)	n.a.
Bedload yield ($\text{t km}^{-2} \text{ yr}^{-1}$)	n.a.

*atmospherically corrected
n.a. = not available

Views of instrumentation and methods

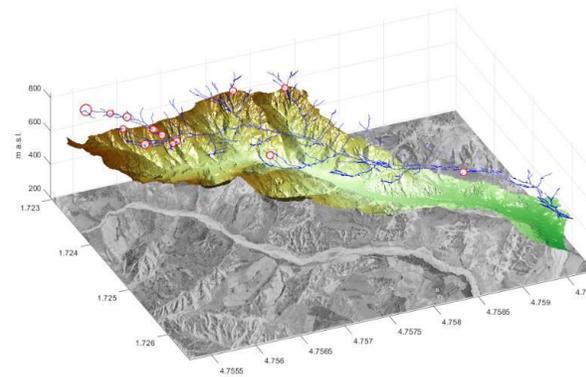


Summary of the mean erosion rates recorded at the monitored calanchi and biancane sites



After Brandolini et al., 2018.

Example of catchment scale morphometric analysis



Barués catchment

Site overview

The Barués catchment (23 km²) is located in the border of the central Ebro River Depression and drained by an ephemeral stream tributary of the Arba River that delivers high suspended sediment loads to the Ebro River. The climate is characterised by cold winters and hot and dry summers with temperature range between 30°C and -6°C and mean annual rainfall of 650 mm. The catchment structure is dominated by low angle dip sandstones of the Uncastillo Miocene formation bedding and the presence of a Quaternary glaciais. Specific geomorphic features include dispersed eroded areas where subsoil is exposed and stream valley floors infilled by eroded sediment from the surrounding slopes, which are deeply incised. Land use changes happened in the past century from most of the catchment under cultivation at the start of past century until only 16% of cropland at present. Mediterranean open forest and scrubland are over higher altitudes and croplands occupy the valley floors and the glaciais. Localised intense storms occurring during the summer-fall period trigger high erosion in channel banks and bare soil surfaces. Soil redistribution estimates for the last decades indicate that croplands record the highest erosion and deposition rates in agreement with fingerprint present source contributions.

Selected key publications

- Lizaga, I., Bodé, S., Gaspar, L., Latorre, B., Boeckx, P., Navas, A., 2021. Legacy of historic land cover changes on sediment provenance tracked with isotopic tracers in a Mediterranean agroforestry catchment. *Journal of Environmental Management* 288, 112291. <https://doi.org/10.1016/j.jenvman.2021.112291>
- Lizaga, I., Gaspar, L., Blake, W., Latorre, B., Navas, A., 2019. Fingerprinting changes of source apportionments from mixed land uses in stream sediments before and after an exceptional rainstorm event. *Geomorphology*. <https://doi.org/10.1016/j.geomorph.2019.05.015>
- Lizaga, I., Quijano, L., Gaspar, L., Navas, A., 2018. Estimating soil redistribution patterns with ¹³⁷Cs measurements in a Mediterranean mountain catchment affected by land abandonment. *Land Degradation & Development* 29, 105–117. <https://doi.org/10.1002/ldr.2843>
- Lizaga, I., Quijano, L., Palazón, L., Gaspar, L., Navas, A., 2017. Enhancing Connectivity Index to Assess the Effects of Land Use Changes in a Mediterranean Catchment. *Land Degrad. Develop.* 663–675. <https://doi.org/10.1002/ldr.2676>

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Site views



Site key facts

Country: Spain
Geographical coordinates: 42°25' N, 01°12' W
Climate: Mediterranean mountain
Lithology: sandstones, claystones, siltstones
Catchment area: 23 km²
Elevation range: 550 – 915 m a.s.l.

Methods for analysis of denudation

The effect of land use changes from 1957–2010 was assessed from a topography-based index. Multitemporal analysis of several spectral indices of open-access satellite images was performed since 1972 to present to assess the soil-vegetation interaction.

Soil erosion and deposition rates were derived from ^{137}Cs measurements after applying conversion models and were spatially interpolated to estimate the amount of net soil loss.

Radionuclides, stable elements and isotopic tracers (CSSI) modelled with FingerPro identified sediment sources and their apportionments to assess impacts of land covers changes, agricultural practices and storm events on soil loss and export of sediment and particle-bound chemicals.

Site key annual data

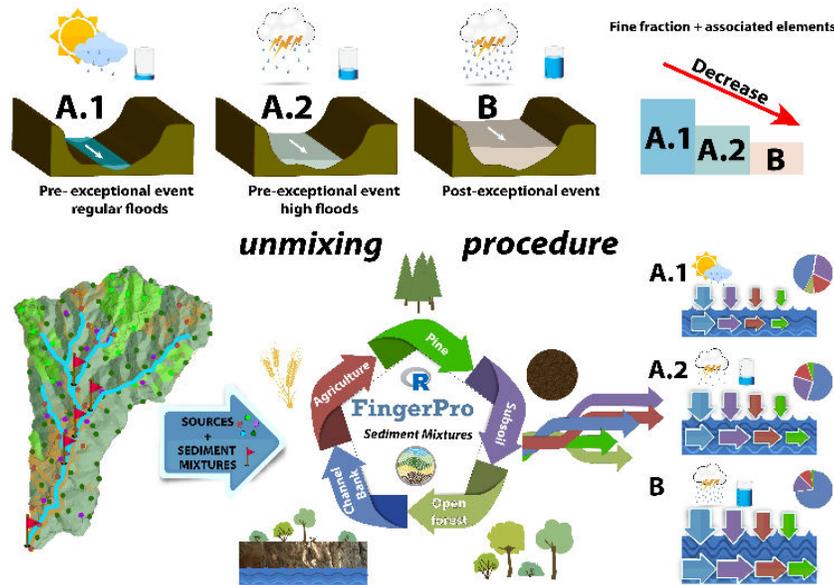
Measuring period	2012-
Meteorological and hydrological data	
Air temperature (°C)	13.4
Precipitation (mm)	650
Runoff (mm)	n.a.
Drainage basin wide denudation rates	
Solute yield* (t km ⁻² yr ⁻¹)	n.a.
Suspended sediment yield (t km ⁻² yr ⁻¹)	n.a.
Bedload yield (t km ⁻² yr ⁻¹)	n.a.

*atmospherically corrected
n.a. = not available

Views of instrumentation and methods



Fingerprinting changes of source apportionments in stream sediments before and after an exceptional rainstorm event with FingerPro model



Barasona catchment

Site overview

The Barasona catchment (1,509 km²), located in the central Spanish Pyrenees, supply sediment to the Barasona reservoir (692 ha) at the catchment outlet, collecting the discharge of the Ésera and Isábena Rivers. The area is characterized by abrupt topography (424 to 3404 m a.s.l.) and has a mountain climate with both Atlantic and Mediterranean influences. Temperature and precipitation gradients are observed for N-S and W-E according to the relief (from > 2000 mm and 4°C in the headwaters to < 500 mm and 12°C at the reservoir). The hydrologic regime is transitional nival-pluvial with two maxima: spring (snowmelt) and late autumn (precipitation). Lithology includes a succession of sedimentary Tertiary to Paleozoic rocks and igneous rocks in the axial Pyrenees overlaid by a variety of soils (Kastanozems, Regosols, Leptosols and Fluvisols). Cultivated lands (20%) occupy lowland southern areas, forest and pastures (50%) and alpine grassland in the highlands. Besides the agricultural lands, badlands on Eocene marls (<1% of the catchment area) are the main sediment sources to the Barasona reservoir that suffered siltation problems since its construction in 1932 losing 1/3 of its capacity, a bathymetric survey in 1995 yielded a specific sediment yield[#] of 3.50 t ha⁻¹year⁻¹.

Selected key publications

- Palazón, L., Latorre, B., Gaspar, L., Blake, W.H., Smith, H.G., Navas, A., 2016. Combining catchment modelling and sediment fingerprinting to assess sediment dynamics in a Spanish Pyrenean river system. *Sci. Total Environ.* 569-570, 1136–1148. <https://doi.org/10.1016/j.scitotenv.2016.06.189>
- Palazón, L., Navas, A., 2016. Land use sediment production response under different climatic conditions in an alpine-prealpine catchment. *Catena* 137, 244–255. <https://doi.org/10.1016/j.catena.2015.09.025>
- Navas, A., Valero-Garcés, B.L., Machín, J., 2004. An approach to integrated assessment of reservoir siltation: the Joaquín Costa reservoir as a case study. *Hydrol. Earth Syst. Sci.* 8, 1193–1199. <https://hess.copernicus.org/articles/8/1193/2004/>
- Valero-Garcés, B., Navas, A., Machín, J., Walling, D. 1999. Sediment sources and siltation in mountain reservoirs: a case study from the Central Spanish Pyrenees. *Geomorphology* 28(1-2), 23-41. [https://doi.org/10.1016/S0169-555X\(98\)00096-8](https://doi.org/10.1016/S0169-555X(98)00096-8)

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Site views



Site key facts

Country: Spain
Geographical coordinates: 42°11' N, 0°20' E
Climate: mountain climate
Lithology: limestones, marls, sedimentary rocks
Catchment area: 1509 km²
Elevation range: 424 – 3404 m a.s.l.

Methods for analysis of denudation

The SWAT model for assessing specific sediment yields from different land uses. Reservoir coring to evaluate the sedimentary dynamic and date changes. Fingerprinting procedure for quantifying sediment sources to sediment mixtures in river channels and assessing changes in catchment source contribution both over a longitudinal river reach and to a reservoir delta deposit. The SWAT and FingerPro models were used in parallel to assess the viability of a combined modelling and tracing approach to evaluate soil erosion processes and sedimentary dynamic. A simulation experiment was achieved by using SWAT to investigate differences in sediment productions from the land uses under different climatic conditions.

Site key annual data

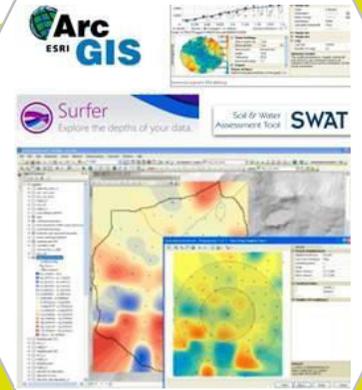
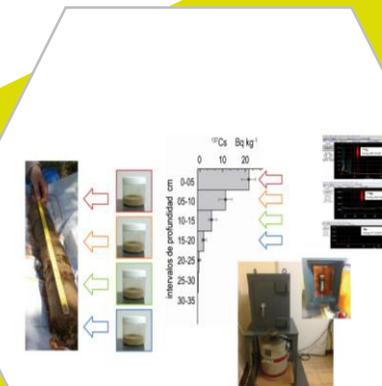
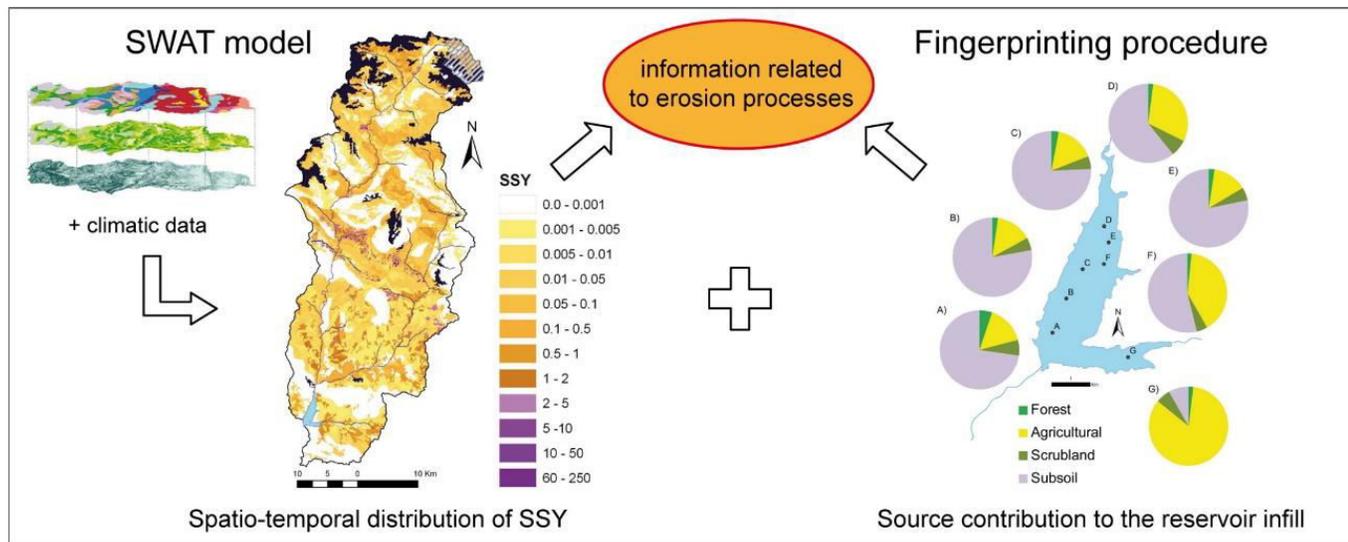
Measuring period	1995-
Meteorological and hydrological data	
Air temperature (°C)	12
Precipitation (mm)	500
Runoff (mm)	755
Drainage basin wide denudation rates	
Solute yield* (t km ⁻² yr ⁻¹)	n.a.
Suspended sediment yield (t km ⁻² yr ⁻¹)	n.a. [#]
Bedload yield (t km ⁻² yr ⁻¹)	n.a. [#]

*atmospherically corrected
n.a. = not available

Views of instrumentation and methods



Combining catchment modelling with SWAT and sediment fingerprinting for assessing sediment dynamics



Estaña catchment

Site overview

The Estaña catchment (2.5 km²), located in the karstic region of the Pyrenean External Ranges is an endorheic system included in the European NATURA 2000 Network that holds 3 small lakes. Characterized by abrupt topography (676 and 894 m a.s.l.) its climate is Mediterranean-continental (mean annual rainfall and temperature of 590 mm and 12.2°C). The hydrological network consists of a gully system that does not inflow into the lakes as it was diverted through agricultural areas surrounding the lakes. The bedrock consists of gypsiferous marls and limestones of Mesozoic age and main soils are Calcisols, Leptosols and Regosols. The intense anthropogenic activity has greatly modified the landscape by creating numerous linear landscape elements aimed at protecting the soil from erosion. Around the lakes barley is the main crop occupying most of the gentle surfaces (23%), whereas Mediterranean forests and scrublands (57%) extend over steeper slopes. The main processes are sheet, rill and interrill erosion. Large spatial variability of ¹³⁷Cs soil redistribution rates that record low to moderate rates under forest while highest rates in cultivated soils highlight the key role of the landscape topography, the effect of runoff on different land uses and the importance of the intrastorage of sediments in the catchment.

Selected key publications

- Gaspar, L., Lizaga, I., Navas, A. 2021. Spatial distribution of fallout and lithogenic radionuclides controlled by soil carbon and water erosion in an agroforestry South-Pyrenean catchment. *Geoderma* 391, 114941. <https://doi.org/10.1016/j.geoderma.2021.114941>
- Gaspar, L., Mabit, L., Lizaga, I., Navas, A. 2020. Lateral mobilization of soil carbon induced by runoff along karstic slopes. *Journal of Environmental Management* 260, 110091. <https://doi.org/10.1016/j.jenvman.2020.110091>
- Navas, A., López-Vicente, M., Gaspar, L., Palazón, L., Quijano, L. 2014. Establishing a tracer-based sediment budget to preserve wetlands in Mediterranean mountain agroecosystems (NE Spain). *Science of the Total Environment*, 496: 132-143. <https://doi.org/10.1016/j.scitotenv.2014.07.026>
- Gaspar, L., Navas, A., Walling, D.E., Machín, J., Gómez Arozamena, J. 2013. Using ¹³⁷Cs and ²¹⁰Pb to assess soil redistribution on slopes at different temporal scales. *Catena*, 102: 46-54. <https://doi.org/10.1016/j.catena.2011.01.004>

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Site views



Site key facts

Country: Spain
Geographical coordinates: 42°01' N, 0°31' E
Climate: Mediterranean continental
Lithology: marls, limestones, dolomites
Catchment area: 2.5 km²
Elevation range: 676 – 894 m a.s.l.

Methods for analysis of denudation

Nuclear techniques (¹³⁷Cs, ²¹⁰Pb) are used to assess soil redistribution rates and estimate sediment budgets. Geospatial interpolation is applied to create soil erosion and deposition maps. Sediment budgets are established by computing pixels corresponding to different ¹³⁷Cs rates of soil loss and gain and comparing with sediment accumulation rates recorded in lake cores dated with ¹³⁷Cs. Perceptual models are applied to display the mobilisation of soil, nutrients and elements by water fluxes considering linear landscape elements. Measurements with a cosmic ray neutron sensor allow assessing the temporal variation of soil water content as a key control of hydrological and erosive processes.

Site key annual data

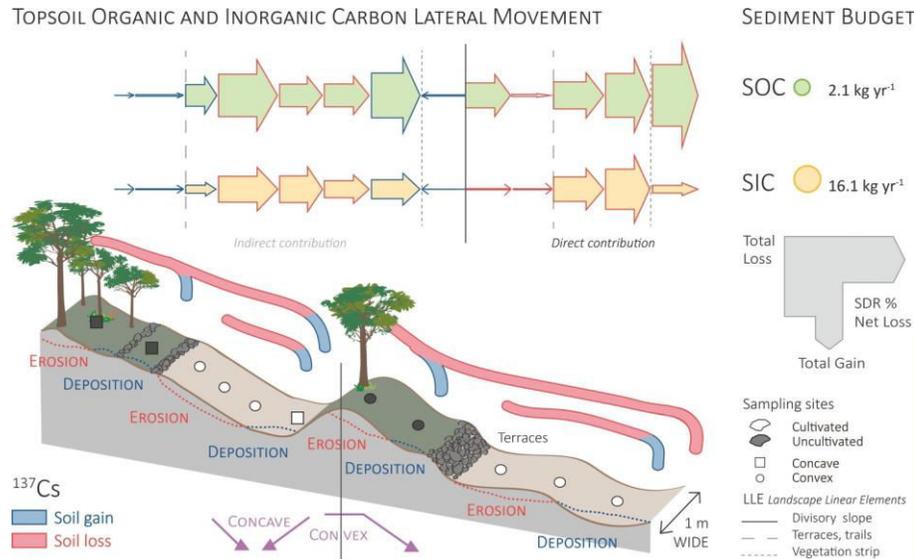
Measuring period	2003-
Meteorological and hydrological data	
Air temperature (°C)	12.2
Precipitation (mm)	595
Runoff (mm)	n.a.
Drainage basin wide denudation rates	
Solute yield* (t km ⁻² yr ⁻¹)	n.a.
Suspended sediment yield (t km ⁻² yr ⁻¹)	n.a.
Bedload yield (t km ⁻² yr ⁻¹)	n.a.

*atmospherically corrected
n.a. = not available

Views of instrumentation and methods



Lateral mobilization of soil carbon by runoff along a karstic slope based soil ¹³⁷Cs redistribution rates



137Cs - Sediment Budget
"Estuaire Grande de Abay" sub-catchment

Surfer
Explore the depths of your data

ArcGIS

SWAT
Soil & Water Assessment Tool

CSIC
Cosmic Ray Neutron Sensor

Pou Roig-Quisi and Mascarat catchments

Site overview

The Pou Roig-Quisi and Mascarat catchment systems in eastern Spain (Calpe) are located in a Mediterranean, mostly mountainous and anthropogenically modified environment. The selected area is characterized by a mild Mediterranean climate with a mean annual air temperature of ca. 18°C and a mean annual precipitation sum around 400 mm (measured slightly above sea level). During the coldest months (January, February) it can be comparably cold even with frost and snow in the high mountains although the mountain ranges are situated close to the coast. In contrast, maximum summer temperatures (July, August) can easily exceed 30°C and south-facing hillslopes and rockwalls are exposed to high solar radiation. The lithology in the area is clearly dominated by marine limestones. Elevation ranges from sea level up to 1126 m a.s.l. Sediment connectivity is significantly reduced by extended terraced areas. Geomorphological processes include chemical and mechanical weathering, rock falls, debris flows, splash and slope wash, fluvial erosion, and fluvial solute, suspended sediment and bedload transport. Sediment transfers, the intermittent runoff and fluvial transport are almost entirely controlled by pluvial events.

First publications

- Beylich, A.A., Laute, K., 2020. Sediment sources, denudational processes and sedimentary budgets in three Mediterranean catchment systems in eastern Spain. Geophysical Research Abstracts, EGU2020-3492, 2020. <https://meetingorganizer.copernicus.org/EGU2020/EGU2020-3492.html>
- Beylich, A.A., Laute, K., 2019. Drivers and rates of denudational processes and source-to-sink fluxes under changing climate and anthropogenic impacts in selected Mediterranean catchment systems in eastern Spain. IAG Regional Conference on Geomorphology. Athens, Greece, 19- 21 September 2019. Abstracts.
- Laute, K., Beylich, A.A., 2019. Drivers of rockwall retreat and denudational hillslope processes in two selected cold climate and Mediterranean mountain environments. Geophysical Research Abstracts, Vol. 21, EGU2019-4315, 2019. <https://meetingorganizer.copernicus.org/EGU2019/EGU2019-4315.pdf>

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Site views



Site key facts

Country: Spain
 Geographical coordinates: 38°38' N, 0°03' E
 Climate: Mediterranean
 Lithology: Marine limestones
 Catchment area: i.p.
 Elevation range: 0 – 1126 m a.s.l.

Methods for analysis of denudation

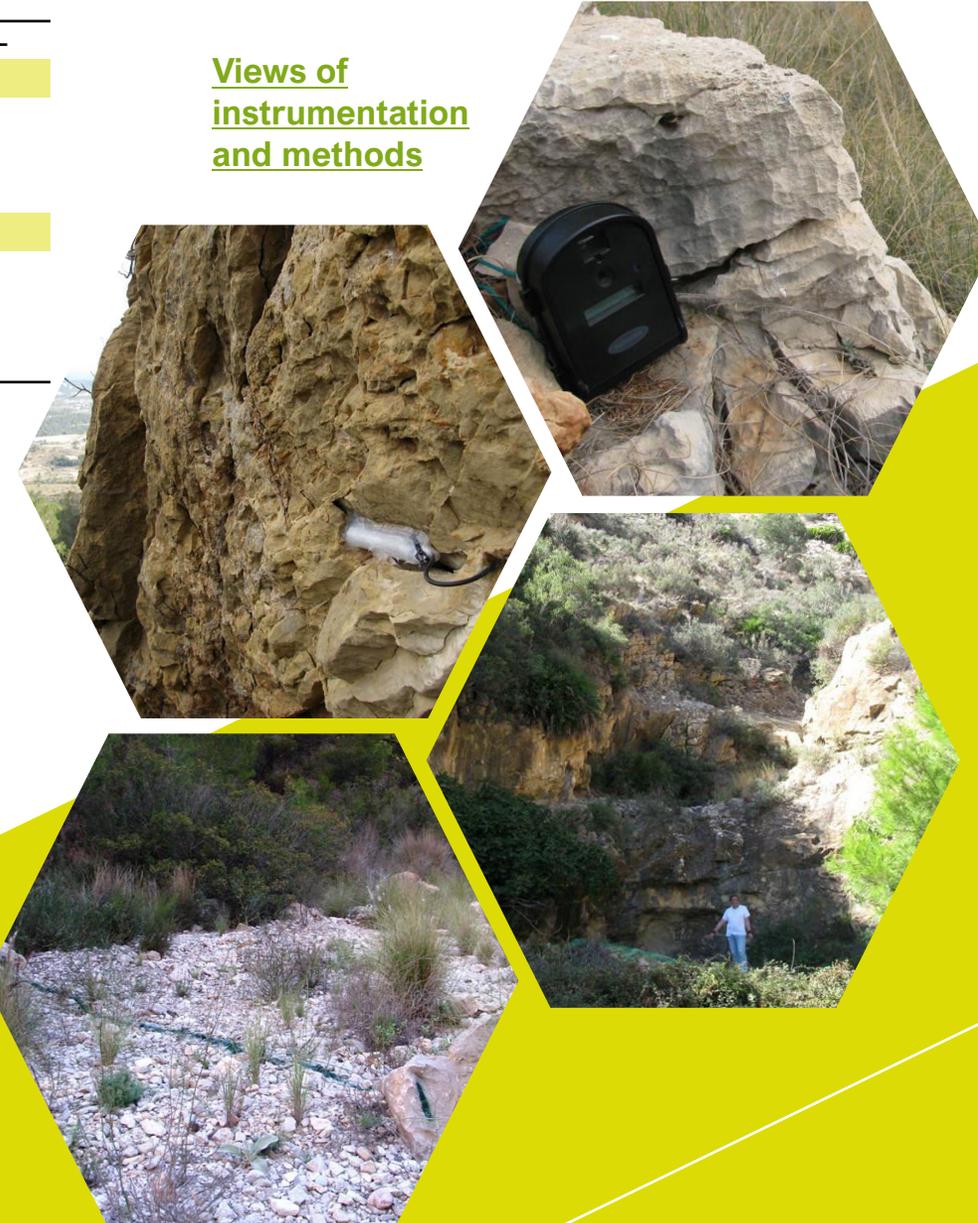
This ongoing GFL research on drivers of chemical and mechanical denudation includes detailed field and remotely sensed geomorphological mapping and computing of morphometric catchment parameters combined with the extended statistical analysis of high-resolution meteorological and rock temperature data and the observation and monitoring of sediment-transfer, runoff and fluvial transport events. In the field we are using a combination of different observation, monitoring and sampling techniques, including different tracer techniques and sediment traps in stream channels, remote time-laps cameras, and event-based high-resolution field monitoring combined with frequent water and sediment samplings.

Site key annual data

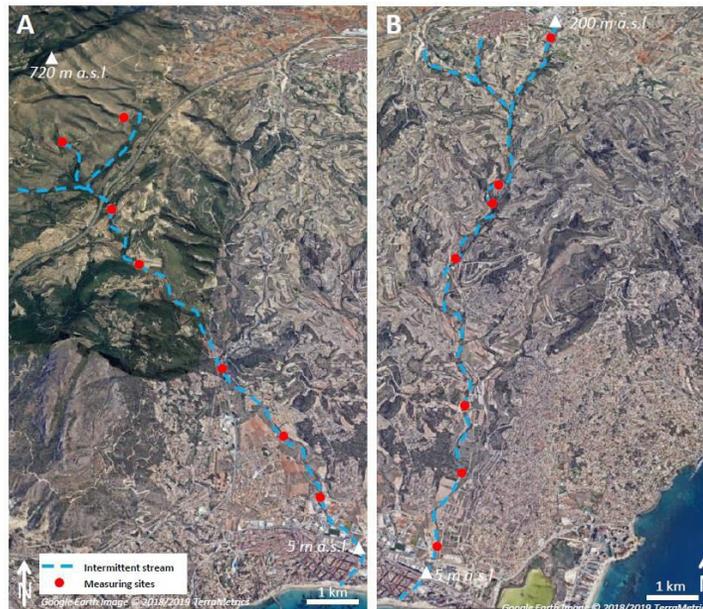
Measuring period	2018-
Meteorological and hydrological data	
Air temperature (°C)	18
Precipitation (mm)	400
Runoff (mm)	i.p.
Drainage basin wide denudation rates	
Solute yield* (t km ⁻² yr ⁻¹)	i.p.
Suspended sediment yield (t km ⁻² yr ⁻¹)	i.p.
Bedload yield (t km ⁻² yr ⁻¹)	i.p.

*atmospherically corrected
i.p. = in progress

Views of instrumentation and methods



Intermittent streams and measuring sites in the Pou Roig (A) and Quisi (B) catchments



Tuotuohe basin

Site overview

The Tuotuohe (TTH) basin, located in central-eastern Tibetan Plateau, is the most remote headwater of the Yangtze River. It has a catchment area of ~18000 km², with 98% of the land underlain by permafrost and 2% underlain by glaciers. Permafrost thaw starts in May and ends in September, and the active layer thickness ranges from 2.5 to 3.2 m. The vegetation mainly comprises sparse grassland. The TTH region is a pristine headwater basin with negligible human activities. There is only one small town at the basin outlet, Tangula (34.22 N, 92.44 E), with ~1300 local Tibetan inhabitants. The undisturbed environment provides a unique opportunity to assess the impacts of climate change on fluvial processes in naturally changing systems.

Geologically, the TTH basin comprises mesozoic clastic sedimentary rocks such as conglomerates, sandstones, siltstones, and claystones. Moraines deposited since the last glacial maximum are limited and occur in the upstream mountains (> 5000 m a.s.l.). The river channels are characterized by sand-gravel bed braided rivers with well-developed floodplains. The main thermally-induced sediment sources include thaw slumps, thermal gullies, snowmelt erosion, and glacial erosion. Conventional erosional processes such as slope wash, mass wasting, and fluvial channel erosion are also important sediment sources.

Selected key publications

- Li, D., Overeem, I., Kettner, A. J., Zhou, Y., & Xixi, L. (2021). Air temperature regulates erodible landscape, water and sediment fluxes in the permafrost-dominated catchment on the Tibetan Plateau. *Water Resources Research*, 56, e2020WR028193. <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2020WR028193>
- Li, D., Li, Z., Zhou, Y., & Lu, X. (2020). Substantial increases in the water and sediment fluxes in the headwater region of the Tibetan Plateau in response to global warming. *Geophysical Research Letters*, 47(11), e2020GL087745. <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2020GL087745>
- Li, D., Lu, X., Overeem, I., Walling, D. E., Syvitski, J., Kettner, A. J., Bookhagen, B., Zhou, Y., Zhang, T. (2021). Exceptional increases in fluvial sediment fluxes in a warmer and wetter High Mountain Asia. *Science*, 374(6567), 599-603. <https://www.science.org/doi/10.1126/science.abi9649>
- Zhang, T., Li, D., Kettner, A. J., Zhou, Y., & Lu, X. (2021). Constraining Dynamic Sediment-Discharge Relationships in Cold Environments: The Sediment-Availability-Transport (SAT) Model. *Water Resources Research*, 57(10), e2021WR030690. <https://agupubs.onlinelibrary.wiley.com/doi/abs/10.1029/2021WR030690>

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Site views



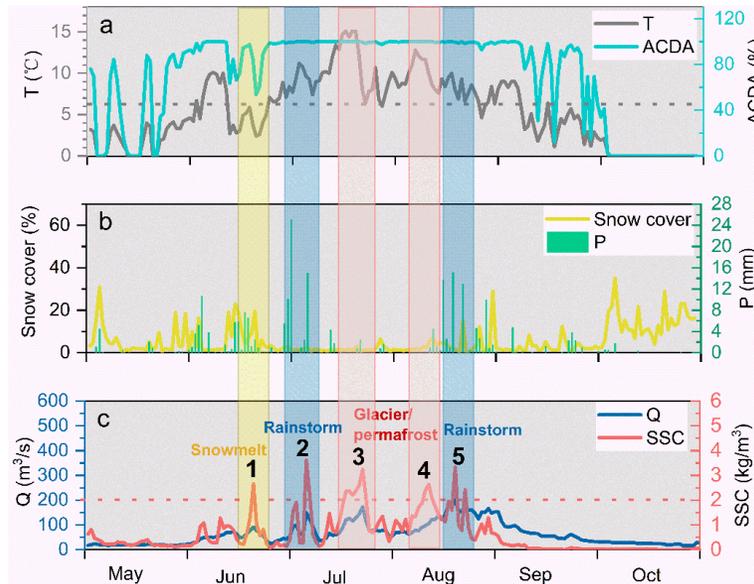
Site key facts

Country: China
 Geographical coordinates: 33°22' N, 90°31' E
 Climate: semi-arid cold
 Lithology: sedimentary rocks
 Catchment area: 18000 km²
 Elevation range: 4500 – 6600 m a.s.l.

Methods for analysis of denudation

The TTH gauging station is the most upstream hydrometeorological station of the Yangtze River. Daily data on temperature, precipitation, water level, discharge, and suspended sediment concentration (SSC) since 1985 have been recorded. Discharges are calculated by the site-specific stage-discharge rating curves, which are calibrated over a wide range of ADCP-measured discharge. SSC samples are collected by depth-integrating samplers. Normally, daily measurement of SSC is conducted, while more frequent, sub-daily measurements are collected during the flood season. Daily mean SSC is estimated from a combination of point and depth-integrated measurements spanning the monitored cross-section of the channel with at least four sampling points along the cross-section. In the sediment laboratory, SSC samples are volumetrically-filtered, oven-dried, and weighed.

Daily Q and SSC controlled by air temperature (T), active contributing drainage area (ACDA), snow cover, precipitation (P), and glacier-permafrost processes in the hydrological year of 2006



Site key annual data

Measuring period		1985-2017
Meteorological and hydrological data		
Air temperature (°C)		-4
Precipitation (mm)		290
Runoff (mm)		67
Drainage basin wide denudation rates		
Solute yield* (t km ⁻² yr ⁻¹)		n.a.
Suspended sediment yield (t km ⁻² yr ⁻¹)		50
Bedload yield (t km ⁻² yr ⁻¹)		n.a.

*atmospherically corrected
n.a. = not available

Views of instrumentation and methods



Estero Morales

Site overview

The Estero Morales is a high-gradient stream in the central Chilean Andes. The basin drains an area of 27 km², with elevation ranging from 1,780 to 4,497 m.a.s.l. The basin hosts glacierized areas, some uncovered and some covered by debris. The biggest portion of the glacier is called San Francisco, and the glacierized area has a current extent of 1.8 km². This glacier and glaciers in other basins in the larger Maipo valley are in a retreating trend. The basin is elongated and features a classical glacier-formed U-shape valley. The bedrock geology of the catchment consists of volcanic metamorphic rock and conglomerate-sand deposits. The mean annual precipitation is around 570 mm, mainly falling as snow and concentrated in autumn and winter. Runoff is dominated by snowmelt in spring and glacier melt in summer months. The mean denudation processes are associated with snowmelt and especially glaciermelting. The main source of sediments are the well-connected hillslopes in the upper and middle portion of the basin during the snowmelt period, and the very dynamic proglacial area during the glaciermelting period. The basin is protected by Chilean CONAF (<https://www.conaf.cl/parques/monumento-natural-el-morado/>) and is an important tourist site in the Maipo valley.

Selected key publications

- Carrillo, R., Mao, L. (2020). Coupling Sediment Transport Dynamics with Sediment and Discharge Sources in a Glacial Andean Basin. *Water* 2020, 12(12), 3452. <https://doi.org/10.3390/w12123452>
- Mao, L., Toro, M., Carrillo, R., Brardinoni, F., Fraccarollo, L. (2020). Controls over particle motion and resting times of coarse bed load transport in a glacier-fed mountain stream. *Journal of Geophysical Research: Earth Surface*, 125 Issue 4. <https://doi.org/10.1029/2019JF005253>
- Mao, L., Carrillo, R. (2017). Temporal dynamics of suspended sediment transport in a glacierized Andean basin. *Geomorphology*, Volume 287, Pages 116-125. <https://doi.org/10.1016/j.geomorph.2016.02.003>
- Ravazzolo, D., Mao, L., Escauriaza, C., Pastén, P., Montecinos, M. (2019). Rusty river: Effects of tufa precipitation on sediment entrainment in the Estero Morales in the central Chilean Andes. *Science of The Total Environment*, Volume 652, Pages 822-835. <https://doi.org/10.1016/j.scitotenv.2018.10.287>

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Site views



Site key facts

Country: Chile
Geographical coordinates: 33°49' S, 70°03' W
Climate: Andean
Lithology: volcanometamorphic rocks, conglomerates
Catchment area: 27 km²
Elevation range: 1780 – 4497 m a.s.l.

Methods for analysis of denudation

The study reach was equipped with a pressure transducer and a multiparameter water quality probe to monitor water temperature and electrical conductivity. Suspended sediment concentration was monitored with a turbidity sensor, which was calibrated using multiple direct water sampling. Bedload was measured using a combination of methods, integrating both direct and indirect techniques. For monitoring continuously the transport of coarse particles, an acoustic pipe sensor was fixed on the channel bed. The sensor was calibrated in order to transform the signal into bedload sediment transport rates. The calibration was carried out by taking direct bedload samples using Bunte samplers. Coarse sediment mobility was also investigated using natural clasts equipped with radio frequency identification transponders. The location and displacement length of transported clasts was detected using a portable antenna.

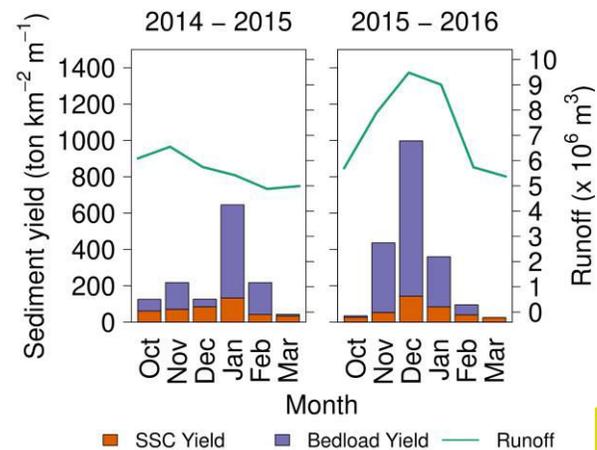
Site key annual data

Measuring period	2012-2018
Meteorological and hydrological data	
Air temperature (°C)	n.a.
Precipitation (mm)	570
Runoff (mm)	n.a.
Drainage basin wide denudation rates	
Solute yield* (t km ⁻² yr ⁻¹)	n.a.
Suspended sediment yield (t km ⁻² yr ⁻¹)	~400
Bedload yield (t km ⁻² yr ⁻¹)	~1000
*atmospherically corrected n.a. = not available	

Views of instrumentation and methods



Suspended and bedload transport yield grouped by month for two different ablation seasons (2014-15 and 2015-16)



Modified from Carrillo & Mao (2020).

Funds for the monitoring devices and activities were provided by CONICYT (ANID). We are grateful to the Chilean National Park Service (CONAF) for providing access to the sample locations and onsite support of our research.

