GIS and geomatics for hydrogeodiversity assessment of glaciated mountains: examples from the Western Alps (Italy) and the Coast Mountains (Canada)

Luigi Perotti[1], Manuela Lasagna[1], Gilda, Carraro[1]
Cristina Viani[1], Federico Tognetto[1], Domenico De Luca[1]
Gioachino Roberti[2], Marco Giardino[1]

(1) University of Torino, Earth Sciences Dept., Italy
(2) Minerva Intelligence, Vancouver, BC, Canada

luigi.perotti@unito.it

Università degli Studi di Torino

Dipartimento di Scienze della Terra
Università degli Studi di Torino

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Geological and geomorphological constrains to mountain geodiversity

Structure of the contribution

1. FOREWORD - Theoretical issues related to both spatial and temporal dimensions of natural components of the geo-environmental system

2. METHODS - Systematization of knowledge related to geodiversity of mountains (issues related to scale of analysis and representation)

3. RESULTS – GIS mapping and qualitative-quantitative assessment of geodiversity (Examples from glaciated/deglaciated mountains of Europe and Canada)

4. DISCUSSION - Classification and presentation of components of mountain geodiversity based on their spatial and temporal dimension, and the related geomatics tools

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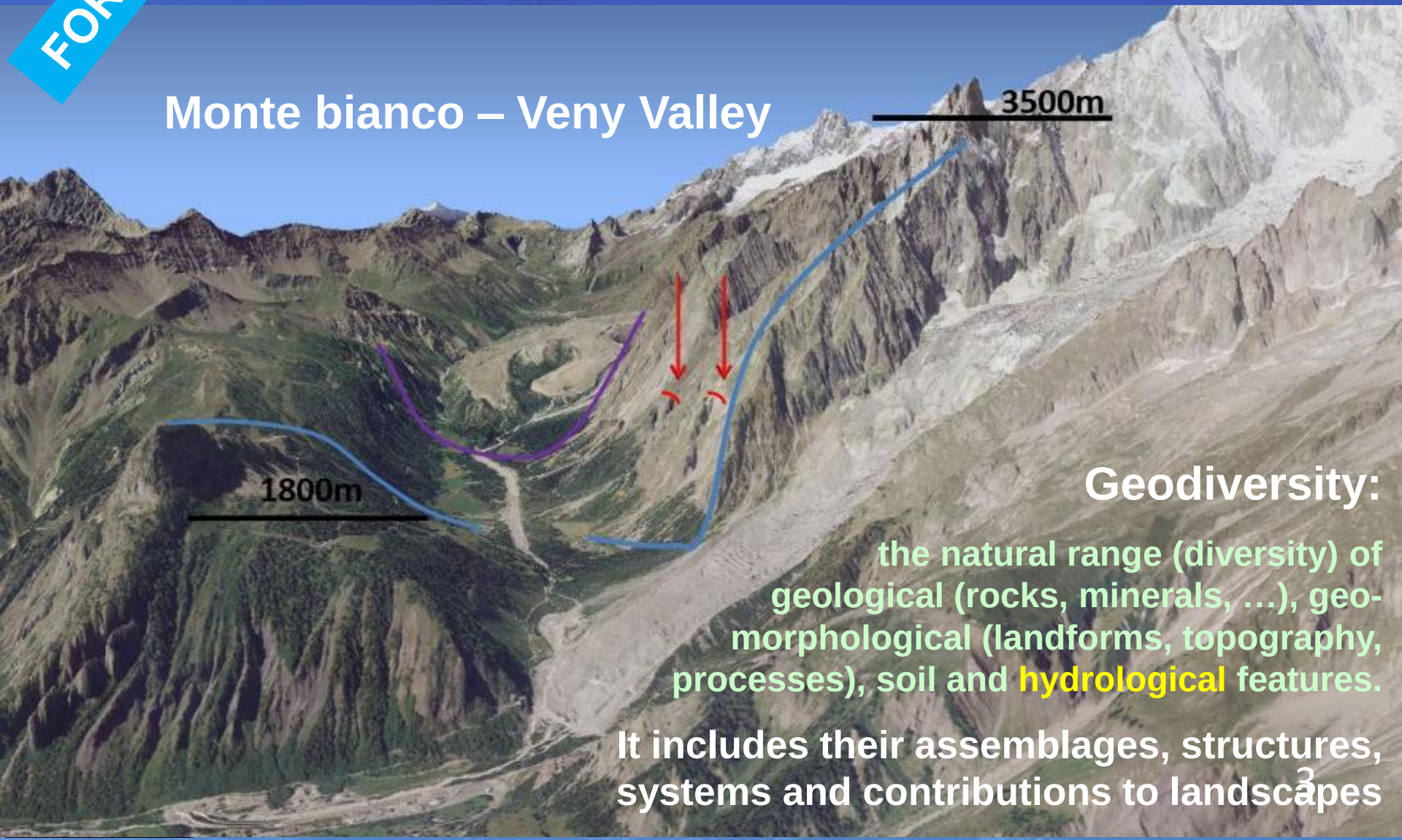
FOREWORD

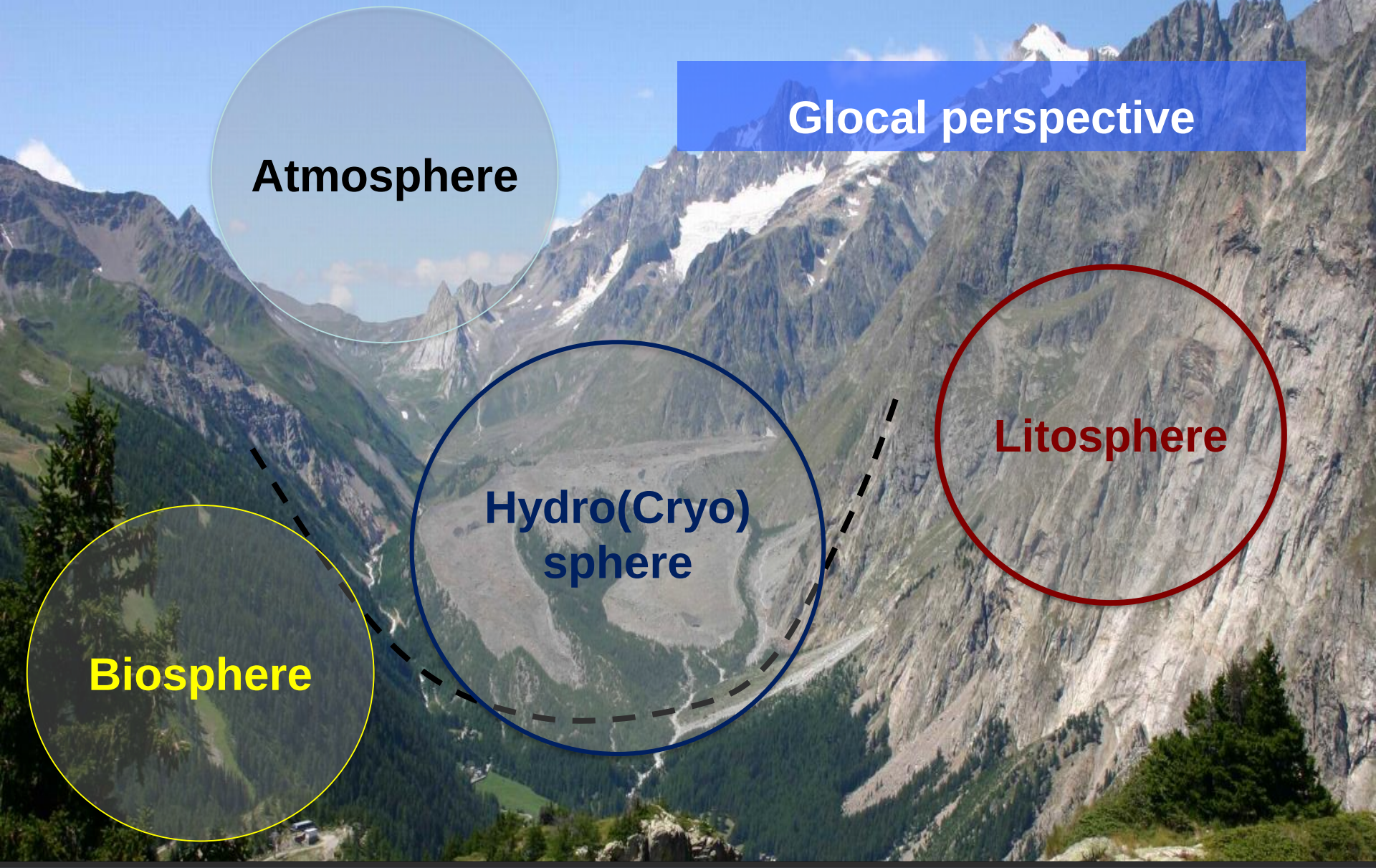
Geological, geomorphological, …, *(E.g. many)* constrains to mountain (hydro)Geodiversity



Geodiversity:

the natural range (diversity) of geological (rocks, minerals, …), geomorphological (landforms, topography, processes), soil and hydrological features.

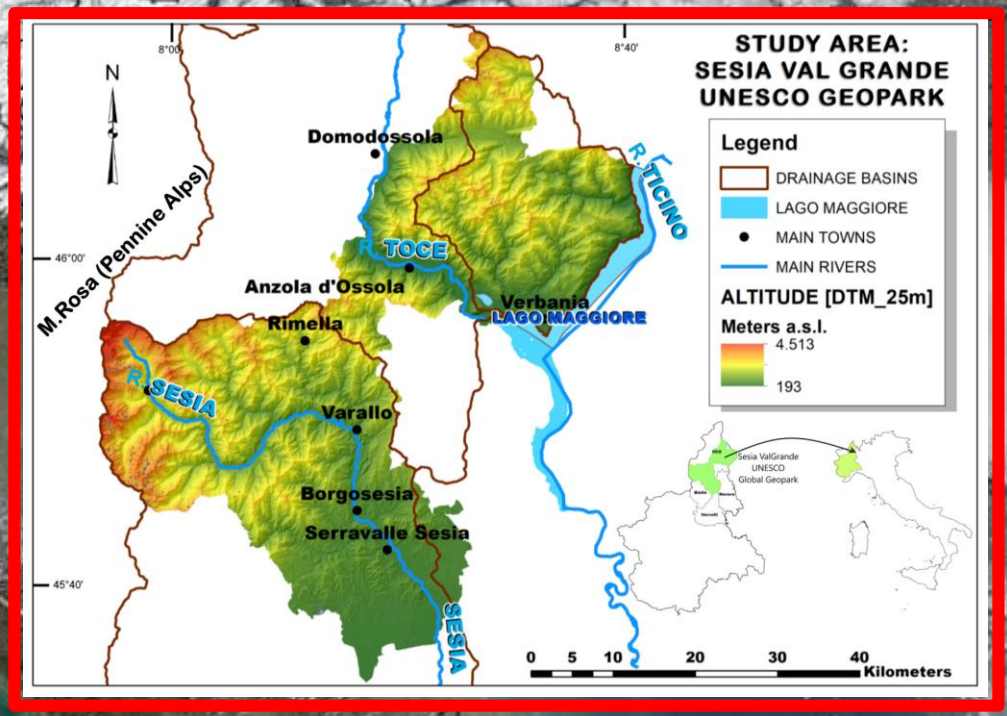
It includes their assemblages, structures, systems and contributions to landscapes



Conceptual framework at a global scale, field mapping and remote sensing at regional and local scales

Western Alps, Piemonte Region, Italy

Sesia Val Grande UGG



Coast Mountains, BC, Canada

The study area is on the Mount Meager Volcanic Complex (MMVC), 200 km N of Vancouver

Structure of the presentation

1. FOREWORDS on Geodiversity Glocal Approach

1. **METHODOLOGY – Assessment of regional geodiversity connected to hydro(cryo)sphere by means of: 1) base data acquisition and mapping; 2) qualitative-quantitative GIS process (factor maps, map algebra, comparison to ecosystem services)**

2. RESULTS – Hydrogeodiversity Assessment Map, Identifed hydrogediversity landscapes and promote their conservation,

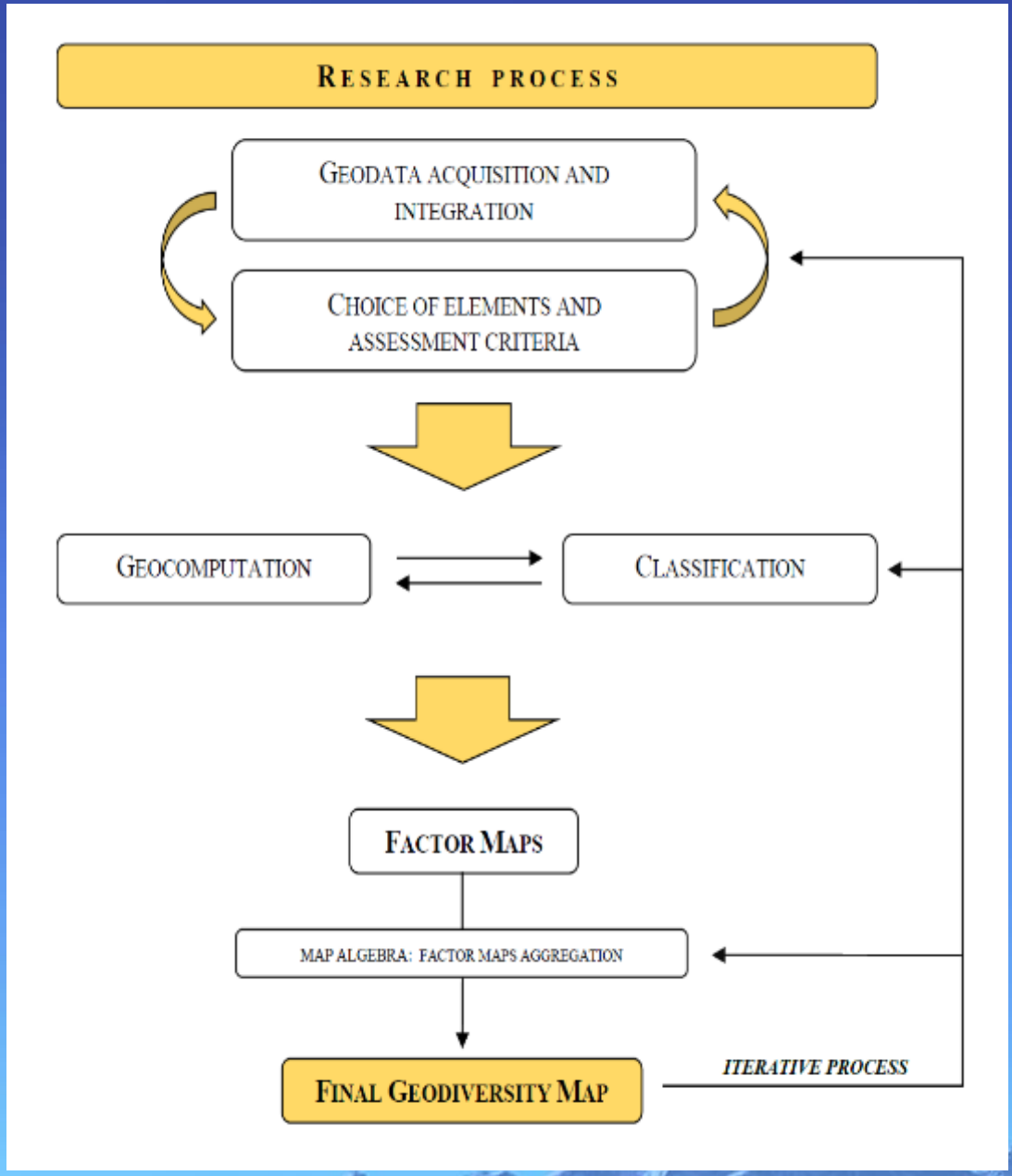
3. GENERALIZATION – Examples of dynamic geodiversity in the glacial environment of the Alps and effects of landscape and ecosystem services

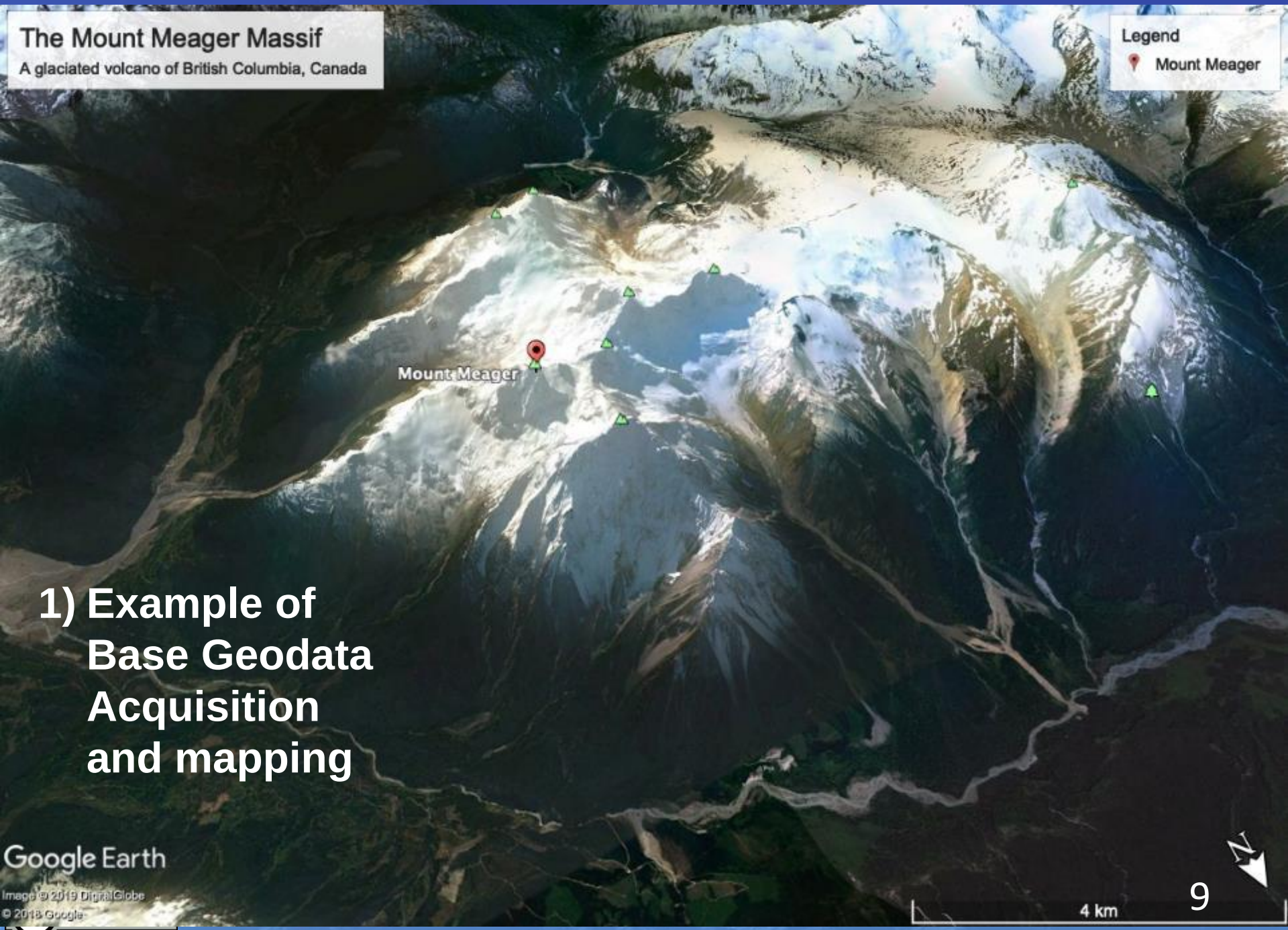
METHODOLOGY

1) Geodata Acquisition and mapping

2) Qualitative-quantitative GIS process (factor maps, map algebra, Zwolinsky et al., 2018)

Comparison of final hydrogeodiversity to ecosystem services





1) Example of Base Geodata Acquisition and mapping

Geodata acquisition and elaboration

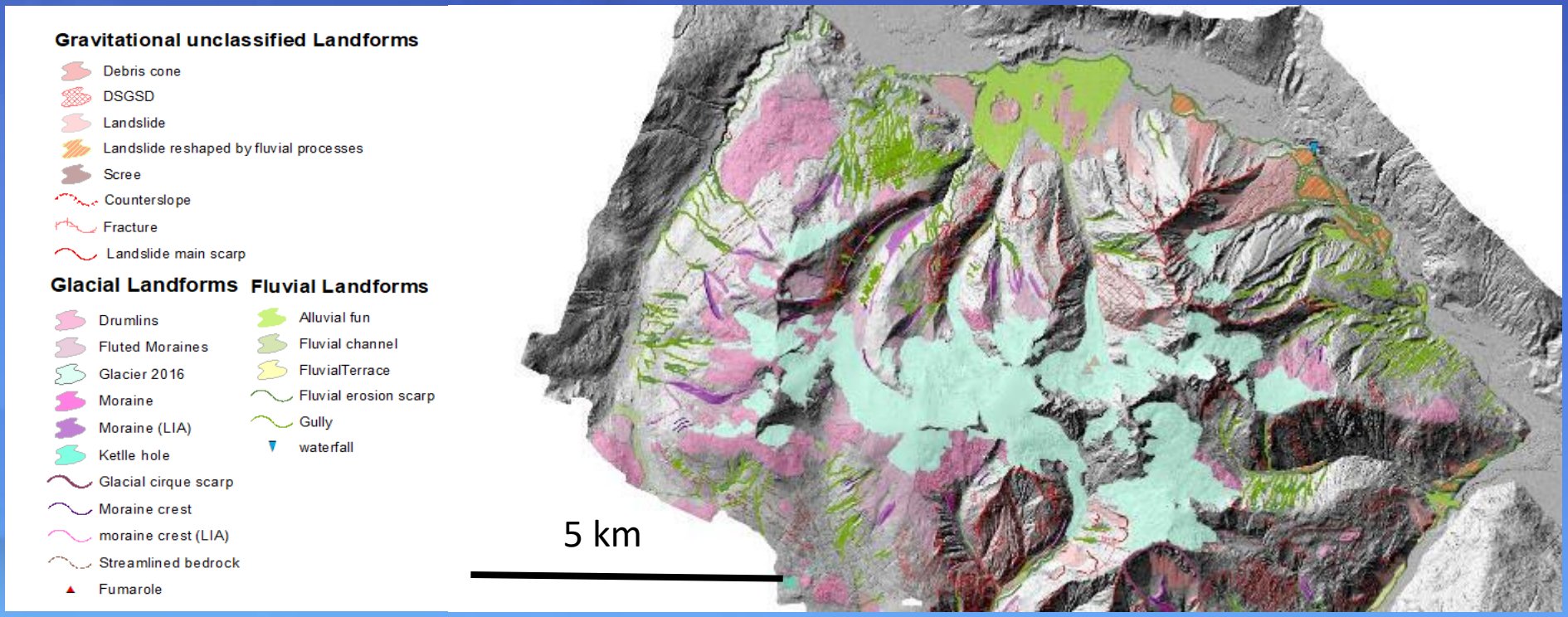
Data	Source Data	Year	File	GIS layer name
Thematic Layer	Geomorphological Geodatabase	2015	.gdb	Mount Meager landforms
	Glaciers	1947-2016	.shp	Glacier 1947…2016
Base Data	GLIMS	2009	.shp	Glacier GLIMS
	Lidar	2015-2016	.geotiff	DEM
	Multitemporal Orthophoto	1947-2006	.geotiff	Orthophoto 1947…2006

Total layers: **41**

Geomorphological map **Land system map**

Geomorphological Map

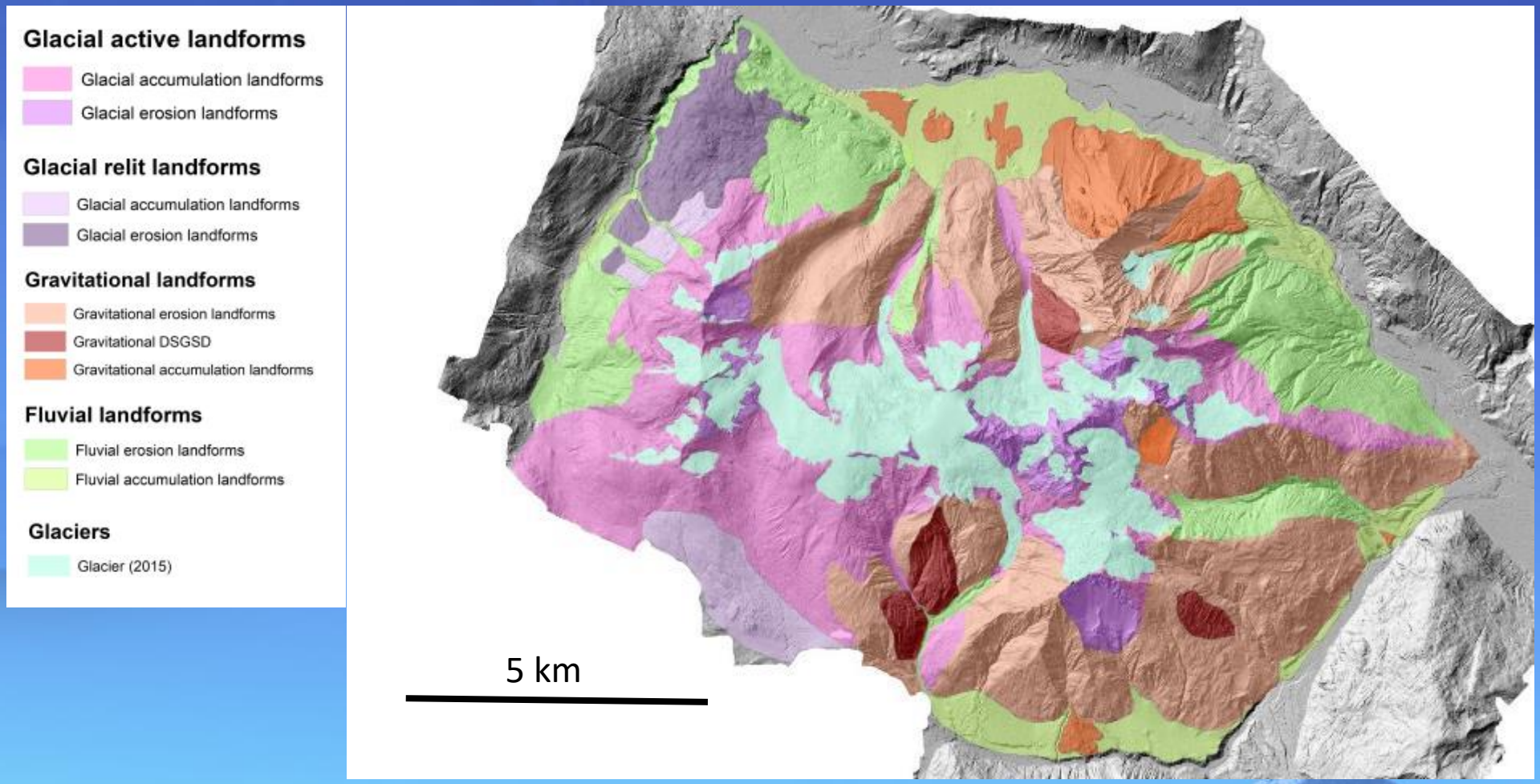
Mt. Meager Massif



Multi-Spatial Interpretation: Mount Meager Geomorphological setting

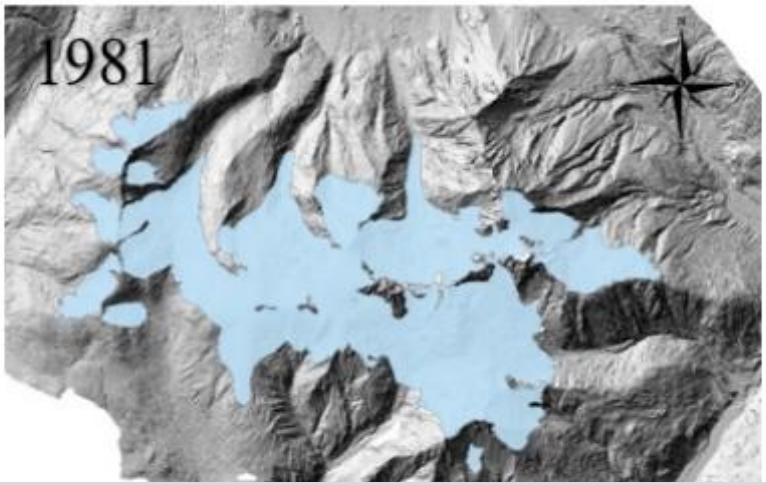
Land System Map

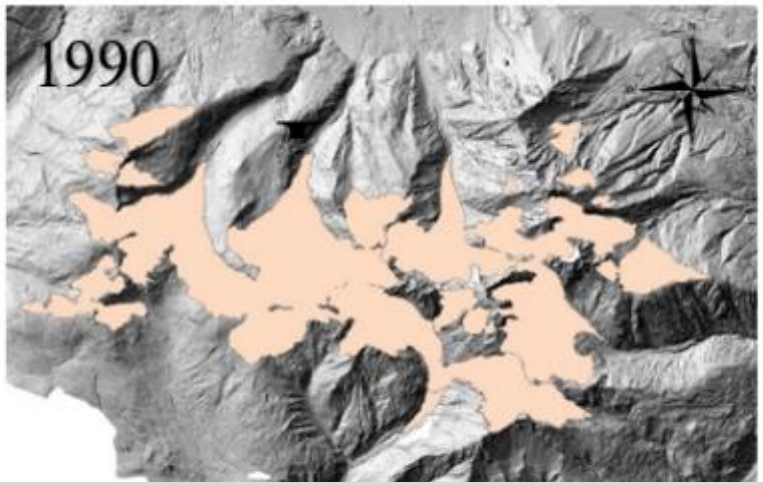
Mt. Meager Massif



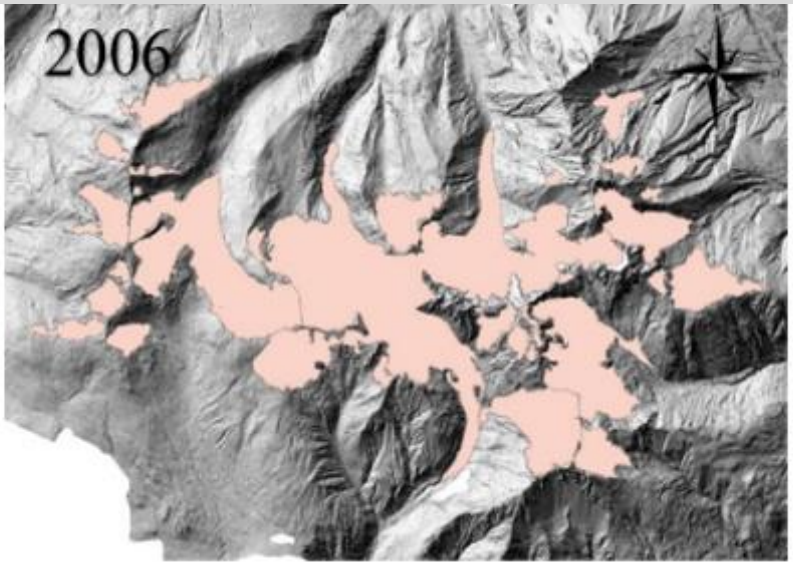
A land-systems map defines those areas, which certain predictable combinations of landforms and their associated soils and vegetation are likely to be found.

Multi-Temporal Interpretation: Mount Meager's glaciers

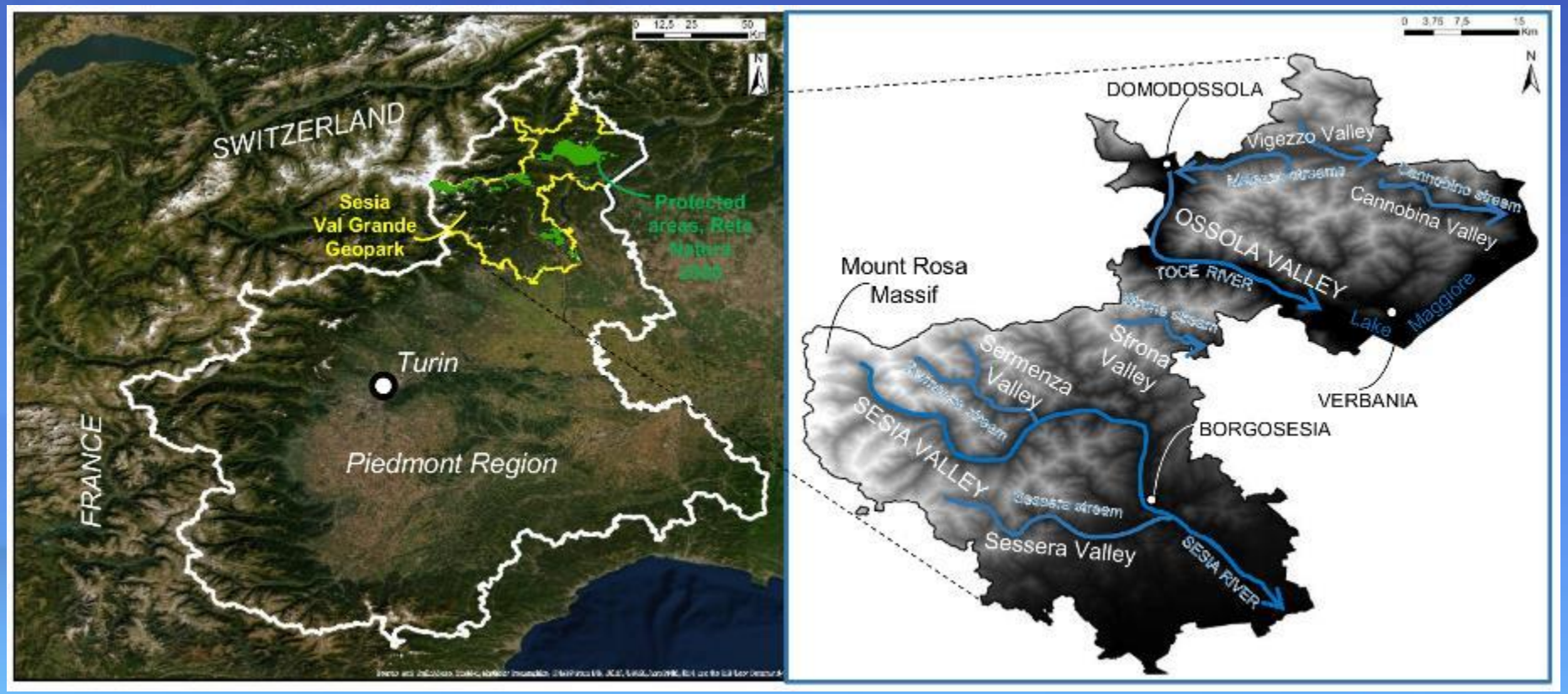




It was possible to document the glacial fluctuations that took place between 1947 and 2016, thanks to geomorphological analysis based on Orthophotos and DEM shaded relief model.



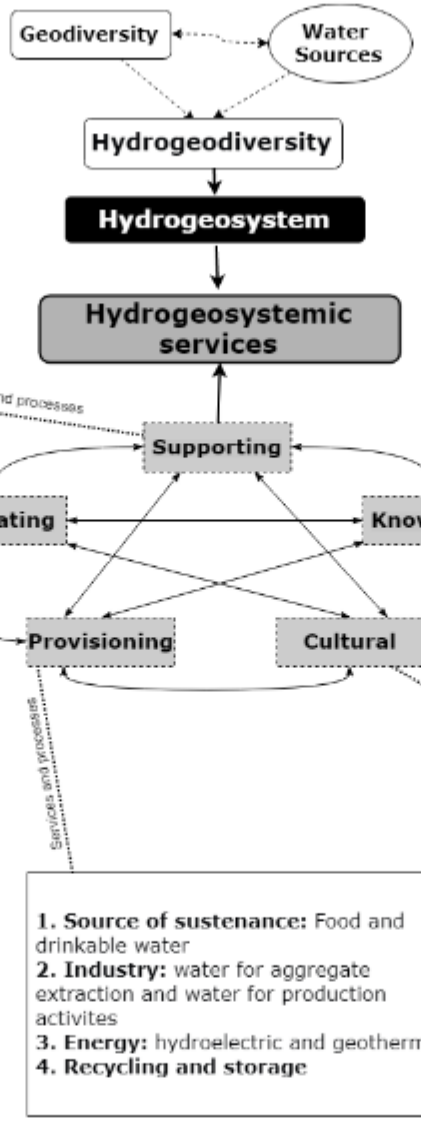
Sesia-Val Grande UNESCO Global Geopark



Choosen parametres for hydrogeodiversity assessment

Purpose	1°= COGNITIVE	1°: Define a conceptual structure of geodiversity linked to water resources
	2°= OPERATIONAL	2°: Identifed areas characterized by high hydrological geodiversity
Data Source	INDIRECT	CNR-REGIONE PIEMONTE [22] SIRI - REGIONE PIEMONTE[23] PPR PIEMONTE[24] ARPA PIEMONTE[25] AUTORITÀ DI BACINO PO[26] SESIA VAL GRANDE UGGp [27] CORINE LAND COVER [28]
Subject	SELECTIVE APPROACH	Choice of a set of components of the natural abiotic enviroment
Spatial Scale	REGIONAL	Analysis Scale 1:100.000
Time Scale	CURRENT	Most updated data
Evaluation Criterion	RELATIVE	Hydrogeosystem services, human-centred
Evaluation Technique	MIXED= QUANTITATIVE-QUALITATIVE	Expert and automatic classification
Representation of the results of evaluation	CARTOGRAPHIC	ESRI ArcGis

METHODOLOGY



1. Water and groundwater storage
2. Soil processes and habitat provision: costitution of enviroments, infiltration rate, human settlements
3. Peat and fossil fuels storage

1. Evolution and terrestrial cycles: climatic dynamics, glacialism, fluvial-glacial dynamics, landforms origin
2. Research and environmental monitoring: origin of biological organisms, geophysics and georadar for groundwater research, monitoring of water quality and quantity
3. Local development and landscape conservation: hydrogeological risk management, educational and professional oportunities , development of skills for climate change adaptation strategies

1. Atmospherical processes:rainfall quantity, slope exposure, moisture regulation
2.Geological processes: conditioning of permeability, fracturation, mineral composition and soil types in groundwater quality and productivity, water surfacing
3. Geomorphological processes (fluvial, glacial, vulcanic processes): drainage density, oxigenation, deposit sediments, flow control, hot springs locationing, glaciers formation and dynamics
4. Antrophic processes: conditioning of cementification and overbuilding in riverbed permeability and lithological permeability,flow control,level base changes, groundwater productivity

1. Source of sustenance: Food and drinkable water
2. Industry: water for aggregate extraction and water for production activites
3. Energy: hydroelectric and geothermal
4. Recycling and storage

1. Development of cultural, spiritual and religious identities: sites such as bridges, waterfalls, caves that represent myths, legends related to the element of water or ice or sites theater of important historical or war events, sites of artistic inspiration, sites of wellbeing
2. Geotourism, sport and leisure: geo-touristic itineraries through hydrogeosites and hydrogeomorphosites, sports activities such as rafting, canyoing, sport fishing, ice climbing, snowshoeing, places for recreation: hot springs, hydrotherapy, bathing/swimming

The 4 main factors of hydrogediversity

1. Basement rocks and deposits permeability, integrated with Fracturing Index (tP), for the **Factor Map of Total Permeability**

2. Land use, integrated with Slope Instability Index (tLU), for the **Factor Map of Total Land Use;**

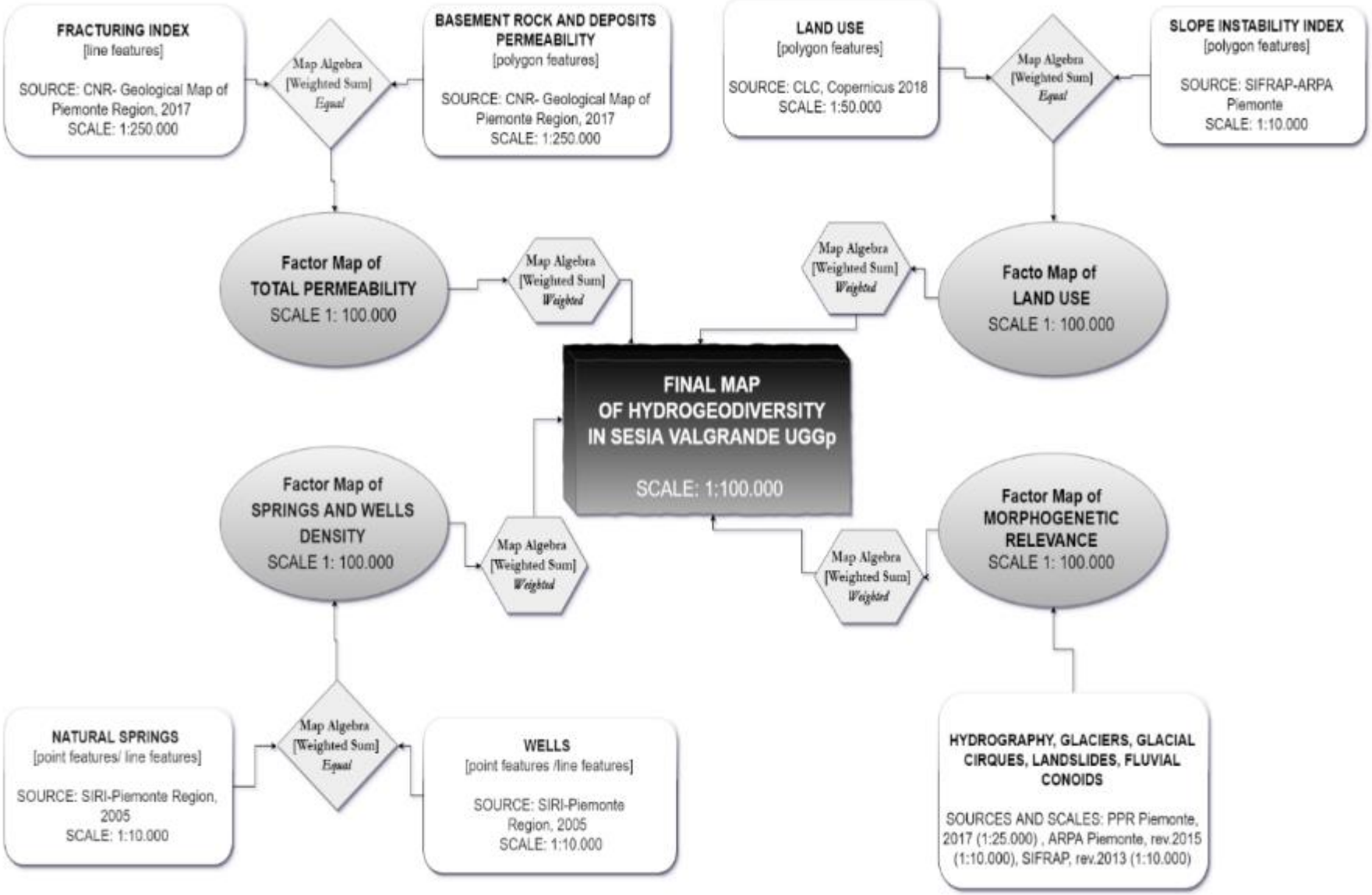
3. Springs and wells location (SWD) for the **Factor Map of Springs and Wells Density;**

4. Hydrography, glaciers location, glacial cirques, landslides and fluvial conoids location (MR) for the **Factor Map of Morphogenetic Relevance.**

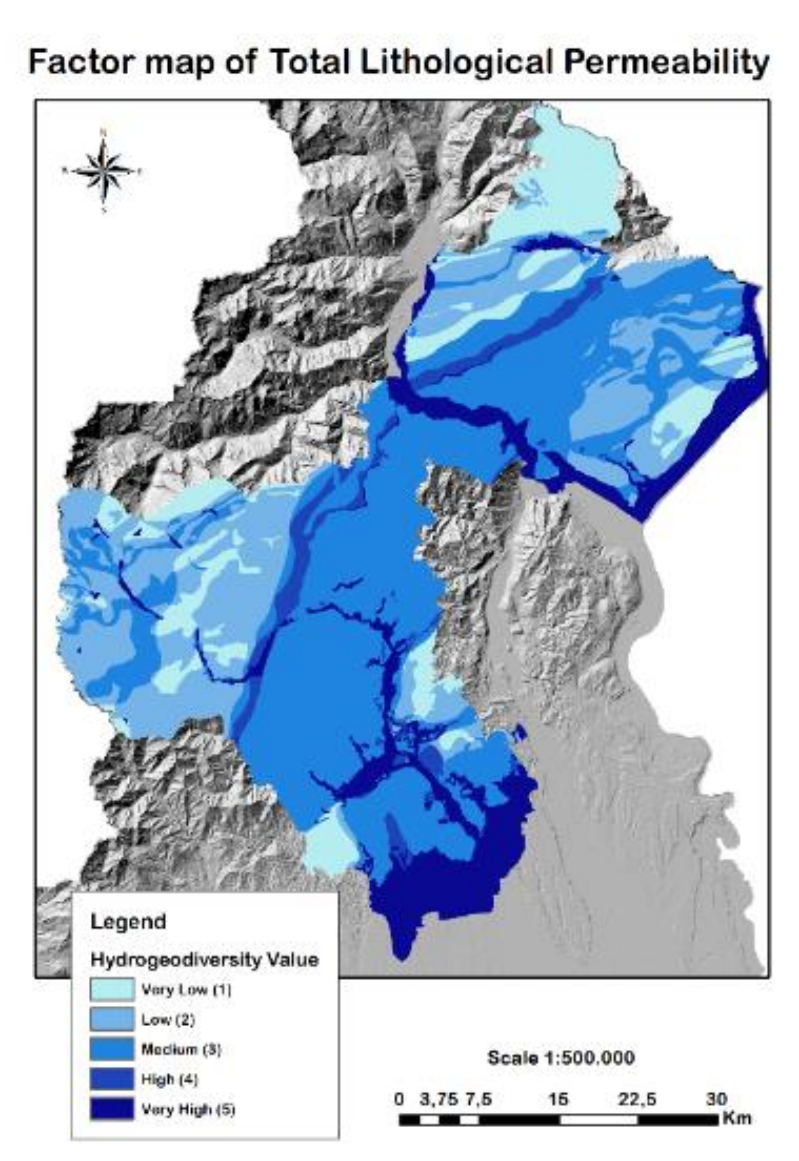
These factors represent the variables of the hydrogeodiversity (HGD) equation, that can be summarized as:

HGD = tP+tLU+SWD+MR

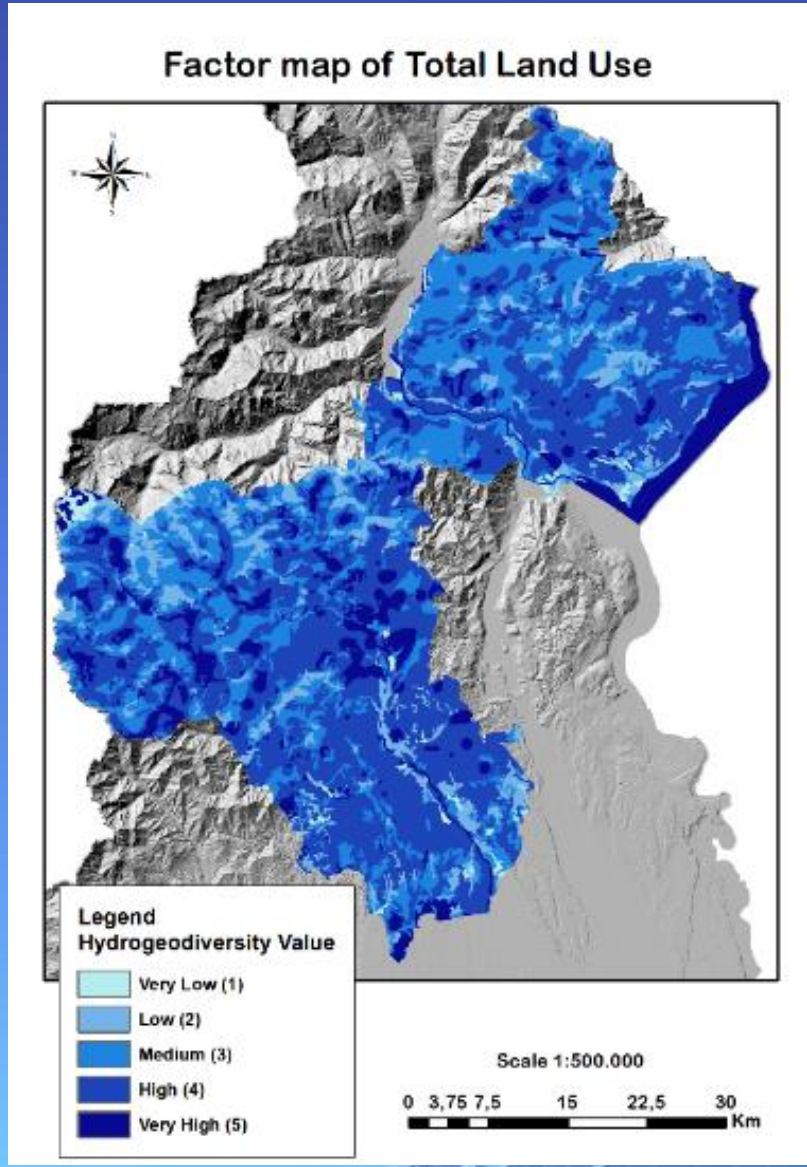
Hydrogediversity facto map construction scheme



Sesia Val Grande - Factor maps examples

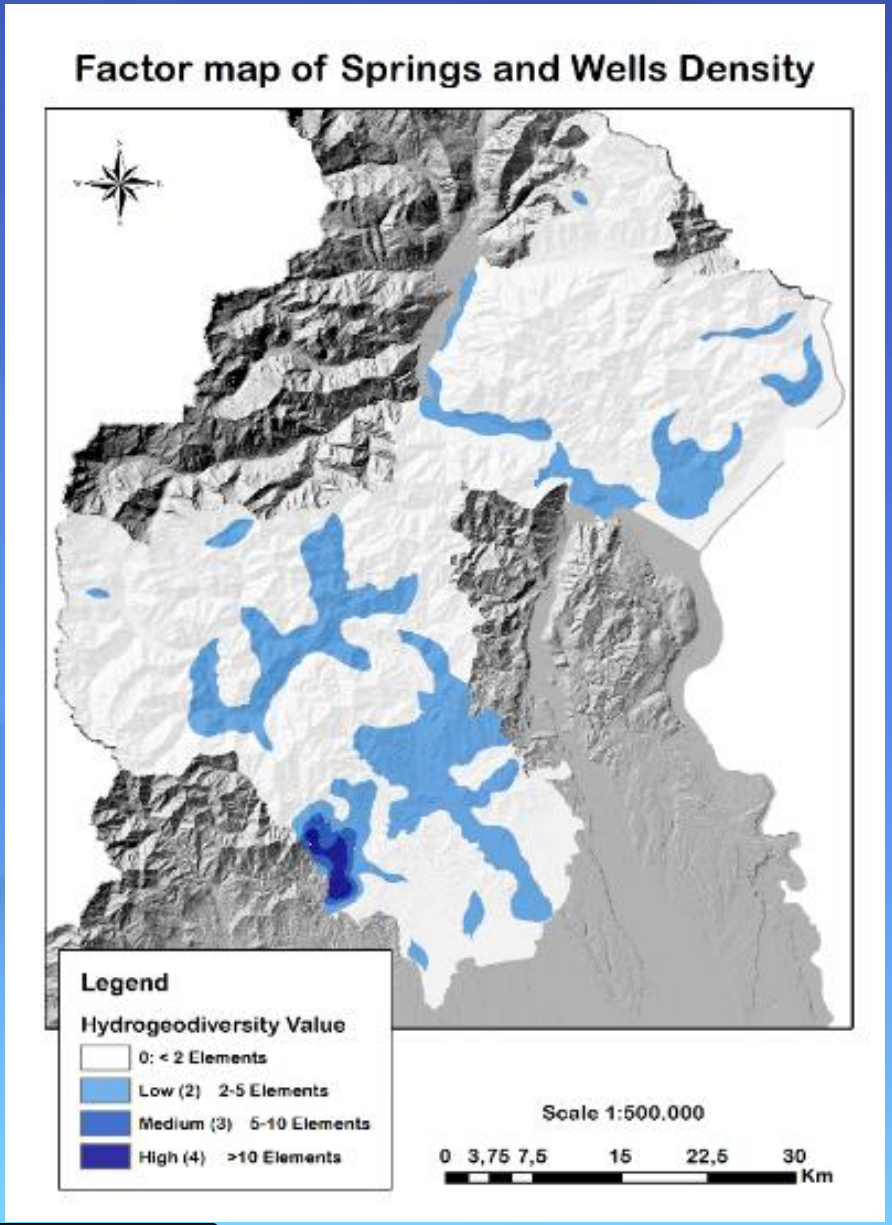


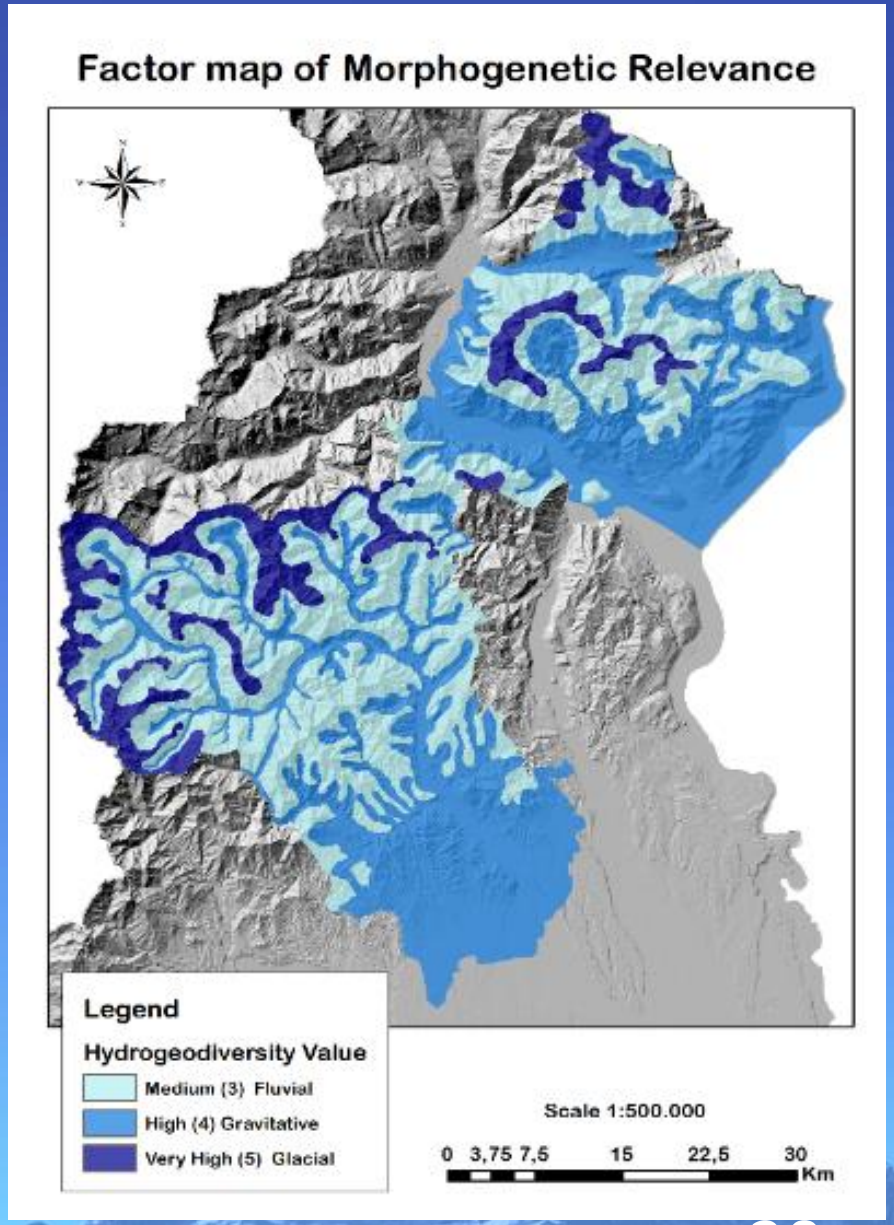
Factor map of Lithological Permeability integrated with Fracturing Index.



Factor map of Land Use integrated with Landslides Density Index.

Sesia Val Grande - Factor maps examples





Structure of the lecture

1. FOREWORDS on Geodiversity Glocal Approach

1. METHODOLOGY – Assessment of regional geodiversity connected to hydro(cryo)sphere (qualitative-quantitative GIS process: (factor maps, map algebra, comparison to ecosystem services)

2. **RESULTS – Hydrogeodiversity Assessment Map, Identifed hydrogediversity landscapes and promote their conservation,**

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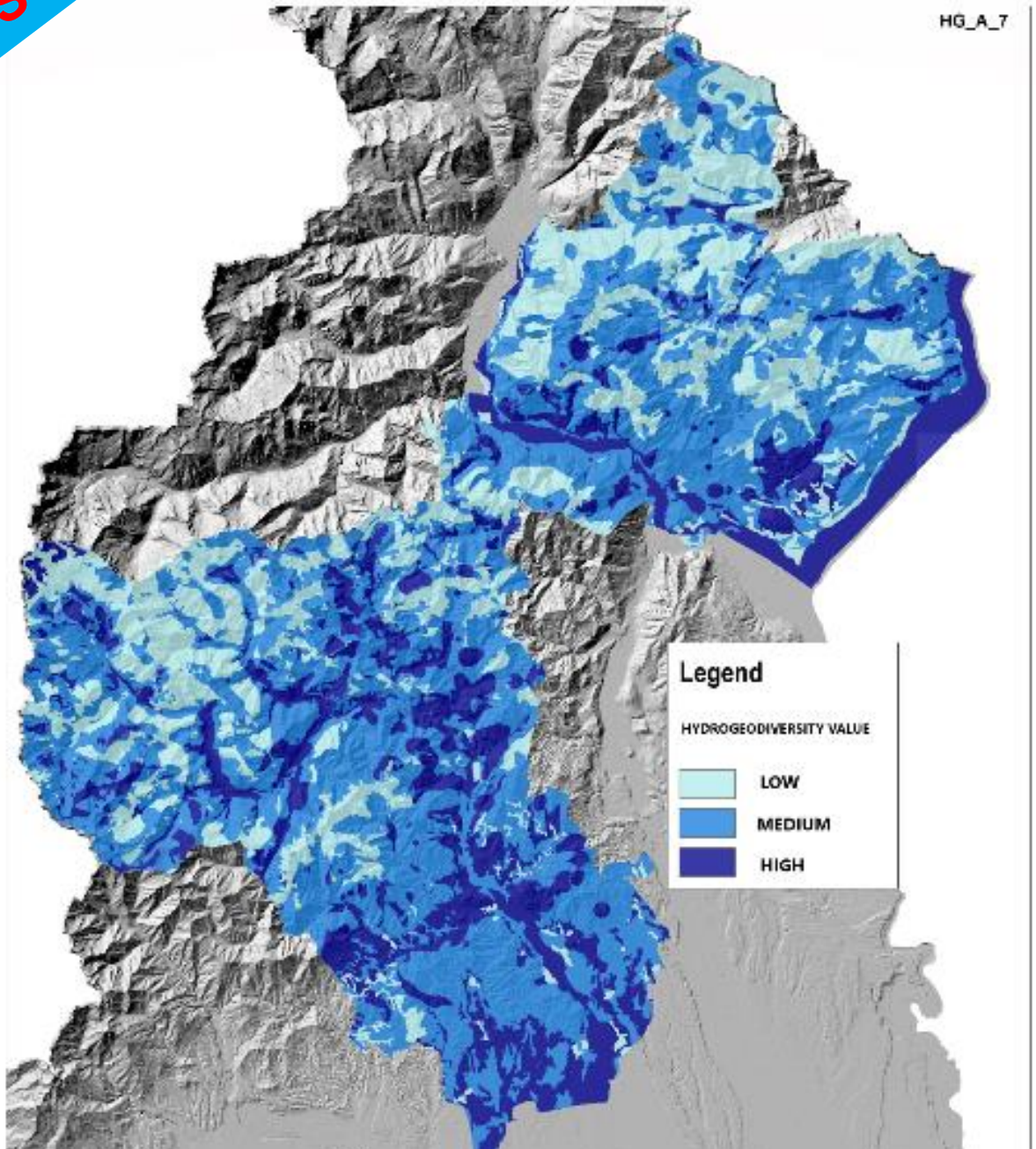
RESULTS

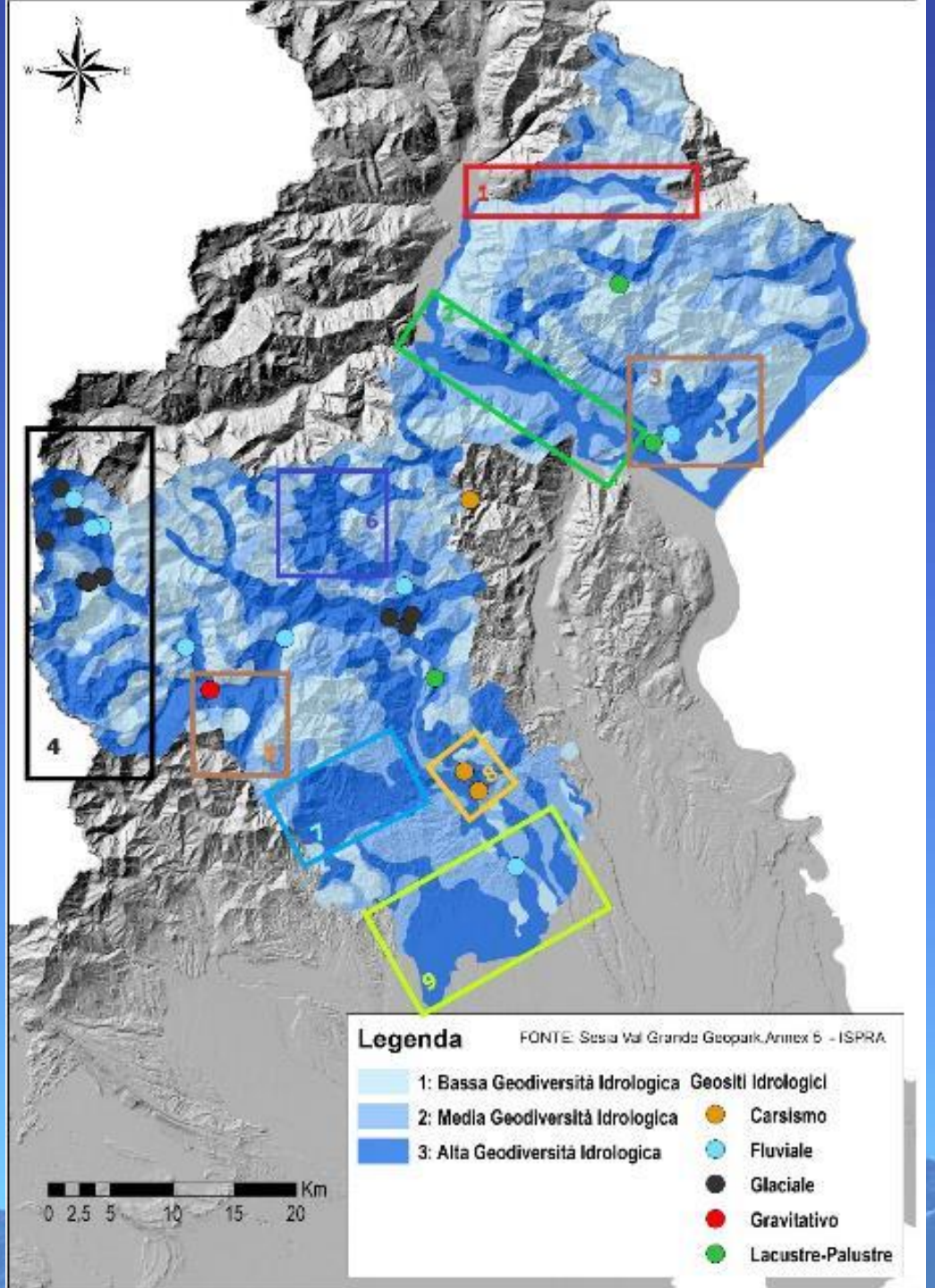
Hydrogeodiversity Map of the Sesia ValGrande UNESCO Global Geopark



RESULTS

Comparison of final hydrogeodiversity to ecosystem services

Focus on Glacial Landscape of Monte Rosa



RESULTS

HYD… …STEMIC SERVICES PROVIDED:

…ulating:

…limate: precipitation density, humidity and winds

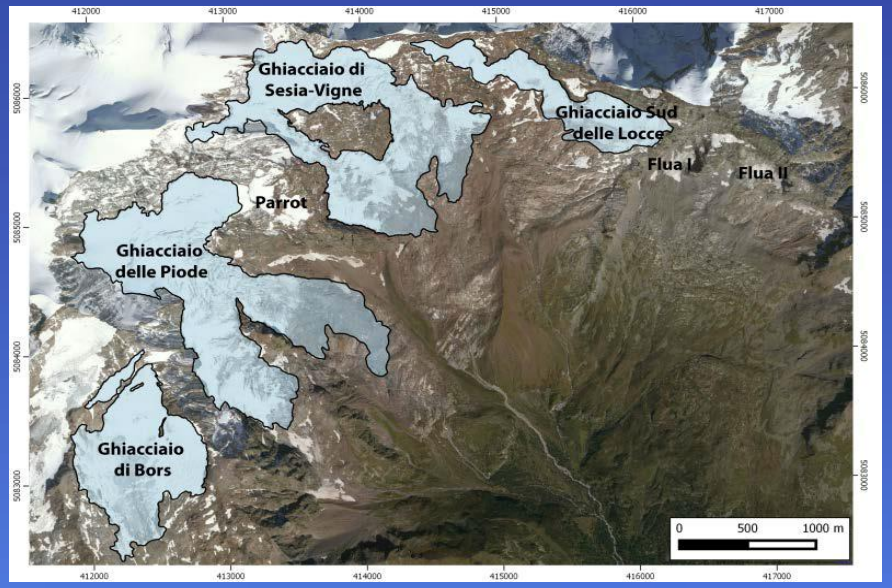
Geomorphology: flow of melt water and hydrographic network, slope stability

Support: surface water reserve and establishment of natural habitats (glacial, periglacial environments, rockwalls, lakes) and platforms for human settlement (basins and glacial valleys), pedogenesis.

Provisioning: drinkable water, energy.

Culture: places of spirituality, myth, conquest, artistic inspiration (*Dragon glacier, Fata Morgana in the Anthropocene*), Celebrations (*Rosario Fiorito).* GeoTourism, sports, leisure.

Knowledge: Glacial evolution and stages, current deglaciation, climate-sensitive landscape, adaptation strategies.



Geological and geomorphological constrains to mountain geodiversity

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2. METHODS - Systematization of knowledge related to geodiversity of mountains (addressing issues related to scale of analysis and representation)
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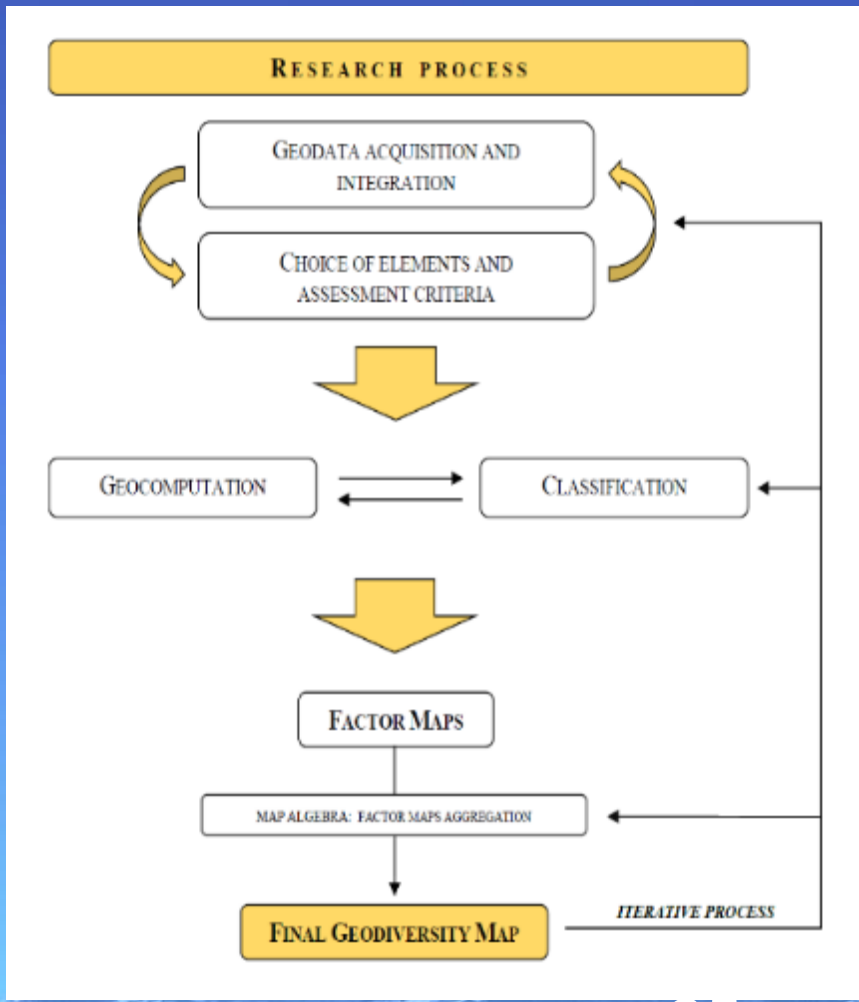
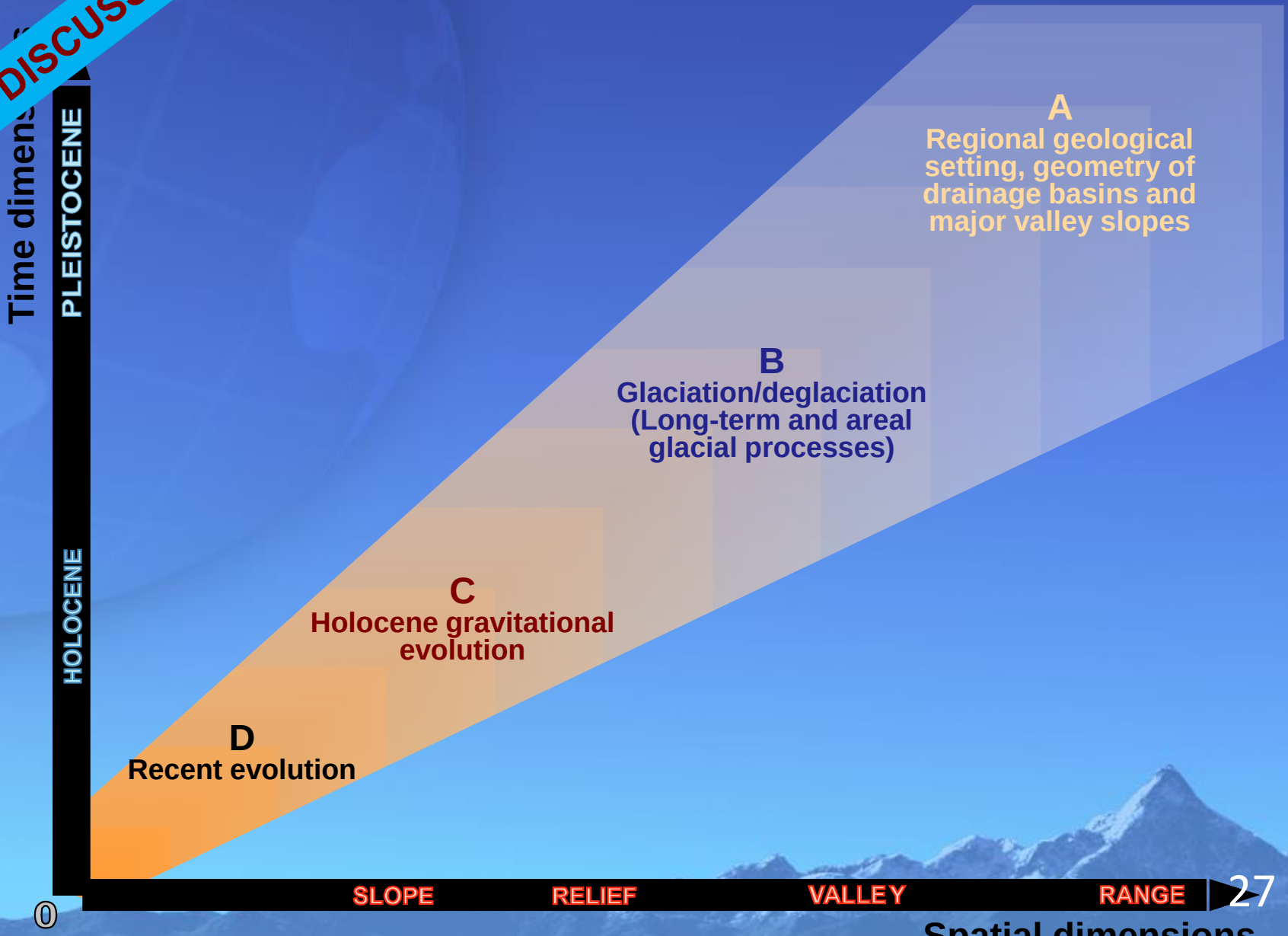
Tools for assessment of geodiversity



DISCUSSION

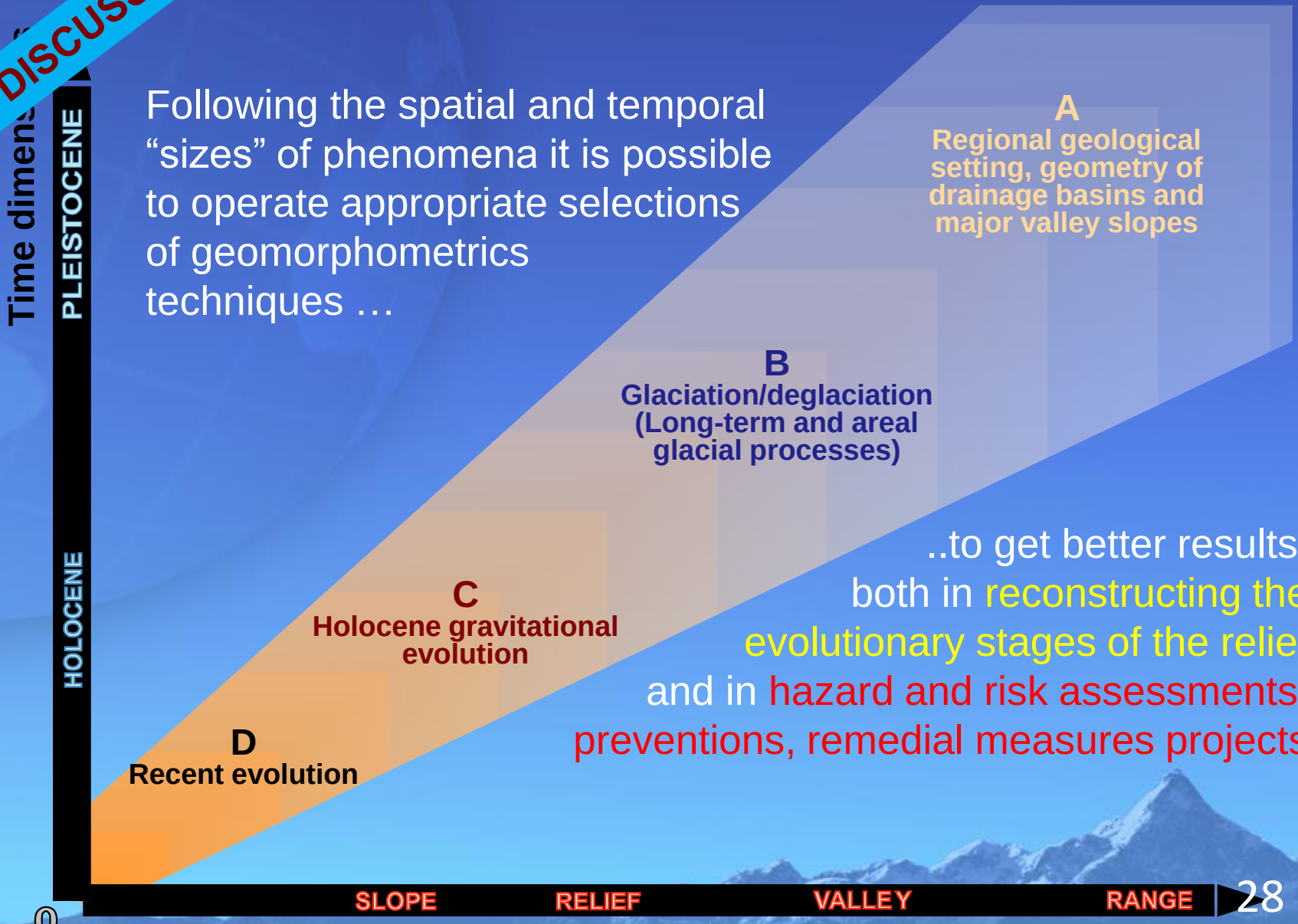
Possible outputs for analysys of geological and geomorphological contrainns to geodiversity in mountain areas



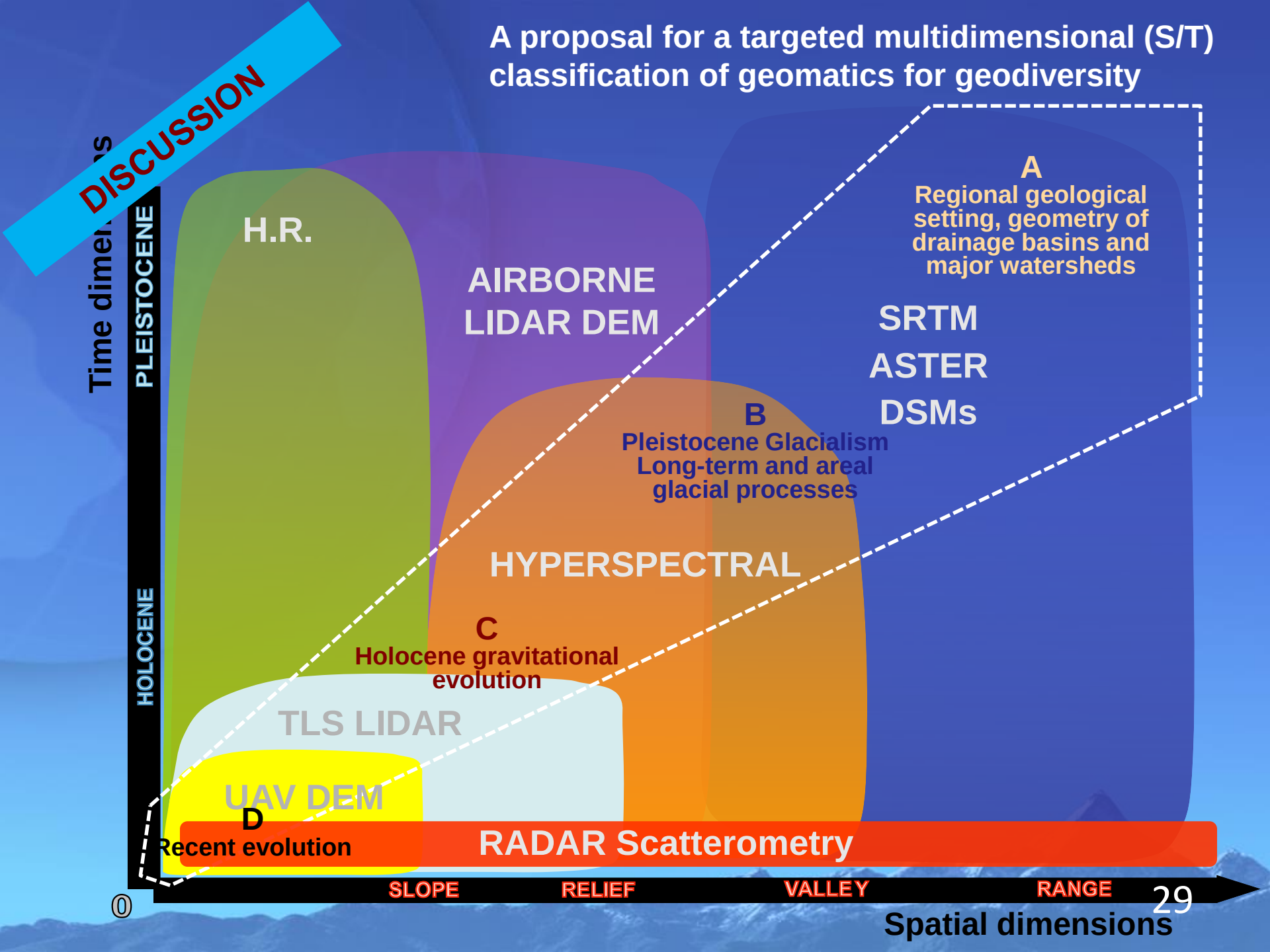
DISCUSSION

Possible outputs for analysys of geological and geomorphological contrains to geodiversity in mountain areas

Following the spatial and temporal "sizes" of phenomena it is possible to operate appropriate selections of geomorphometrics techniques …



..to get better results, both in reconstructing the evolutionary stages of the relief and in hazard and risk assessments, preventions, remedial measures projects


A proposal for a targeted multidimensional (S/T) classification of geomatics for geodiversity
DISCUSSION
Time dimensions
PLEISTOCENE
HOLOCENE
H.R.
AIRBORNE LIDAR DEM
SRTM
ASTER
DSMs
A
Regional geological setting, geometry of drainage basins and major watersheds
B
Pleistocene Glacialism
Long-term and areal glacial processes
HYPERSPECTRAL
C
Holocene gravitational evolution
TLS LIDAR
UAV DEM
D
Recent evolution
RADAR Scatterometry
0
SLOPE
RELIEF
VALLEY
RANGE
Spatial dimensions
29