



# Global change impacts on ecosystem services of mountain grassland

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# Benefits from mountain grassland

Hazard  
regulation

Climate  
regulation

Recreation

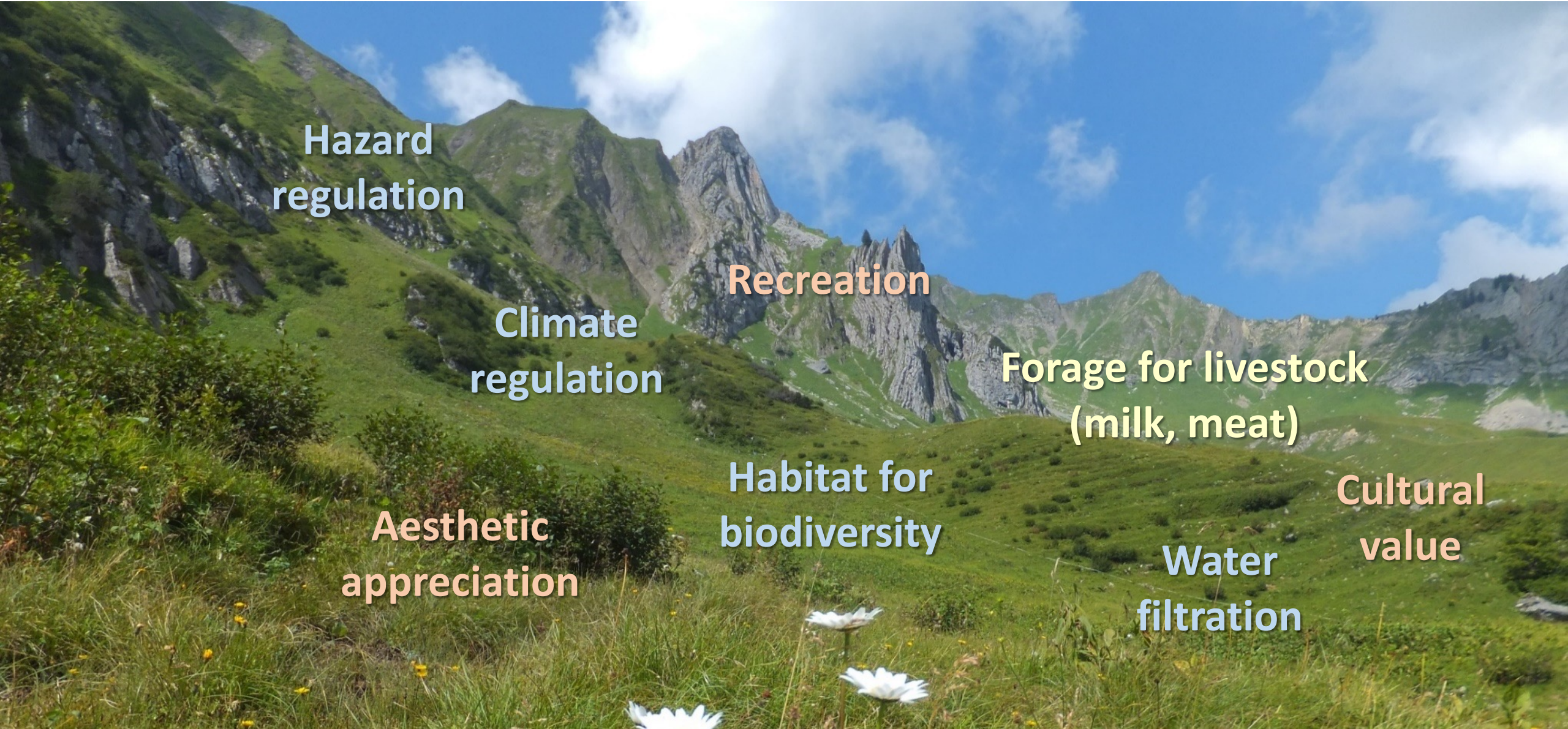
Forage for livestock  
(milk, meat)

Aesthetic  
appreciation

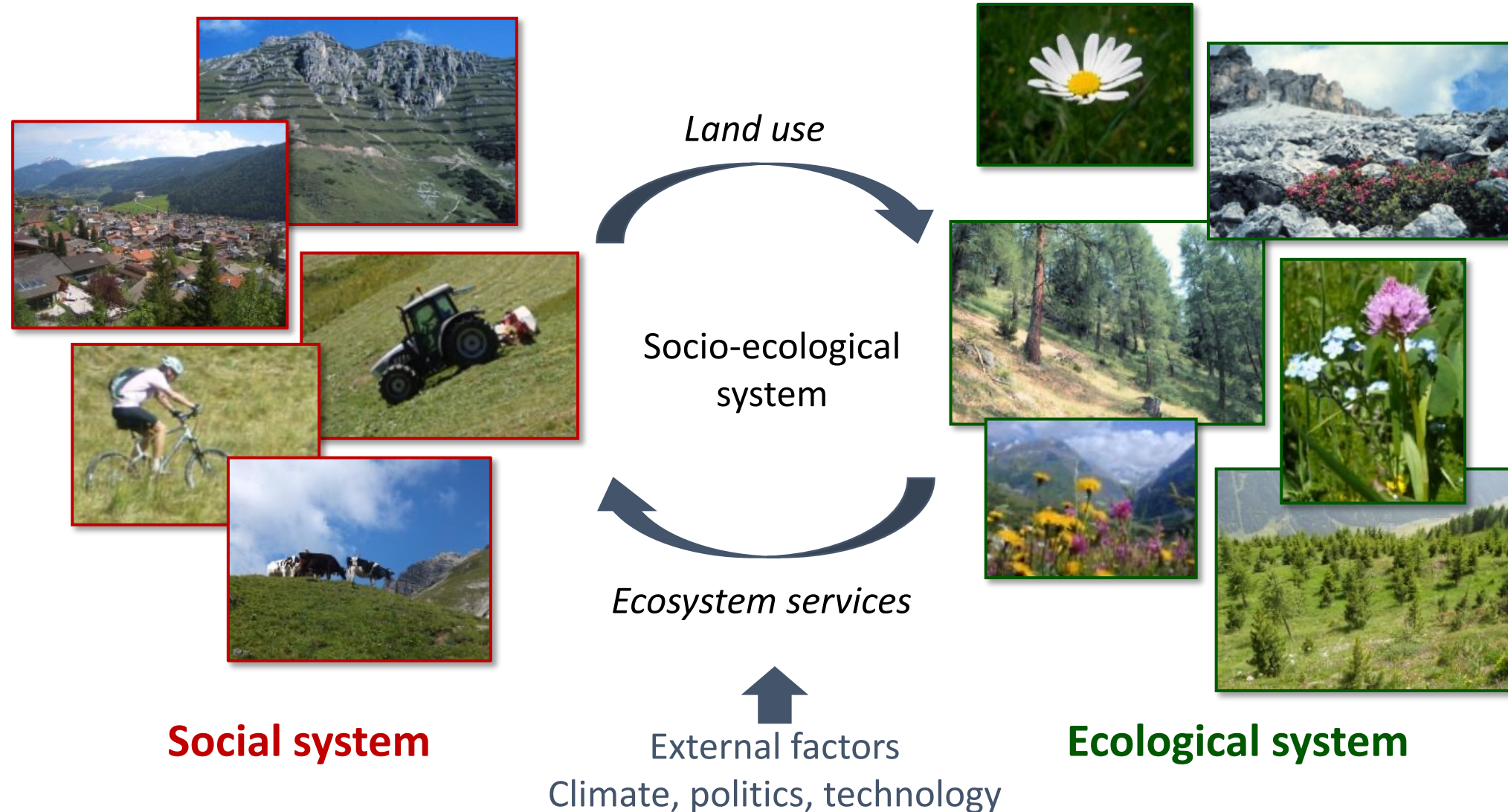
Habitat for  
biodiversity

Water  
filtration

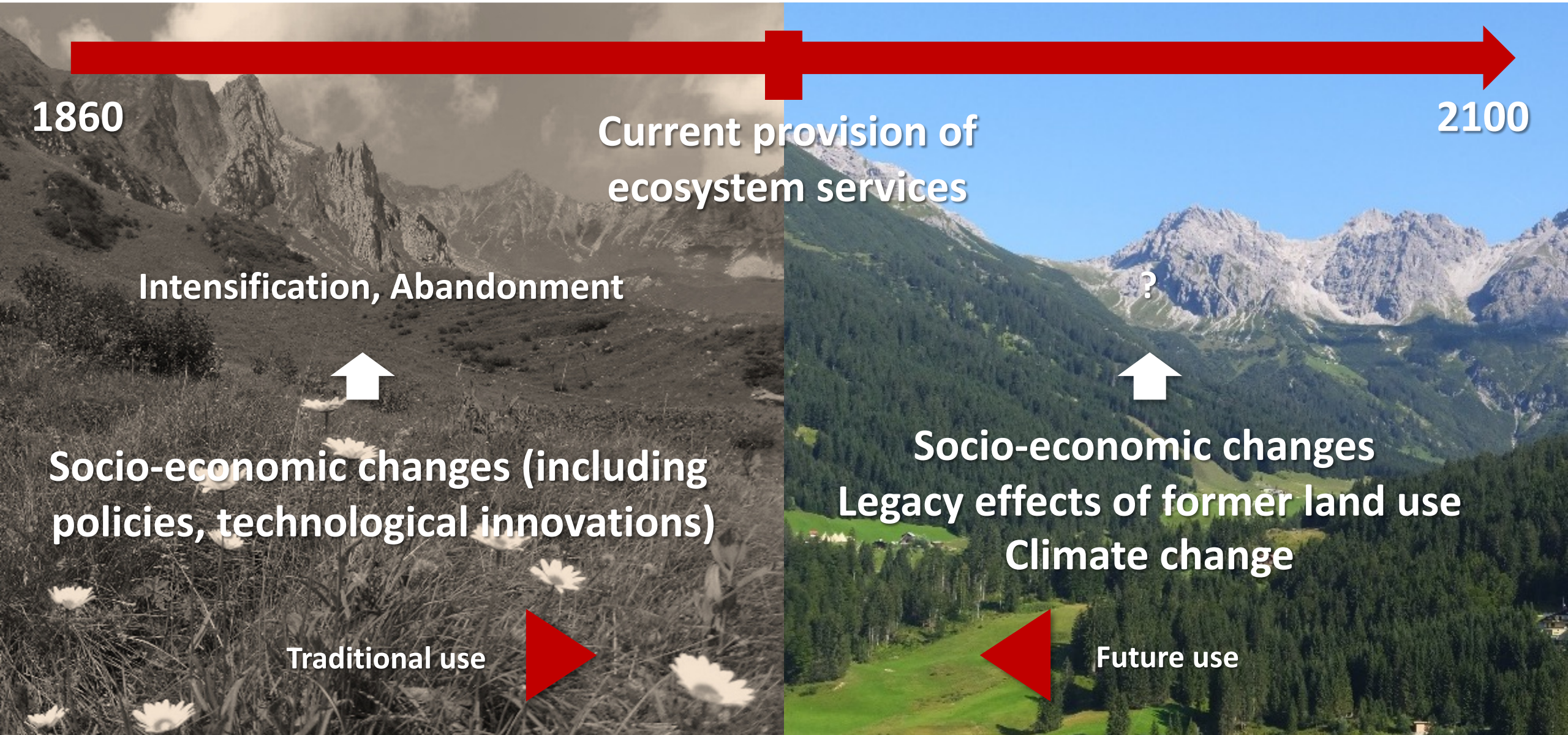
Cultural  
value



# Socio-ecological system

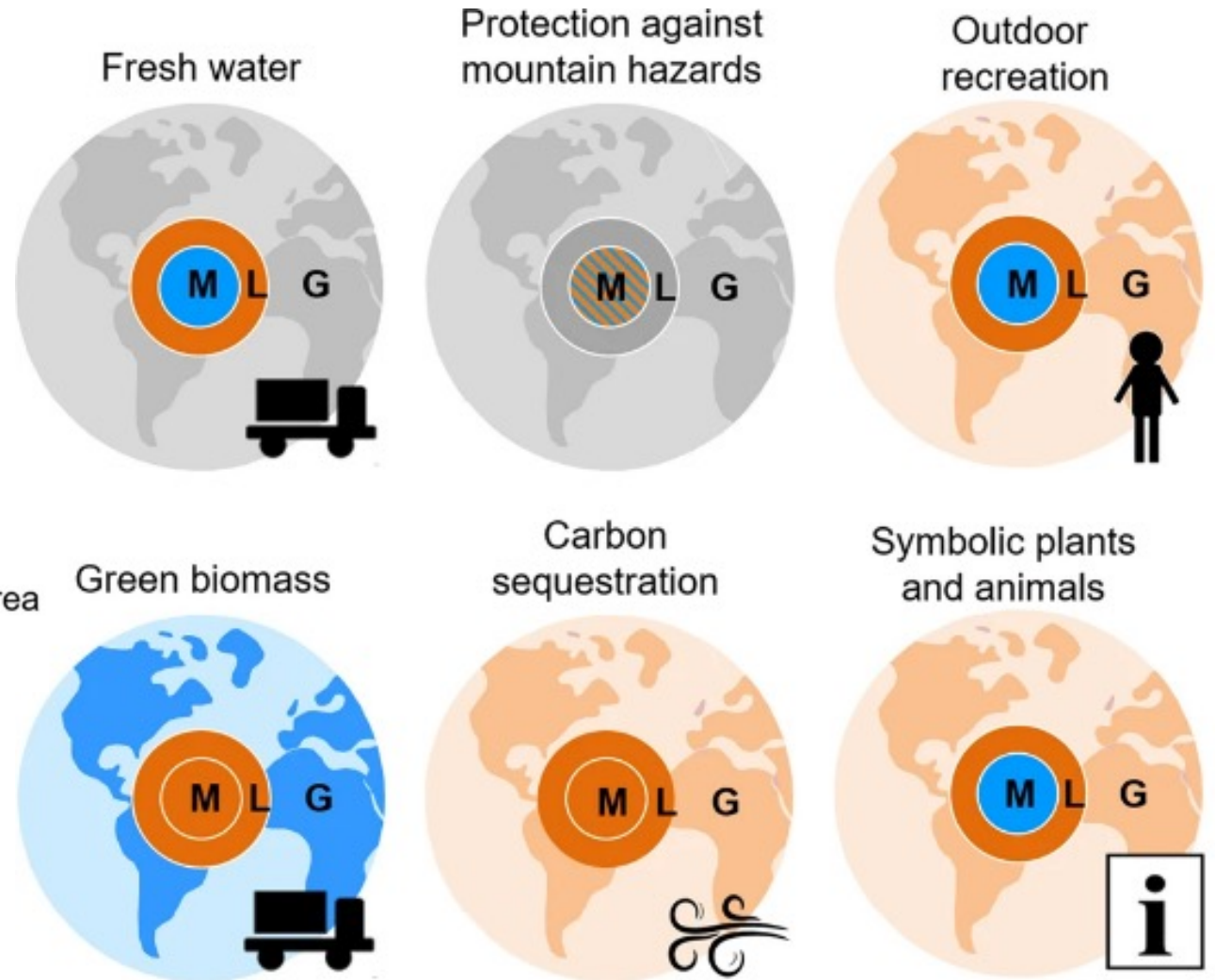


# Drivers of change



# Spatial relationships of ecosystem services

Mountain regions supply abundant and diverse ecosystem services to people within and beyond mountain regions







## Ecosystem service balance

- supply > demand
- demand > supply
- not applicable

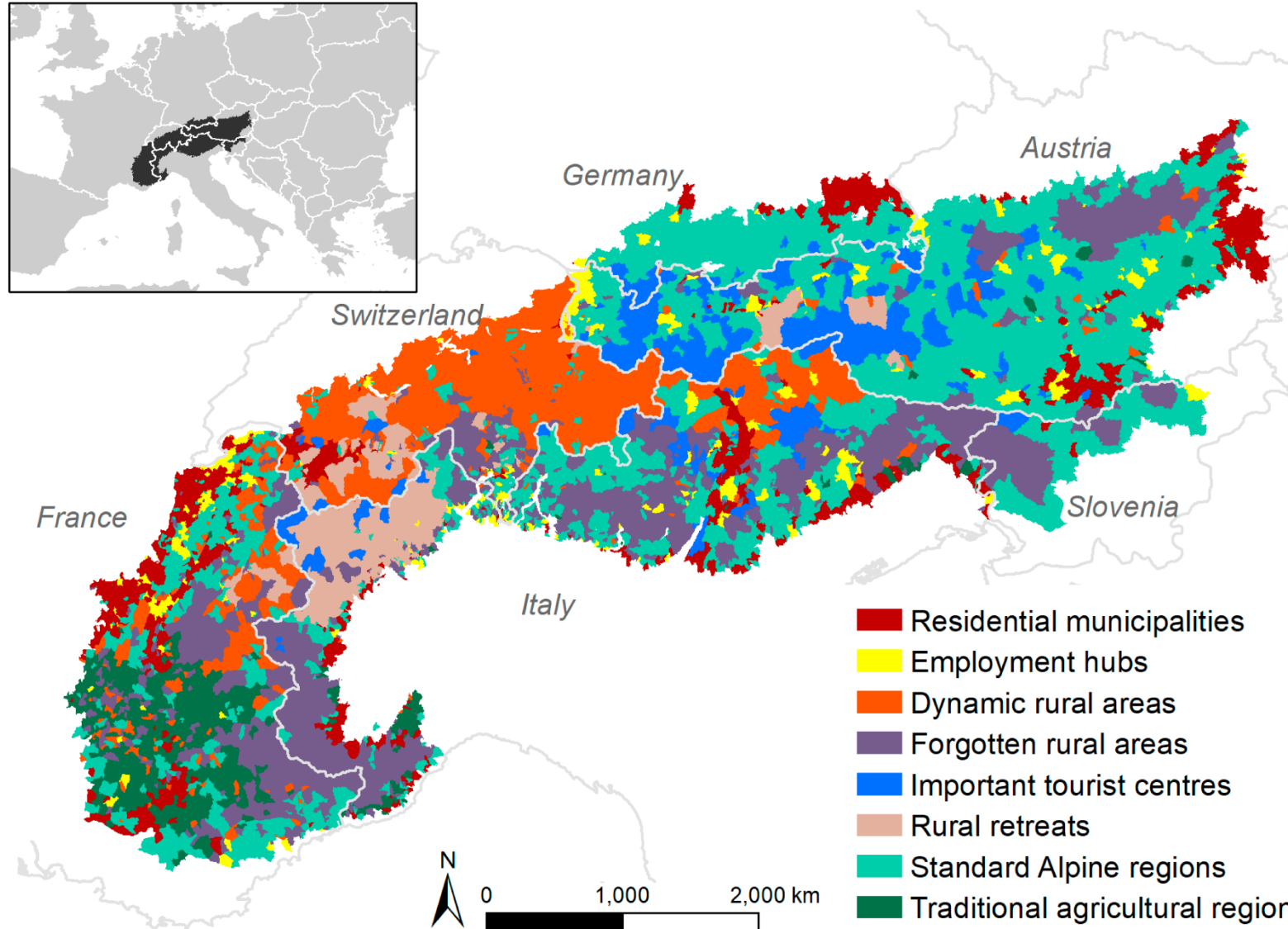
## Spatial reference

- M** mountain area
- L** surrounding lowland area
- G** global

## Transportation process

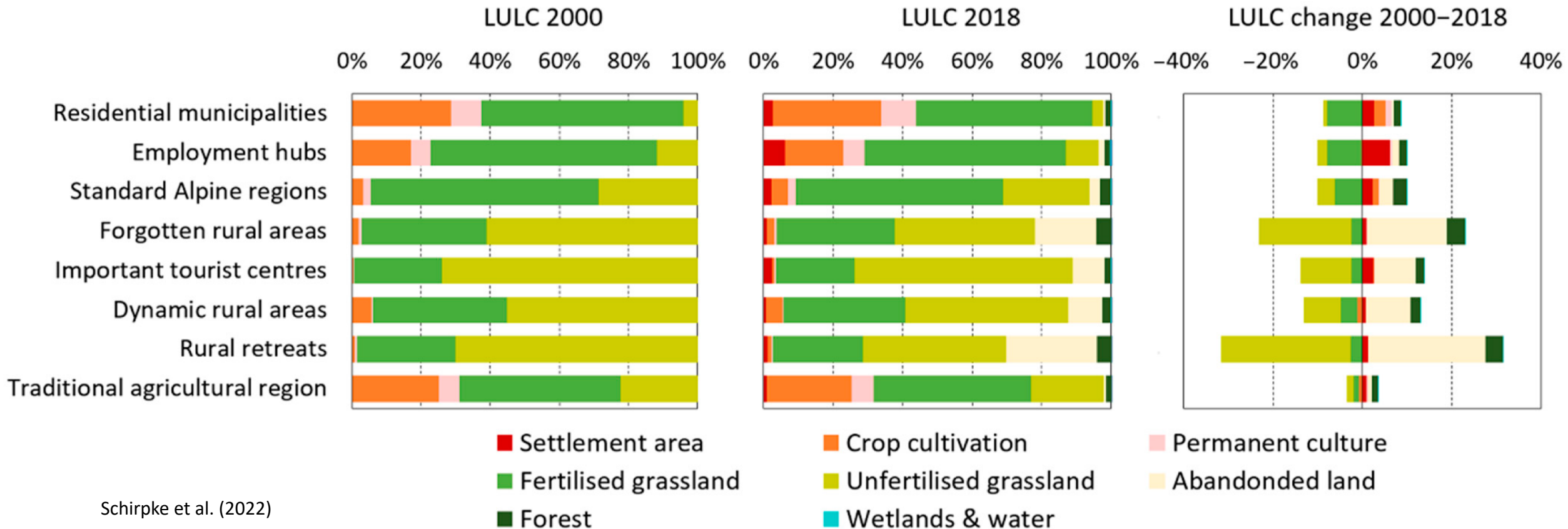
-  1) transport through human infrastructure
-  2) passive biophysical transport
-  3) active movement of people
-  4) transfer of ideas or information

# Case study 1: European Alps



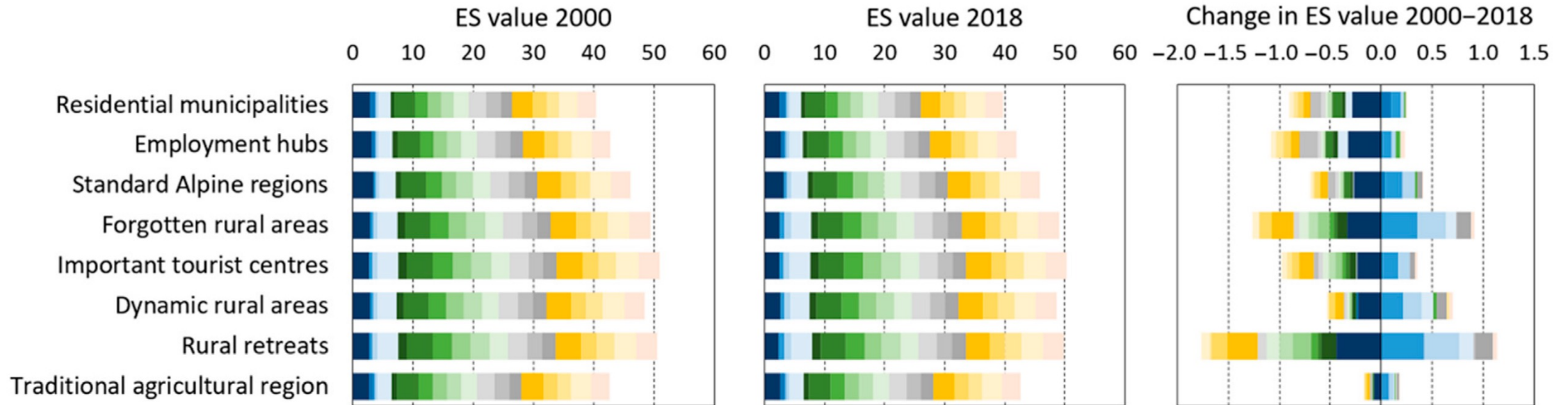
## Agrarian Structure Regions (ASR) in the European Alps

# Land cover change between 2000 and 2018



Schirpke et al. (2022)

# Impacts on ecosystem services



## Provisioning ES

- Pasture and fodder production (P1)
- Agricultural food production (P2)
- Timber production (P3)
- Gathering mushrooms and wild berries (P4)
- Provision of clean drinking water (P5)

## Regulating ES

- Protection from hazards (R1)
- Prevention of water scarcity (R2)
- Provision of habitats (R3)
- Maintaining biodiversity (R4)
- Providing habitats for pollinating insects (R5)
- Pest control (R6)
- Disease control (R7)
- Maintenance or increase of soil fertility (R8)
- Positive effect on the climate (R9)

## Cultural ES

- Opportunities for leisure activities (C1)
- Attractive housing and living space (C2)
- Experience of animals & plants (C3)
- Aesthetic inspiration (C4)
- Cultural heritage (C5)



# Case study 2: South Tyrol (Italy)



## Socio-economic scenarios

### Business as usual (BAU)

Land use dynamics of the **past 50 years** into the future assuming that there will be **no major changes**.

### Liberalisation

Due to increasing **globalisation pressure**, economically less valuable mountain areas are increasingly abandoned, while areas with **higher economic potential** are preserved for their economic valorisation.

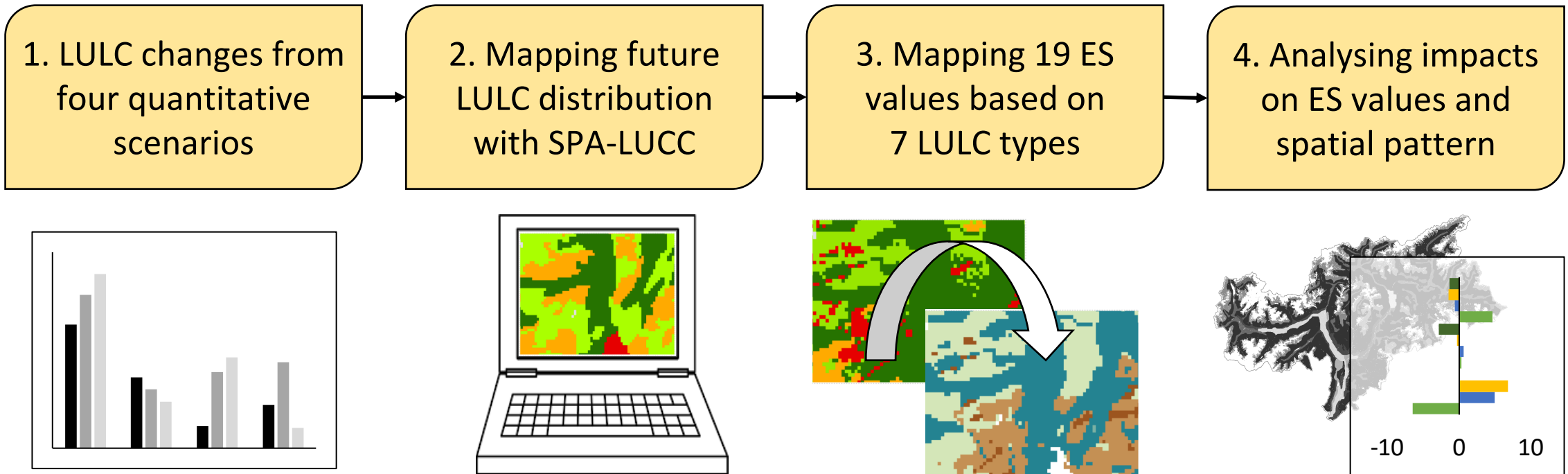
### Rewilding

The **population and economic activities are likely to decline** drastically, concentrating in favoured areas of the valleys due to a **decline in direct area-based payments**.

### Food sovereignty

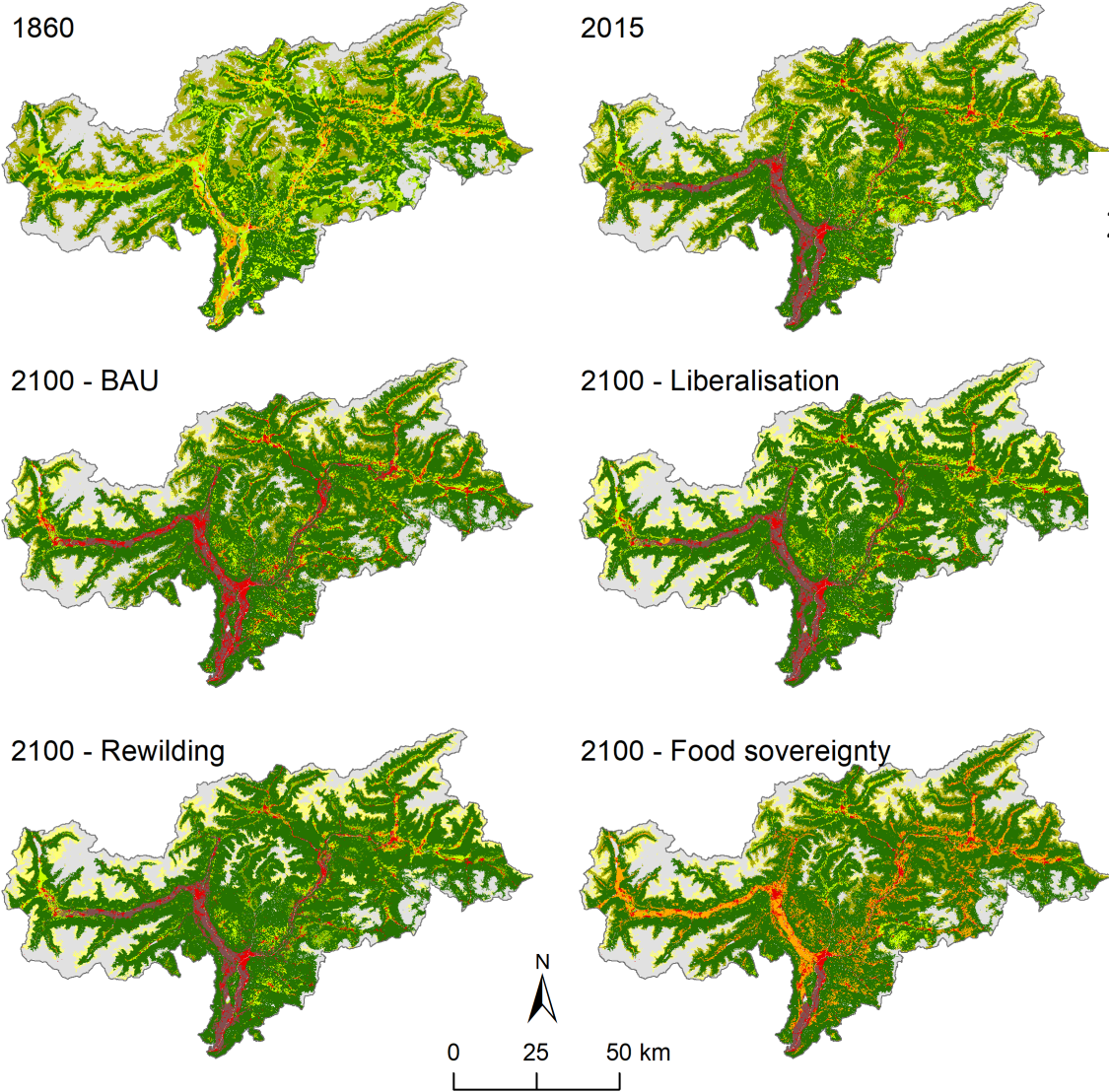
Change from **animal-based products** (milk, eggs, and meat) towards more **arable crops** due to a change towards a **healthier diet** improving the nutritional situation.

# Methodological approach



Schirpke et al. (2020)

# Land-use/cover changes



Schirpke et al. (2020)

2100 - Food sovereignty

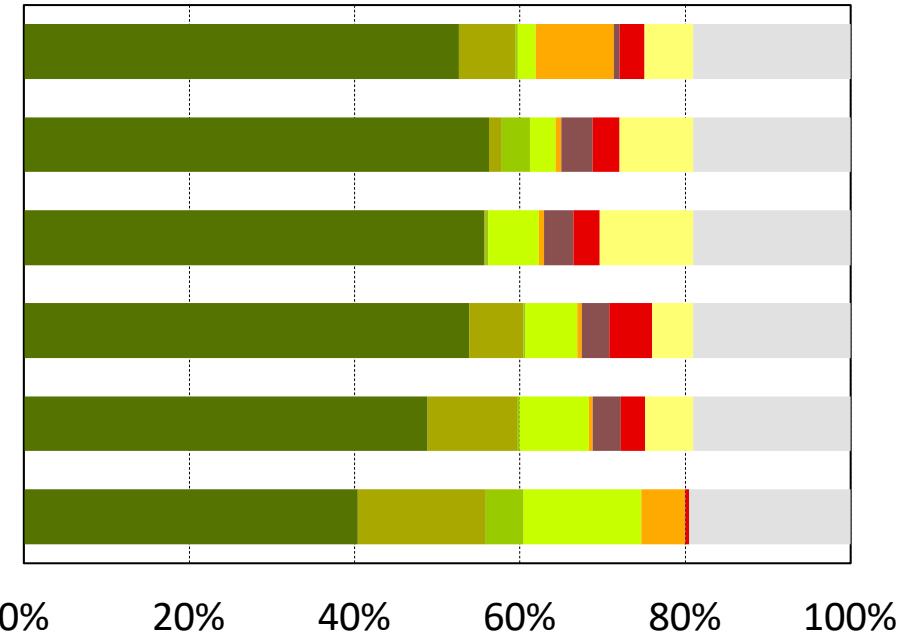
2100 - Rewilding

2100 - Liberalisation

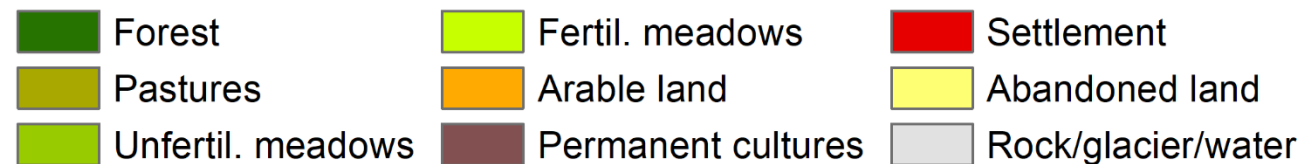
2100 - BAU

2015

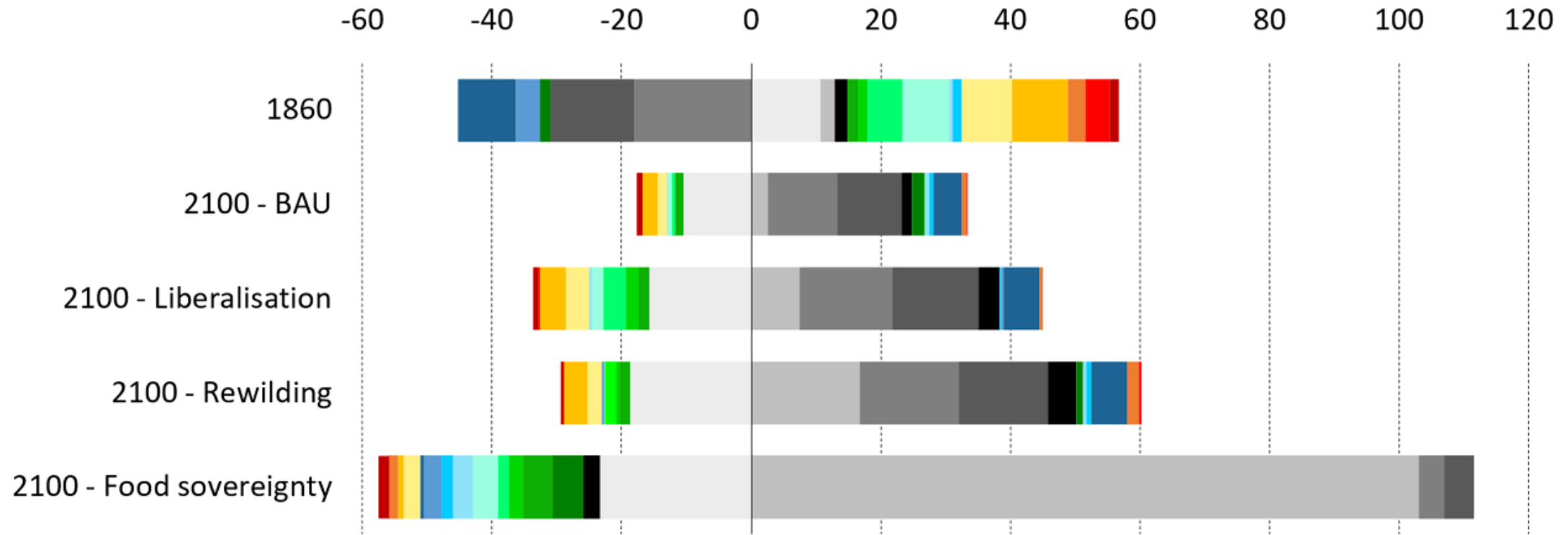
1860



## LULC types



# Change in ecosystem service values (%)



Provisioning ES: P1 P2 P3 P4 P5

Regulating ES: R1 R2 R3 R4 R5 R6 R7 R8 R9

Cultural ES: C1 C2 C3 C4 C5

Schirpke et al. (2020)

Pasture and fodder production (P1),  
Agricultural food production (P2),  
Timber production (P3),  
Gathering mushrooms and wild berries (P3),  
Provision of clean drinking water (P4),

Protection from hazards (R1),  
Prevention of water scarcity (R2),  
Provision of habitats (R3),  
Maintaining biodiversity (R4),  
Providing habitats for pollinating insects (R5),

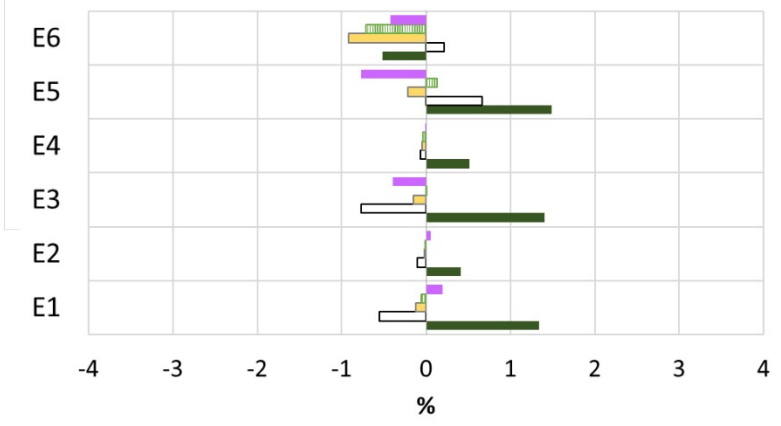
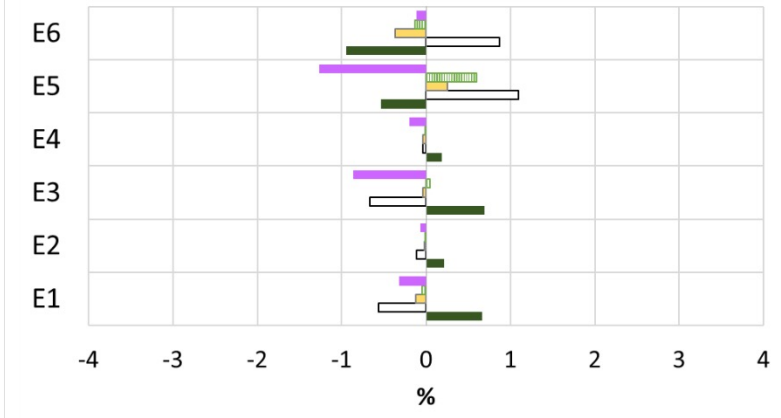
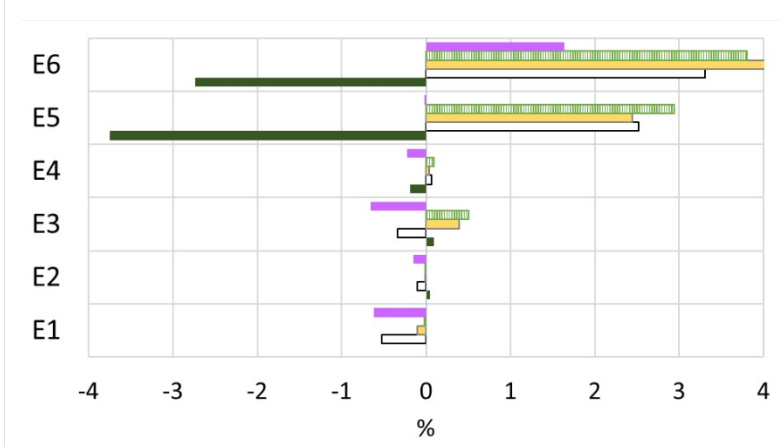
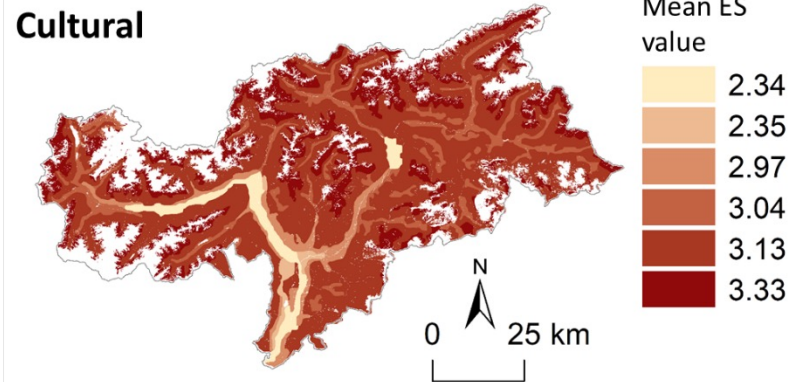
Pest control (R6),  
Disease control (R7),  
Maintenance or increase of soil fertility (R8),  
Positive effect on the climate (R9),

Opportunities for leisure activities (C1),  
Attractive housing and living space (C2),  
Experience of animals & plants (C3),  
Aesthetic inspiration (C4),  
Cultural heritage (C5)

# Ecoregions

- E6 - Agriculturally used alpine pastures, subalpine/alpine
- E5 - Forest belt, montane-subalpine
- E4 - Agriculturally used valley slopes, montane
- E3 - Agriculturally used valley bottom, montane
- E2 - Agricultural used valley slopes, colline
- E1 - Agricultural used valley bottom, colline

- 1860
- 2100 Liberalisation
- 2100 Food Sovereignty
- 2100 BAU
- 2100 Rewilding



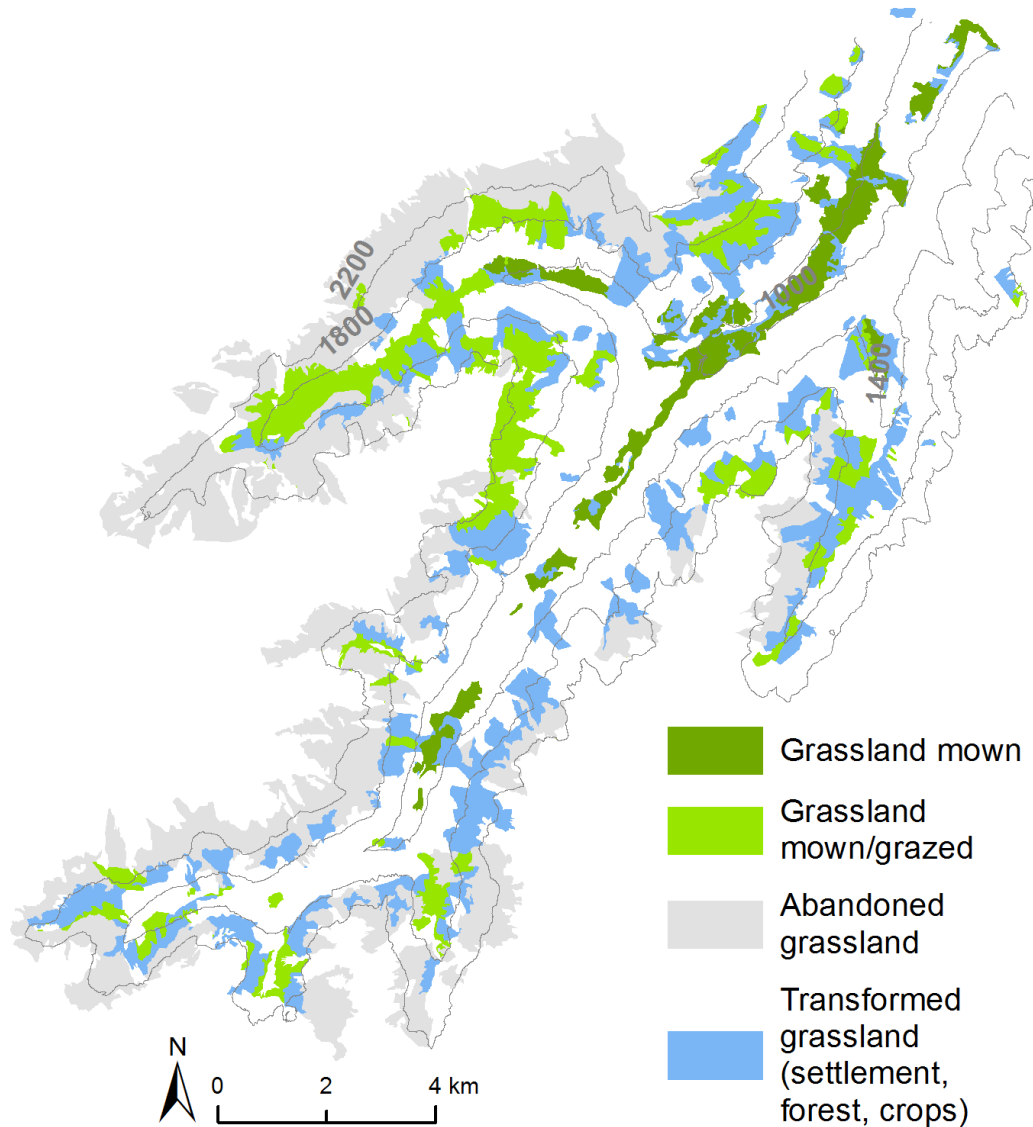
# Case study 3: Stubai valley (Austria)



- Part of a long-term socio-ecological research (LTSER) site
- Size 249 km<sup>2</sup>, elevation 920 m - 3450 m a.s.l.
- **54% forest, 16% grassland** shaped by livestock farming, **29% abandoned area**

- **Annual precipitation:**  
850 - 1087 mm  
(elevation dependend)
- **Mean annual temperature:** 6.8 - 1.1 °C  
(elevation dependend)

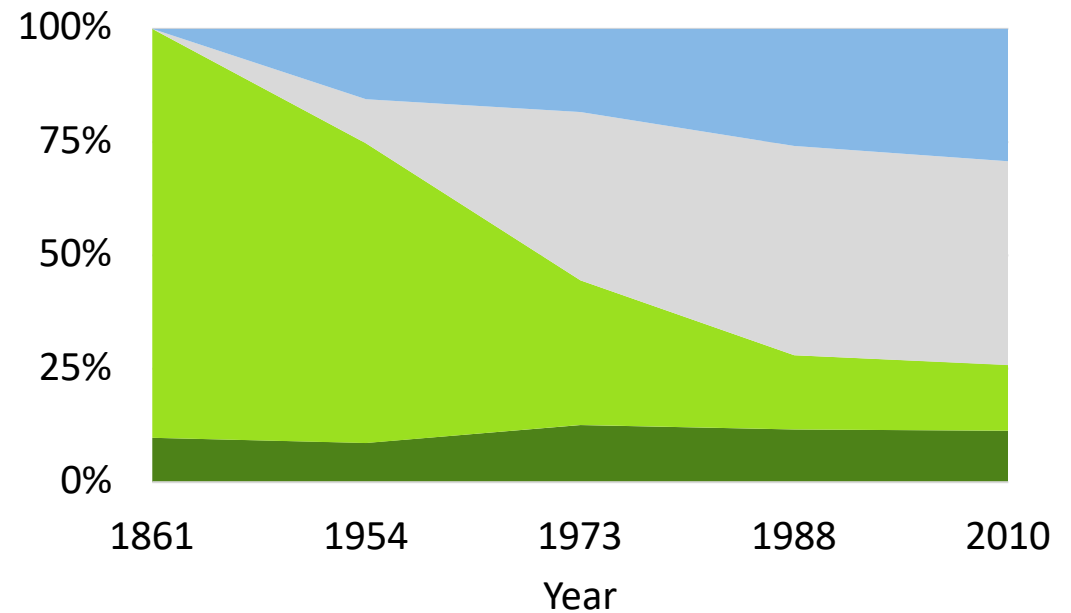
# Past changes in grassland area



## Managed grassland

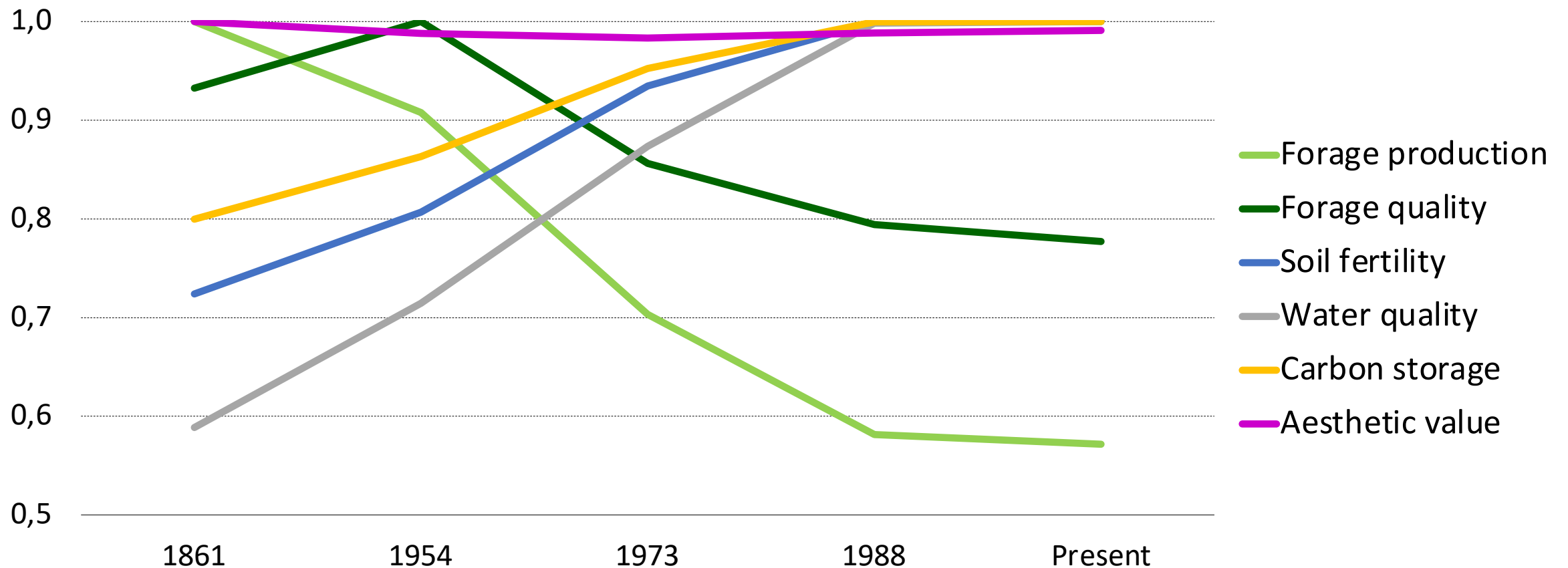
1861 30% of the total area  
57% of the usable area

2010 8% of the total area  
15% of the usable area



# Past changes in ecosystem services

Area-weighted mean for all grassland types for each time step



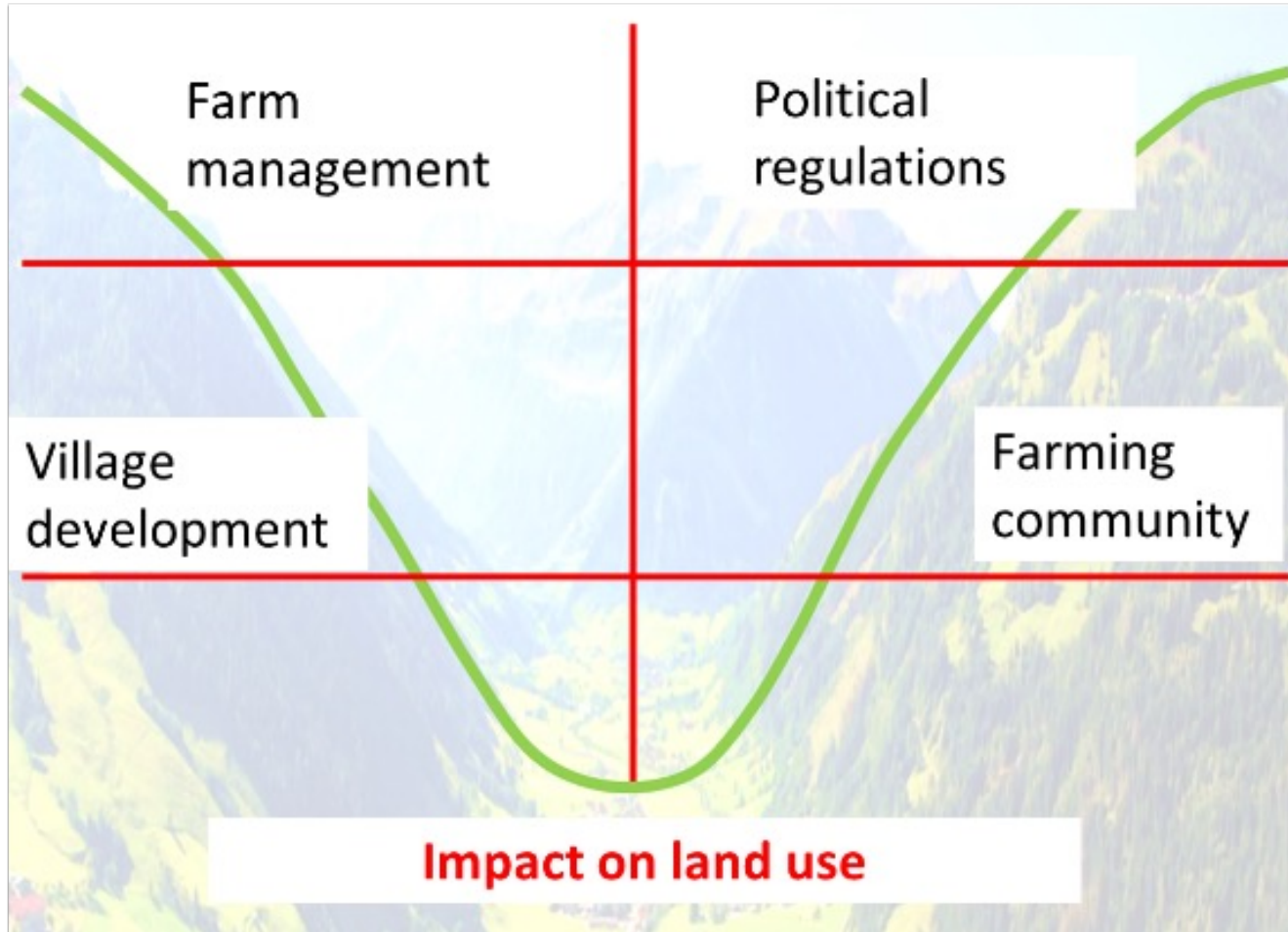


In the future?



# Visions and transformation/adaptation pathways

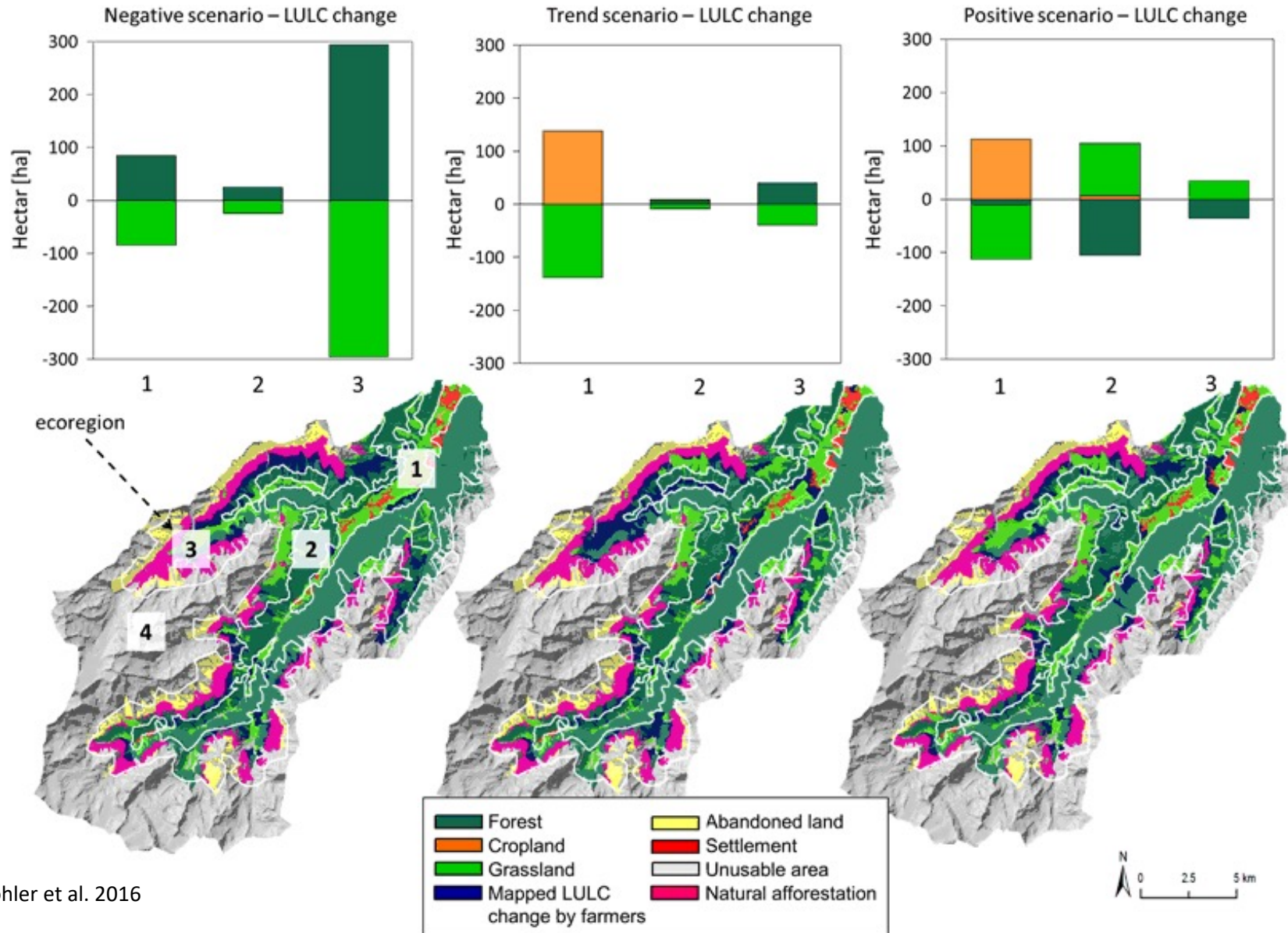
## *Explorative scenarios with stakeholders*



# Key drivers for land-use changes

Key driver	Positive	Trend	Negative
Touristic services, i.e., managed grassland	++	+	-
Demand for local products	++	+	-
Demand for areas for settlement or energy production	+	+	++
Supplementary income (on-/off-farm)	+	+	++
Farm succession	++	+	-
Land-use structural change	+	+	-
Subsidies	+	+	-
Regulations	+	-	-
Cooperation among farmers/with municipality	++	+	-
Sustaining cultural landscape	+	+	-
Climate change	-	-	-

# Land-use scenarios



# Modelling future ecosystem services

## Climate change:

- +1.5K until 2050
- +3.3K until 2100



Extension of growing season  
Up-shift of treeline

## Variations in species relative abundances for 2100:

- fraction of grasses -10.7%,
- fraction of legumes +7.7%
- remaining functional groups +3%



Changes in vegetation  
composition

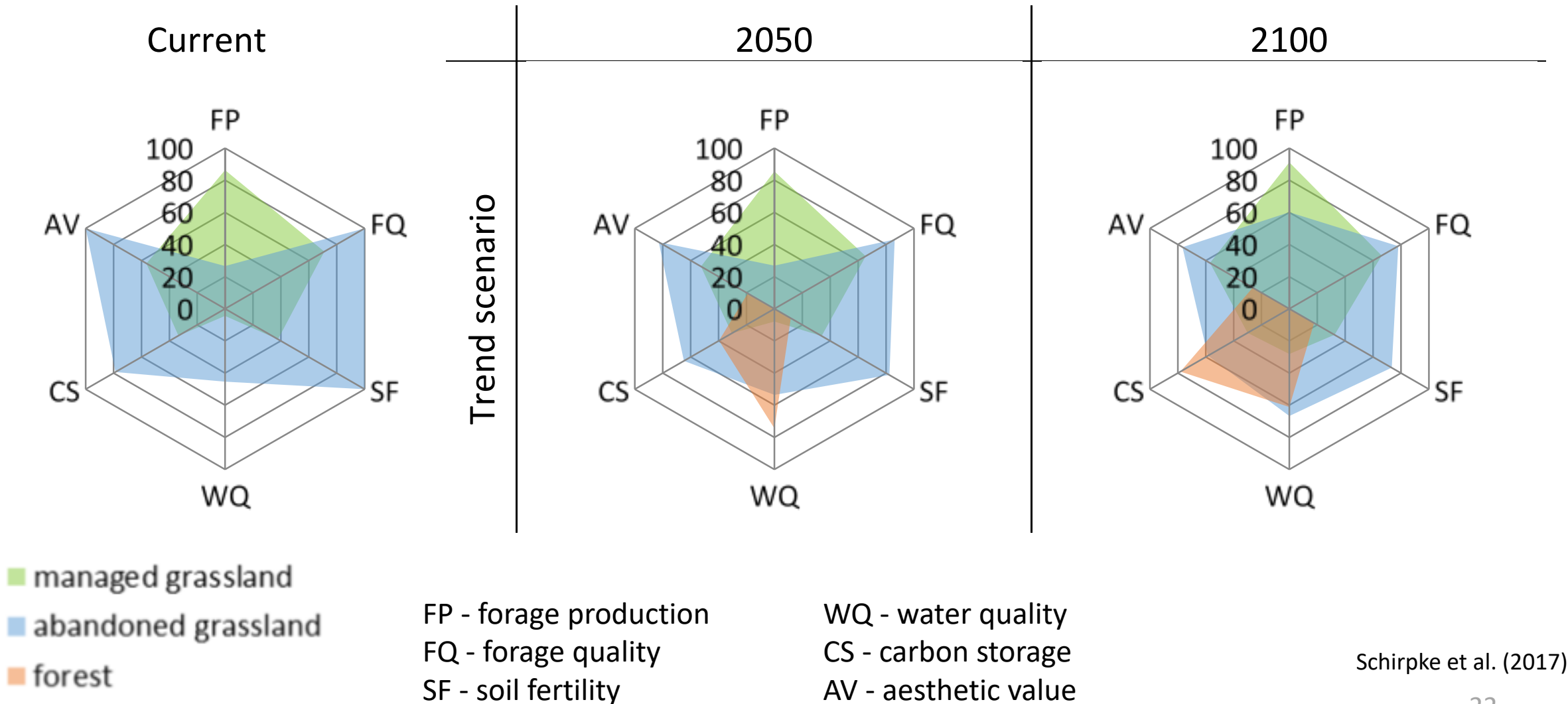
## Changes in plant traits for 2100:

- LNC -18.5%
- LDMC +3.8%



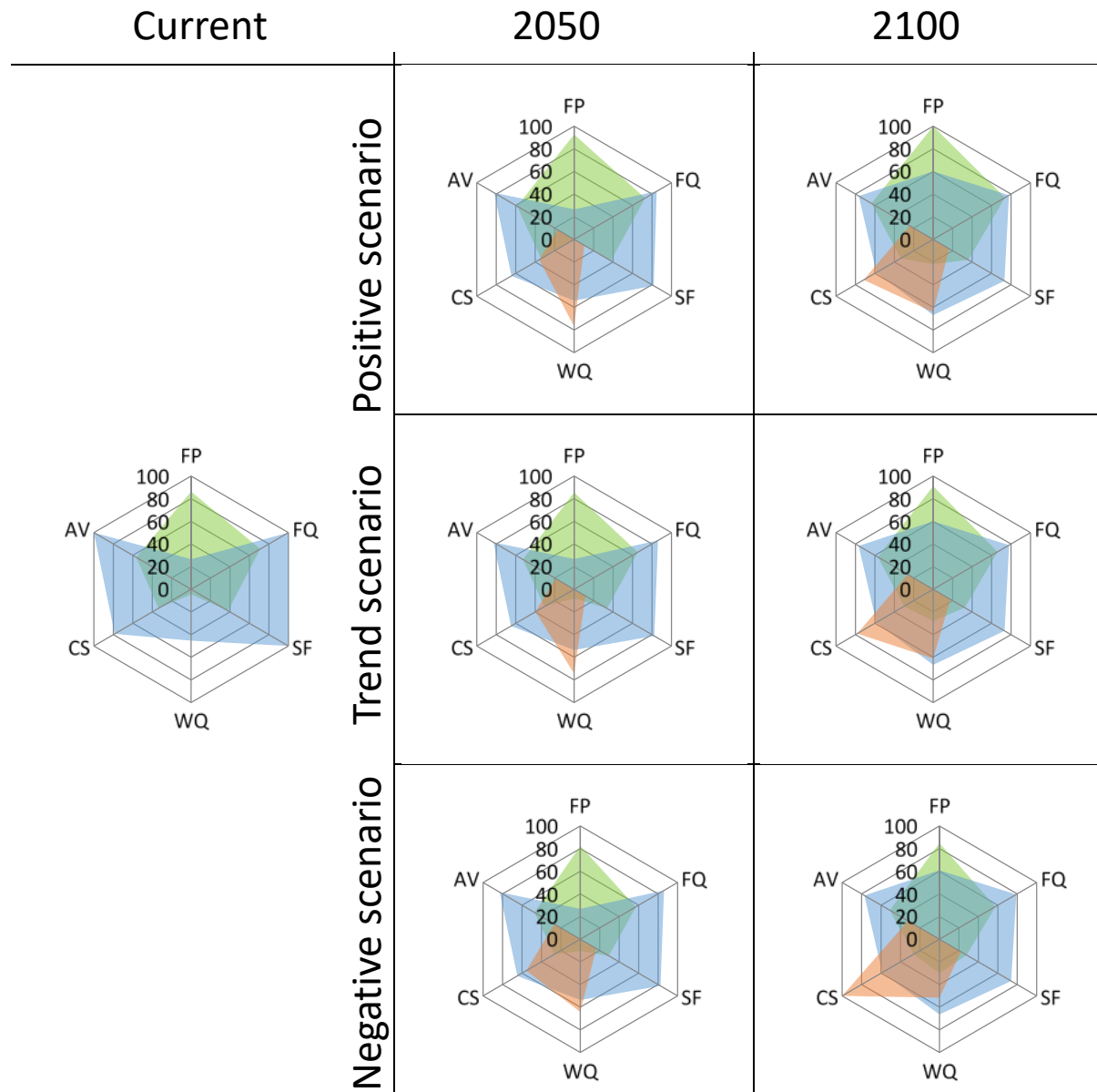
Changes in plant trait-  
based models

# Shifts in ecosystem services



Schirpke et al. (2017)

# Trends in ecosystem services



- managed grassland
- abandoned grassland
- forest

FP= Forage production  
 FQ = Forage quality  
 SF = Soil fertility  
 WQ = Water quality  
 CS = Carbon storage  
 AV = Aesthetic value

# Conclusions

- There is a general trend of a **shift from provisioning services to regulating services**, with municipalities **increasing in multifunctionality** or **decreasing in ecosystem services supply**
- **In the past, land-use changes** were mainly driven by **socio-economic conditions**, whereas **in the future, legacy effects** and accelerating **climate change** will become the more important drivers of change, especially at high altitudes







# Conclusions

- **Decision makers and land managers** will be faced with the **higher vulnerability of ecosystem services** and **less management possibilities** due to **climate change**
- **Sharing visions among stakeholders** may support the **development of adaptive pathways** in **mountain socio-ecological systems**

# Literature

- Kohler et al. (2017). Participative spatial scenario analysis for Alpine ecosystems. *Environmental Management*, 60(4), 679-692.
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- Schirpke et al. (2020). Spatio-temporal changes in ecosystem service values: Effects of land-use changes from past to future (1860–2100). *Journal of Environmental Management* 272, 111068.
- Schirpke et al. (2022). Using the Ecosystem Services Concept to Assess Transformation of Agricultural Landscapes in the European Alps. *Land* 11, 49(1).



Thank you for your attention!

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