Targeted grazing of robust livestock for the restoration of green alder-encroached pastures

Doctoral thesis defense

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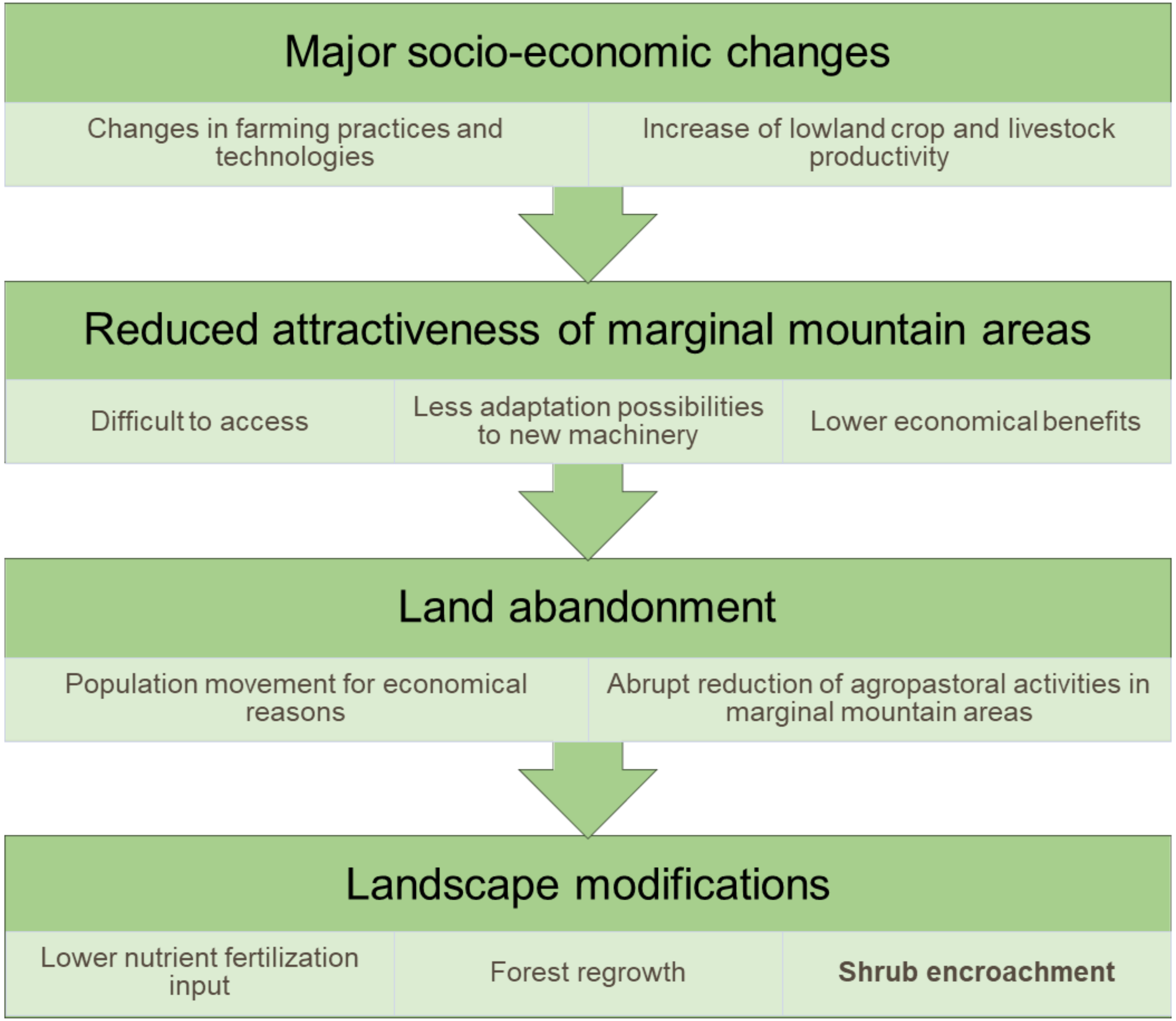
Alpine and subalpine pastures are key providers of ecosystem services:

- High species diversity
- Valuable forage yield and quality for meat and dairy production
- Fiber and fuel provision
- Water and carbon balance regulation
- Pollination
- Protection from natural hazards
- Cultural landscape aesthetic

→ **Constituents of the population well-being**

Sources: MacDonald et al. 2000; Reid et al. 2005; Niedrist et al. 2009; Schirpke et al. 2013

<u>During the 20th century</u>:



<u>Sources</u>: Mack et al. 2013; Schirpke et al. 2013; Strebel and Bühler 2015; Orlandi et al. 2016

During the 20th century:

Major socio-economic changes

- Changes in farming practices and technologies
- Increase of lowland crop and livestock productivity

↓

Reduced attractiveness of marginal mountain areas

- Difficult to access
- Less adaptation possibilities to new machinery
- Lower economical benefits

↓

Land abandonment

- Population movement for economical reasons
- Abrupt reduction of agropastoral activities in marginal mountain areas

↓

Landscape modifications

- Lower nutrient fertilization input
- Forest regrowth
- **Shrub encroachment**

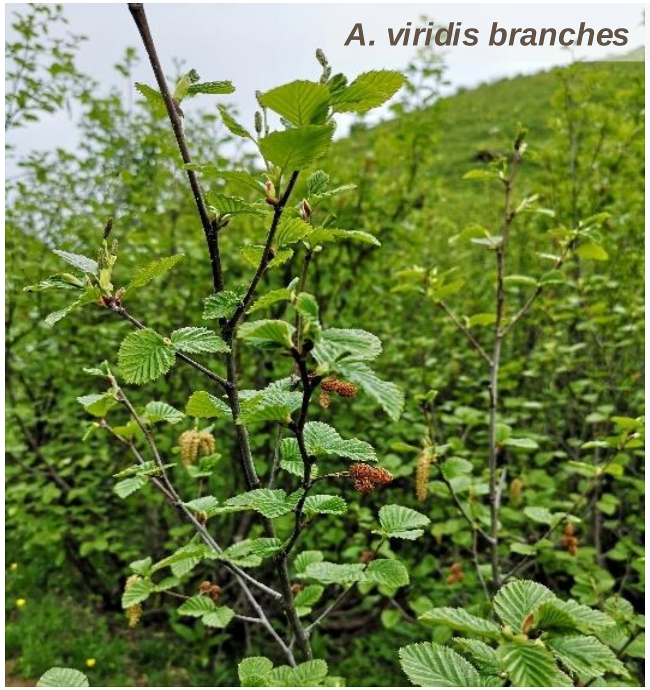
- **Tree and shrub-encroachment** has been massively reported in European mountains.
- Shrubs are expanding and replacing semi-natural open habitats
- Dense stands of shrubs and trees host lower plant and animal biodiversity
- This phenomenon reduces valuable forage resources for grass-fed animal products.

Sources: Mack et al. 2013; Schirpke et al. 2013; Strebel and Bühler 2015; Orlandi et al. 2016

Green alder (*Alnus viridis*) is a pioneer shrub species that invades subalpine pastures.

Features:

- Mainly in north- and west-facing slopes
- Rapid growth (sexual and vegetative reproduction)
- Most rapidly expanding shrub species in Central Europe
- Represents **70%** of shrubland cover of Switzerland
- Symbiosis with nitrogen-fixing actinomycete (*Frankia alni*)



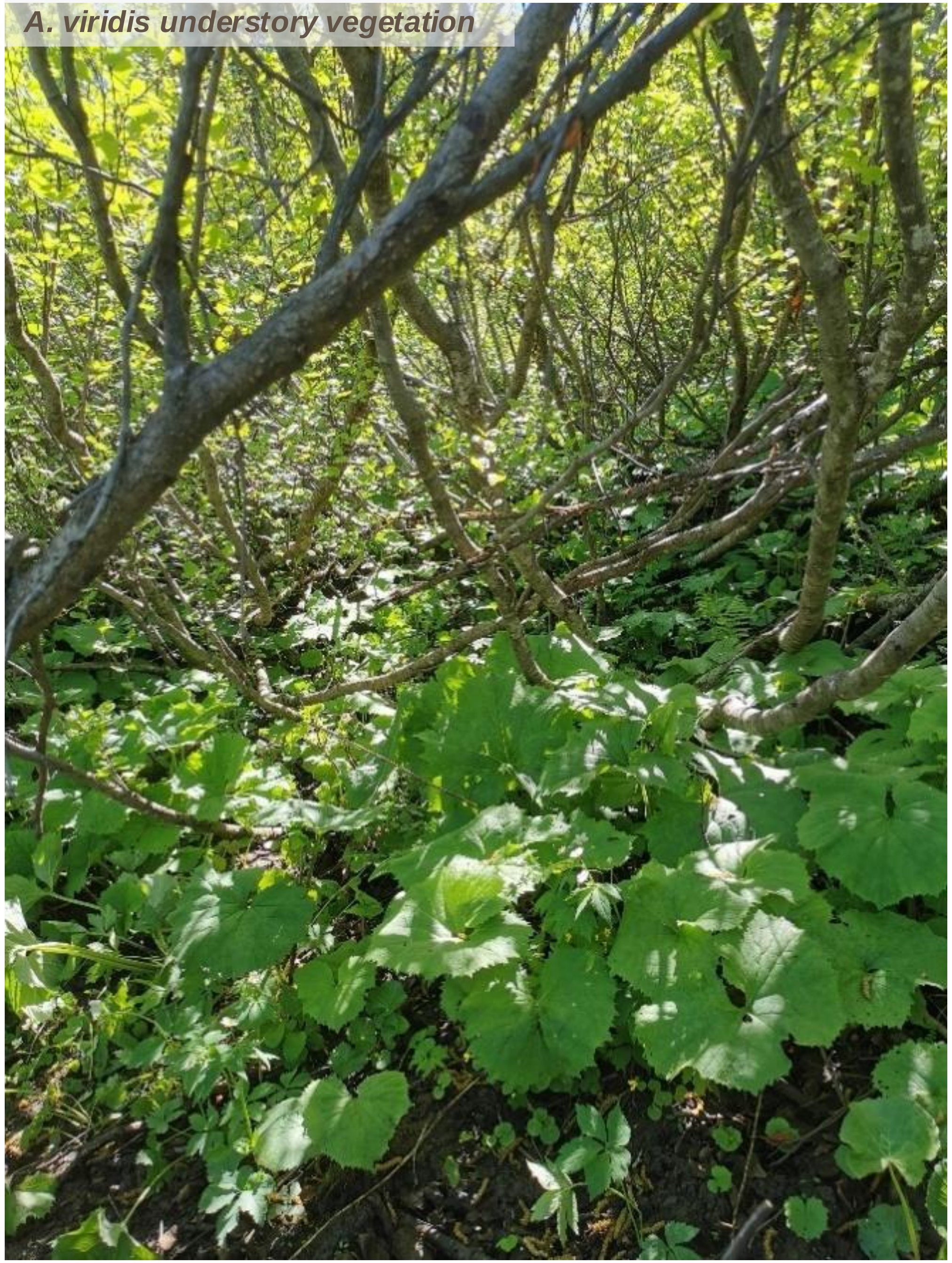
Sources: Farmer et al. 1985; Houle 2001; Anthelme et al. 2002

Green alder encroachment produces several agro-environmental issues:

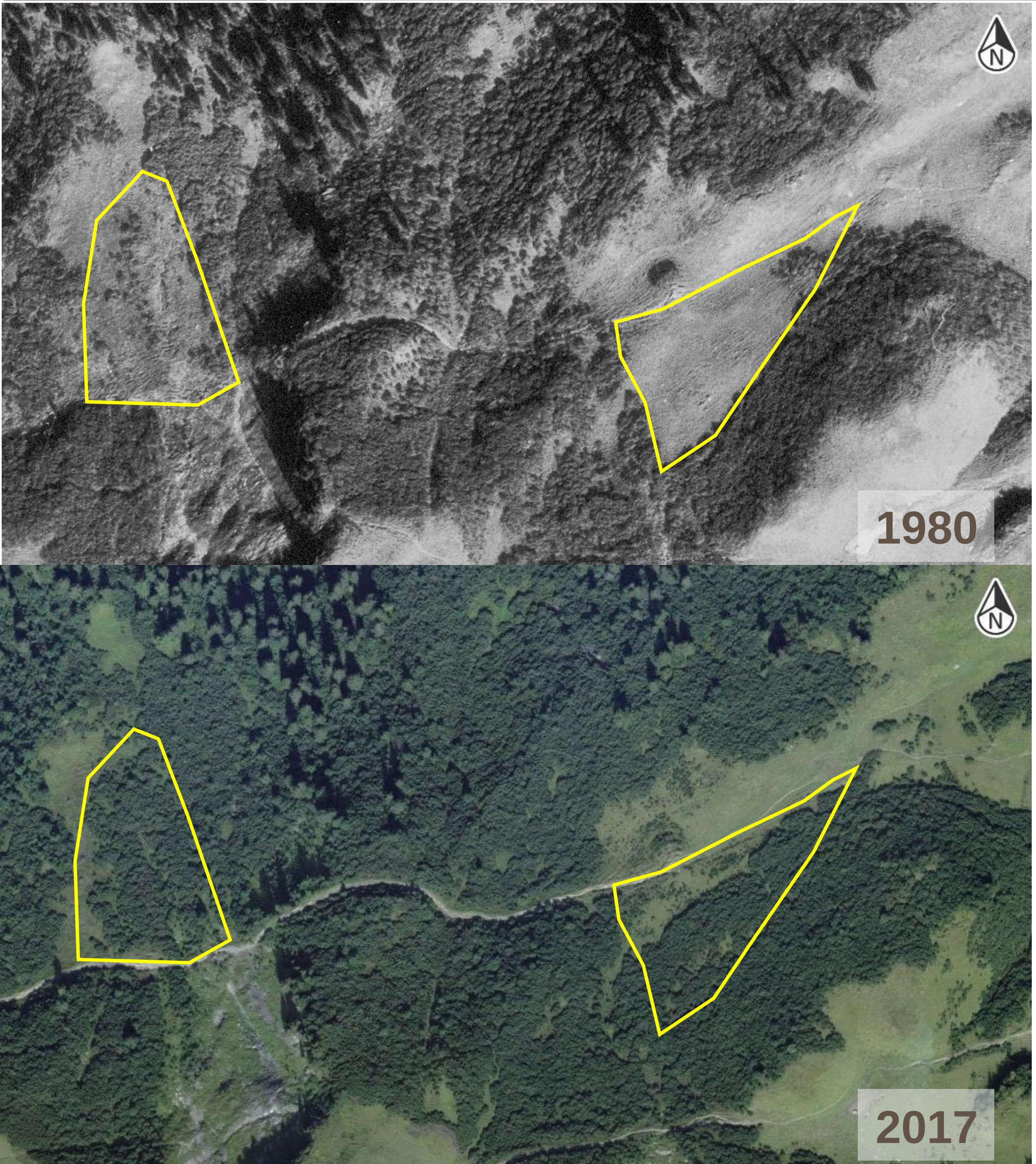
- A loss of grassland areas (reduction of agricultural production)
- Soil acidification
- Nitrates (up to 1.76 g N m^{-2}) and Carbon leaching
- Emission of N greenhouse gases (around 4.2 kg N_2O-N ha^{-1} $season^{-1}$)
- Decrease in temperature and light, and increase of humidity at the soil level
- Loss of animal and plant biodiversity
- No protection from avalanches (flexible branches) and prevents forest succession
- Change of alpine cultural landscape (tourism)

→ Climate change accelerates its encroachment at higher elevations.

A. viridis understory vegetation



Sources: Anthelme et al. 2002; Brüchert et al. 2003; Caviezel et al. 2017



Encroachment over the past years:

Example of the extent of green alder-encroachment over the last decades, in an alpine pasture in Switzerland (used for this project).

Green alder spread is mainly driven by land use intensity

Source: www.geo.admin.ch

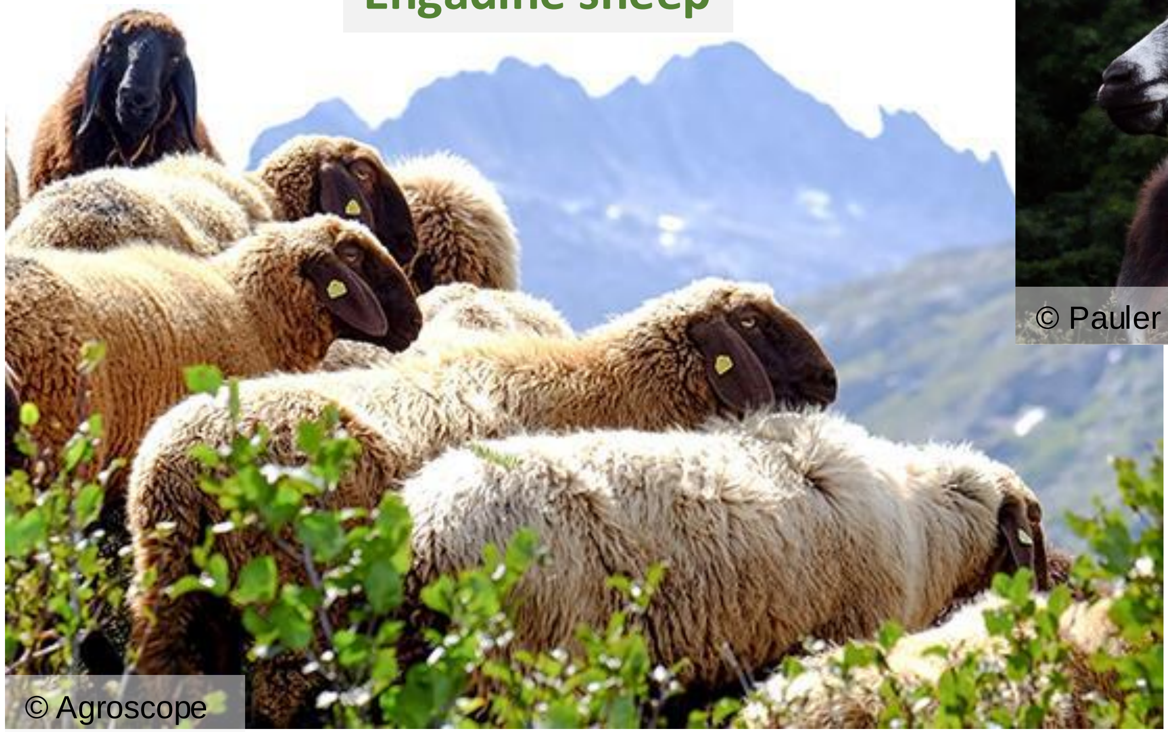
Robust breeds:

- Dairy cows are not able to efficiently graze green alder leaves
- Other livestock species have the ability to forage on woody plants, including green alder

And also… Highland cattle?

Pfauen goats

Engadine sheep



Sources: Zehnder et al. 2016; Marques et al. 2017; Pauler et al. 2019; Pauler et al. 2022

Highland cattle are a robust breed originating from Scotland:

- **Able to graze a large number of woody plants**
- Low maintenance energy requirements
- Higher feeding preference for woody species than production-oriented breeds
- Low veterinary needs
- Able to break branches with their horns
- Able to move in humid and difficult areas (low weight)
- Long fur that may contribute to seed dispersion

Highland cattle have great potential: object of this project

Sources: Pauler et al. 2020 (a,b); Berry et al. 2002

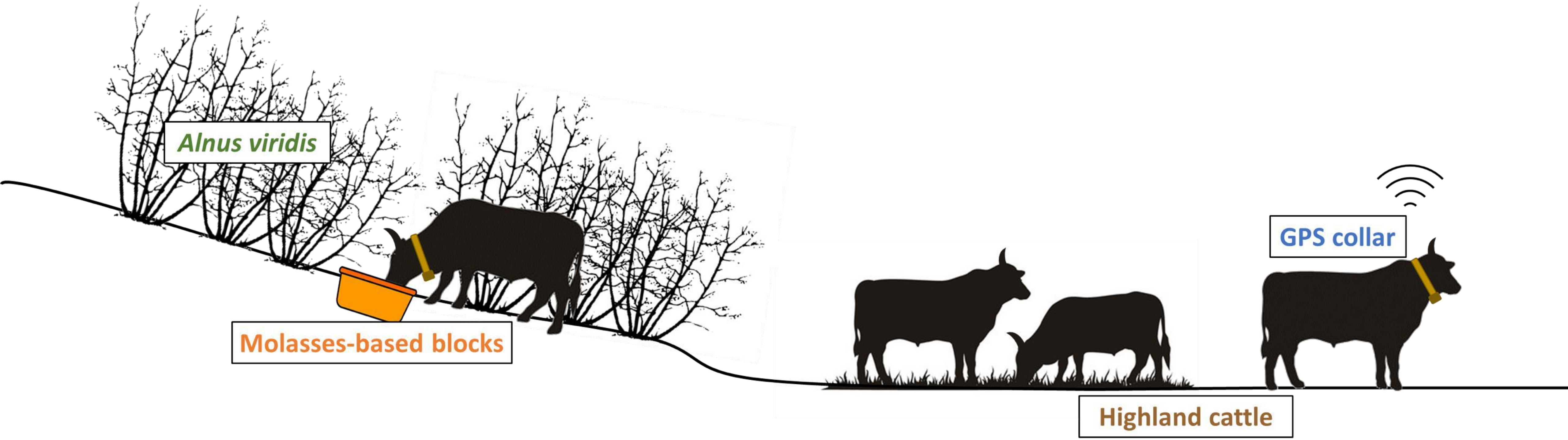
GPS technology

- GPS technology is increasingly used to track livestock grazing patters
- **Very precise** scale and time margin
- **Continuous recording of the activity of the cow**
- Other possible recorded features (altitude, temperature…)
- No alteration of animal behavior

©Followit GPS collars used for this project, recording a point **every 10 minutes**

Objectives: project from 2019 to 2023

Can Highland cattle become a management tool to reduce *Alnus viridis* encroachment?

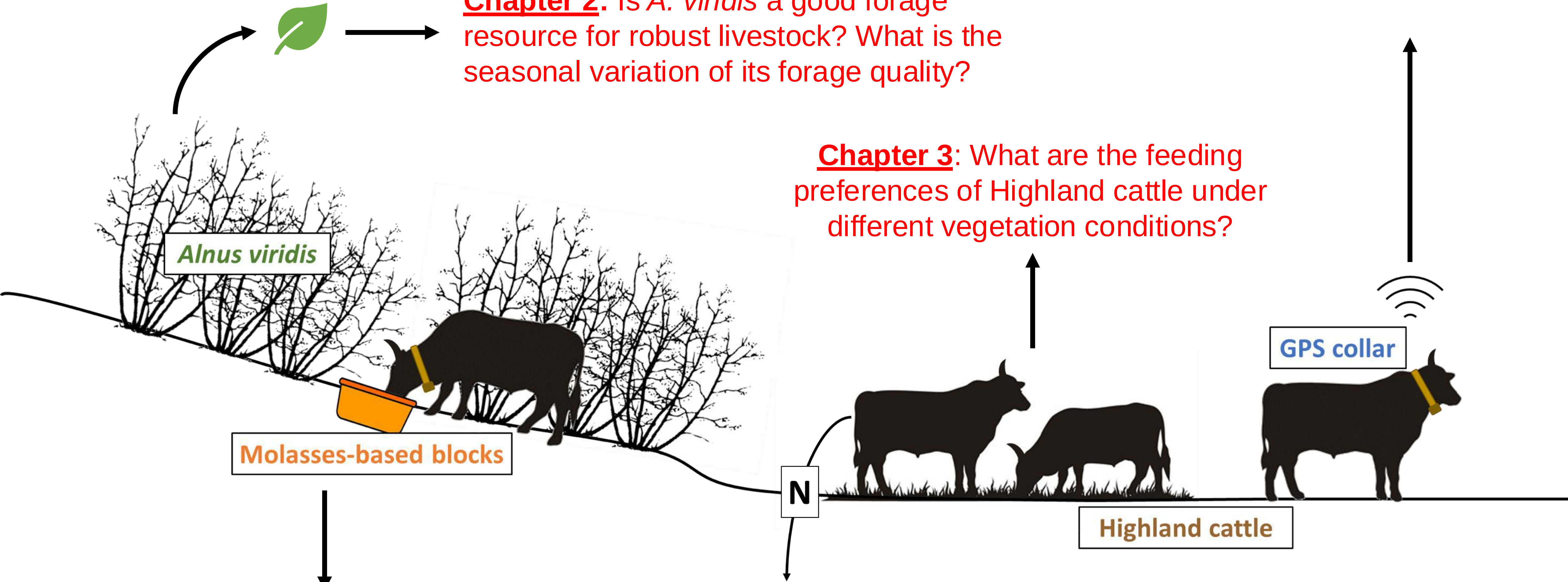


Objectives: project from 2019 to 2023

Chapter 4: What is the spatial distribution of Highland cattle?

Chapter 2: Is *A. viridis* a good forage resource for robust livestock? What is the seasonal variation of its forage quality?

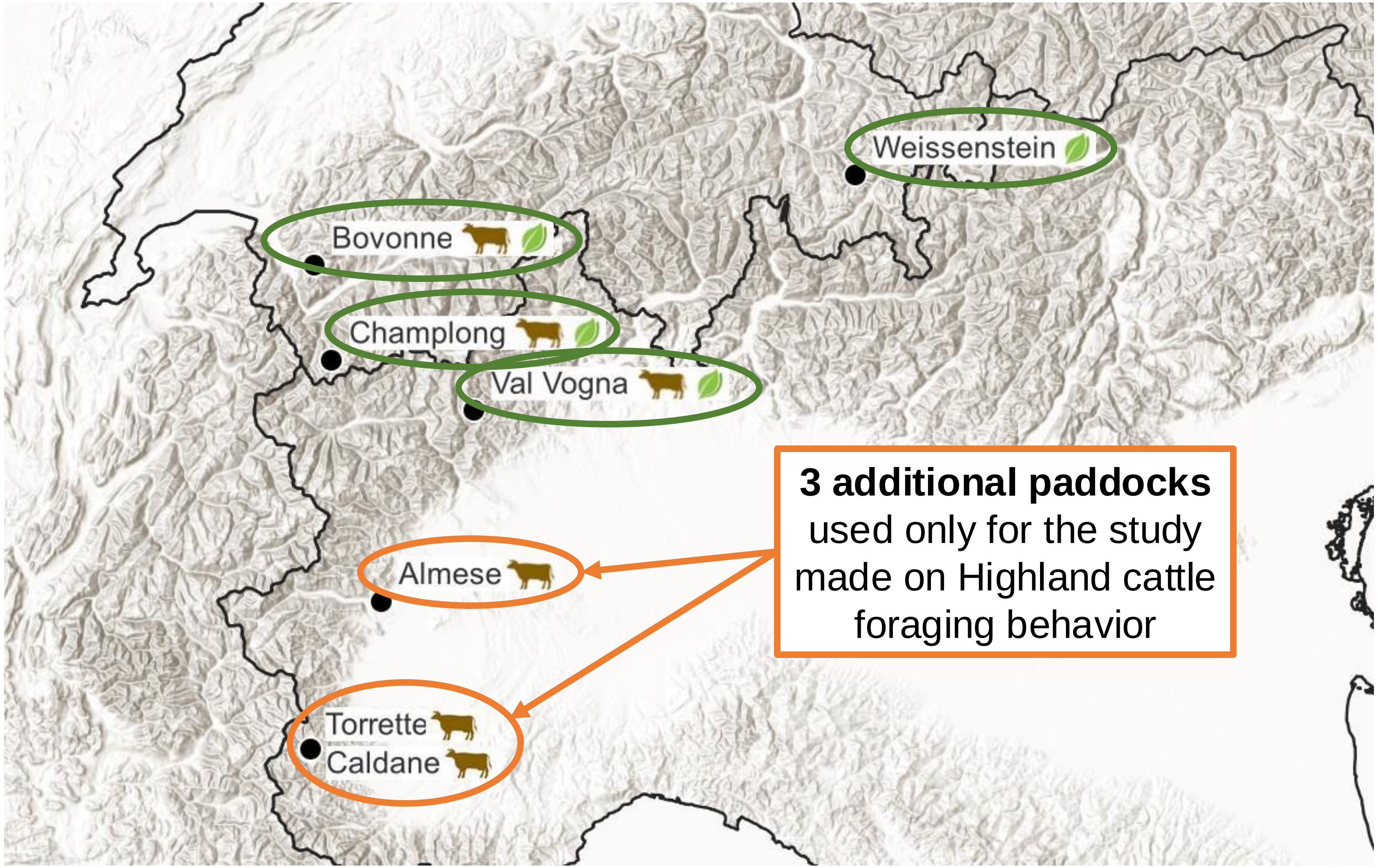
Chapter 3: What are the feeding preferences of Highland cattle under different vegetation conditions?



Chapter 5: Do attractive points change Highland cattle spatial distribution?

Chapter 6 : Is there an active nitrogen translocation from *A. viridis* encroached pastures to adjacent open pastures?

Study sites:



1 additional site for leaf sampling only: **Weissenstein (Switzerland, GR)**

→ Greater geographical representation (varied pedo-climatic conditions, different aspects)

- **Bovonne (Switzerland, VD)**
  - 2 to 3 paddocks
  - 7 to 8 ha per paddock
  - 51 to 71% of *A. viridis* cover
  - Grazed from 2019 to 2022
  - ~30 cows each year

- **Val Vogna (Italy, Vercelli)**
  - 1 paddock
  - 31 ha
  - 20% of *A. viridis* cover
  - Grazed from 2019 to 2022
  - ~80 cows each year

- **Champlong (Switzerland, VS)**
  - 1 paddock
  - 6 ha
  - 44% of *A. viridis* cover
  - Grazed in 2019 only
  - 12 cows

CHAPTER 2: Green alder, a valuable nutritional forage resource reducing livestock greenhouse gas emissions

From **Svensk et al. 2023** (under review in Agriculture, Ecosystems and Environments)

Objectives:

- Assessment of ***A. viridis*** **leaf chemical composition**
- **Temporal variation** of leaf composition across the grazing season

→ Is green alder a good forage resource for robust livestock such as Highland cattle?

→ When is the ideal period for grazing in relation to green alder leaf composition?

Methods:

1) Sampling of green alder leaves in all sites:

- 3 times during the grazing season (June, July and August), for two years (2020,2021)
- At a suitable heigh for grazing by cows (< 1.80 m high)
- 5 trees selected at each sampling, outside the paddocks in each site

2) Measures and analyses in the laboratory:

- **Leaf functional traits**: specific leaf area (SLA) + leaf dry matter content (LDMC)
- **Leaf chemical composition**:
  - Macro-elements : N, P, Ca, K, Mg
  - Micro-elements: Cu, Fe, Mn, Zn
  - Fibers: ADF, ADL, NDF
- **Phenols** : Total extratable phenols (TEP), non-tannins phenolics (NTP), total tannins (TT), condensed tannins (CT), hydrolyzed tannins (HT)
- **Digestibility and gas**: In vitro OM digestibility (IVOMD), CH_4/dOM, CO_2/dOM, CH_4/CO_2

3) Temperature: Growing degree days (GDD) used as a proxy for the seasonal temperature changes

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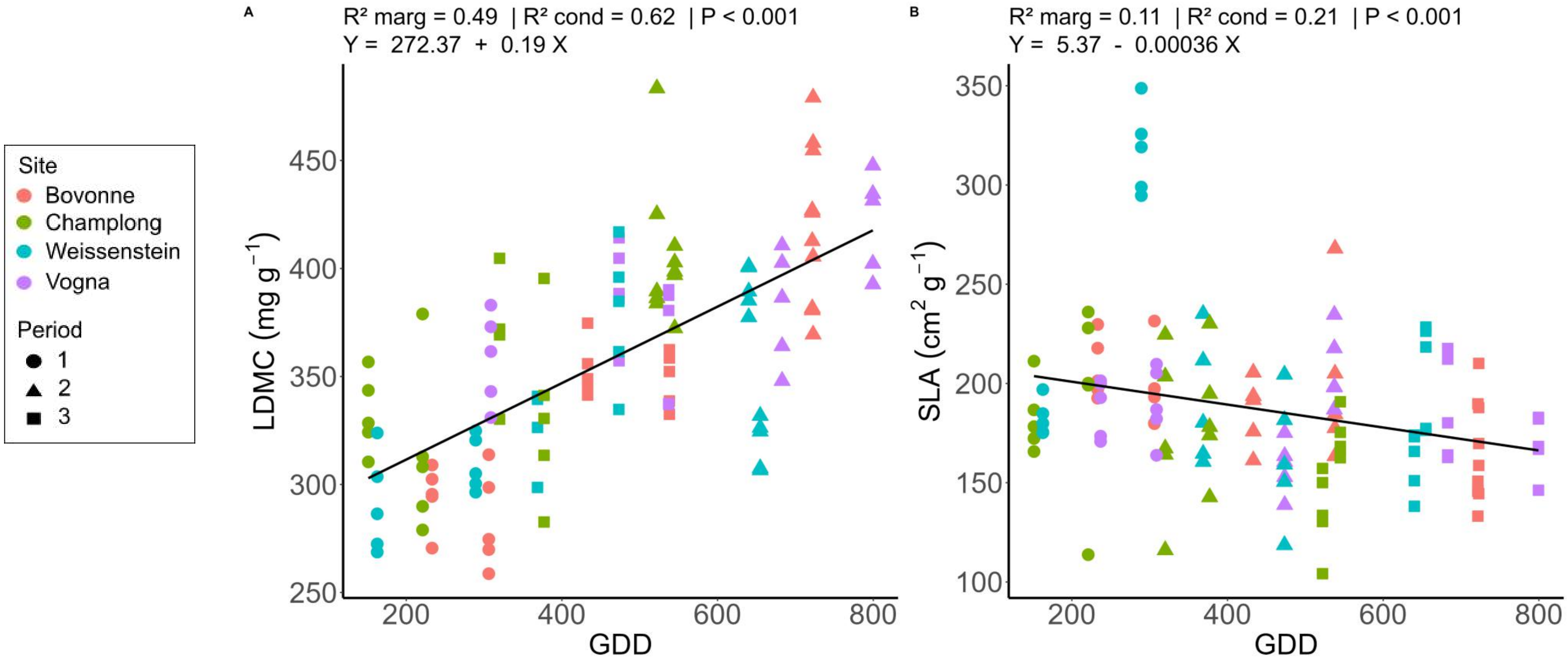
→ **Estimation in vitro** using Brown Swiss cows

Comparison between a diet of:
- **20% green alder leaves + 80% hay**
- **100% hay (control)**

3) Temperature: Growing degree days (GDD) used as a proxy for the seasonal temperature changes

Results:

Leaf functional traits



- SLA and LDMC vary in opposite direction throughout the season
- At the end of the season, the plant focuses on the conservation of acquired resources (Qin et al. 2018)
- Similar results found in other *Alnus* species and woody plants (De Kort et al. 2014; Skoczowski et al. 2021)

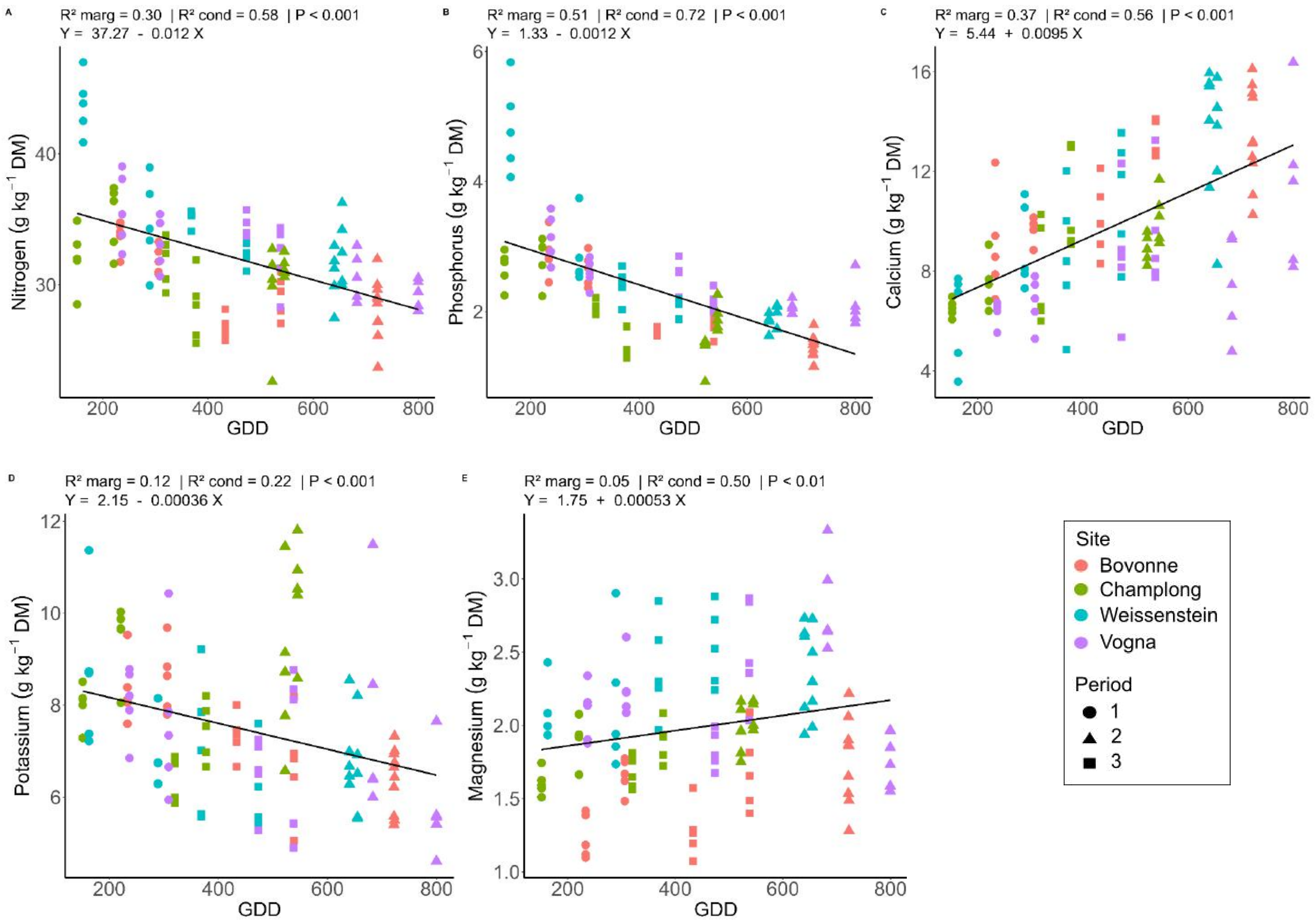
Results:

Leaf chemical composition

- Similar **decrease of N, P and K** and increase of Ca and Mg than found for other alder species (Rodríguez-Barrueco et al. 1984)

- Similar N values than in previous measures of *A. viridis* leaves (Bühlmann et al. 2016)

- N leaf concentration is higher than in other woody plants (Tian et al. 2018)



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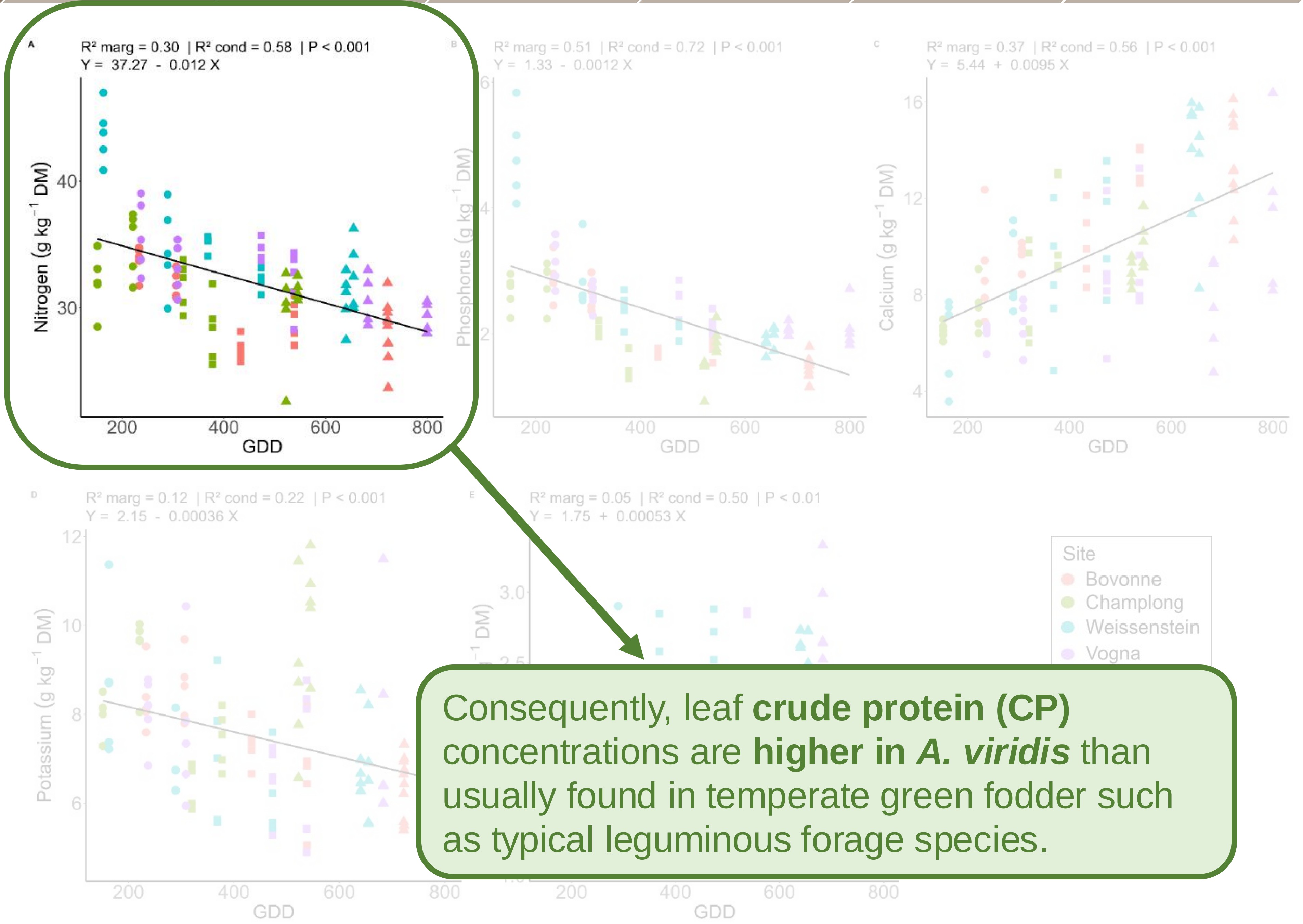
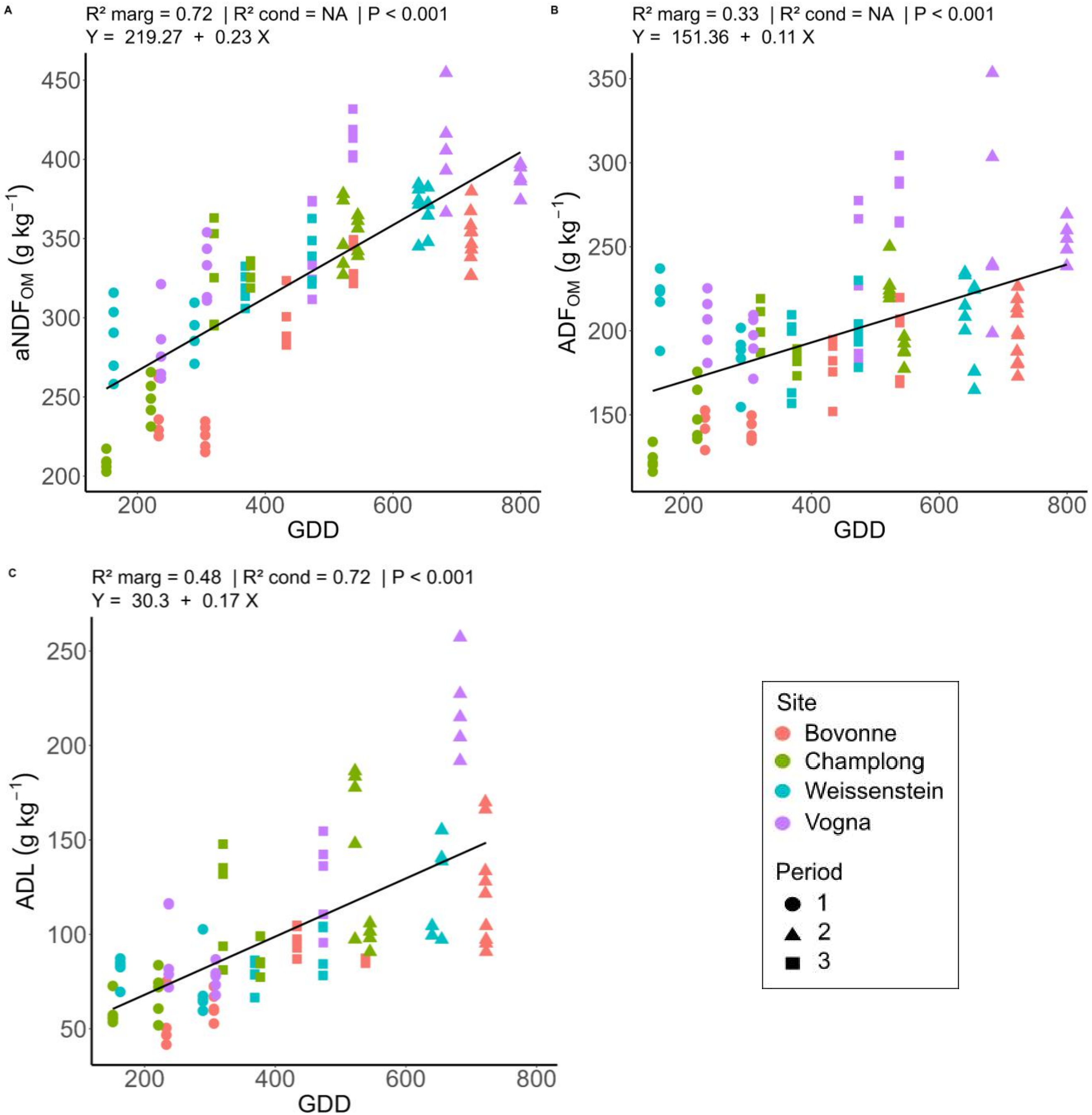


Consequently, leaf **crude protein (CP)** concentrations are **higher in *A. viridis*** than usually found in temperate green fodder such as typical leguminous forage species.

Results: Leaf fibres

- Similar range values than in other alder species (Mahieu et al. 2021)
- Higher values than in herbaceous vegetation (Mahieu et al. 2021)
- Leaves become more fibrous from spring to autumn

Lower forage quality at the end of the summer season



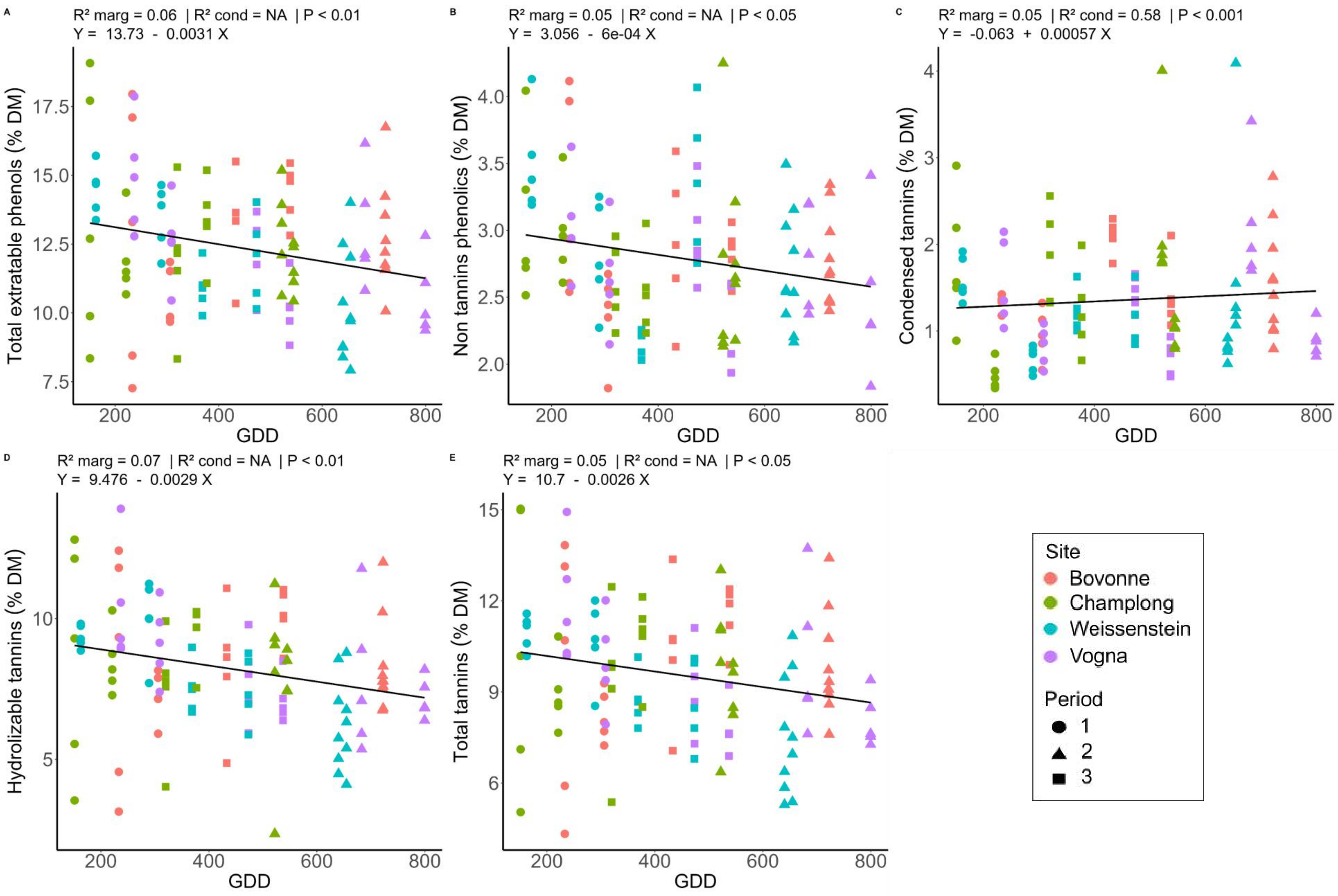
Results:

Phenols

- **Higher leaf TT** concentrations than found in previous studies on *A. viridis* (Stević et al. 2010)

- **Similar phenol decrease for other alder species** and woody plants (González-Hernández et al. 2000)

- Variation of CT is species-dependent (Gowda et al. 2019)



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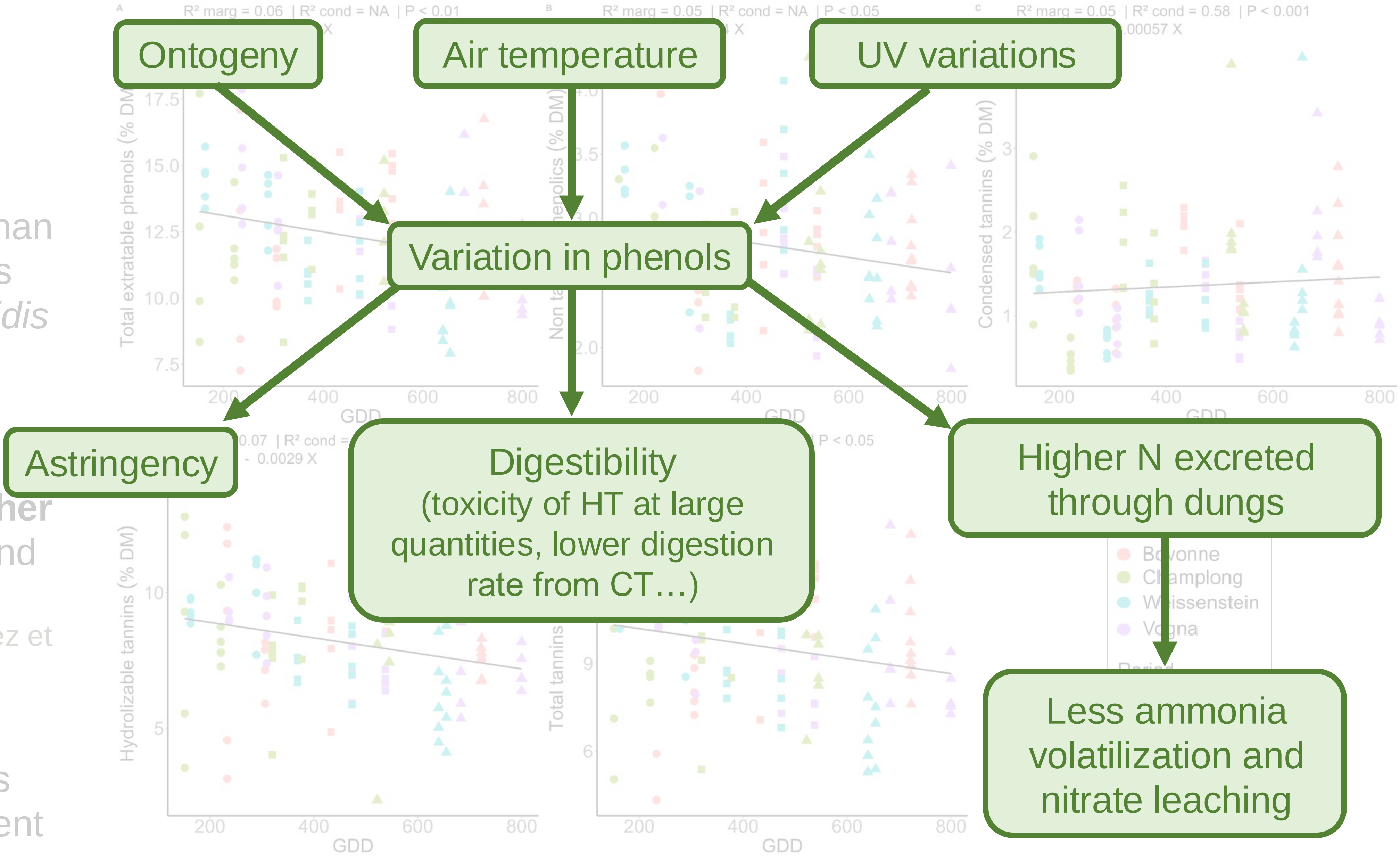
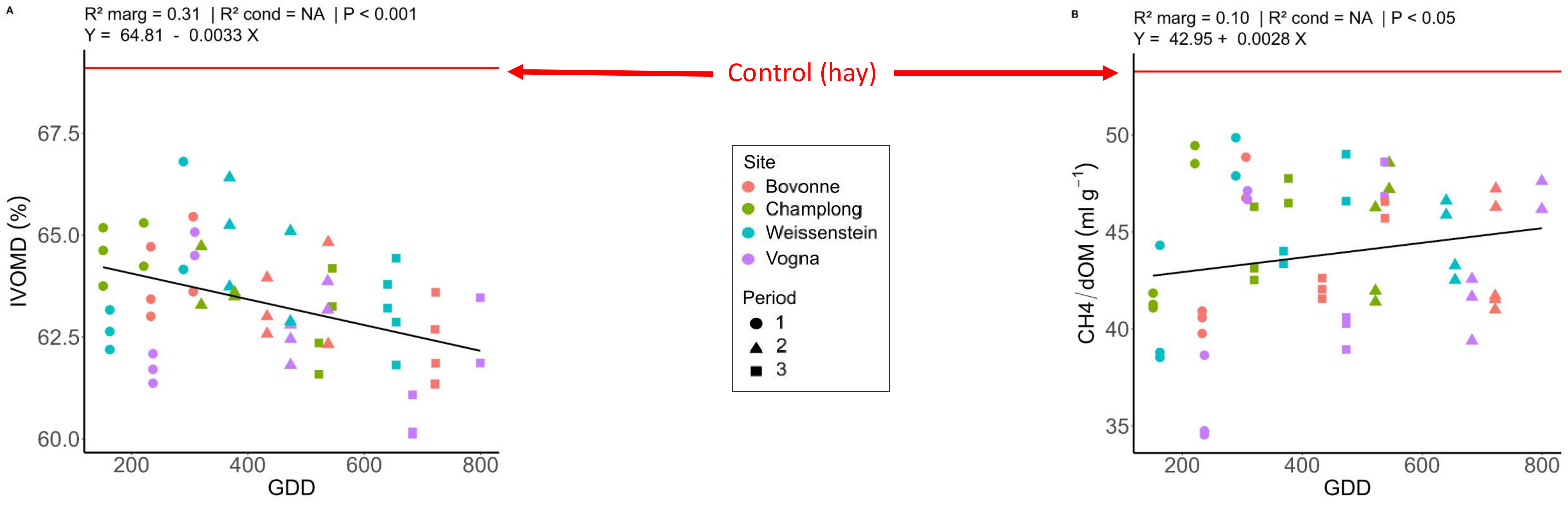


Results: Digestibility and gas production

- **Decrease of digestibility (IVOMD) and CH_4/dOM when the diet is composed by 20% of green alder leaves**, compared to the control (100% hay)
- Decrease of leaf digestibility throughout the grazing season
- Increase of CH_4/dOM throughout the grazing season



Conclusion:

- Green alder has real potential to become a **valuable forage resource for robust livestock**.
- The **beginning of the summer season** seems to be the ideal time for grazing.
- These results will help to define targeted management strategies in overgrown areas to:
  - → **reduce encroachment**
  - → **optimize productivity**
  - → **reduce greenhouse gas emissions**

CHAPTER 3: Foraging behavior of Highland cattle in silvopastoral systems in the Alps

From **Nota et al. 2023** (under review in Agroforestry System)

Objectives:

Investigate Highland cattle feeding behavior in different mountain environments in terms of:

1. **Percent consumption** of woody and herbaceous plants;
2. **Preference indices** for different plant species, particularly woody species;
3. **Relations between amount of consumption and abundance** of species

Which species compose the diet?

Methods:

Direct observations

- 1 cow per observer
- Recording of the grazing behavior for 15 seconds at regular intervals (20 sec rest)
- Two parameters were recorded:
  - **Plant species consumption**, in terms of relative consumption (scale 0-1)
  - **Plant species abundance**, in terms of relative abundance (scale 0-1) in a 1-m buffer area around the head of the cow

All woody plants were identified at the species level.

Herbaceous species were joined in a broad category (except for easy-to-identify tall herbs).

Methods:

Percent consumption of woody and herbaceous plants

$$\% \text{ Consumption}_i = \frac{\sum \text{Consumption}_i}{\sum \text{Consumption}_{i\text{-}n}}$$

Jacob's Selection Index

$$\text{JSI}_i = \frac{(\text{Consumption}_i - \text{Abundance}_i)}{(\text{Consumption}_i + \text{Abundance}_i - 2 * \text{Consumption}_i * \text{Abundance}_i)}$$

$\text{JSI}_i > 0$: Preferred species (consumed more than its availability)
$\text{JSI}_i = 0$: Indifferently consumed species (consumed proportionally to its availability)
$\text{JSI}_i < 0$: Avoided species (consumed less than its availability)

Repetition: cows within days

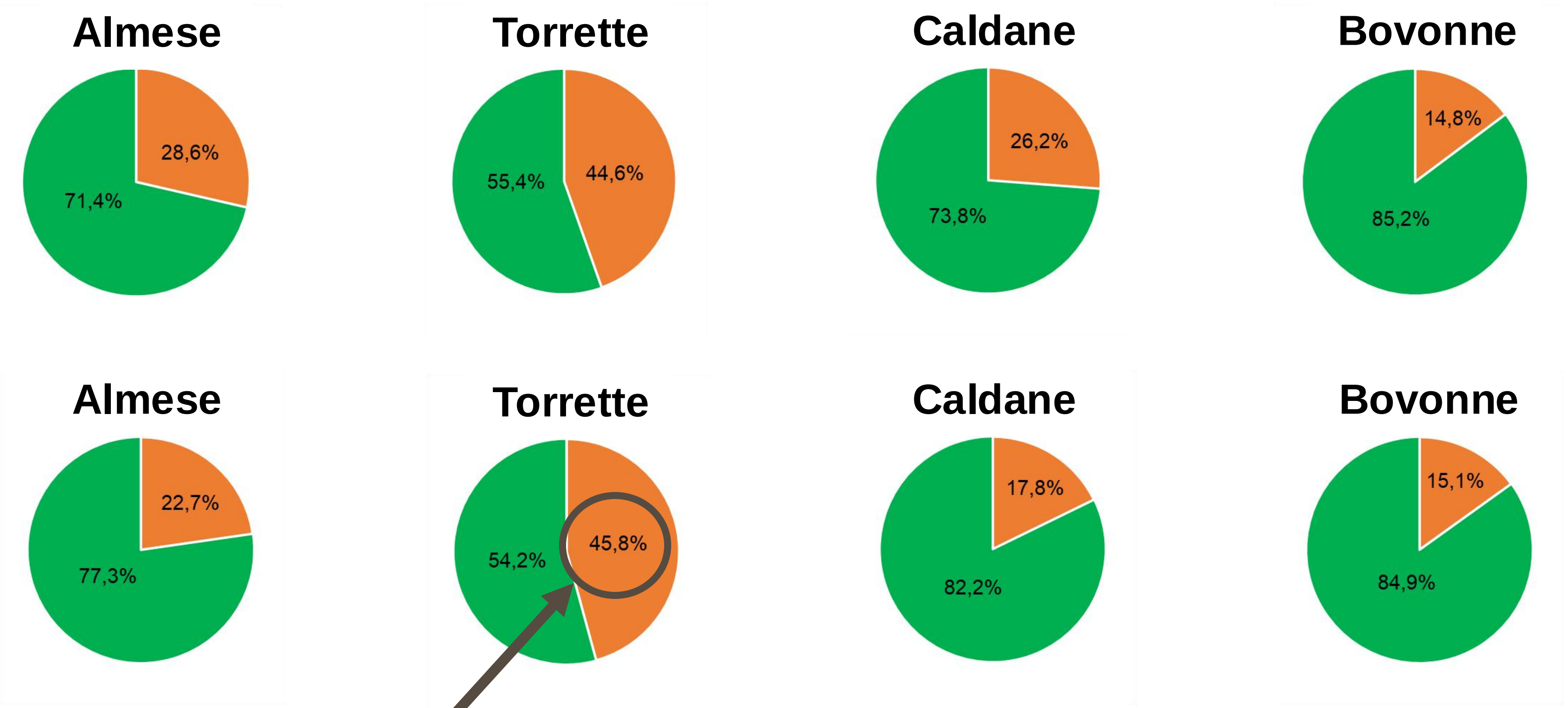
Source: Jacob (1974)

Results: Percent consumption

Highland cattle fed on a **mixture of herbaceous and woody plants** in all study areas
Diet composition **varied among the paddocks** (**different resource availability and forage quality**)

Proportions in the feeding stations

Proportions in the diet



Proportion of woody plants in their diet up to **46%**

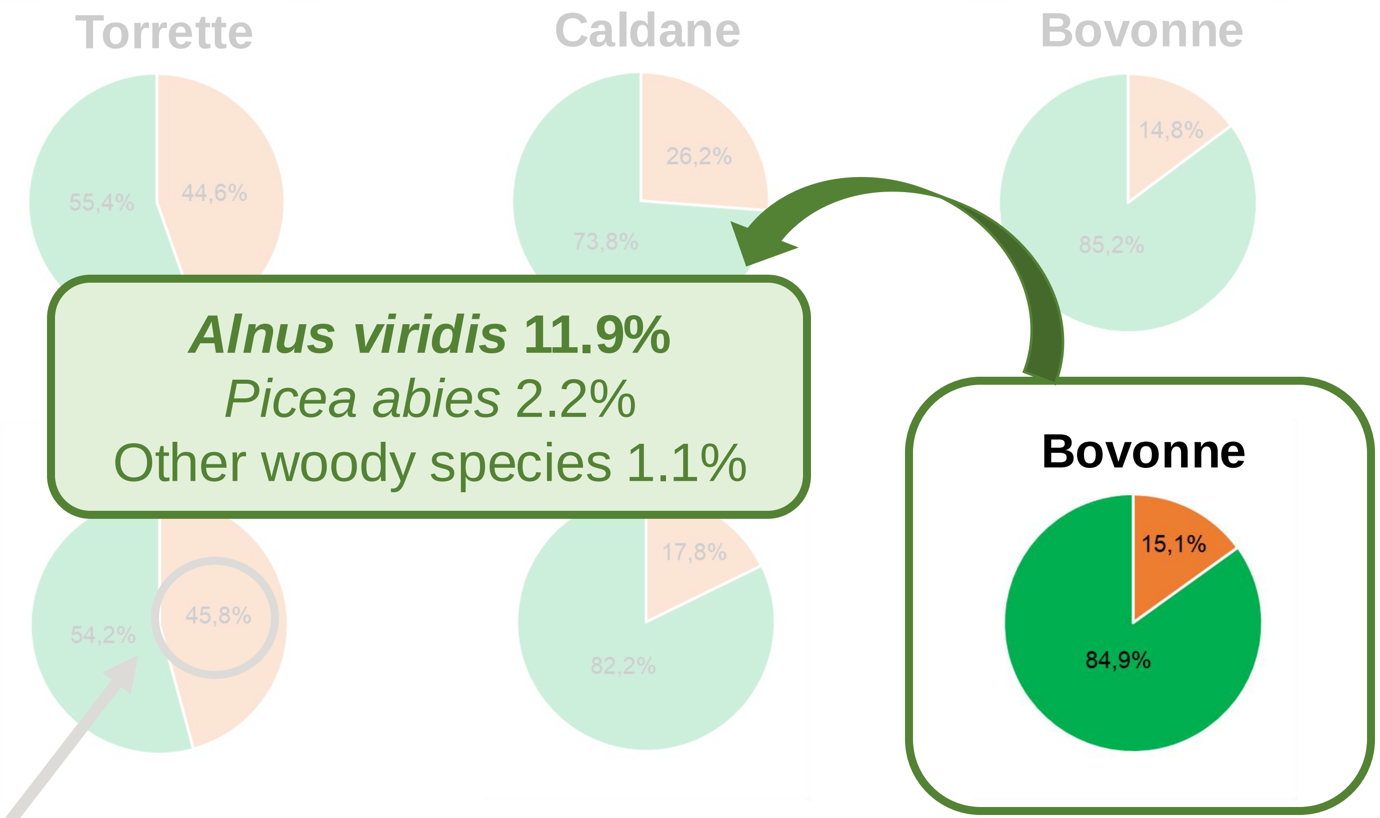
Herbaceous species
Woody species

14 days
150 hours
11’356 observations
29 different cows

Results: Percent consumption

Hi… herbaceous and woody plants in all study areas

Di… paddocks (different resource availability and forage quality)



Herbaceous species

Woody species

14 days
150 hours
11’356 observations
29 different cows

Results:

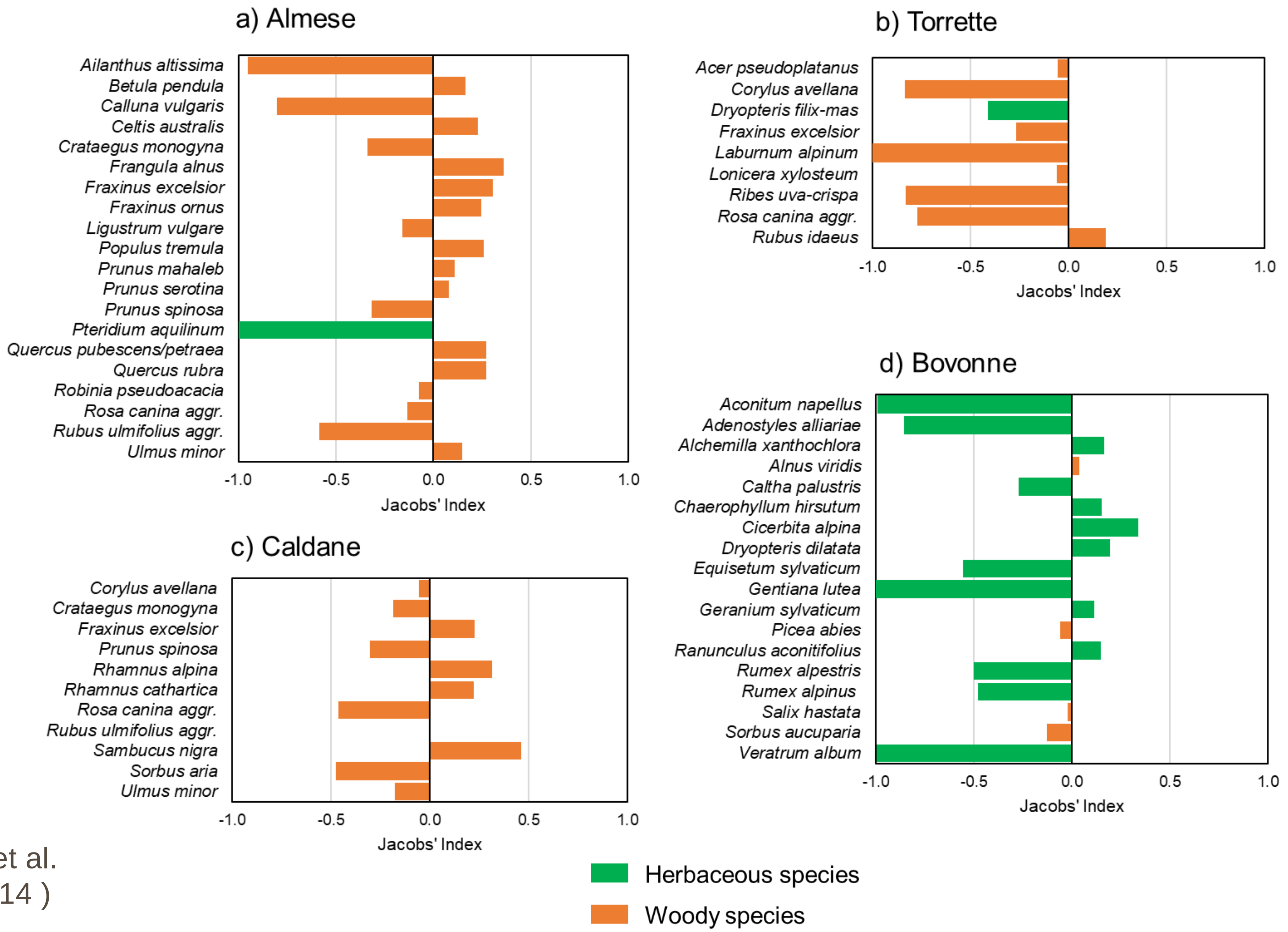
Preference indices

Some **woody plants were palatable** to Highland cattle, and **positively selected:**

- Trees: *Celtis australis, Populus tremula, Fraxinus ornus*
- Shrubs: *Frangula alnus, Sambucus nigra, Rubus idaeus*

Highly-moderatly palatable and nutritious plants

(Mahieu et al. 2021; Singh et al. 2010; Hejcmanová et al. 2014)



Results:

Preference indices

Some woody plants were pal... and ...

Populus tremula,

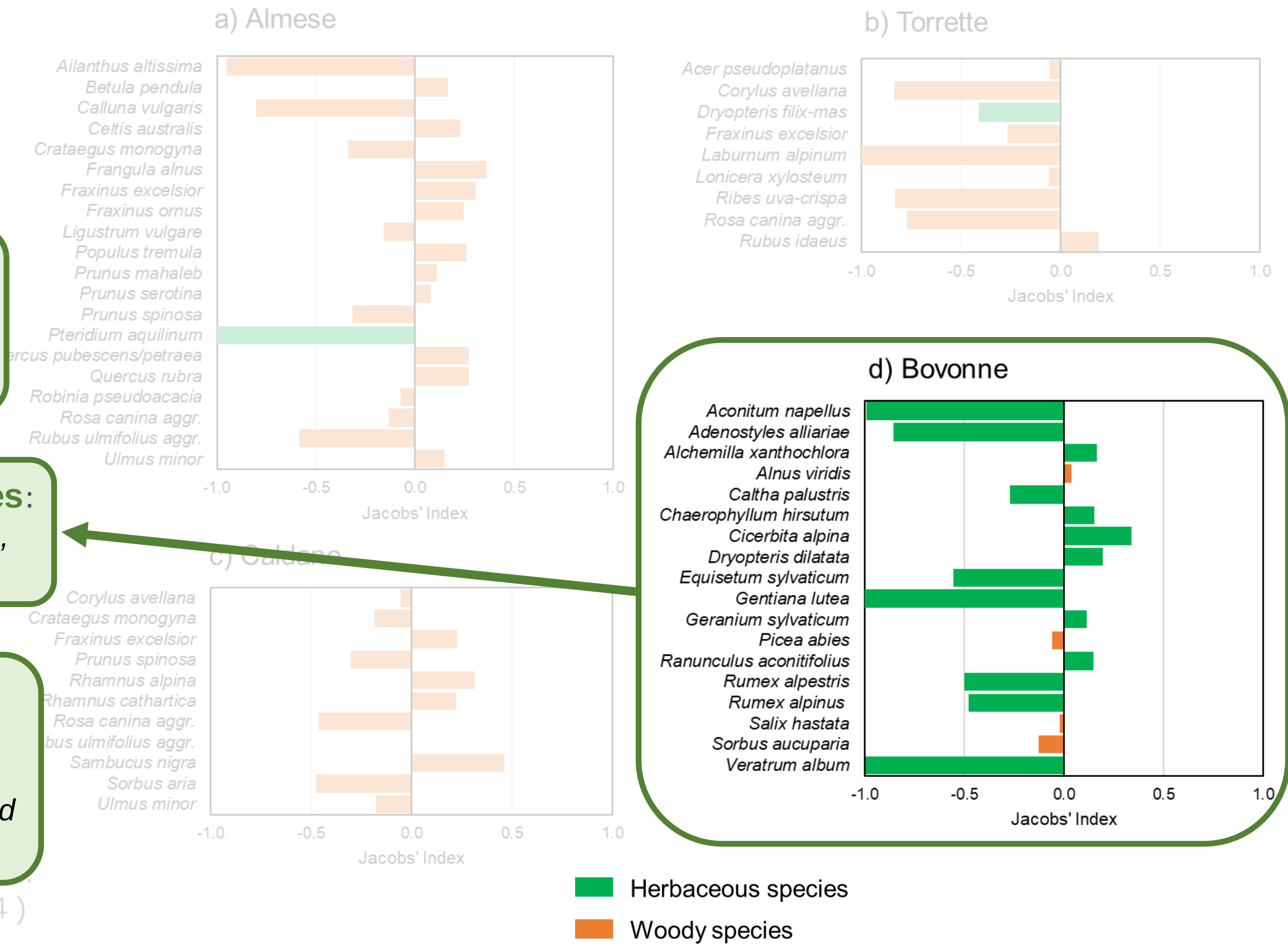
Sambucus nigra, Rubus idaeus

2010; Hejcmanová et al. 2014)

Preferred species:
Alchemilla xanthochlora, Chaerophyllum hirsutum, and *Ranunculus aconitifolius*

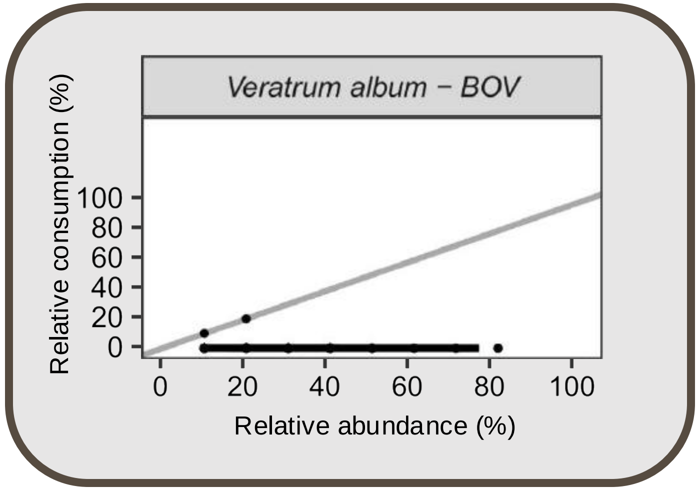
Indifferently consumed species:
Alnus viridis, Geranium sylvaticum, Picea abies, and Salix hastata

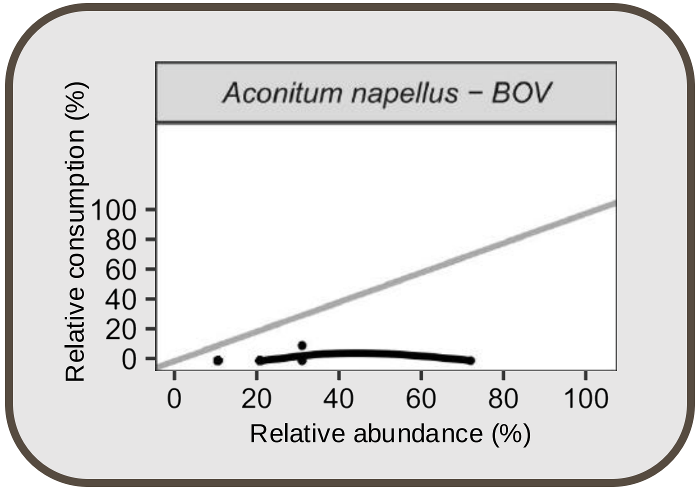
Avoided species:
Aconitum napellus, Adenostyles alliariae, Equisetum sylvaticum, Gentiana lutea, Rumex alpinus, and Veratrum album



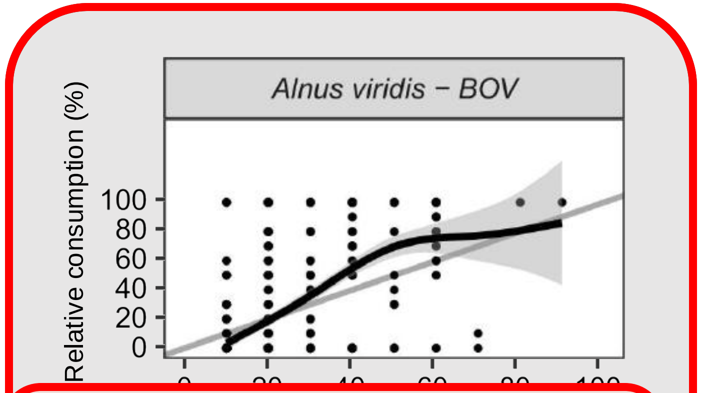
Results: Abundance-consumption in Bovonne

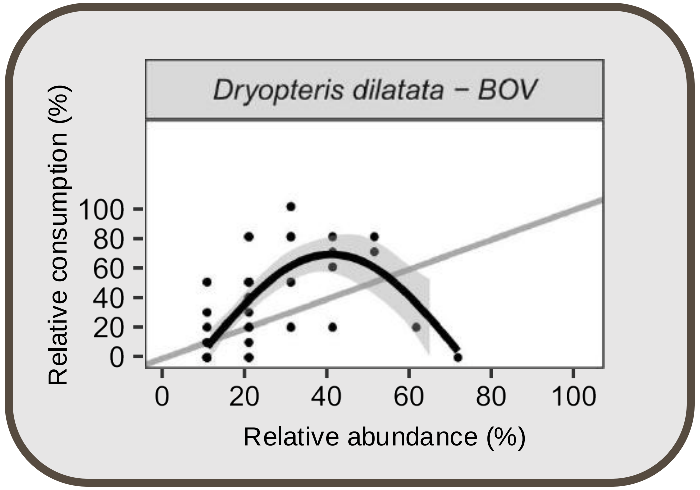
Consumption did not increase with abundance

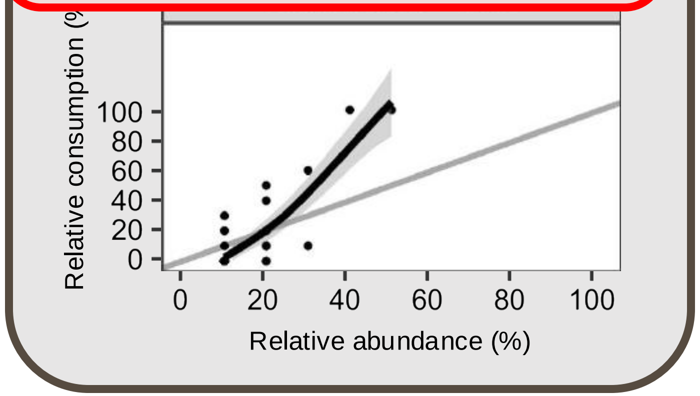


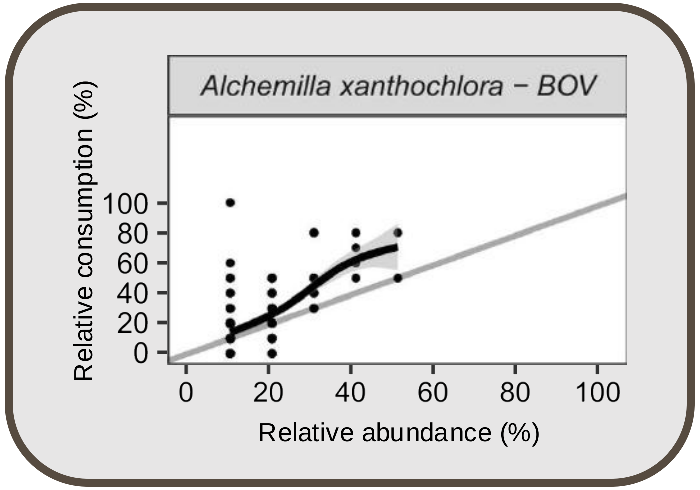


Consumption increased with abundance





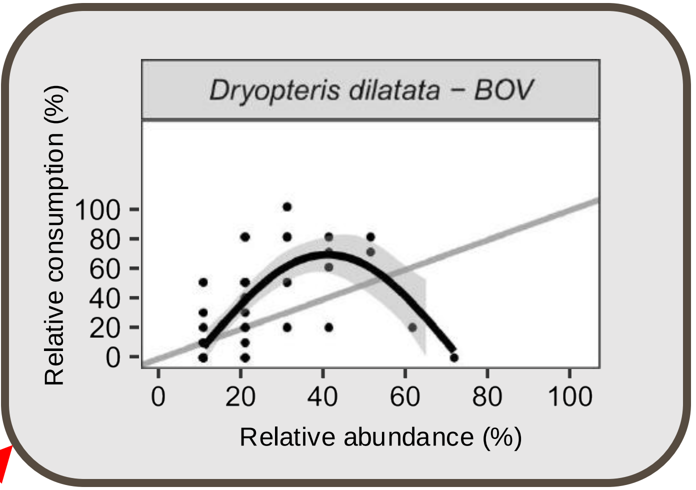


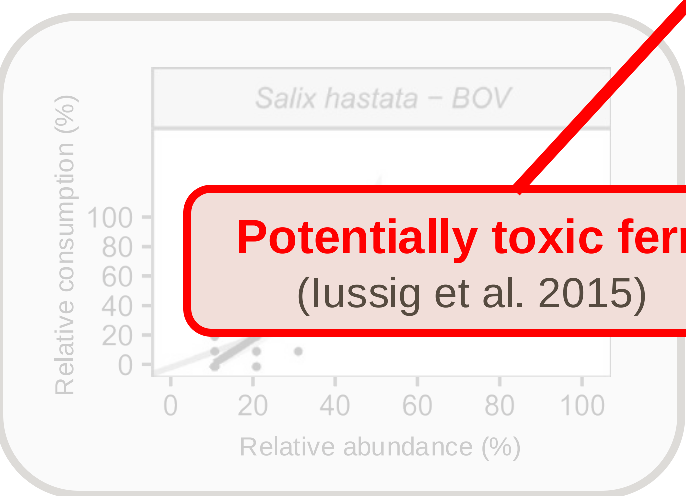


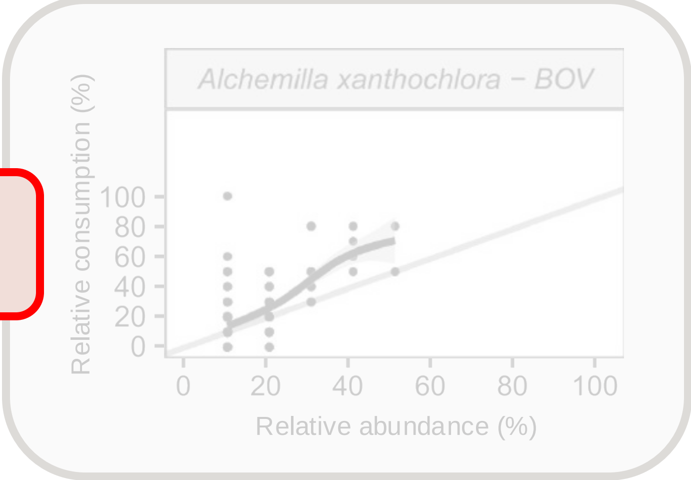
Toxic species in abundance in *A. viridis* understory vegetation

Results: Abundance-consumption in Bovonne

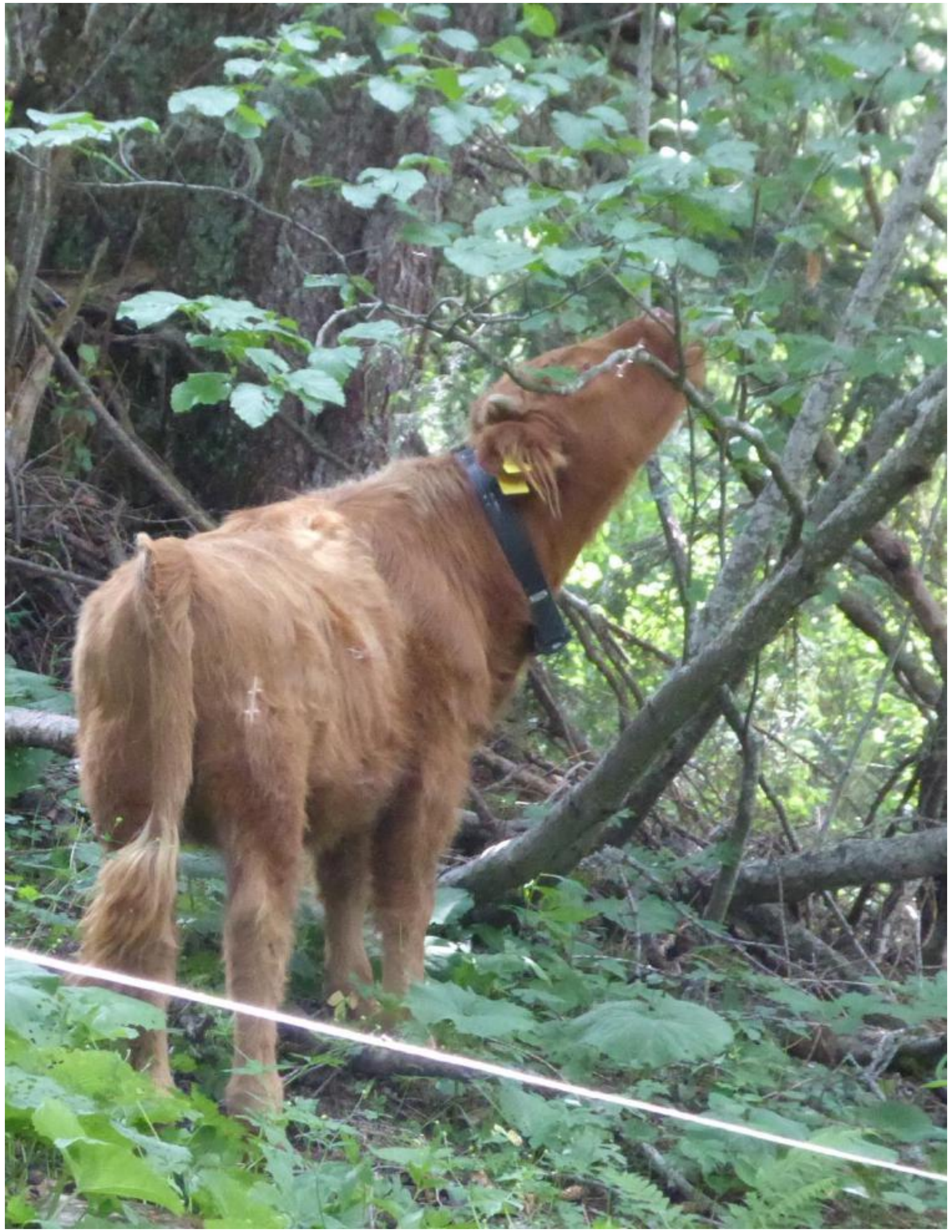
Consumption increased with abundance







Potentially toxic fern
(Iussig et al. 2015)



Conclusion:

- Highland cattle included a **large amount (15-46%) and variety of woody species in the diet**
- They expressed a clear selection towards woody plants
- They consumed **12%** of *A. viridis* when it was present
- *A. viridis* consumption is dependent on its abundance

→ Highland cattle feeding behavior suggest they could be used for the sustainable exploitation of **marginal mountain areas** with abundant woody vegetation

→ This management could contribute to **reduce shrub encroachment.**

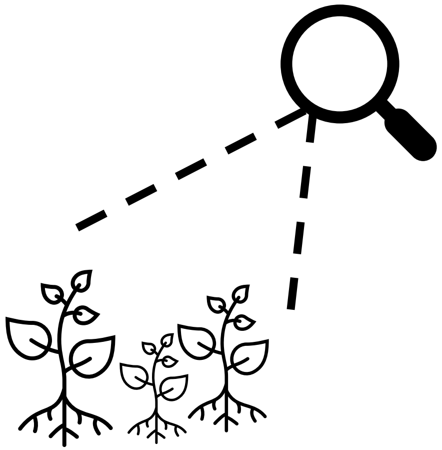
CHAPTER 4: Spatial distribution of Highland cattle in *Alnus viridis* encroached subalpine pastures

Svensk et al. (2021). Spatial Distribution of Highland Cattle in *Alnus viridis* Encroached Subalpine Pastures. Frontiers in Ecology and Evolution, 9, 1–7.

Objectives:

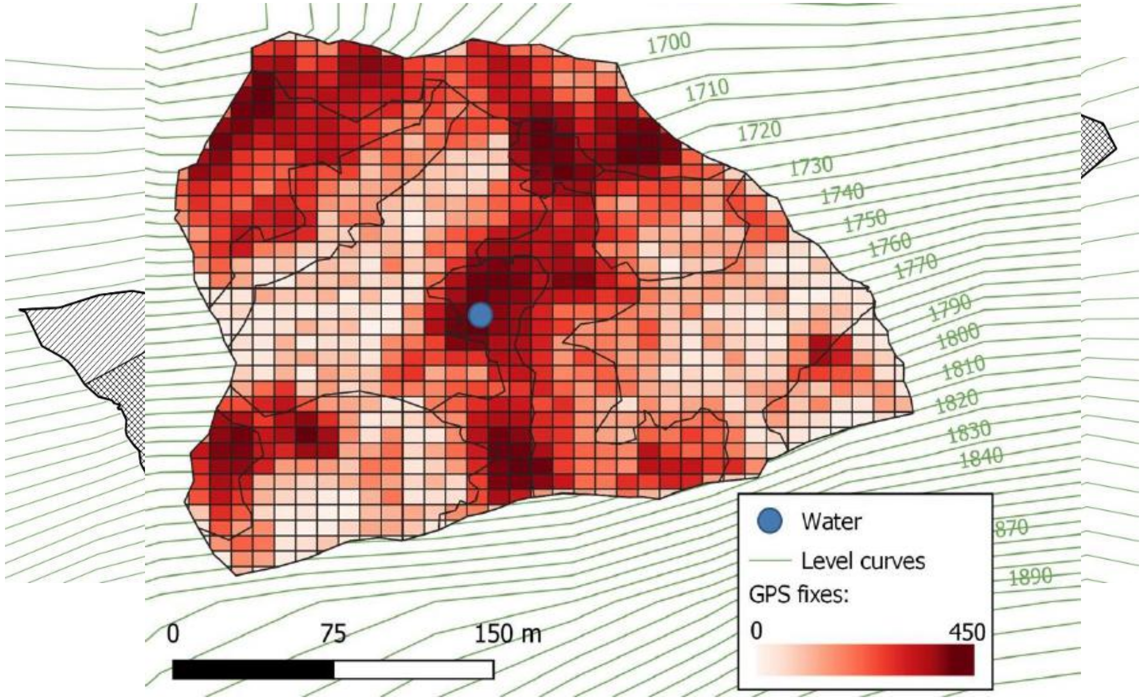
- **Map the spatial distribution of Highland cattle** in *A. viridis*-encroached pastures
- **Estimate the effect of topography and vegetation** on Highland cattle spatial distribution

Methods:



1. **Botanical surveys** in **homogeneous vegetation patches** defined in advance (vertical point-quadrat method):
   - Relative abundance
   - Pastoral value (PV)
   - Landolt indexes (light, moisture, nutrient value)
   - Species richness
   - Shannon diversity index (Hr)
   - *A. viridis* cover (%)

2. **Calculation from GIS, on a 10x10m grid**:
   - Distance to water source
   - Slope
   - Aspect
   - Elevation
   - Number of GPS fixes from the collars

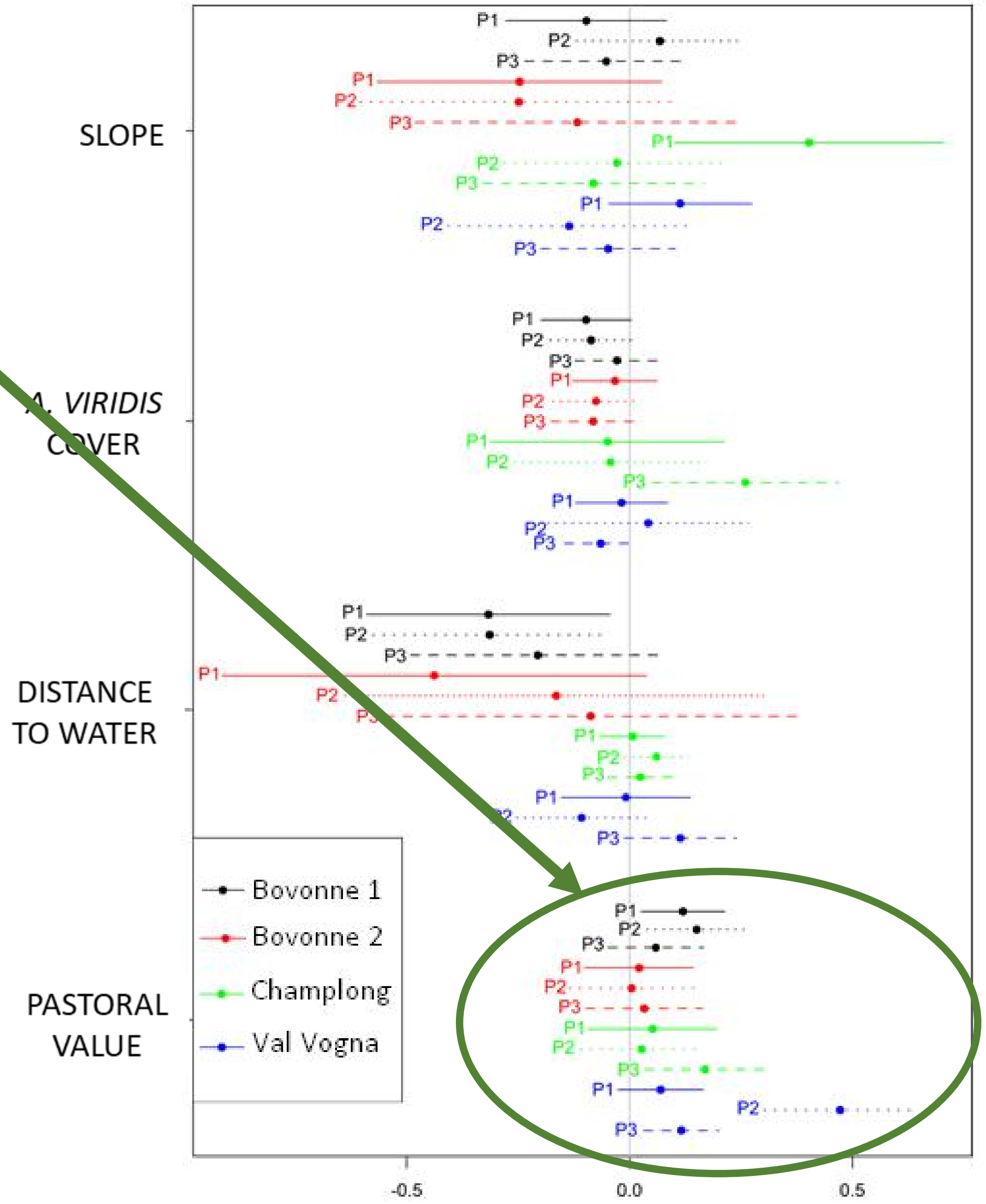


Sources: Daget and Poissonet, 1971; Magurran 1998;

Results:

Integrated Nested Laplace Approximation (INLA)

- **Livestock spatial distribution is often positively influenced by PV**



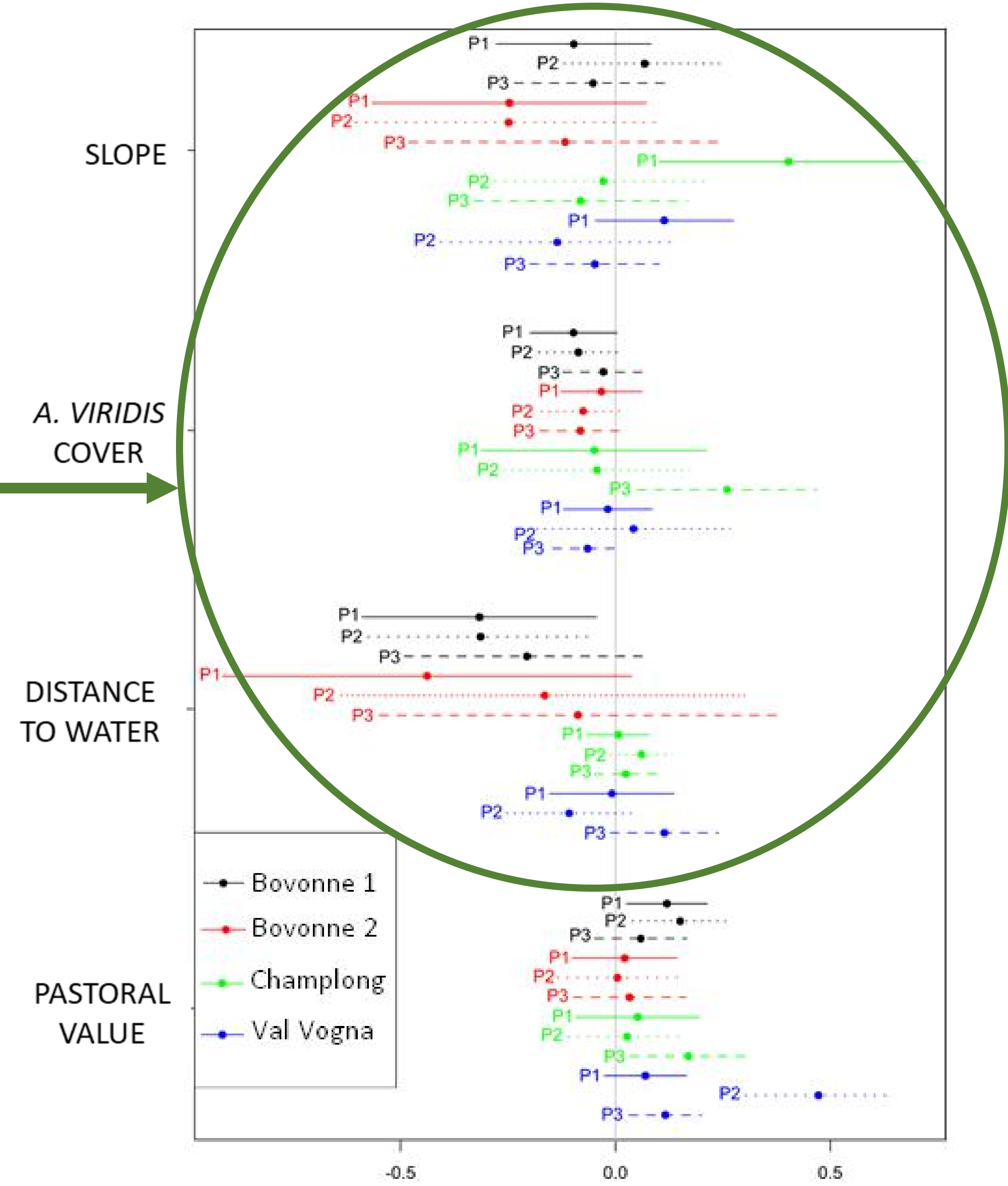
Results:

Integrated Nested Laplace Approximation (INLA)

- **Livestock spatial distribution is often positively influenced by PV**
- ***A. viridis* cover, slope and distance to water sources did not generally affect livestock spatial distribution**

Highland cattle did not avoid areas with harsh conditions

They may explore the paddock at the beginning of the grazing period, at least the first year



Conclusion:

- While **Highland cattle preferred areas with good quality vegetation**, they **did not actively avoid areas with harsh conditions** (steep slope, dense stands of *A. viridis*, or far away from water)

- Their **spatial distribution may change along the season**, following the changes in the vegetation and exploratory behaviors.

CHAPTER 5: Use of molasses-based blocks to modify grazing patterns and increase Highland cattle impacts on *Alnus viridis*-encroached pastures

Svensk et al. (2022). Use of Molasses-Based Blocks to Modify Grazing Patterns and Increase Highland Cattle Impacts on *Alnus viridis*-Encroached Pastures. Frontiers in Ecology and Evolution, 10.

Objectives:

- Assess the **potential of attractive points** (molasses-based blocks) to **lure** Highland cattle into *A. viridis*-encroached areas

- Evaluate their **impacts on *A. viridis* and the surrounding vegetation** in the targeted areas

Methods:

1. **Attractive points**: 5 **molasses-based blocks** were placed in highly encroached areas in every paddock the second year (2020).

2. **Control areas** were defined in comparable areas in terms of:
   - *A. viridis* cover
   - Cattle visit rate in 2019
   - Topography

Molasses-based block composition:

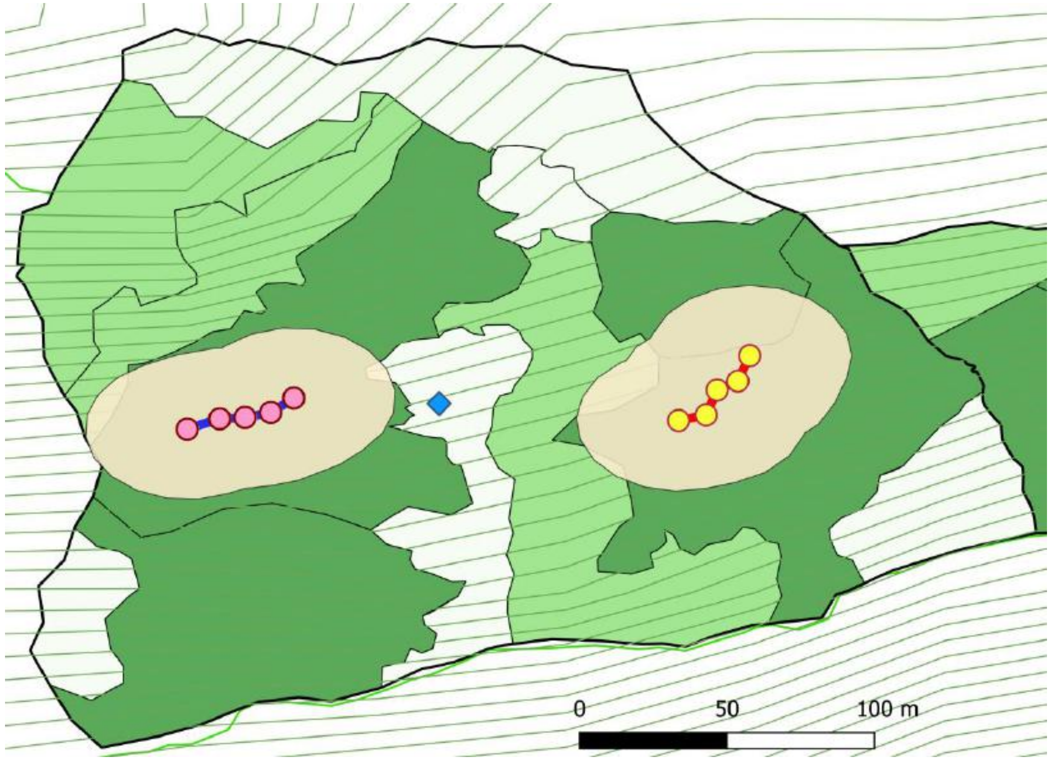
Crude protein	3.0 %
Crude fibre	0.0 %
Crude fat	2.0 %
Crude ashes	24.0 %
Sugar	40.0 %
Calcium	4.0 %
Phosphorus	2.0 %
Magnesium	0.2 %
Sodium	2.5 %

Additives per kg:

Inorganic zinc	900 mg
Inorganic manganese	900 mg
Inorganic iodine	60 mg
Inorganic cobalt	12 mg
Inorganic selenium	9 mg

Example of Bovonne 1:

- Attractive points
- Control points
- Attractive points transects
- Control points transects
- Water
- 50 m buffer
- Contour lines
- Green alder cover < 33 %
- Green alder cover between 33 % and 66 %
- Green alder cover between < 66 %



Methods:

1. **Attractive points**: 5 **molasses-base** strategic areas in every paddock the

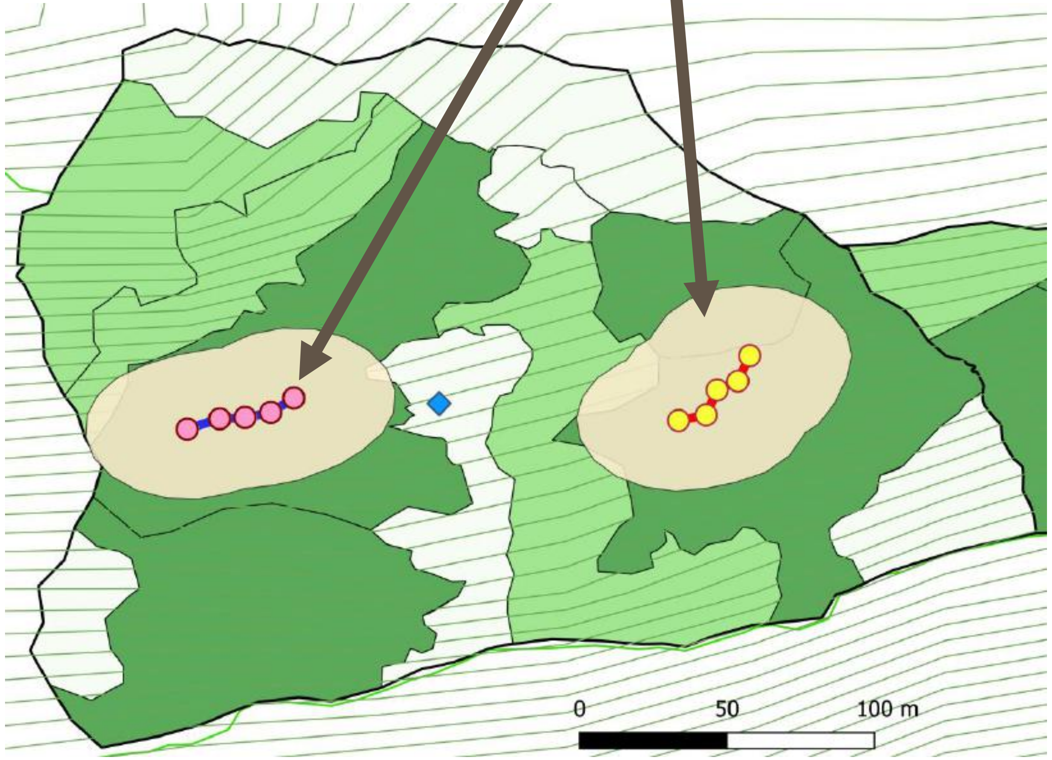
2. **Control areas** were defined in compa

   - *A. viridis* cover
   - Cattle visit rate in 2019
   - Topography

GPS fixes were counted in 10 meter and 50 meter buffers

Example of Bovonne 1:

Attractive points
Control points
Attractive points transects
Control points transects
Water
50 m buffer
Contour lines
Green alder cover < 33 %
Green alder cover between 33 % and 66 %
Green alder cover between < 66 %



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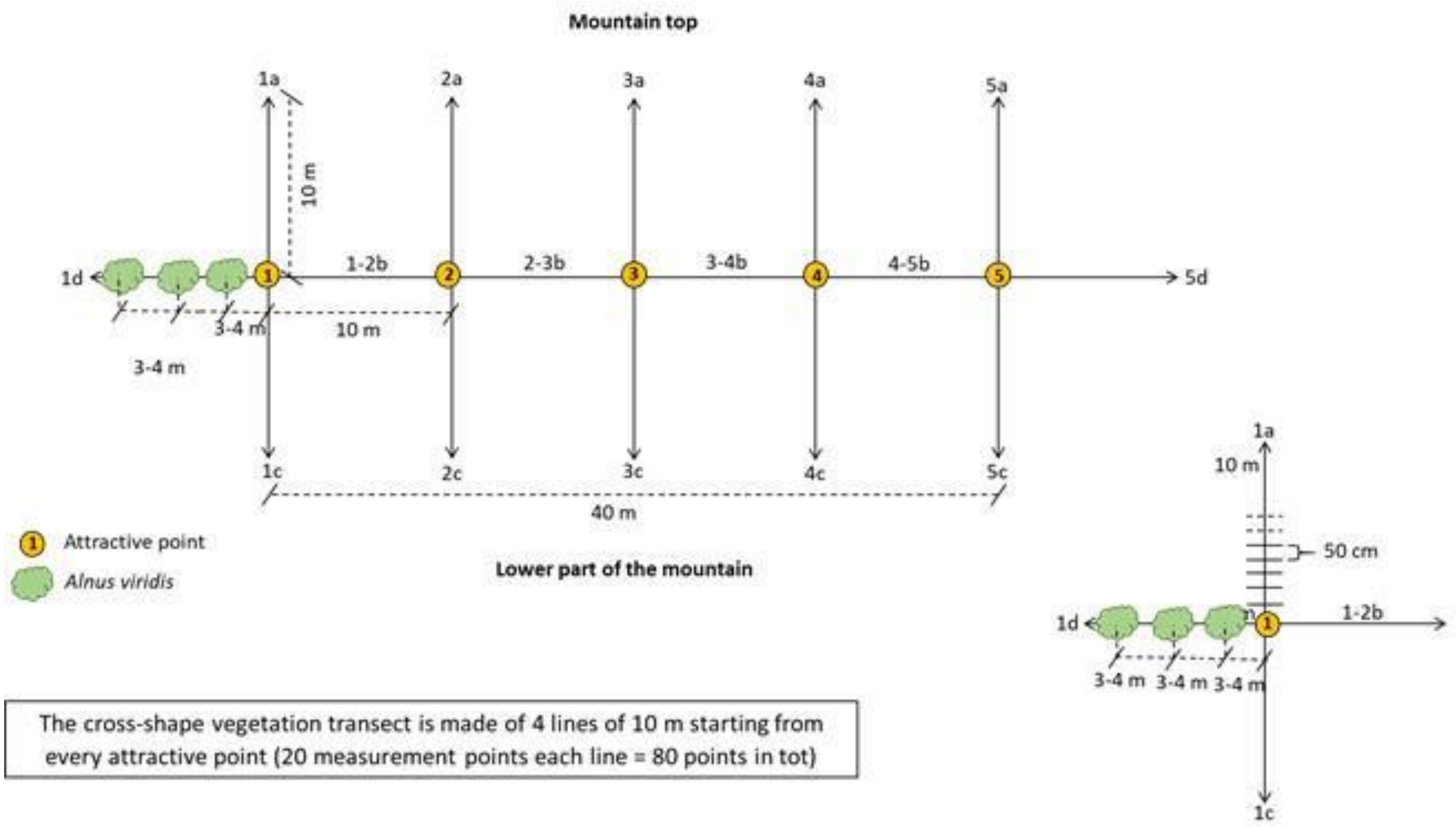
Phosphorus	2.0 %
Magnesium	0.2 %
Sodium	2.5 %

Additives per kg:

Inorganic zinc	900 mg
Inorganic manganese	900 mg
Inorganic iodine	60 mg
Inorganic cobalt	12 mg
Inorganic selenium	9 mg

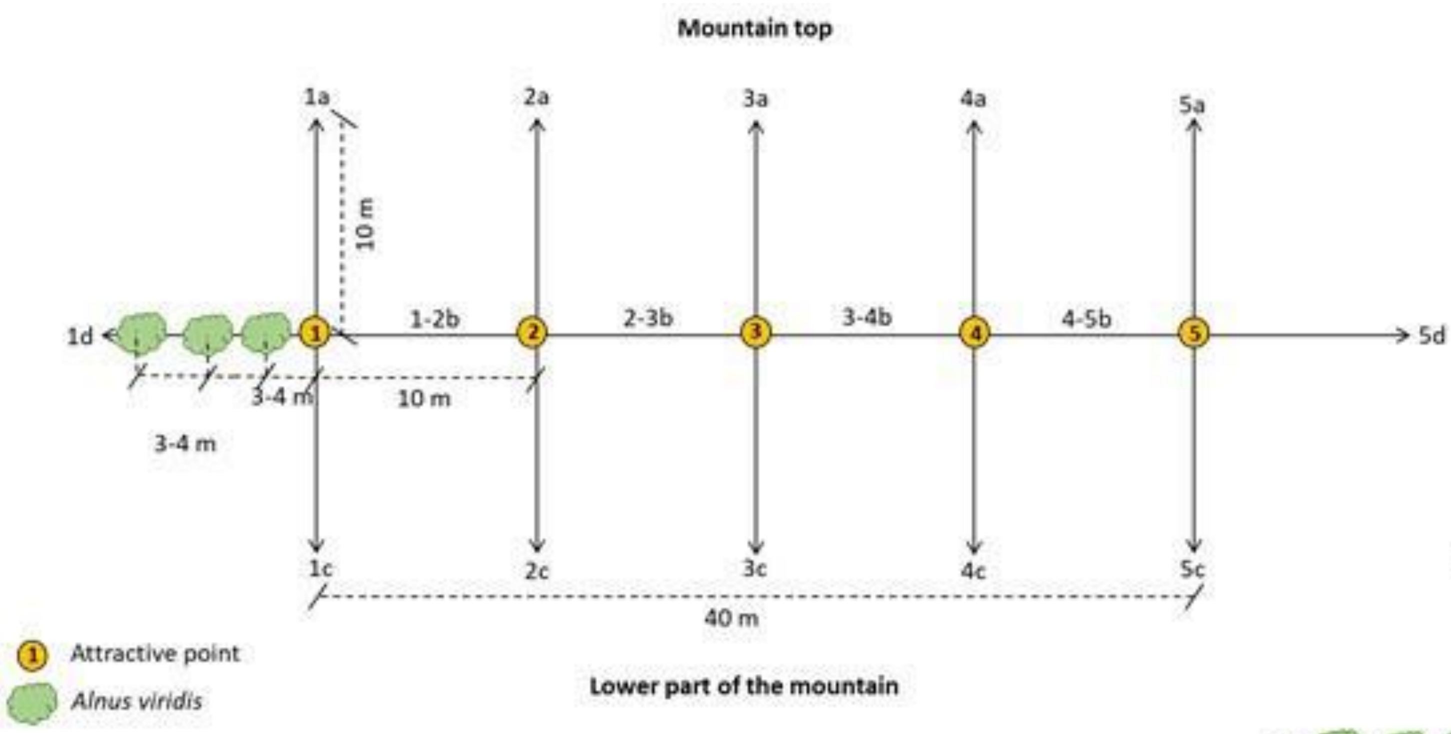
Methods:

- The **5 attractive points** were placed at 10 m from each other
- **Botanical surveys** were made **before AND after grazing**, between and around each attractive point on 10 m transects following the method of Daget and Poissonet (1971)



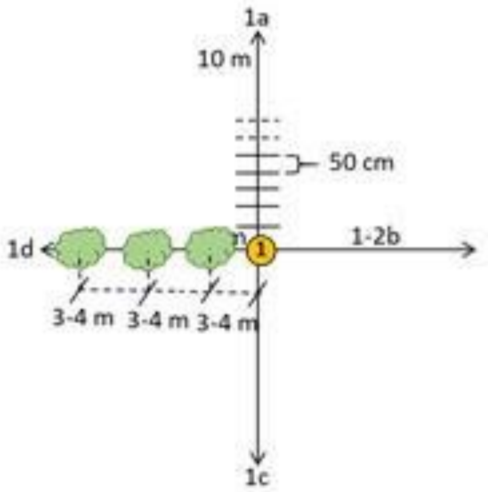
Methods:

- In every transect, **3 shrubs** were selected, and the number of living leaves was counted **before and after grazing.** Damages on branches after grazing were also recorded.



The cross-shape vegetation transect is made of 4 lines of 10 m starting from every attractive point (20 measurement points each line = 80 points in tot)

- On each transect, the percentage of herbaceous and bare soil cover was visually estimated **before and after grazing**



Estimation of **Highland cattle grazing on *A. viridis* leaves and impact (grazing + trampling) on the vegetation cover**

Results:

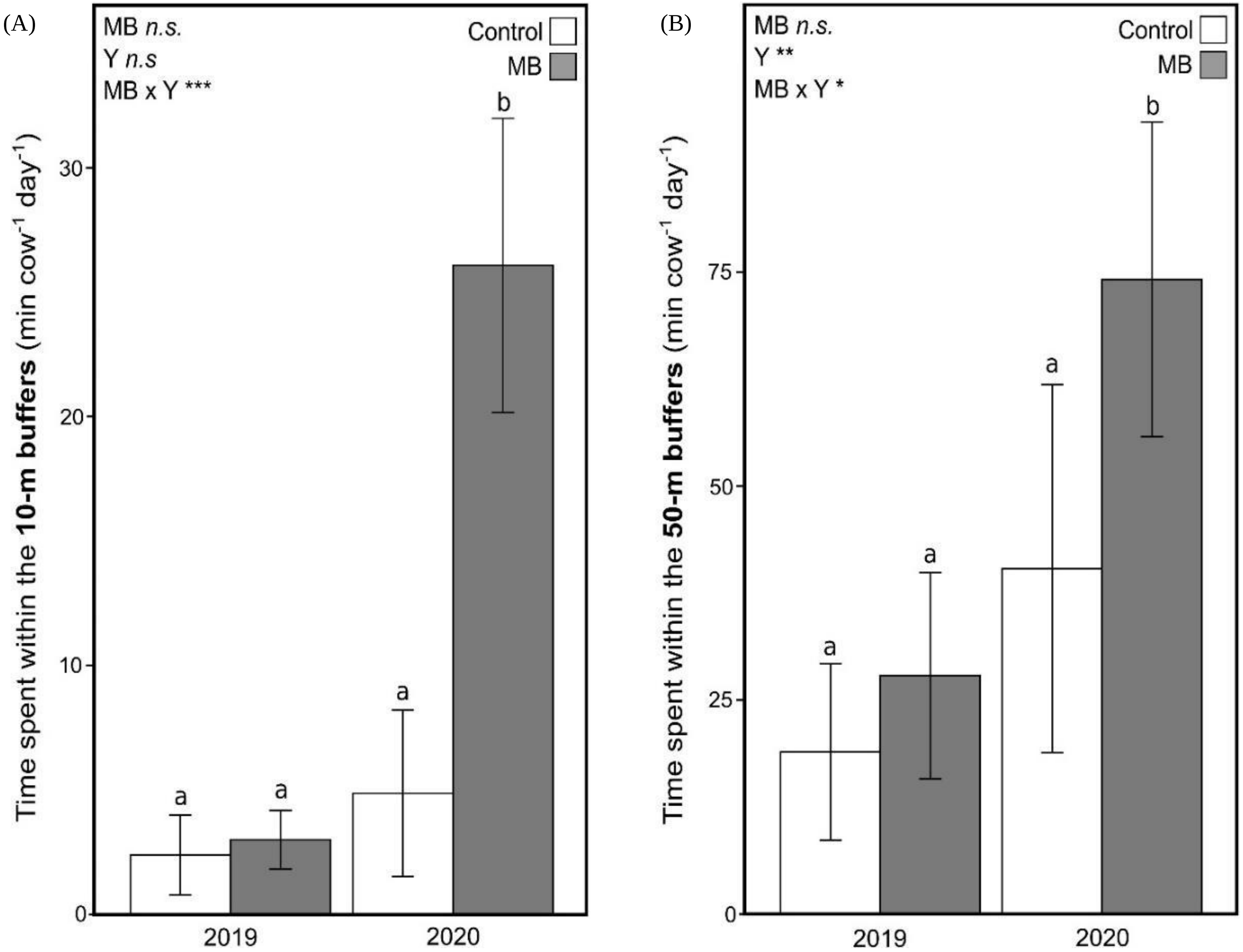
Time spent around attractive points

- The presence of molasses-based blocks **significantly increased Highland cattle frequentation**
    1. Compared to 2019
    2. Compared to control areas

- This effect was recorded **up to 50 meters** around the attractive points

Efficiency of attractive points to attract the herd even in dense parts

10-m buffer **50-m buffer**



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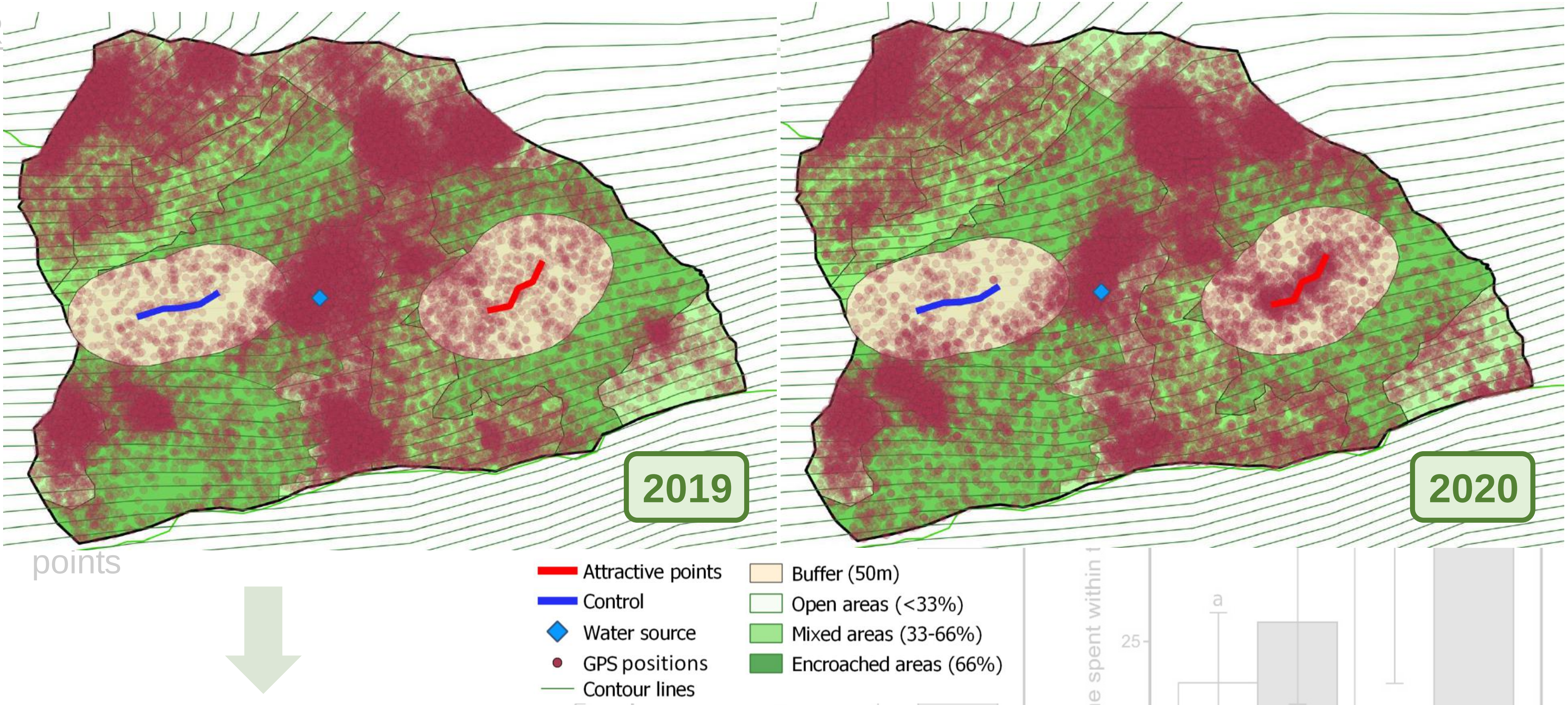


points

Efficiency of attractive points to attract the herd even in dense parts

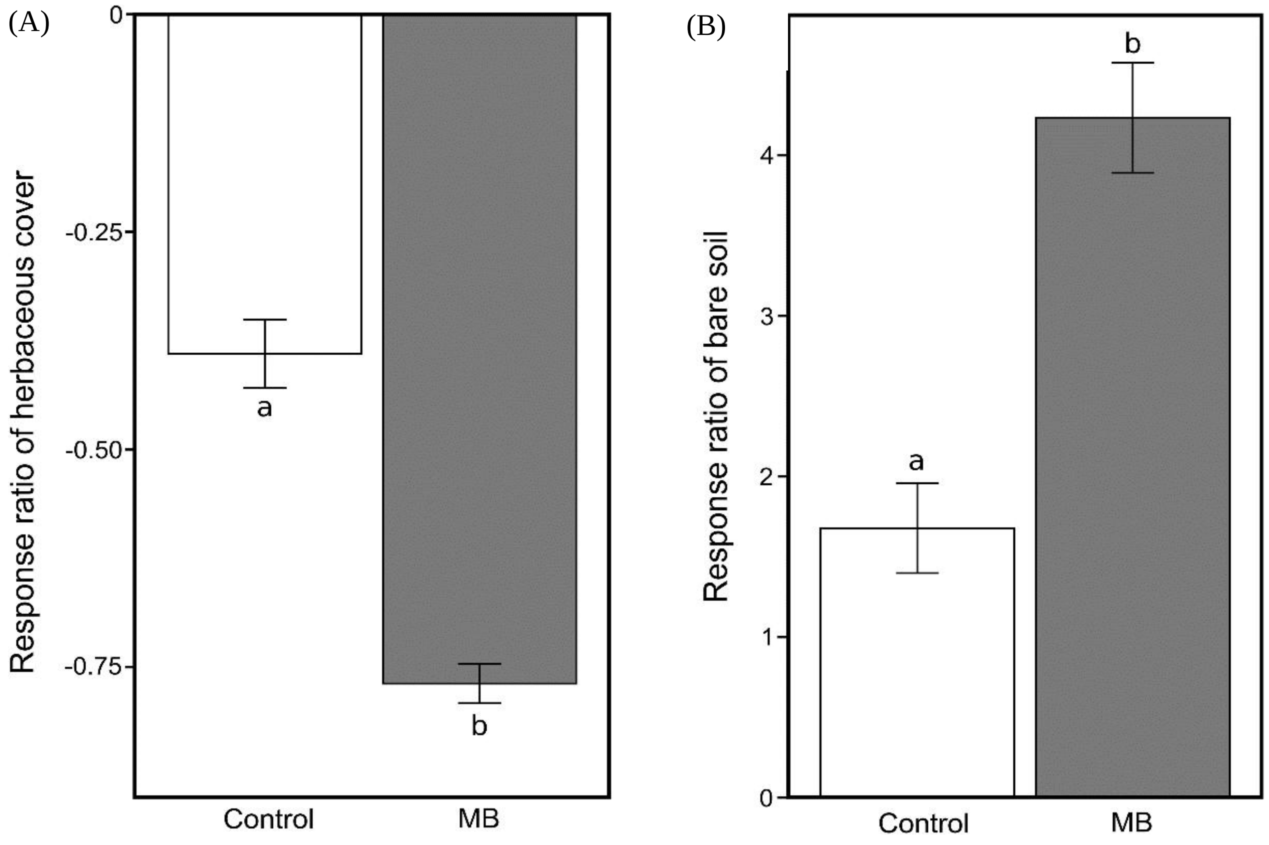
Results: Impact on the vegetation

$$\textit{Response ratio} = \frac{\textit{postgrazing} - \textit{pregrazing}}{\textit{pregrazing}}$$

Positive RR = increase of the data in %
Negative RR = decrease of the data in %

- **Significant effect of grazing and trampling on herbaceous and bare soil cover** around attractive points.

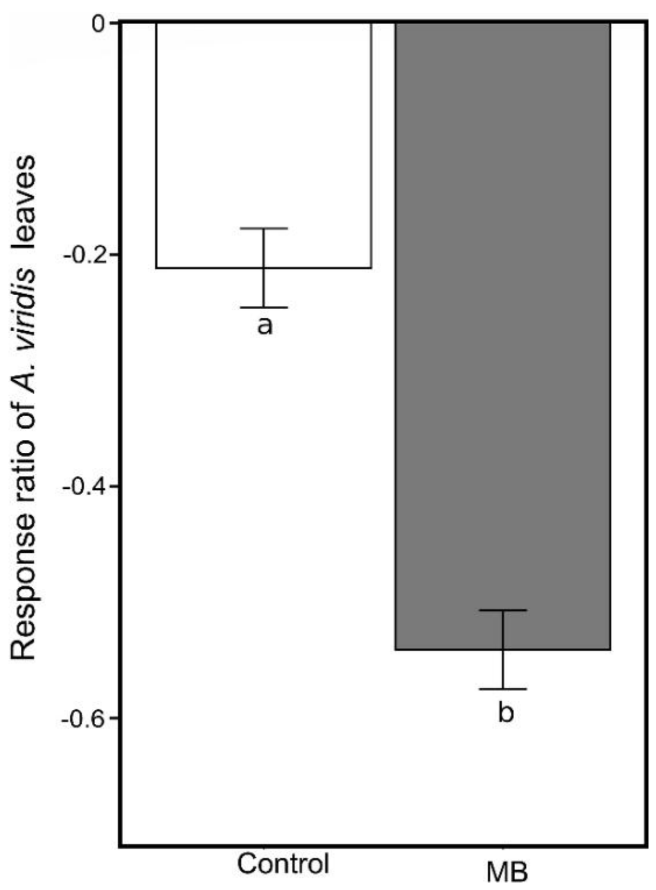
- The impact was significant for **all botanical groups**:
  - Fern and tall herb cover
  - Medium and small herb cover
  - Woody plant cover



Results: **Impact on the vegetation**

Results: **Impact on the vegetation**

Results: **Impact on *A. viridis***

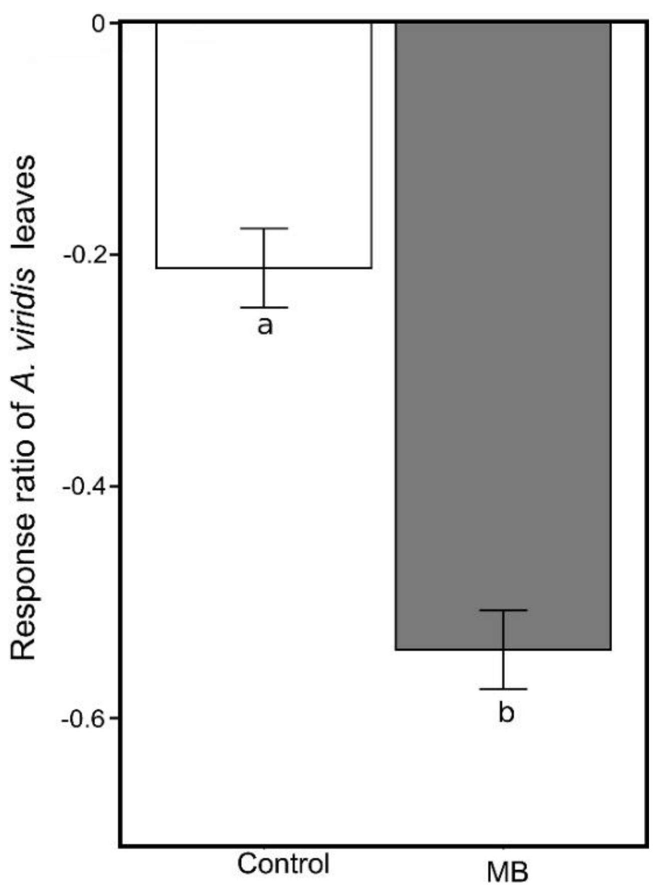


- *A. viridis* **leaves were significantly more eaten around attractive points** (from 3 to 10 meters around molasses-based blocks) except in Bovonne 2.

- Green alder branches were also significantly more damaged around attractive points.

- Some branches were found **broken**.

Results: Impact on *A. viridis*



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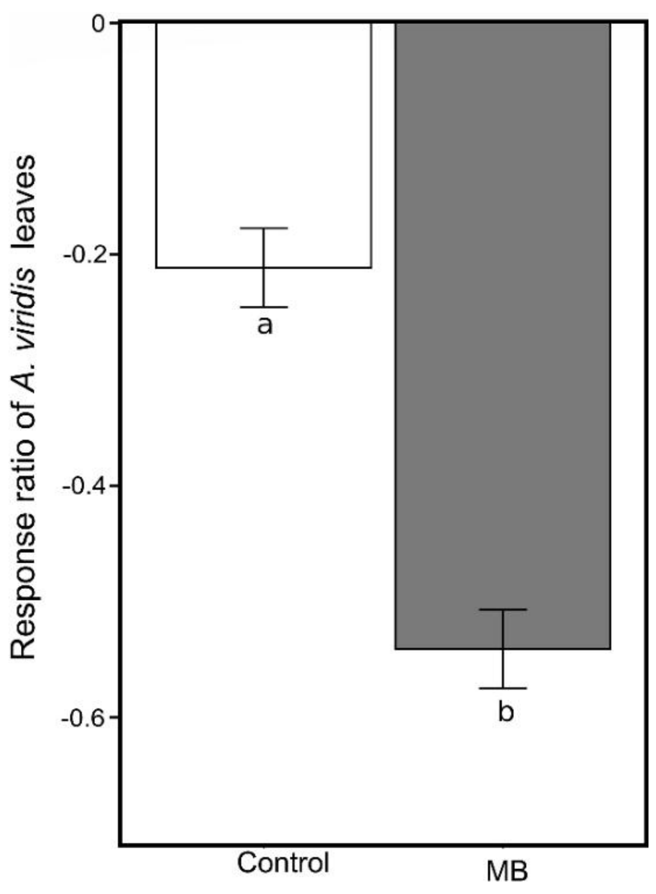
Results: Impact on *A. viridis*



Conclusion:

- **Attractive points had a significant effect** on Highland cattle spatial distribution

- **There was an intensive grazing and trampling around attractive points** which had an important effect on vegetation cover (herbaceous and bare soil cover) AND on green alder leaves and branches

This management could enhance the effect of Highland cattle grazing on *A. viridis* stands

A rotational management is <u>necessary</u> to avoid erosion problems on the targeted areas

CHAPTER 6: Nitrogen translocation by Highland cattle grazing in *Alnus viridis*-encroached pastures

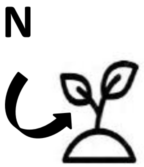
Svensk et al. (2023). Nitrogen translocation by Highland cattle grazing in *Alnus viridis*-encroached pastures. Nutrient Cycling in Agroecosystems, 126, 127–141.

Objectives:

- Measure the nitrogen (N) content in the dungs
- Estimate the amount of N ingested by cows

Link between the N ingested and the N content in dungs

- Estimate the **nitrogen import-export fluxes**



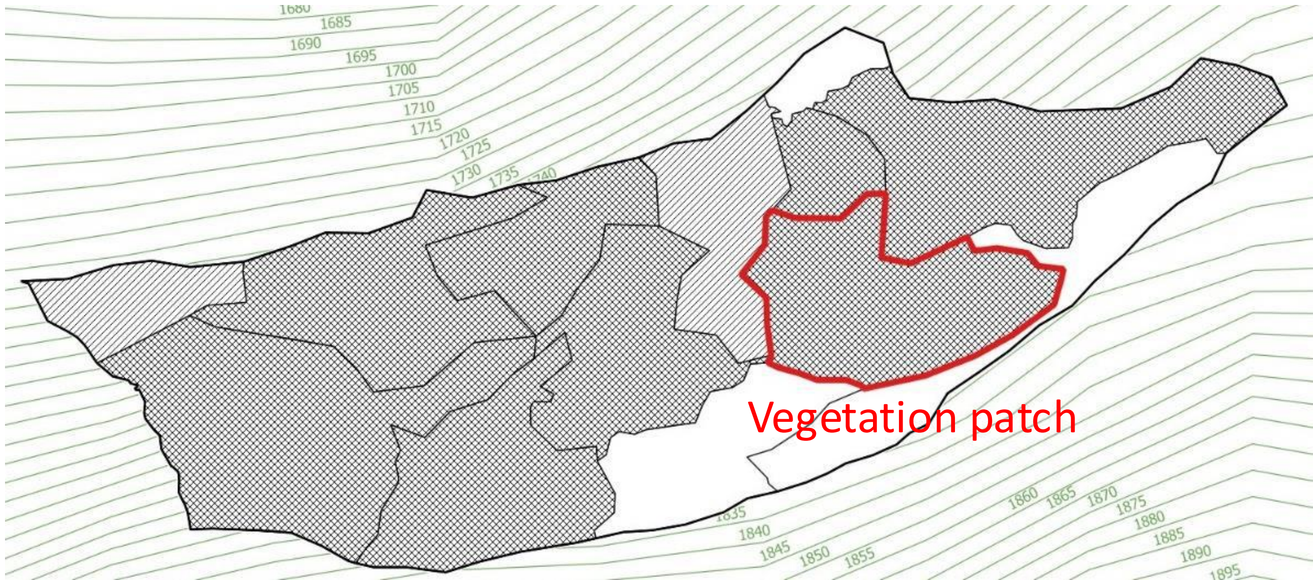
Methods:

Herbaceous vegetation sampling: collection of the plant biomass once in every **vegetation patch (homogeneous vegetation areas)** of each paddock.

Leaf sampling: collection of *A. viridis* leaves at grazable height, 3 times during the grazing season (June, July and August), to assess changes in leaf N content.

Dung sampling: collection throughout the grazing season every 10 days,
2-3 times in each paddock, depending on grazing length (two years).

Analysis of the **nitrogen content** in laboratory.

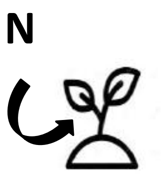


Methods:

- **Highland cattle diet** was estimated **24h** prior to dung sampling, using GPS positions:
  → Count of GPS fixes in each vegetation patch
  → Link to herbaceous and leaves samples

- **Animal activity periods** were identified through GPS collars' activity sensors and distance travelled by cows.

- Estimation of the **N fluxes (kg ha^{-1} yr^{-1}):**



$$N_{fluxes} = N_{excreted} - N_{ingested}$$

Sources: Pauler et al. (2019); Estermann et al. (2003); Berry et al. (2002); Estermann et al. (2002)

Methods:

$$N_{fluxes} = N_{excreted} - N_{ingested}$$

$$N_{excreted} = \text{grazing days} * TS * \text{nb of cows} * (0.93 * [N_{paddock}] * DM)$$

TS: % time spent in vegetation patch (presence/absence)

0.93: % of the N_{intake} is excreted in dungs and urine (from literature)

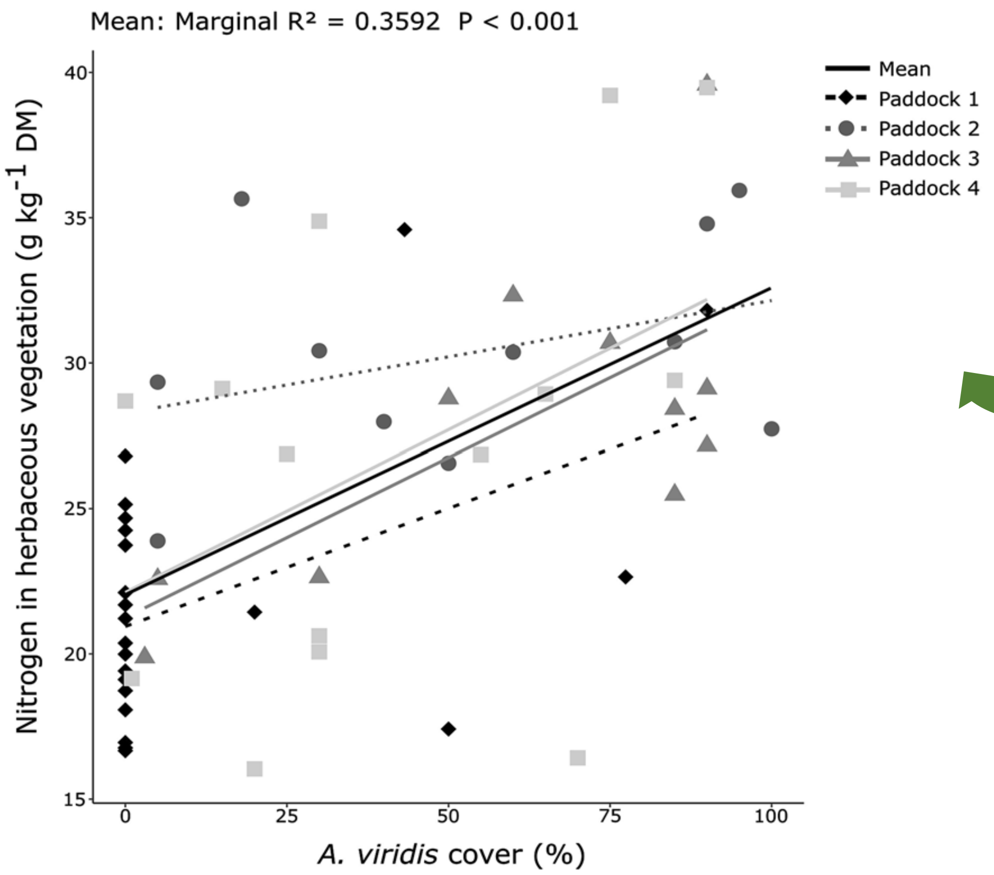
DM: Dry matter ingested by a cow (from literature)

$$N_{ingested} = \text{grazing days} * TG * \text{nb of cows} * [N_{patch}] * DM$$

TG: % time spent grazing in vegetation patch (from GPS sensors and distance)

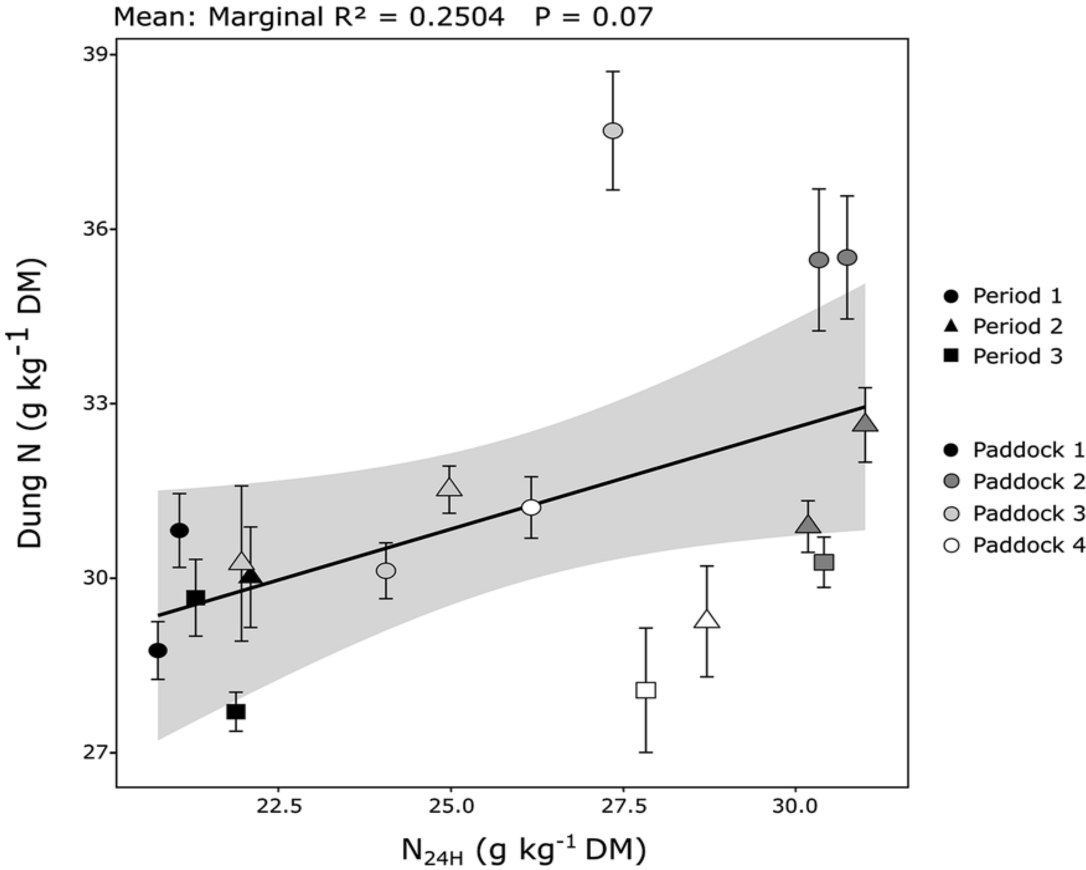
Sources: Pauler et al. (2019); Estermann et al. (2003); Berry et al. (2002); Estermann et al. (2002)

Results: N content in herbaceous vegetation and *A. viridis* cover



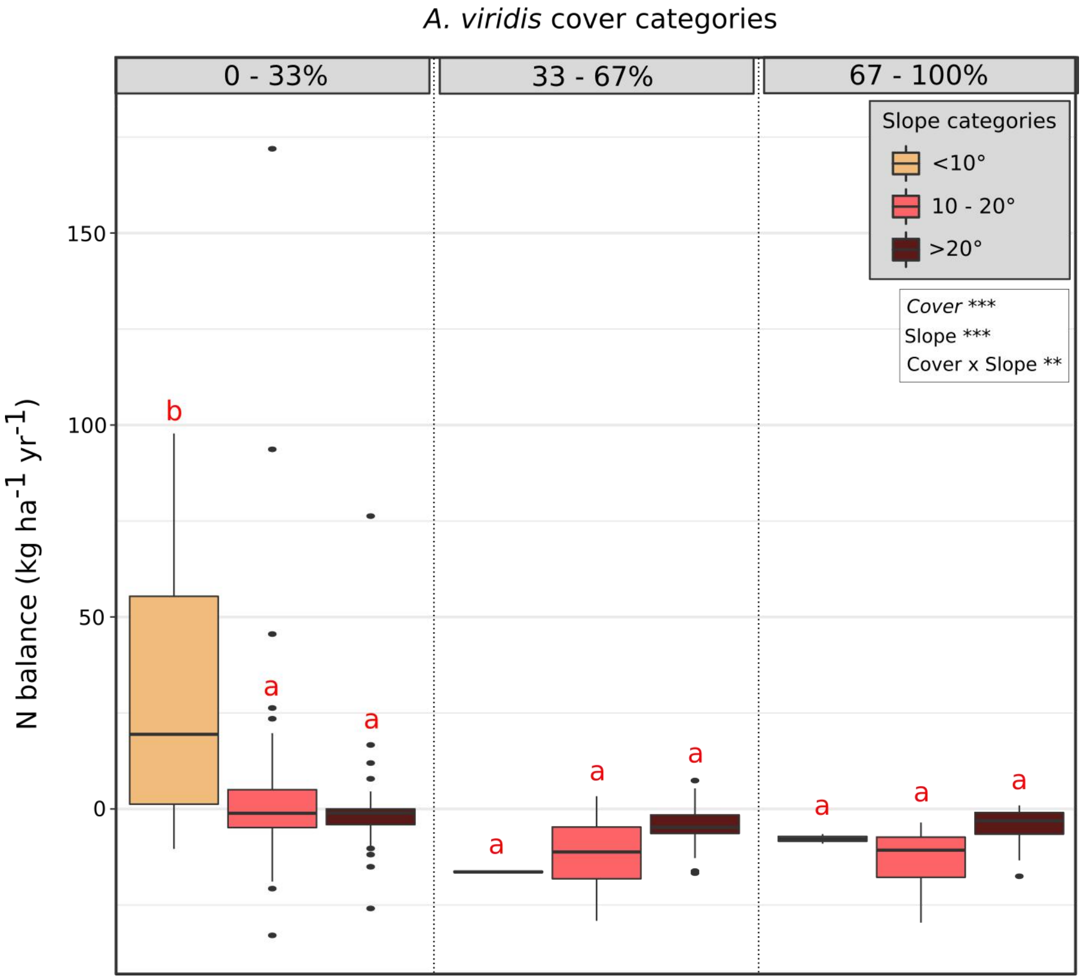
There is a **higher N content in the understory vegetation of *A. viridis***-encroached areas compared to open areas

N intake and dung N



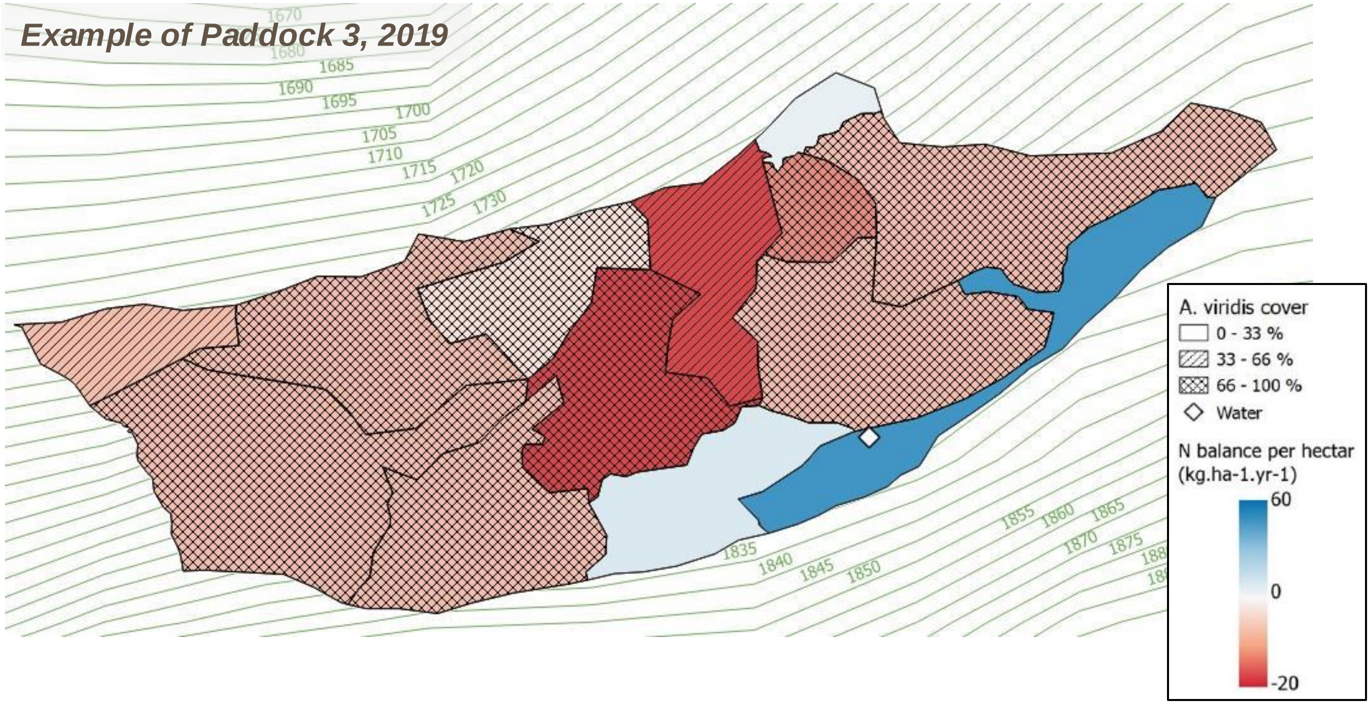
- **The N content in Highland cattle dungs was high** (31.29 ± 2.6 g/kg)
- **Dung N was dependent on the amount of N ingested** during a 24h period before excretion.

Results: N fluxes



- *A. viridis*-encroached and steep areas have overall **negative N fluxes values**
- Flat and open pastures have **positive N fluxes**

There is a significant N accumulation in the open flat (resting) areas, and a N depletion in the highly encroached areas.



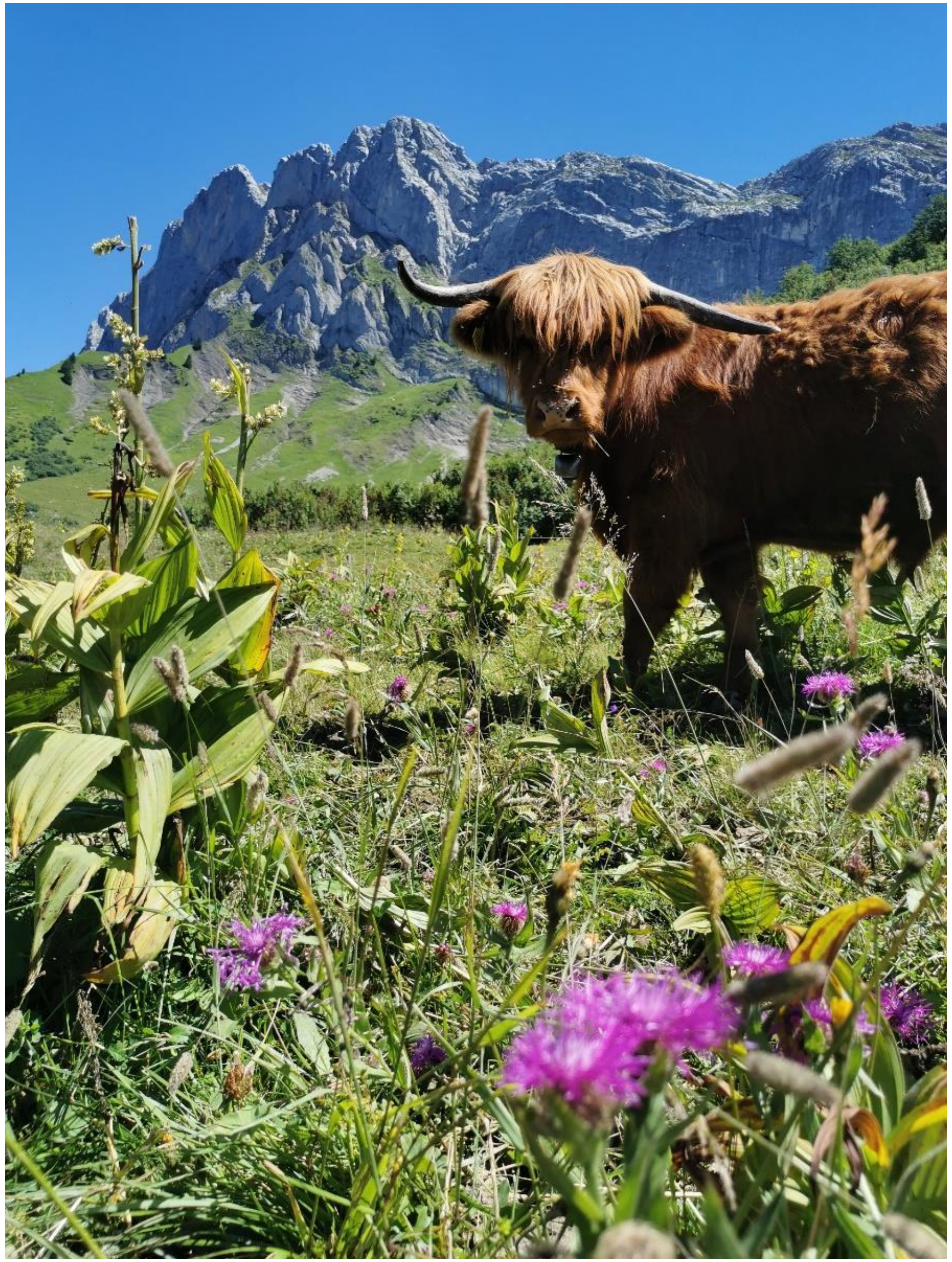
Conclusion:

- **Dungs of Highland cattle are rich in nitrogen,** linked to the high N content of the vegetation as well as to the effect of condensed tannins

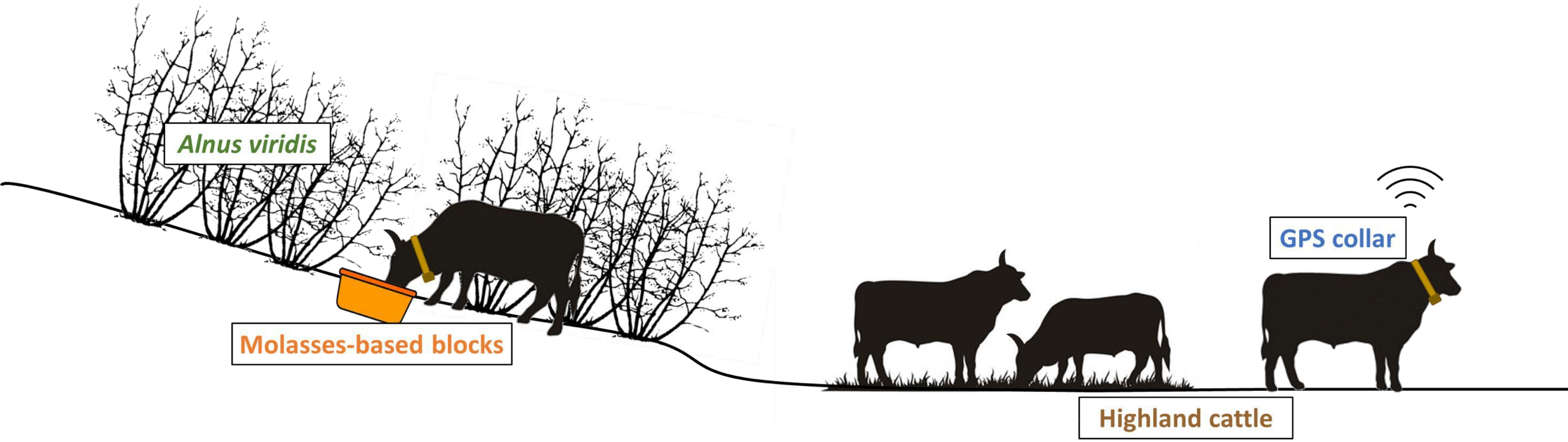
- **The more the animals have eaten in encroached areas** 24h before dung sampling, **the richer in N the dungs are**

- There is an **effective nitrogen translocation** from the open flat (resting) areas, to highly encroached areas.

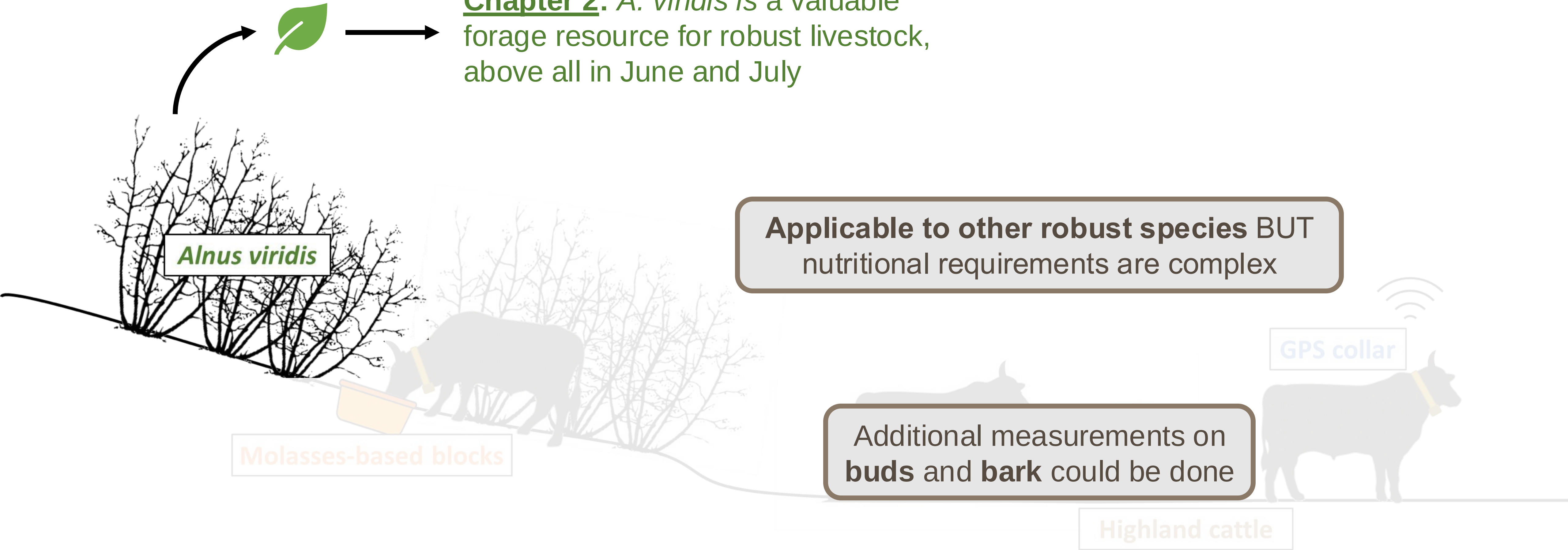
→ **Highland cattle can help to moderately fertilize adjacent open pastures, and can be used as a strategic management tool to translocate nitrogen.**



General discussion and conclusion



General discussion and conclusion



Chapter 2: *A. viridis is* a valuable forage resource for robust livestock, above all in June and July

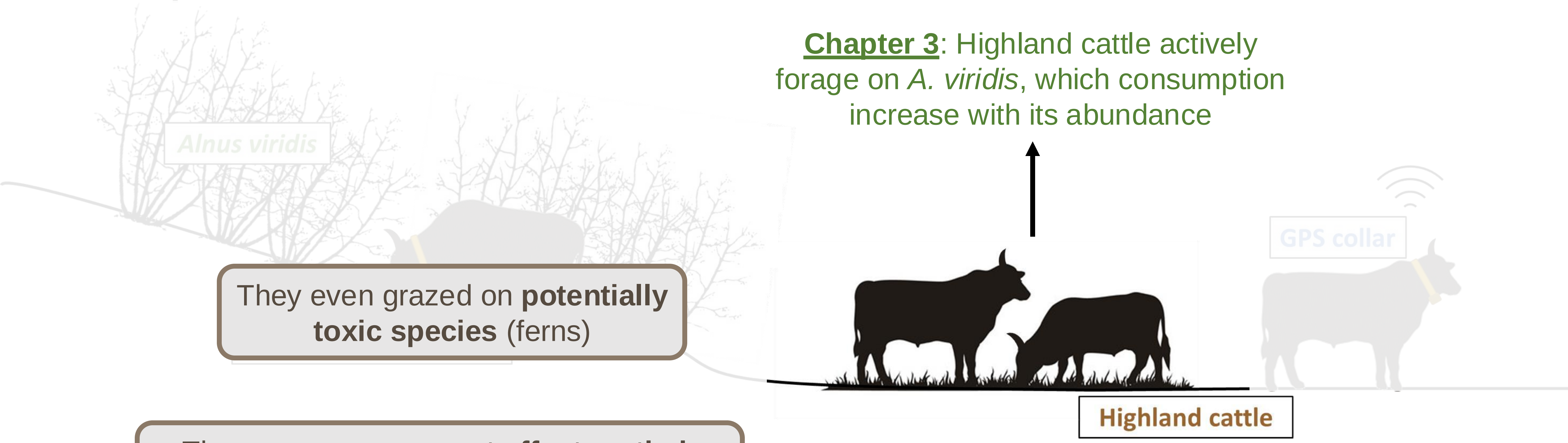
Applicable to other robust species BUT nutritional requirements are complex

Additional measurements on **buds** and **bark** could be done

General discussion and conclusion

Chapter 2: *A. viridis is* a valuable forage resource for robust livestock, above all in June and July

Chapter 3: Highland cattle actively forage on *A. viridis*, which consumption increase with its abundance



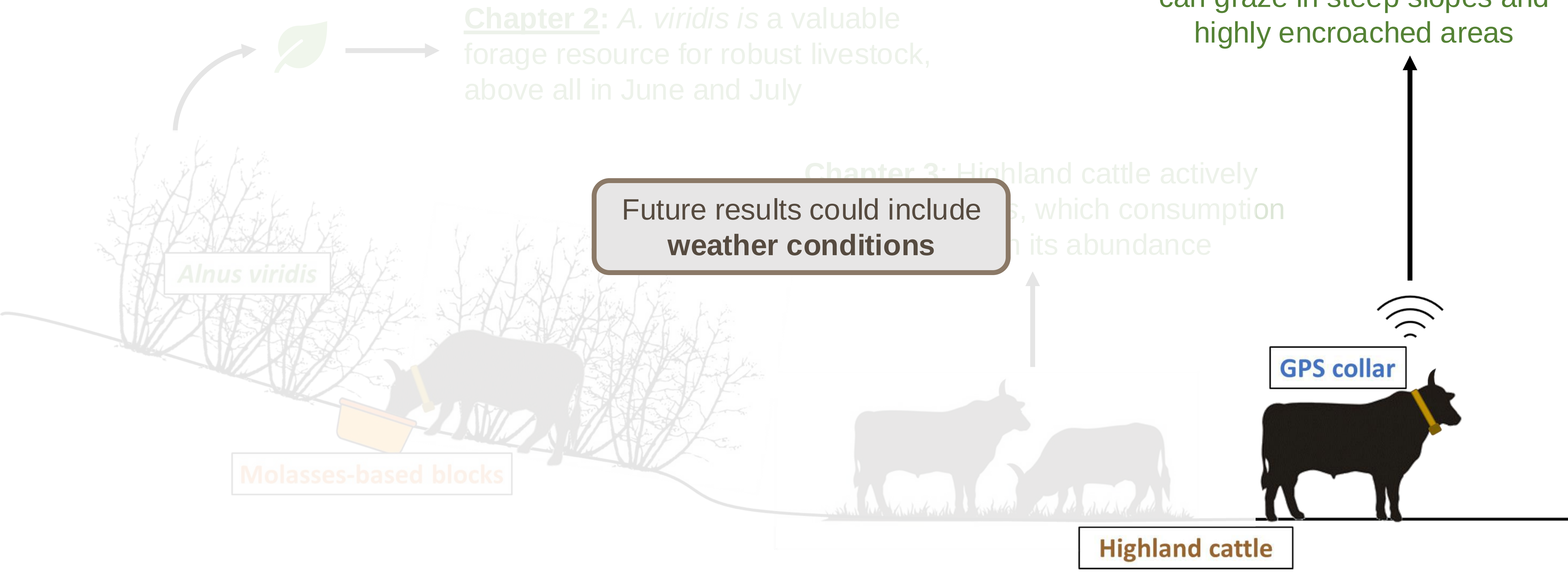
They even grazed on **potentially toxic species** (ferns)

There was **no apparent effect on their productivity** (weight measures)

General discussion and conclusion

Chapter 4: Highland cattle can graze in steep slopes and highly encroached areas

Future results could include **weather conditions**



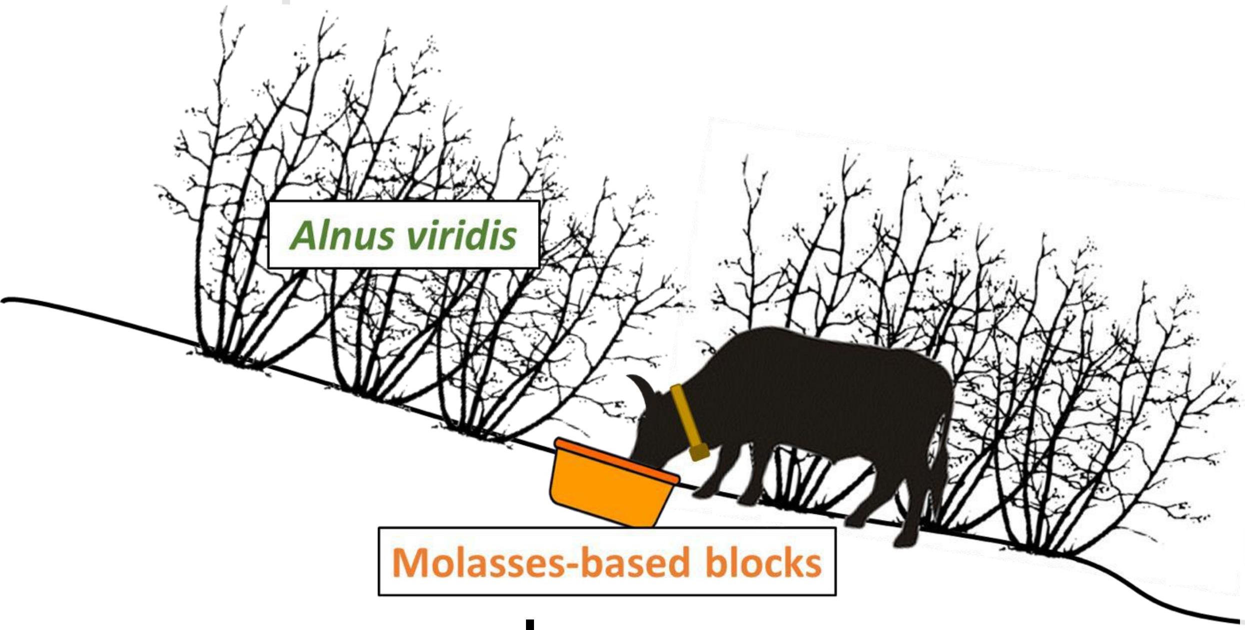
General discussion and conclusion

Chapter 4: Highland cattle can graze in steep slopes and highly encroached areas

Chapter 2: *A. viridis is* a valuable forage resource for robust livestock, above all in June and July

Potential grassland restoration **on the long term**

Chapte… forage on *A. viridis*, which consumptio… increase with its abundance



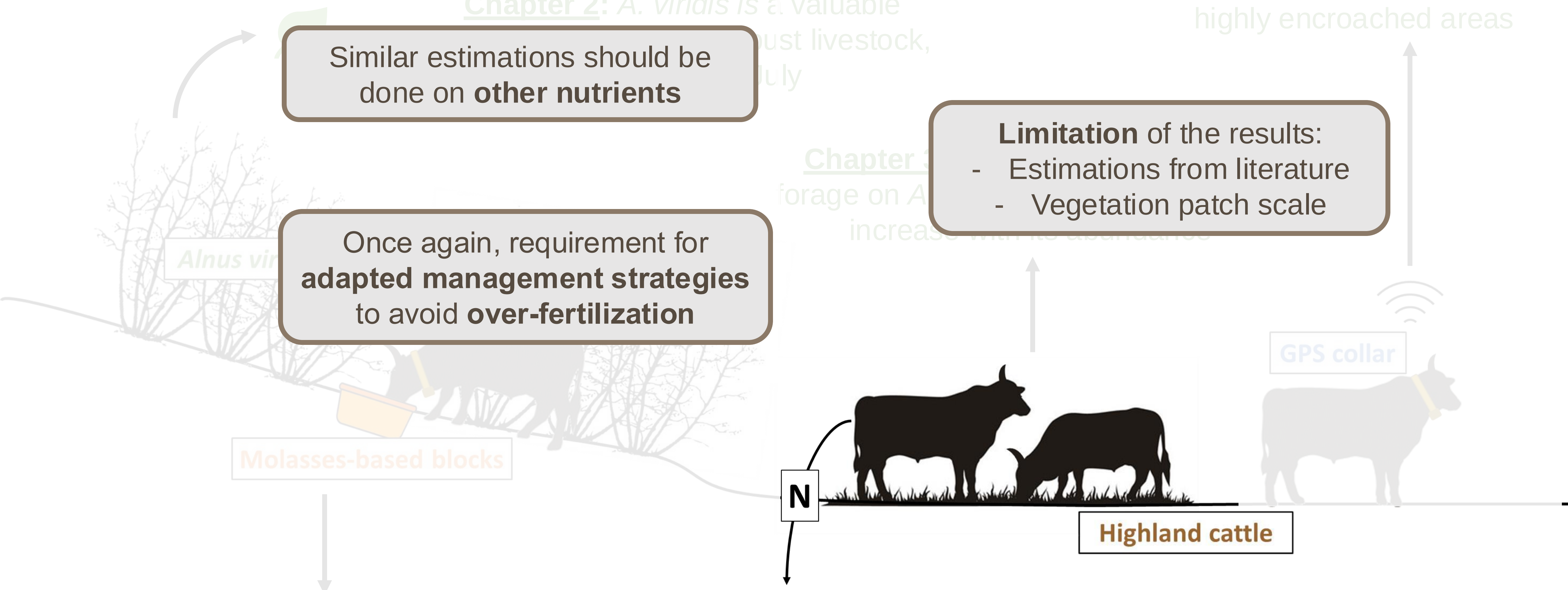
Requirement for **adapted management strategies** (rotational management, relocation of attractive points)

Practical challenges for farmers in remote and hardly accessible areas

Chapter 5: Attractive points significantly attract Highland cattle in denser areas, which maximize their effect on *A. viridis*

General discussion and conclusion

Chapter 4: Highland cattle can graze in steep slopes and highly encroached areas



Chapter 5: Attractive points significantly attract Highland cattle in denser areas, which maximize their effect on *A. viridis*

Chapter 6: There is an active nitrogen translocation from *A. viridis* encroached areas to adjacent open pastures

General discussion and conclusion

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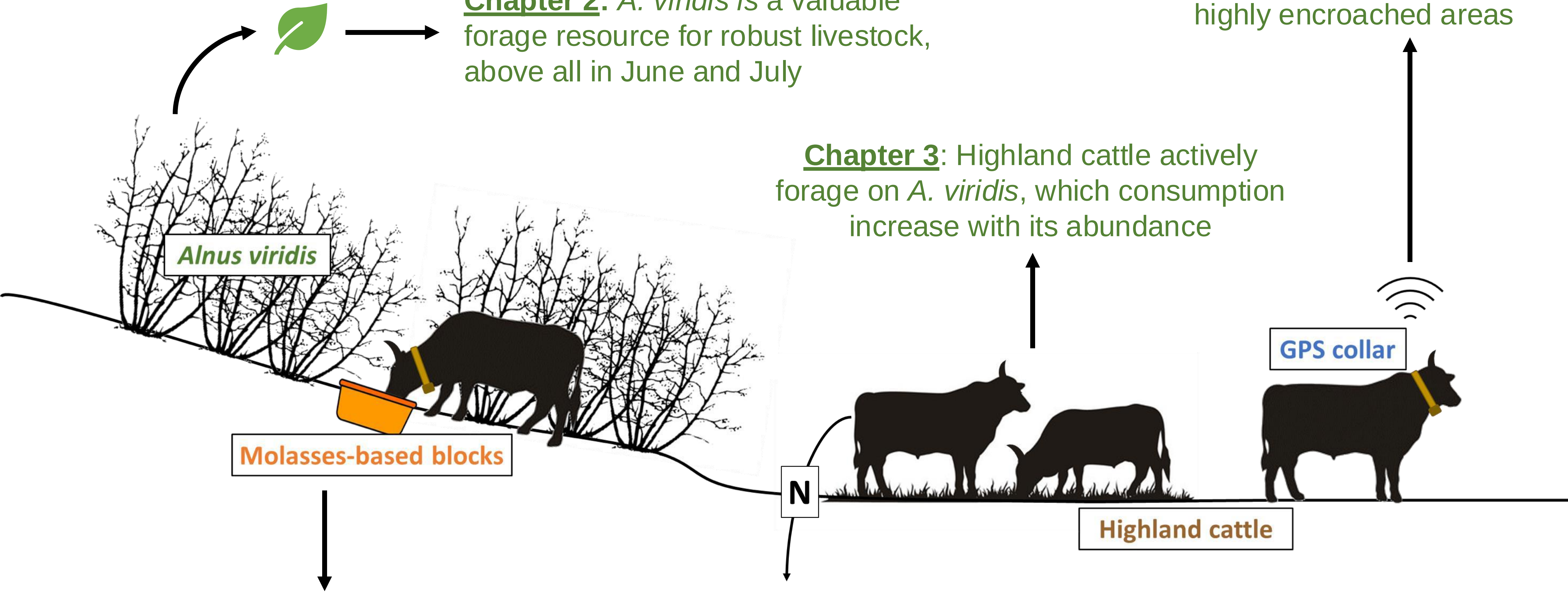
Chapter 3: Highland cattle actively forage on *A. viridis*, which consumption increase with its abundance



Chapter 5: Attractive points significantly attract Highland cattle in denser areas, which maximize their effect on *A. viridis*

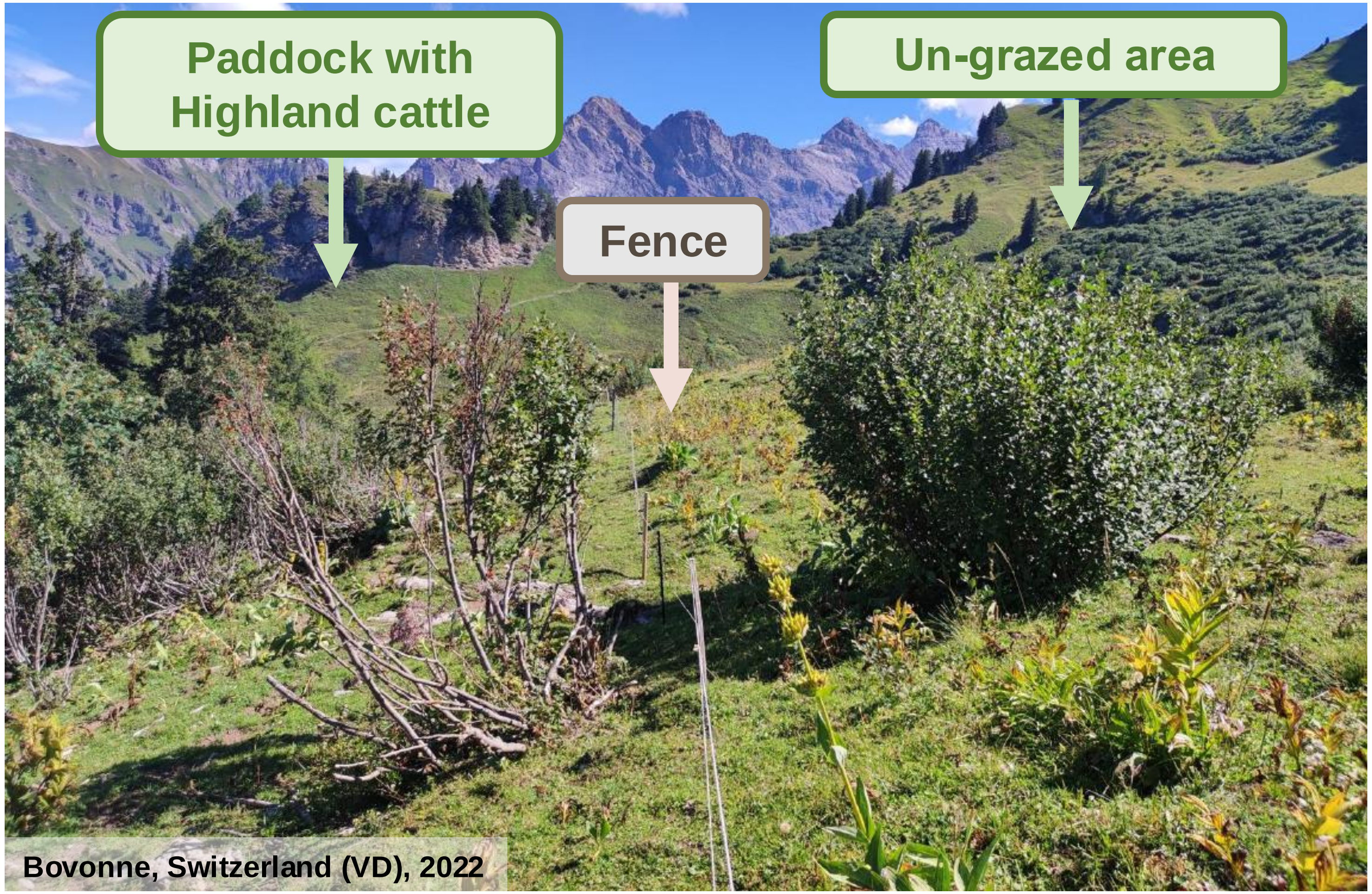
Chapter 6: There is an active nitrogen translocation from *A. viridis* encroached areas to adjacent open pastures

Perspectives

1. **Long term objectives**:
   - It may take several years to effectively restore former open grasslands
   - Even more in the most encroached areas where a strong grazing impact is needed

Objective to monitor the vegetation in permanent transects on the long-term

Important effects have already been observed, specially at the edge of encroached areas or on young shrubs:



Bovonne, Switzerland (VD), 2022


Un-grazed area
Paddock with Highland cattle
Fence
Bovonne, Switzerland (VD), 2022


Vogna, Italy, 2022
© Marco Pittarello
2 years after the placement
of attractive points:
Phleum rhaeticum

Perspectives

2. **Result communication**:
   - Challenge for farmers to keep such management in remote areas after the funded project ends
   - Several actors are involved in pastures maintenance: farmers, municipality, canton/region…

Communication outside of the scientific community scope to persuade and unlock potential political measures for fundings

3. **Technological devices for monitoring**:
   - **Virtual fencing** could relieve the practical challenges in remote areas
   - Satellite and drone images for vegetation monitoring

Further studies are needed to investigate their applicability in mountain areas

Drone images in Bovonne, Switzerland:

Drone images in Bovonne, Switzerland:

Many thanks to:

- **Groupe Systèmes pastoraux** (Agroscope)
- **Eric Allan** (University of Bern)
- **DISAFA** group (University of Torino)
- **Agrovet Strickhoff** (ETH Zurich)
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Thank you for your attention