Czech University of Life Sciences, Prague
Faculty of Environmental Sciences
Department of Ecology

Management Legacies, Restoration Pathways, and Nutrient Dynamics in Semi-Arid and Temperate Grassland Ecosystems



PhD student: Isa Bandak

Supervisor: Prof. Dr. Vilém Pavlů

Consultant: Dr. Lenka Pavlů, Technical University of Liberec

Why grasslands matter

Provide essential ecosystem services

- biodiversity
- carbon storage
- productivity

Cover large global areas and support livelihoods

Highly sensitive to environmental and management changes

research question?

How does long-term management shape grassland ecosystems?

Vegetation
Soil carbon & nitrogen
Nutrient dynamics

Scientific Novelty

Integrated ecosystem approach
(vegetation – soil – nutrients)

Combined methodology
(observational + experimental)

Rare long-term dataset
(40–47 years of consistent management)

Approach: three levels of analysis

Vegetation level

Grazing vs mowing

Soil level

Land-use effects on soil

Process level

Nutrient dynamics (faeces)

LEVEL 1: VEGETATION RESPONSE TO MANAGEMENT

Research focus:
How do grazing and mowing shape vegetation?

Diversity (species richness)
Structure (canopy cover, functional groups)
Productivity (biomass, palatability)

Experimental Design – Vegetation

Study design

Seasonal grazing vs annual mowing
Long-term management (40+ years)
Comparable environmental conditions

Measured variables

Species richness
Canopy cover
Functional groups
Biomass & palatability

Research Question (Vegetation Study)

Research Question

How do grazing and mowing affect:

- vegetation structure
- diversity
- biomass?

Hypothesis

Grazing ↑ species richness and canopy cover

Mowing ↑ total biomass

Trade-off between diversity and productivity

Study Area: Saral Grasslands

Mowing Management (Scythe)

During

After

Vegetation Sampling Design

Study area: 600 & 500 ha
Replication: 3 sites per treatment
Sampling: 15 transects per site (900 plots)
Method: Quadrat (Hanley, 1978)
Measurement: Canopy cover

Vegetation Measurements

Structure: canopy cover

Diversity: functional groups

Function: palatability classes

Productivity: total biomass
(live, dead, litter)

Floristic Diversity (Alpha Diversity)

Grazed sites → **higher diversity**
Strongest difference at **species level**
Many species shared, but
grazing increases richness

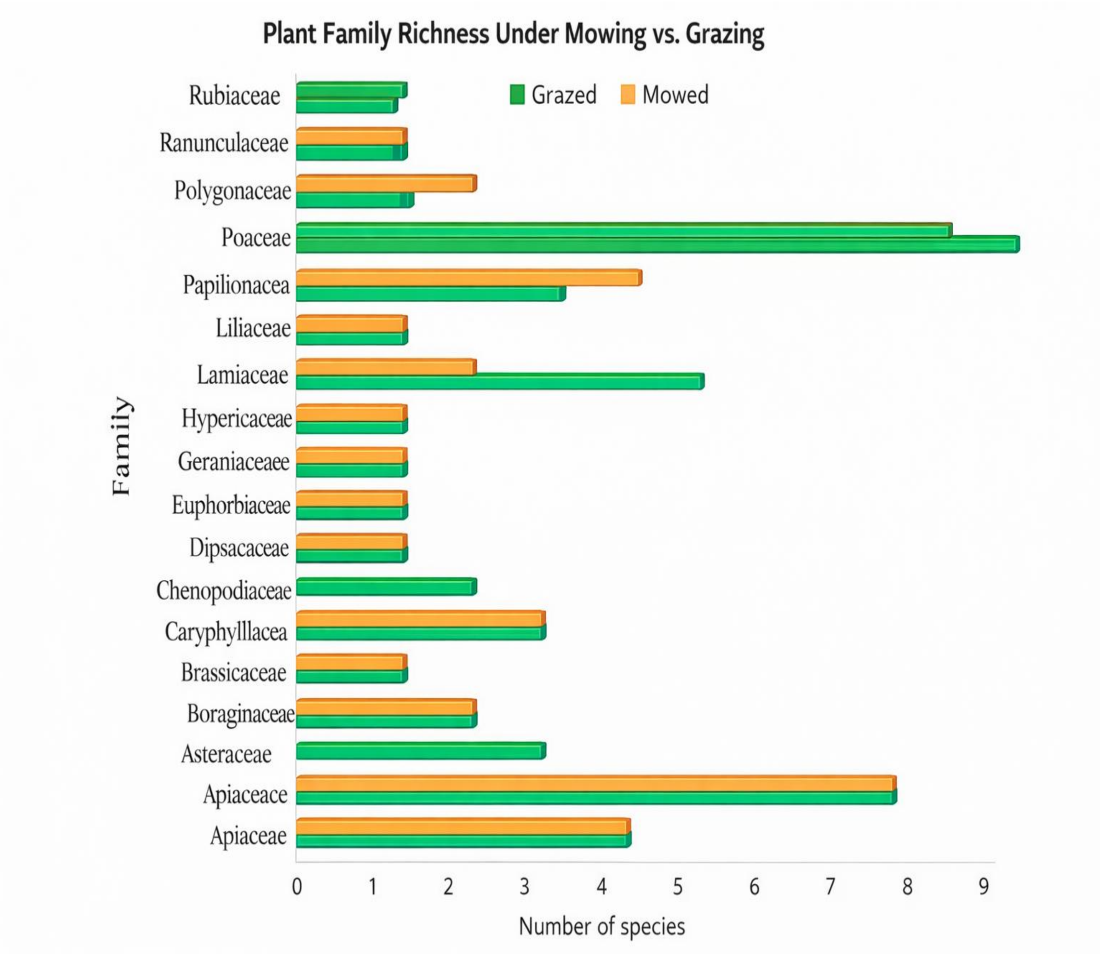
Taxonomic level	Grazed sites	Mowed sites	Species in common
Family	19	18	18
Genus	43	37	30
Species	**48**	**42**	32

Plant Family Richness: Grazing vs Mowing

Most families → **similar richness**

Poaceae (grasses) ↑ under grazing

Minor differences for other families



Total Canopy Cover

Total canopy cover was **higher in grazed areas** than mowed areas

Grazed: **95–98%**

Mowed: **77–80%**

Pattern was **consistent across both years**

The effect of management was **statistically significant**

Key Point:
Grazing leads to denser vegetation cover

Total Plant Material (Biomass)

Total plant material was **higher in mowed areas** compared to grazed areas

Mowed: **271 → 306.7 g/m^2**

Grazed: **216 → 244.2 g/m^2**

Biomass **increased from 2017 to 2018** in both treatments

The effect of management (**mowing vs grazing**) was **statistically significant ($P < 0.01$)**

Key Point:

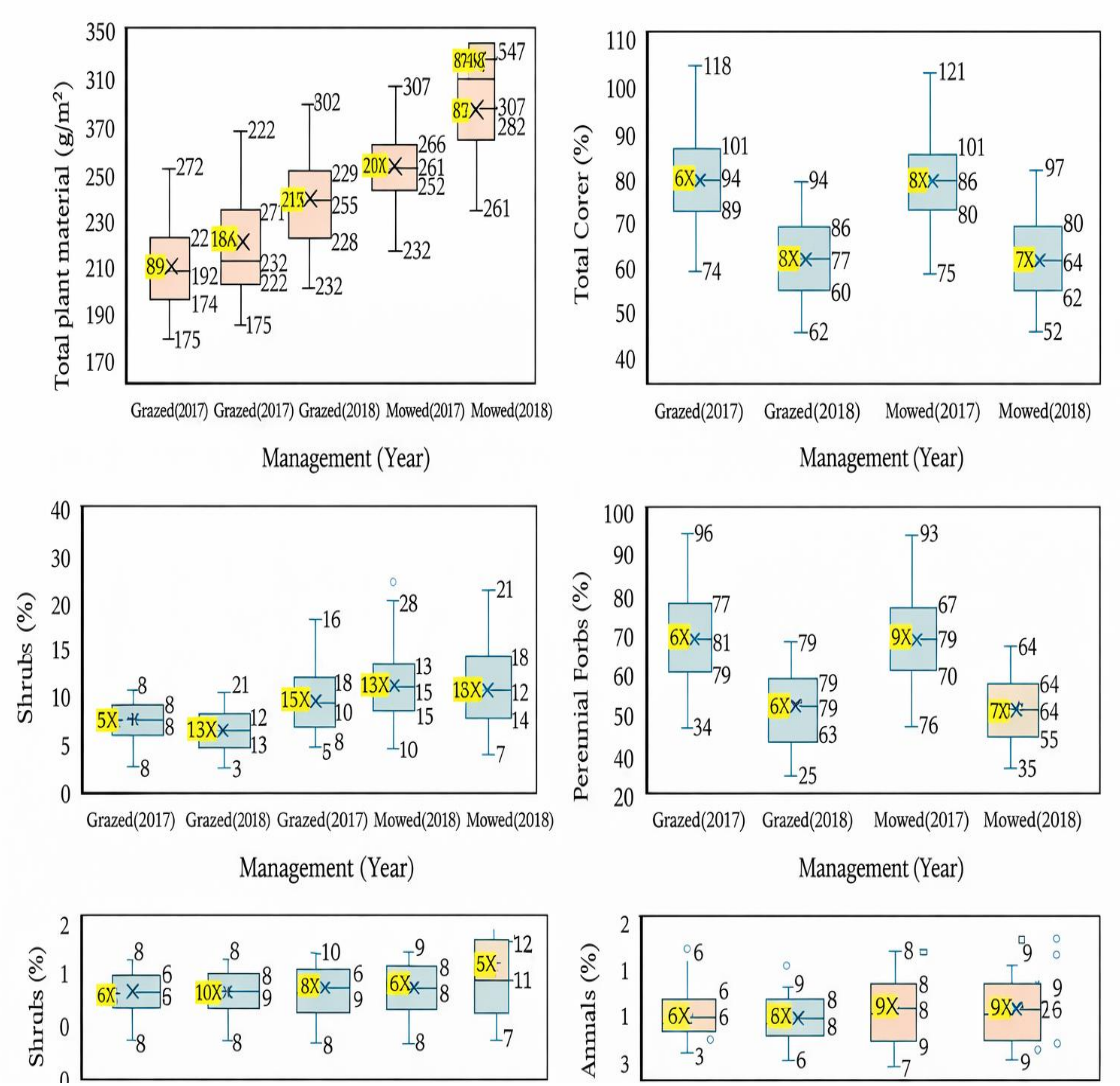
Mowing results in greater accumulation of plant material

Vegetation Structure and Biomass

Mowing ↑ total biomass

Grazing ↑ canopy cover

Functional groups →
different responses



Palatability Classification & Distribution

Class I (high palatability) dominated in both treatments:

- Grazed sites: **51%**
- Mowed sites: **41%**

No significant differences between **years (2017 vs 2018)** for any class

Key Point:

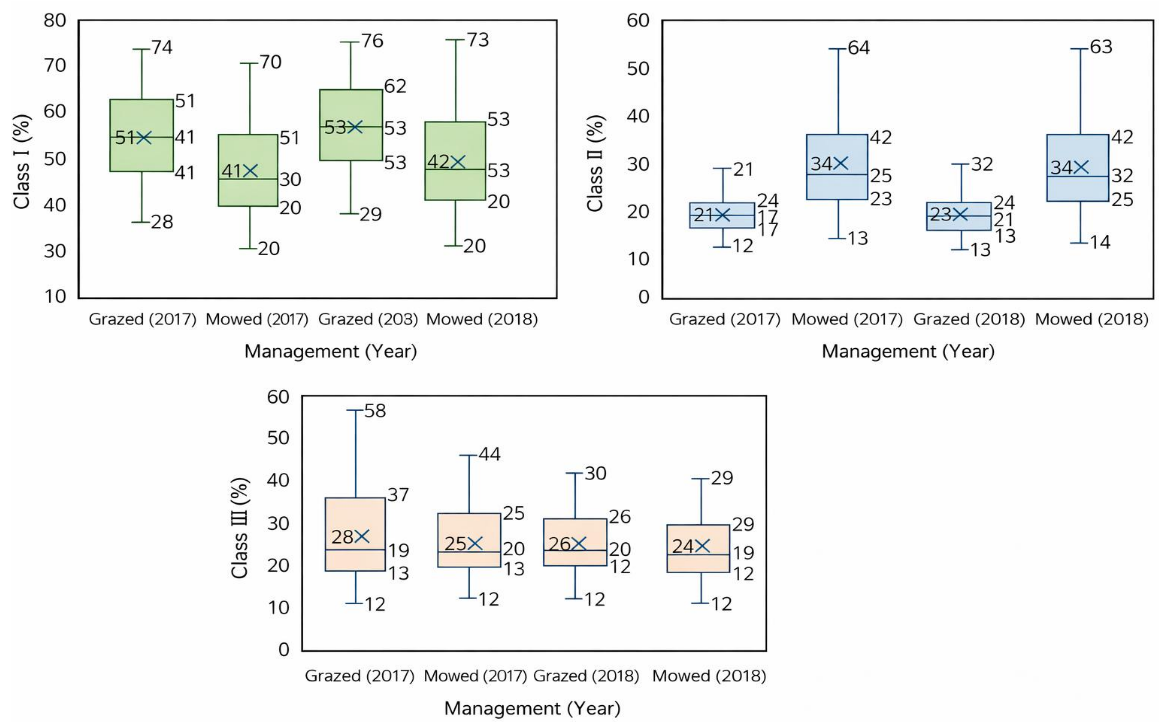
Highly palatable plants were the most abundant across both management types

Palatability Classes: Grazing vs Mowing

Grazing ↑ palatable species (Class I)

Mowing ↑ less palatable species (Class II–III)

Management shifts **forage quality**



Main Result: Trade-offs Between Grazing and Mowing

Grazing
Higher species richness
Higher canopy cover
More palatable species

Mowing
Higher total biomass
Less palatable species
Lower diversity

Ecological Mechanisms Behind Observed Patterns

Grazing promotes **spatial heterogeneity and selective pressure**
→ supports species coexistence and higher diversity

Mowing acts as a **uniform disturbance**
→ reduces competition but favors biomass accumulation

Differences reflect **contrasting ecosystem pathways**:

- Grazing → diversity-driven systems
- Mowing → productivity-driven systems

Indicates a **fundamental trade-off** between biodiversity and productivity

Level 2: soil response to land use

Land-use types:

Exclosure

Grazing

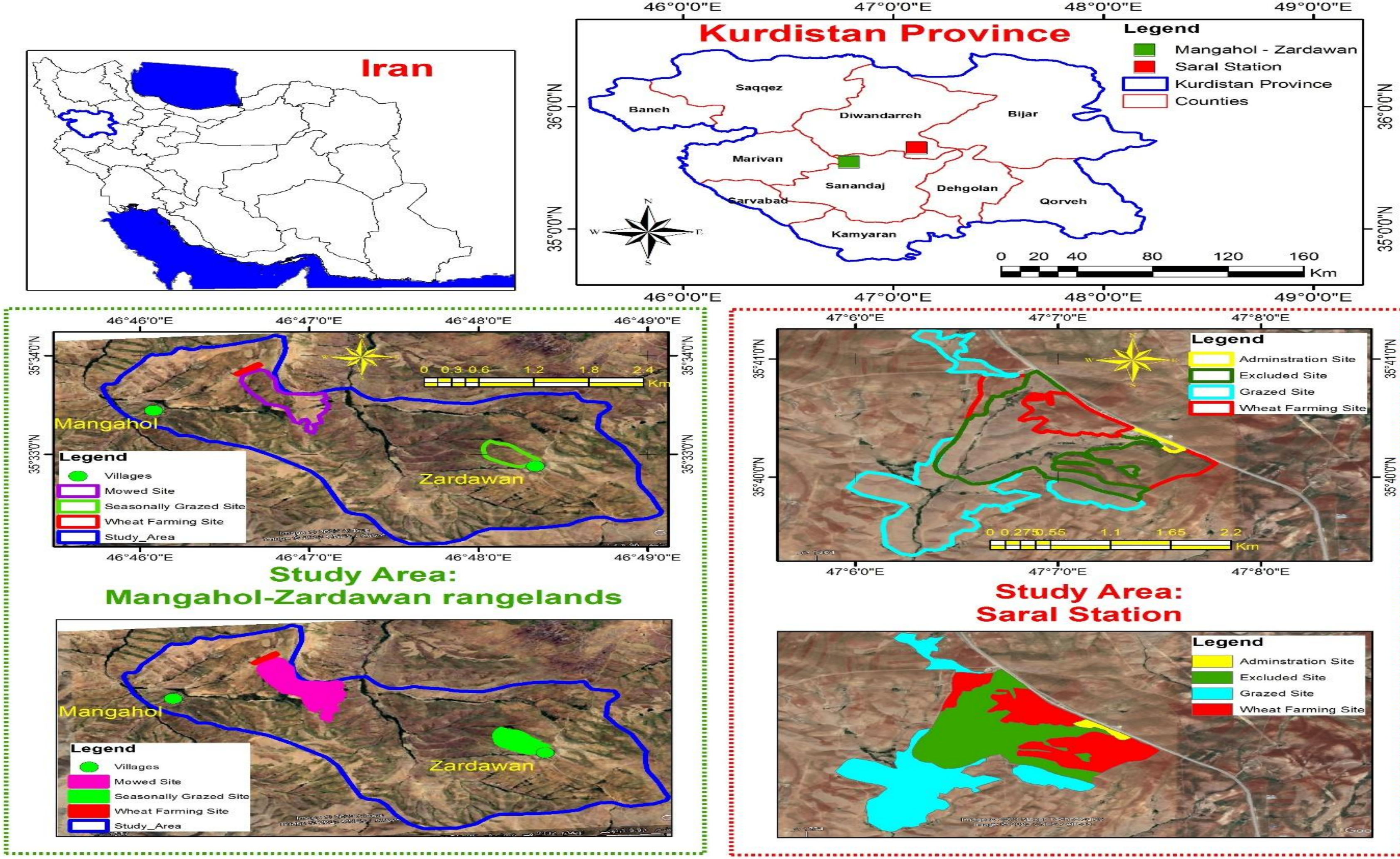
Continuous

Seasonal

Mowing

Wheat farming

Location of study area in Kurdistan province, Iran



Soil Study: Research Question & Hypothesis

Research Question

How do long-term land uses affect **SOC and TN**?

Hypothesis

Moderate use increases **SOC and TN**

Intensive use decreases **SOC and TN**

Land-use change leads to **soil degradation**

Land-Use Types in the Study Area

Methods: Soil Study

Sampling design

Years: **2009, 2013, 2017, 2021**

18 transects (5 × 40 m)

10 subplots (1 × 1 m) per transect

Composite soil sample per transect

Soil analysis

SOC: **Walkley–Black**

TN: **Kjeldahl**

Statistics

ANOVA (land-use effects)

Duncan test (group differences)

Soil Properties: Statistical Results

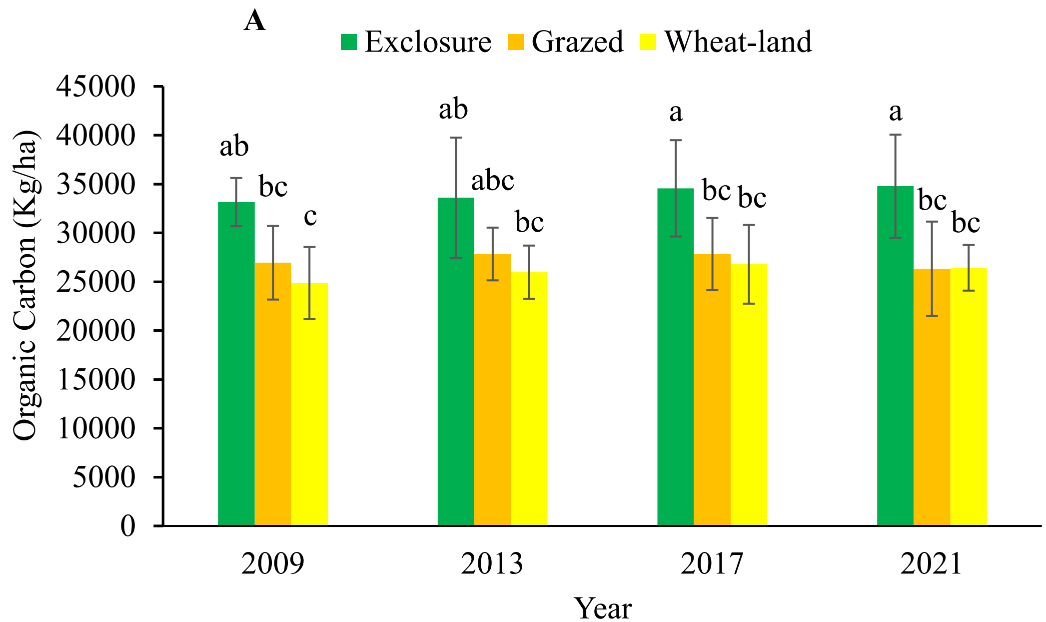
Strong responses at **Saral**
Weaker responses at **Mangahol–Zardawan**
Soil response depends on site

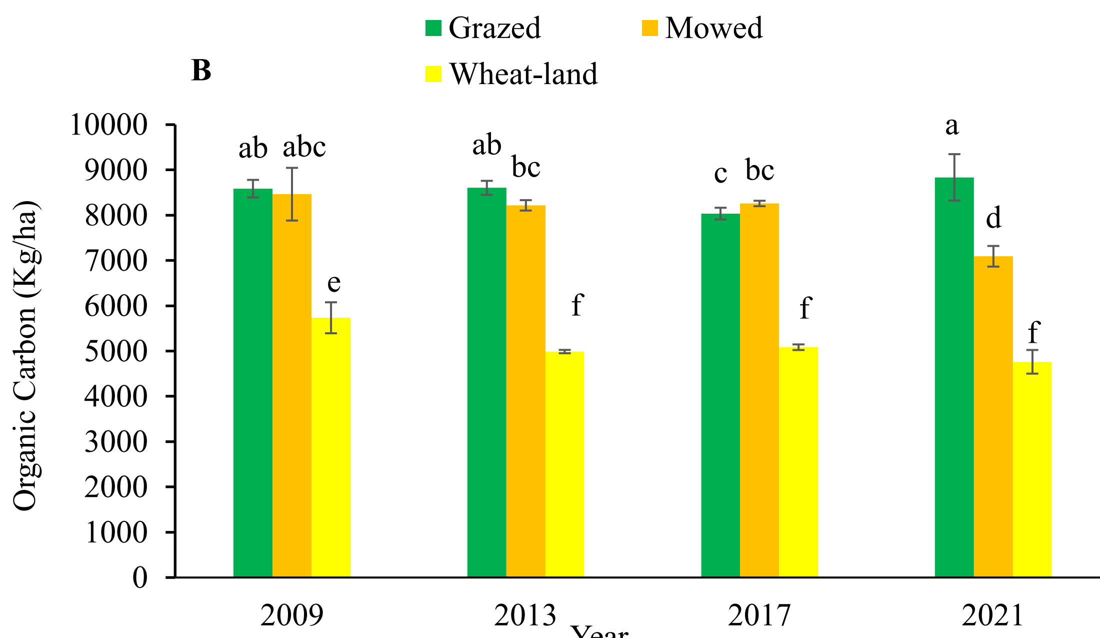
Soil Organic Carbon (SOC)

Low-intensity use → highest SOC (exclosure & grazing)

Wheat farming → consistently lowest SOC

SOC increases over time across treatments



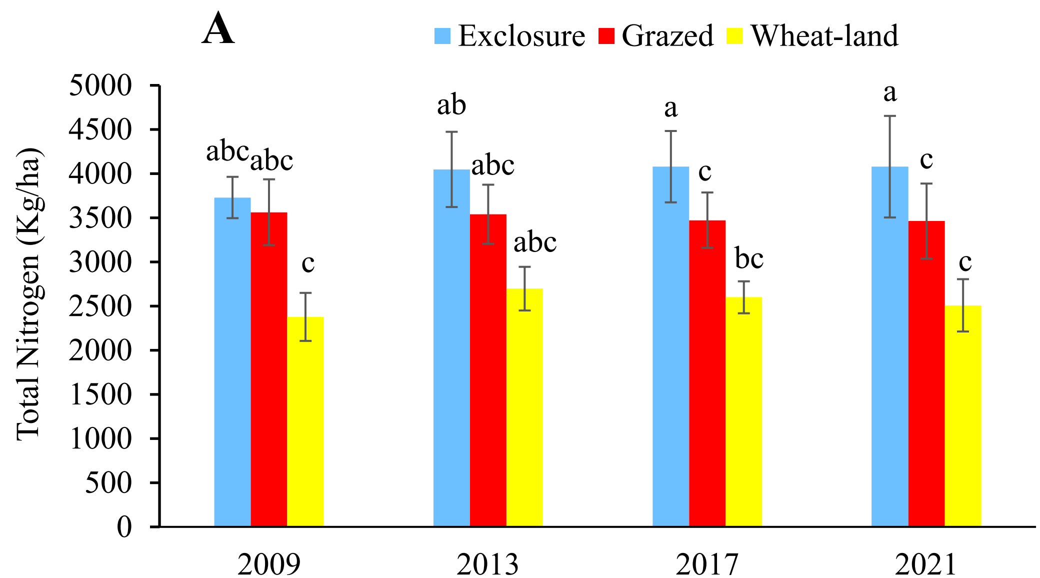


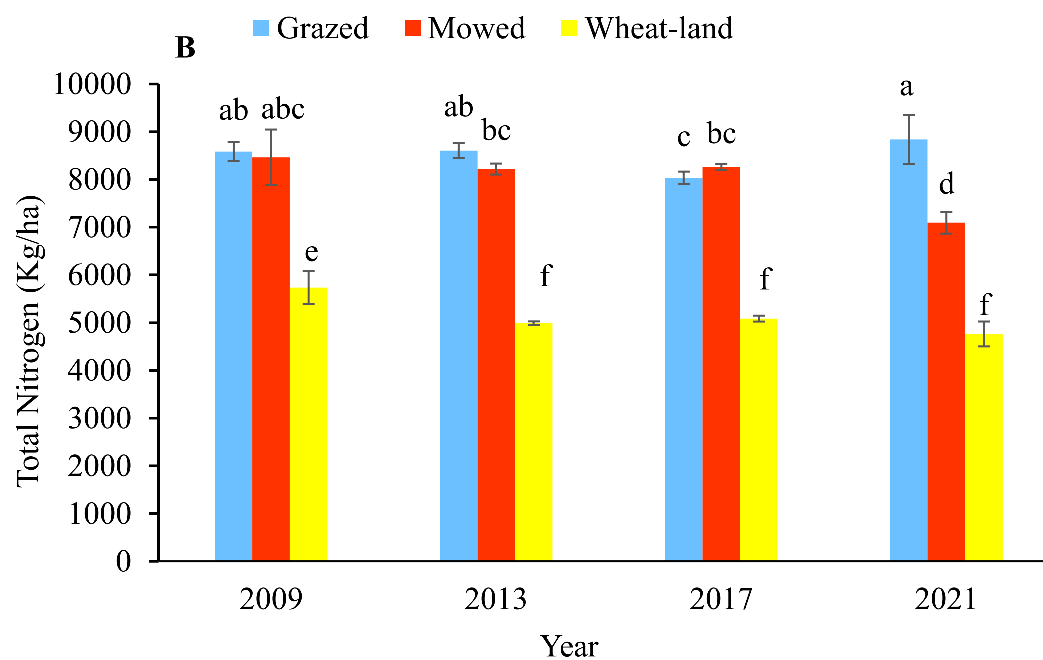
Total Nitrogen (TN)

Highest under low-intensity use (exclosure & grazing)

Lowest under wheat farming

TN trends vary over time depending on management





C/N ratios Reslts

C/N Ratio

C/N ratio shows **minor variation across land uses**

No clear consistent trend with management

Indicates **relatively stable nutrient balance**

Main Result: Management Effects on SOC and TN

High (SOC & TN)
Exclosure
Seasonal grazing

Intermediate
Mowing

Low
Wheat farming
Continuous grazing

Key Mechanisms Behind Results

Vegetation recovery (AT & RG) drives nutrient accumulation
→ Increased SOC and TN linked to litter input and root turnover

Heavy grazing causes nutrient depletion
→ Loss of SOC, TN, N, P, K due to reduced inputs and soil degradation

Fertilization alone is NOT sufficient

→ Despite equal inputs, outcomes diverged strongly across land uses
→ Vegetation and management determine nutrient retention

Soil recovery is a long-term process (26 years)

→ Significant increases only observed under restoration or agroforestry
→ Degradation persists under continuous grazing

Level 3: Nutrient Processes Under Grazing

Dung inputs (faeces)

Soil layers: **0–10 cm, 10–20 cm**

Biomass and nutrient relationships

Background

Grazing redistributes nutrients via **livestock faeces**

Faeces create **localized nutrient hotspots**

Long-term effects on soil nutrients and plant uptake remain **unclear**

Research Question

How do faecal inputs affect soil nutrient dynamics and plant biomass over time?

Hypotheses

Faeces **increase nutrient availability (short term)**

Effects **decline over time** due to losses and transformations

Increased biomass **does not necessarily mean higher nutrient content**

Experimental Design & Sampling

Experimental Design
Field experiment with **controlled faeces addition**
Treated vs. control plots (randomized)
Sampling
Soil: **0–10 cm, 10–20 cm**
Repeated sampling (short- & long-term)
Biomass and faeces **sampled**
Measurements
Total C & N (Kjeldahl)
Mineral N (NH_4^+, NO_3^-)
Macronutrients (P, K, Ca, Mg)

“Rapid nutrient turnover without long-term accumulation”

Faeces **decompose rapidly**

N transformations:

C ↓ → organic matter loss

NH_4^+ ↑, NO_3^- ↓ → active N cycling

Soil response:

Short-term fluctuations

No consistent long-term accumulation

Plant response:

Biomass increases

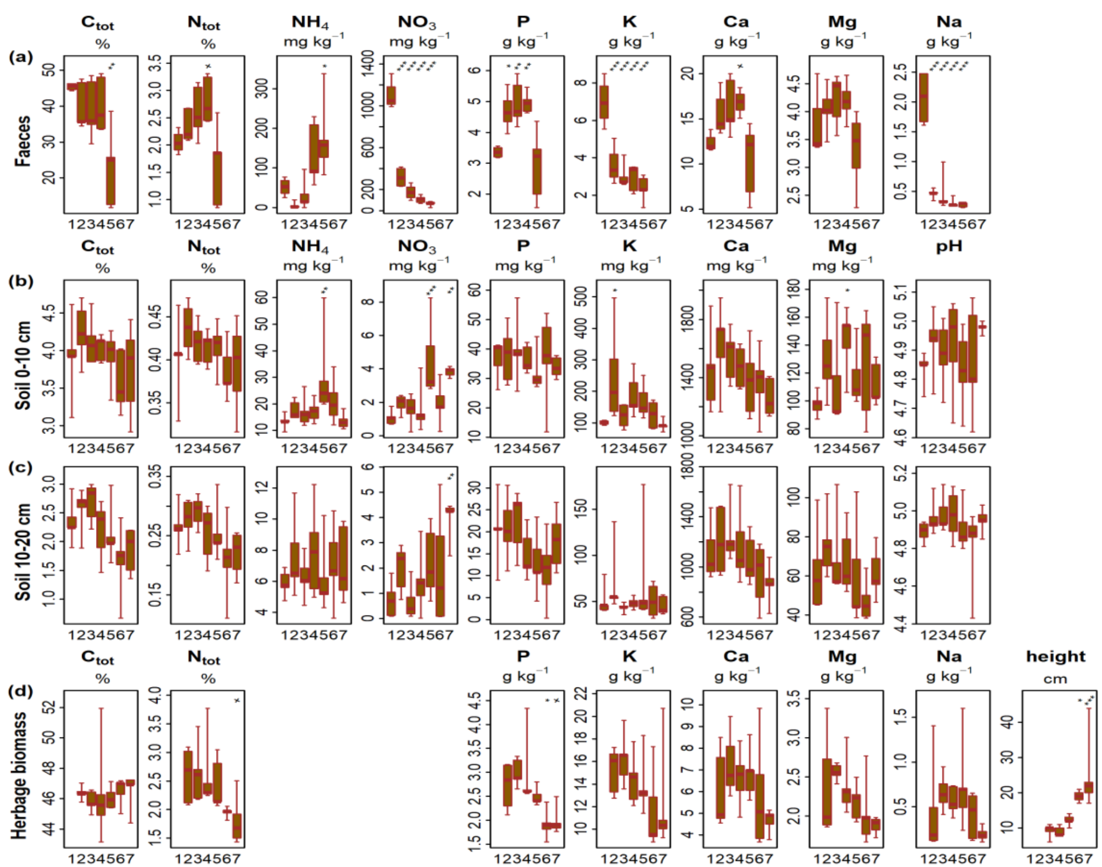
BUT nutrient concentrations **do not increase**

“Rapid nutrient turnover without long-term accumulation”

Faeces **decompose rapidly**

Biomass increases,

but **nutrient concentrations do not**

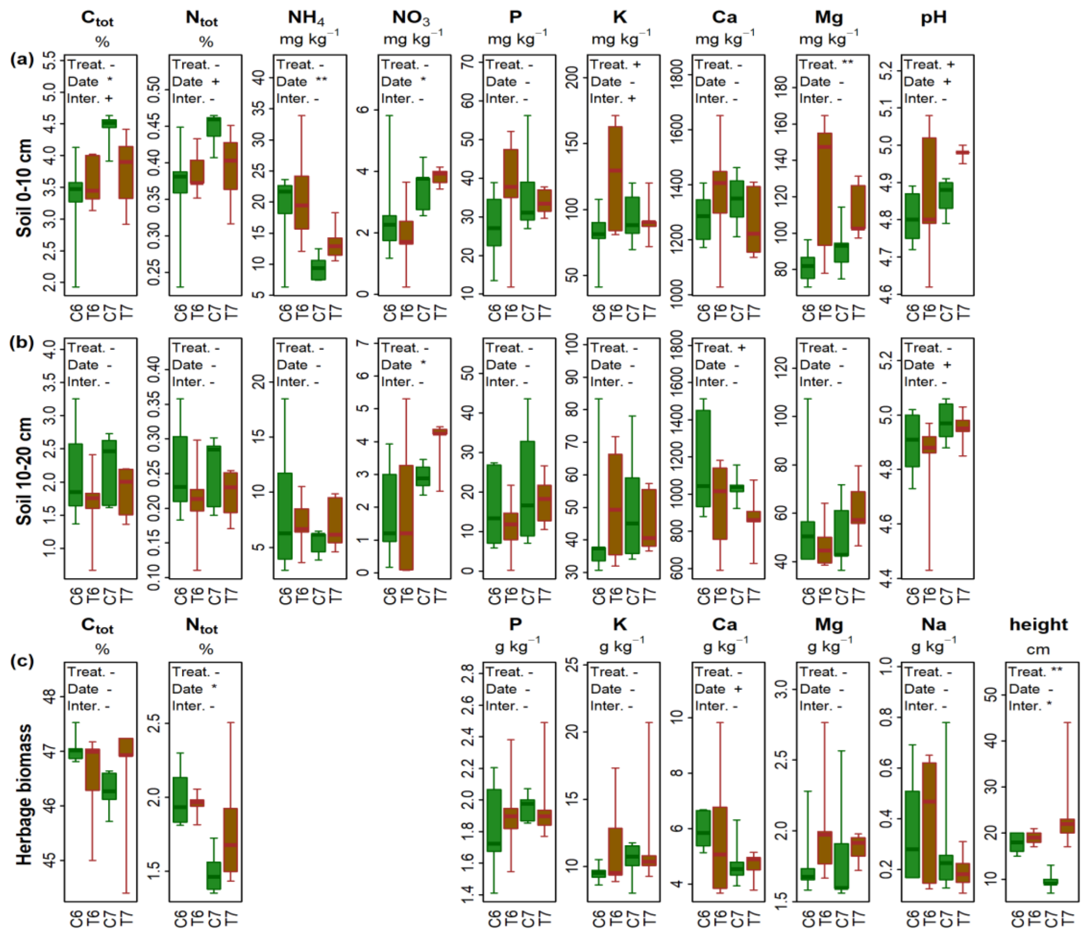


Treatment vs Control Effects

No strong treatment effect
Strong time effect

Surface soil: **minor response**
Subsoil: **no response**

Biomass: **growth ↑, nutrients unchanged**

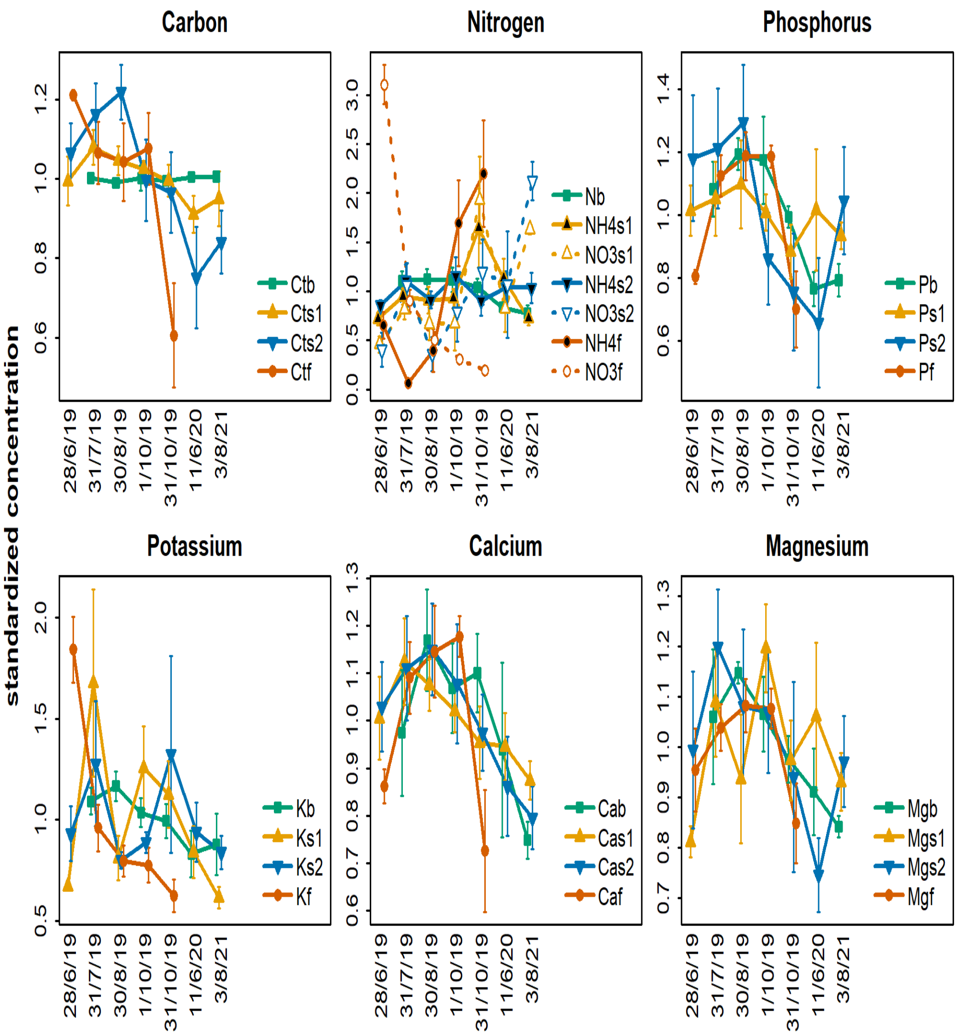


Soil and plant relationship

Soil–Plant Nutrient Relationship
Are soil nutrients reflected in plant nutrients?
No significant correlation

Nutrient changes occur:
faeces → soil → plant

BUT these changes are **not directly linked**



1. Rapid nutrient pulses

Faeces decompose quickly

↑NH_4^+, ↓NO_3^- → fast N transformations

2. No long-term storage

Short-lived nutrient peaks

No increase in soil nutrient pools

3. Limited movement in soil

NO_3^- leaches deeper

Other nutrients remain at surface

4. Soil and plant nutrients are decoupled

Biomass ↑

Nutrient concentration ↓

❗ **No soil–plant link**

Overall conclusion

Faeces create **short-term nutrient hotspots**, but effects are transient
Soil nutrient changes are **limited and depth-dependent**
(weak response below 10 cm)

Increased biomass does **not improve plant nutrient content**

Soil and plant nutrients are decoupled

Synthesis across the three levels

Management shapes **vegetation structure**
Management shapes **soil nutrient pools**
Grazing drives **short-term nutrient dynamics**

But

These processes are not linked
Soil nutrients do not control plant nutrients

Thank you