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Virtual Fencing for the Management of Dairy Cows in Alpine Pastures: Opportunities, Challenges, and Integrated Technological Solution

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Plantahof, Landquart, 17
June 2026

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**Mountain Grassland and
Livestock Joint Conference**



Introduction

Livestock Alpine pasture-based system

High
Nature
Cultural
Value



**In the Italian Alps 27% of meadows
and pastures were abandoned
between 1990 and 2010**

Battaglini et al. 2014

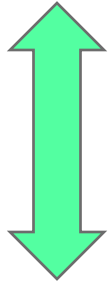
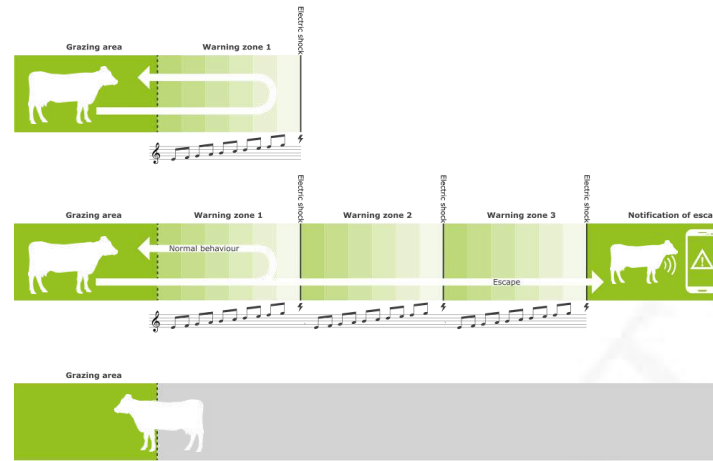


Introduction

Innovative strategies

- **Virtual fencing system**

For the herd management



- **Remote sensing techniques**

For pastures management



Research questions

- **Virtual fencing system**

For the herd management

Can virtual fencing (VF) be used in alpine pasture-based dairy system (alpage)?

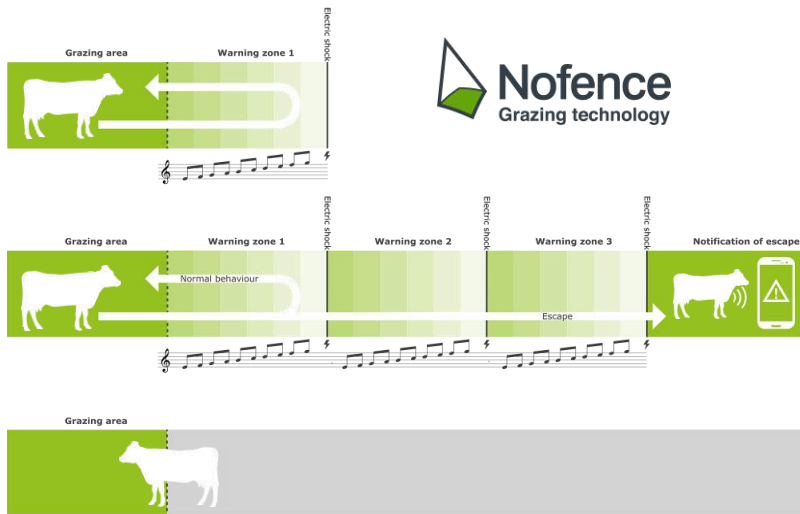
- **Remote sensing**

For pastures management

Can the synergic use of VF collar data with RS imagery provide advantages for a tailored management of the grazing areas, e.g., by providing insights into animal feed uptake?

Animals and Sensor

- 25 Lactating Bruna dairy cows
- Nofence Virtual fencing collars
(Nofence AS, Batnfjordsøra,
Norway)



Study area

Mount Zoncolan, IT 1600m a.s.l.

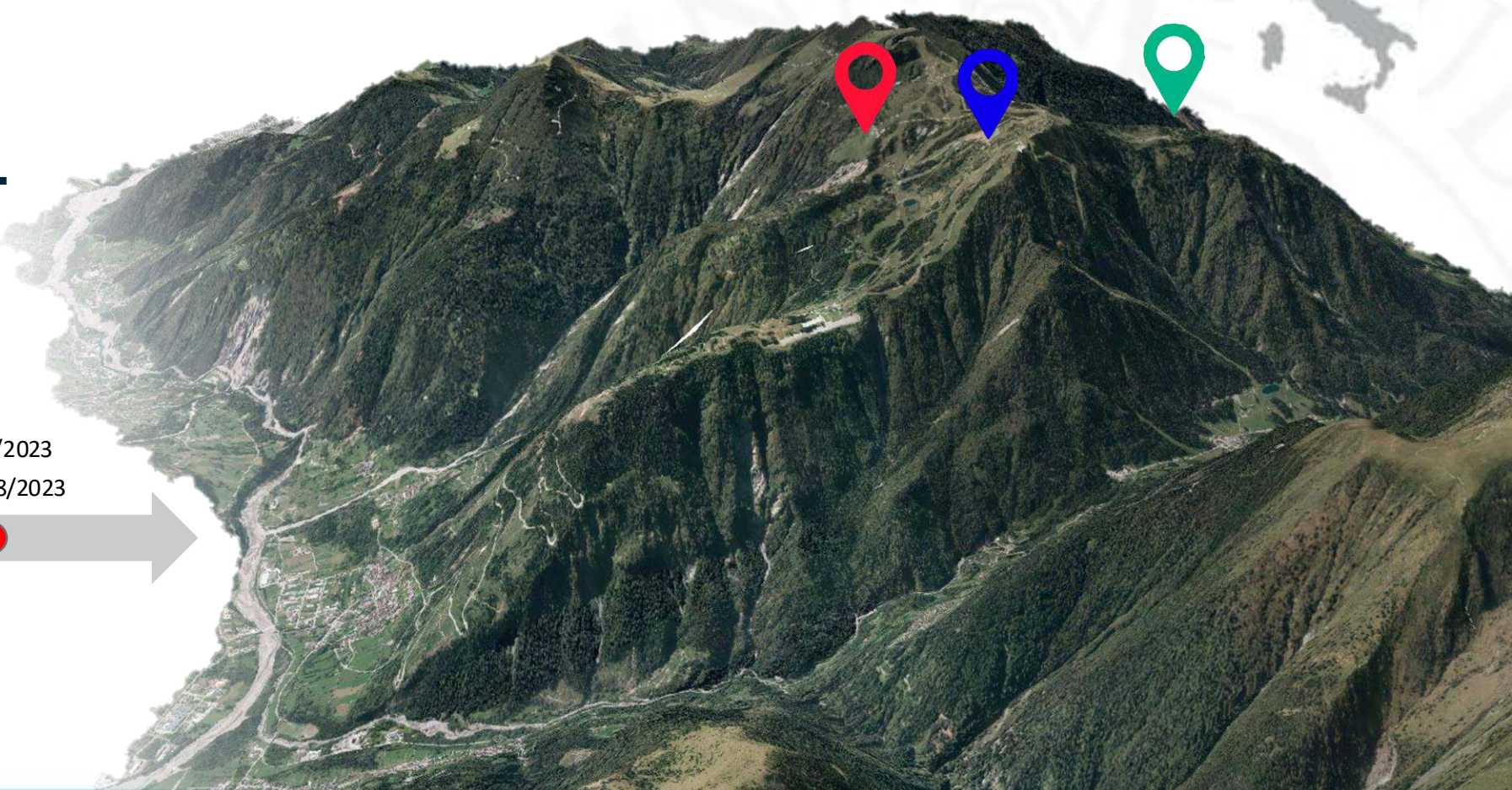
- Malga Pozof 1583m a.s.l.
- Malga Tamai 1600m a.s.l.
- Ski slopes 1600m a.s.l.

20/06/2023 to
11/07/2023

07/08/2023
to 26/08/2023

11/07/2023
to 07/08/2023

68 Days in total



Materials and Methods

VF collars data collection, processing and analysis

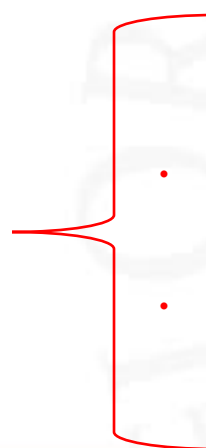
- Time-stamped (TS) GPS position
(every 15-30 minutes)
- TS Acoustic warnings delivered
- TS Electric pulses delivered



Dependent Variables

Acoustic warnings
(n/day/animal)

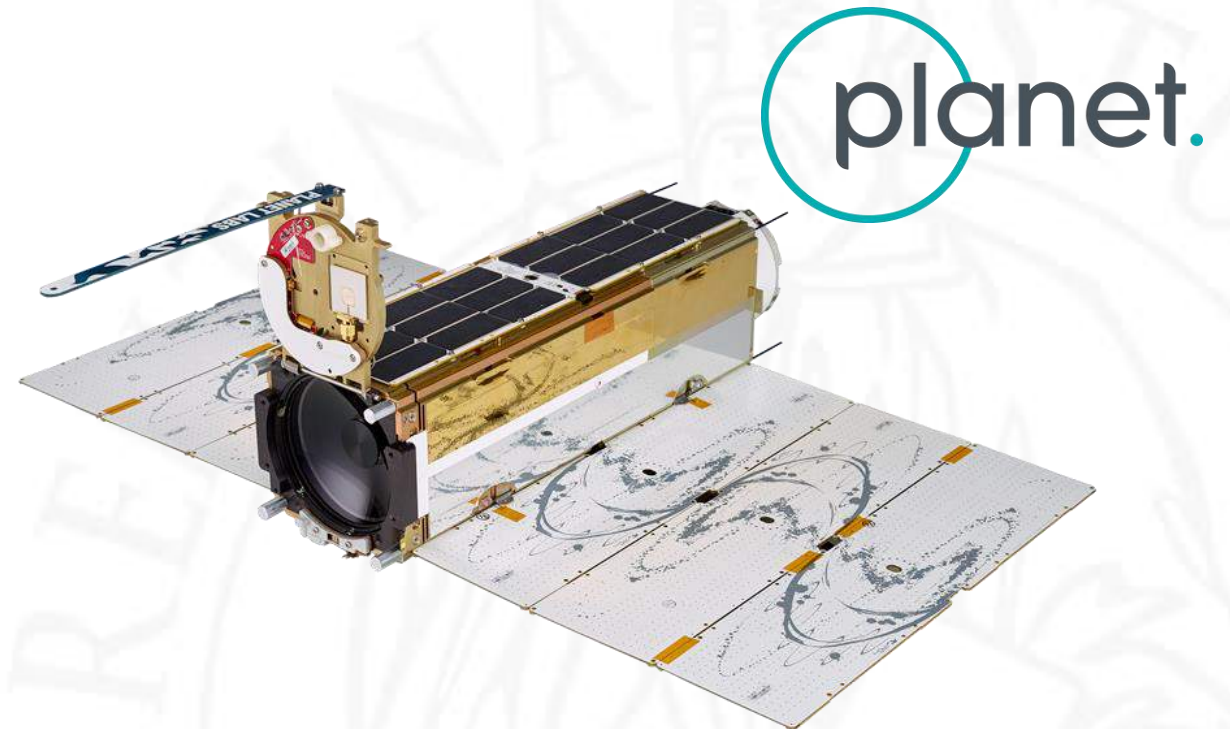
Electrical pulses
(n/day/animal)

- 
- **Grazing area effect**
 - Three levels: Pozof, Tamai, and Ski slopes
 - **Days within each grazing area effect**

Satellite images acquisition, processing and spatial analysis

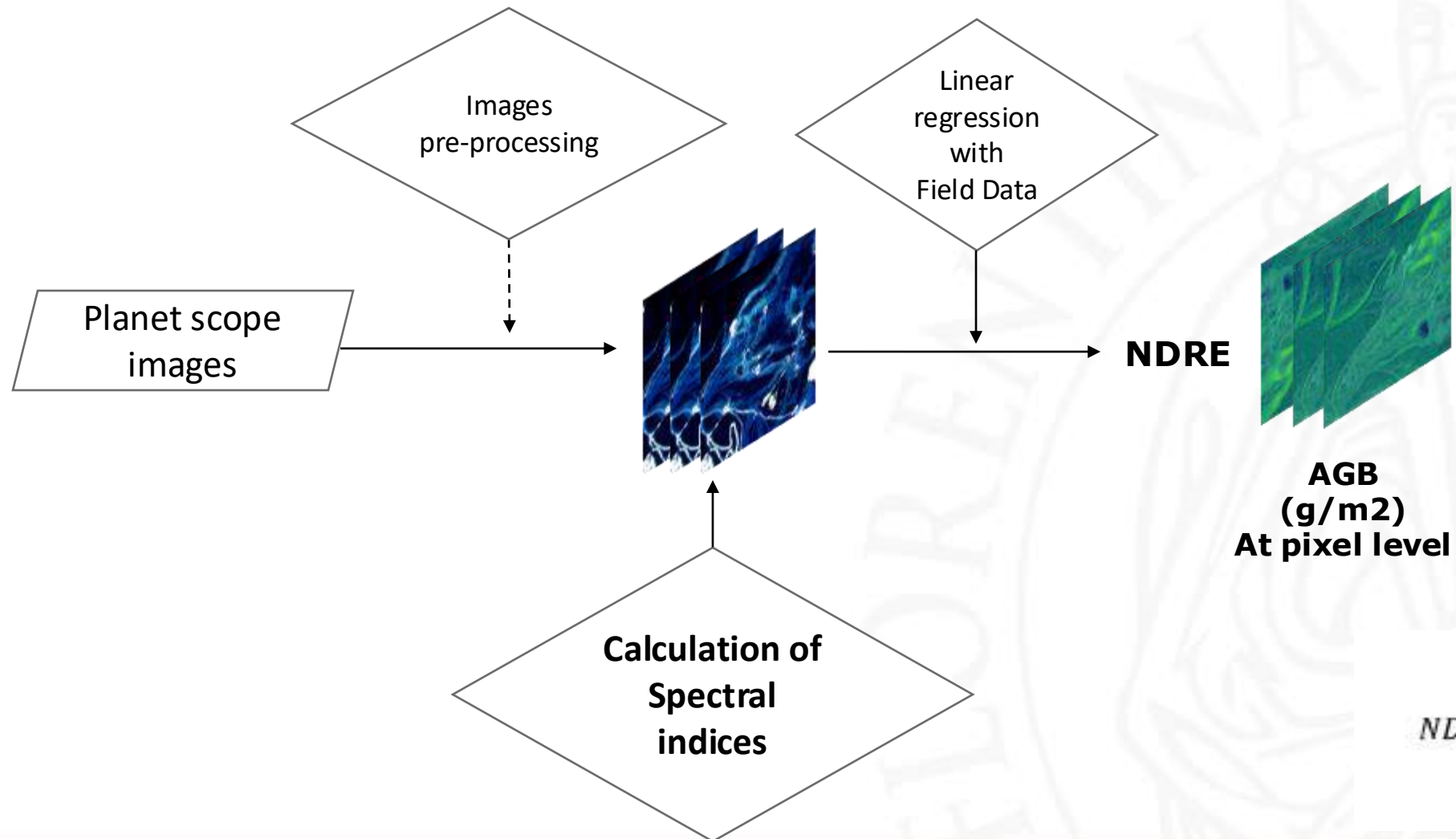
Planet scope images

- 8 spectral bands:
 - **RED**
 - **GREEN**
 - GREEN I
 - **BLUE**
 - COASTAL BLUE
 - YELLOW
 - **NIR (Near Infrared)**
 - **Red-Edge**
- **Temporal resolution:** 1 image per day??
- **Spatial resolution:** 3m/pixel



Materials and Methods

Satellite images acquisition, processing and spatial analysis



$$NDRE = \frac{NIR - Red\ Edge}{NIR + Red\ Edge}$$

Satellite images acquisition, processing and spatial analysis

AGB

AGB



NG



Ski slopes

20/06/2023 to
11/07/2023

07/08/2023
to 26/08/2023

11/07/2023
to 07/08/2023

3 sub-periods

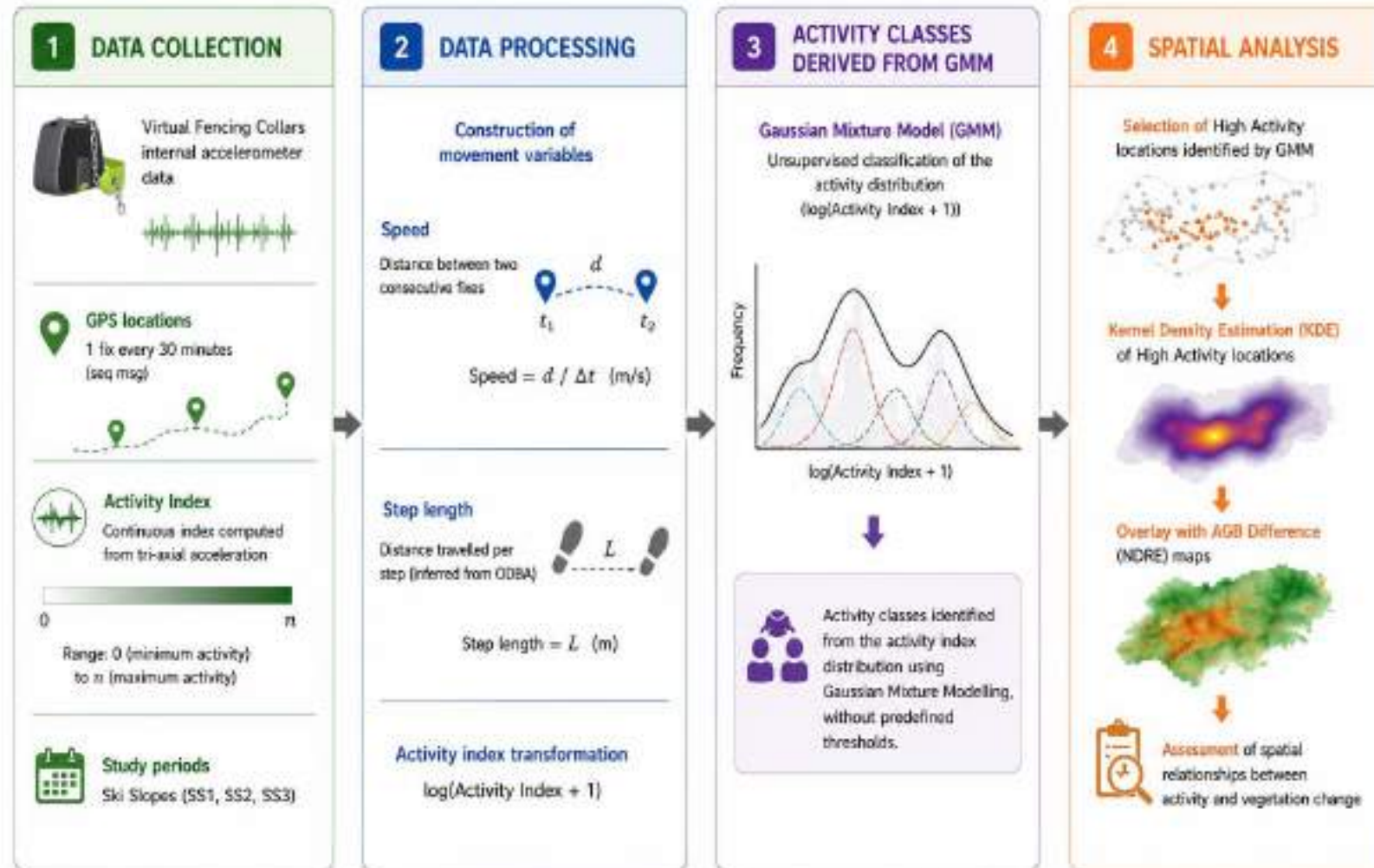
SS2 16/08/2023 to 21/08/23

SS1 7/08/2023 to 16/08/23

SS3 21/08/2023 to 26/08/23

Materials and Methods

Satellite images acquisition, processing and spatial analysis



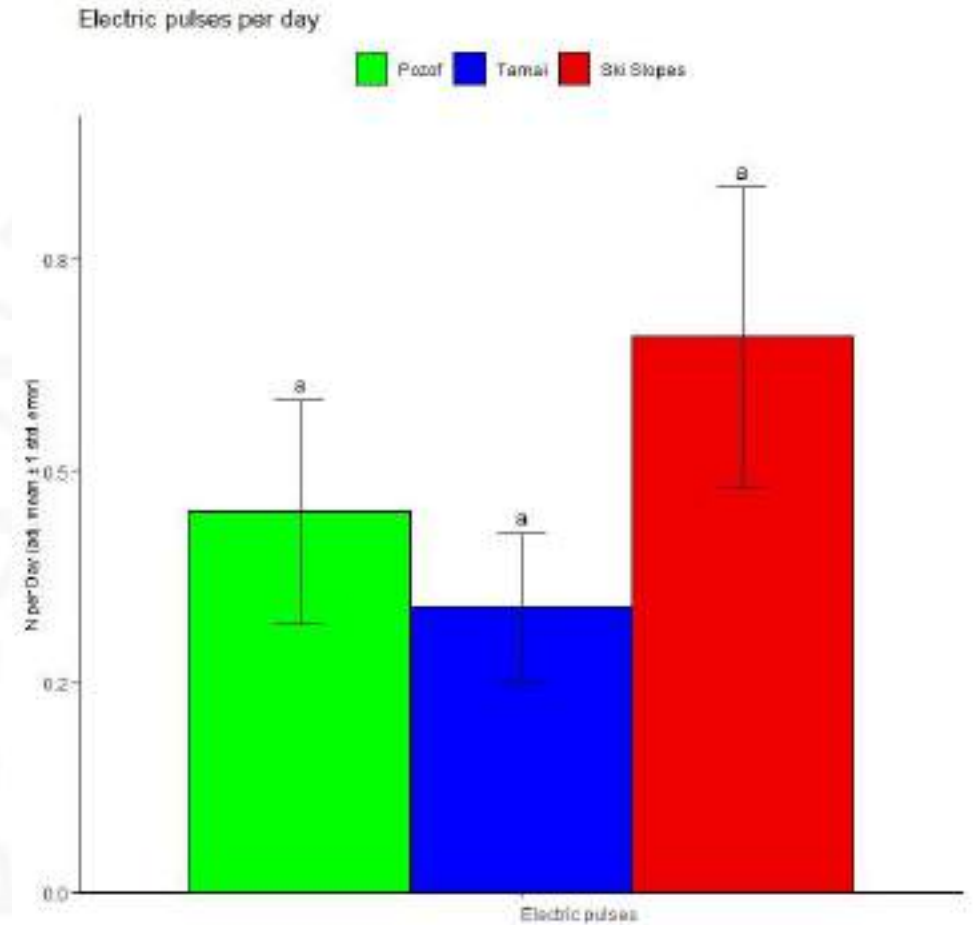
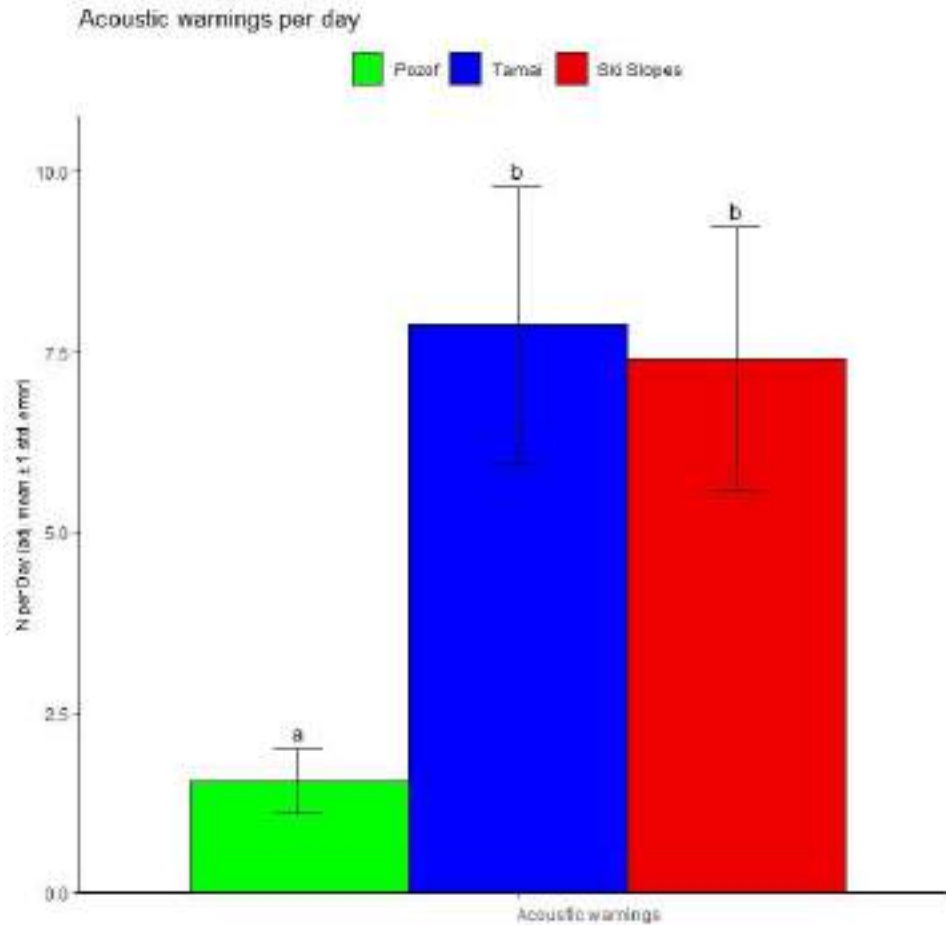
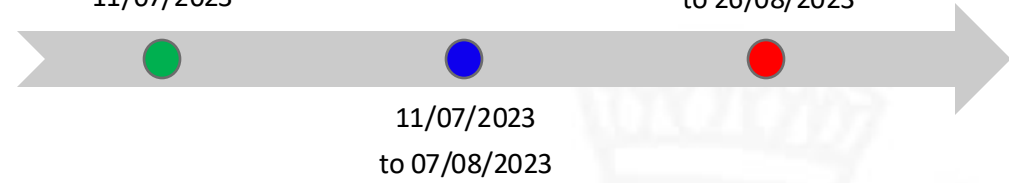


Results and discussion

Animals' response to VF

20/06/2023 to
11/07/2023

07/08/2023
to 26/08/2023



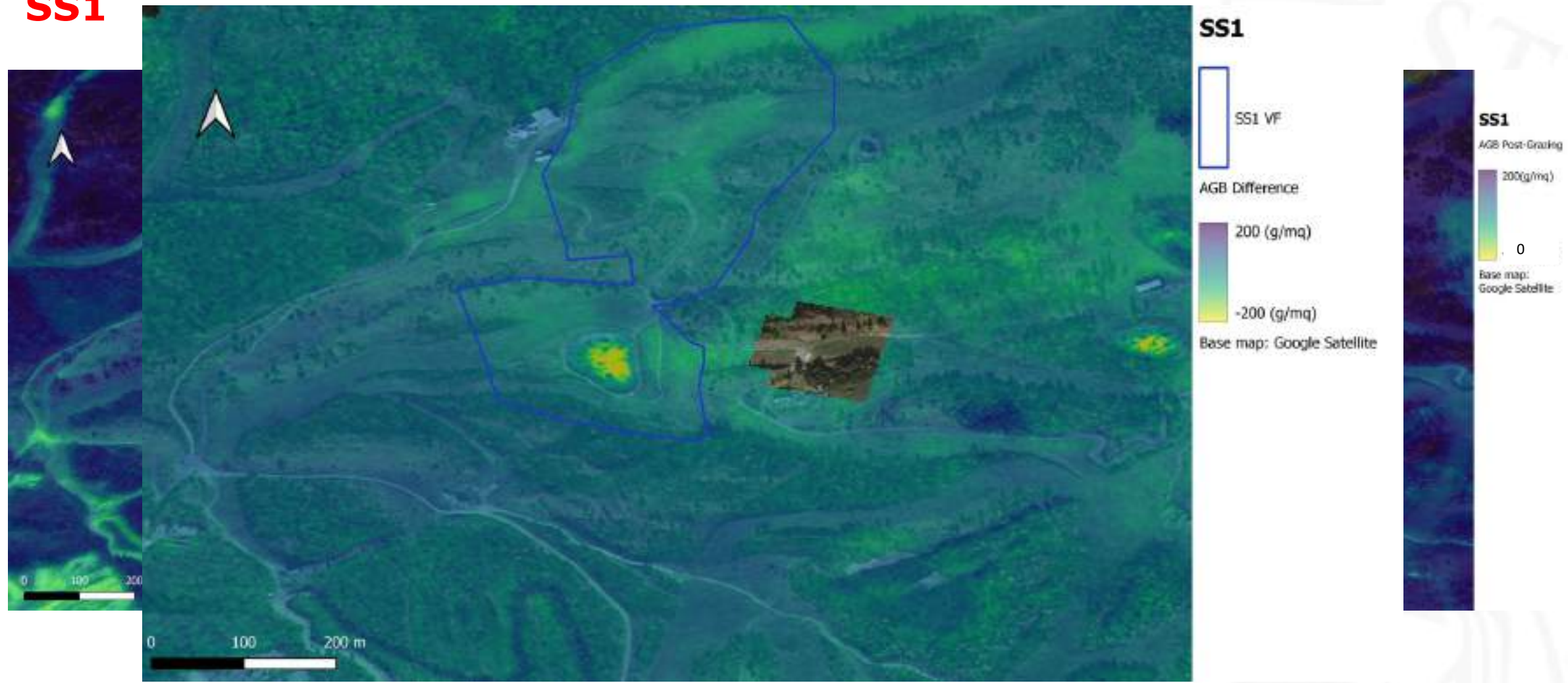
Results and discussion

SS2 16/08/2023 to 21/08/23

SS1 7/08/2023 to 16/08/23

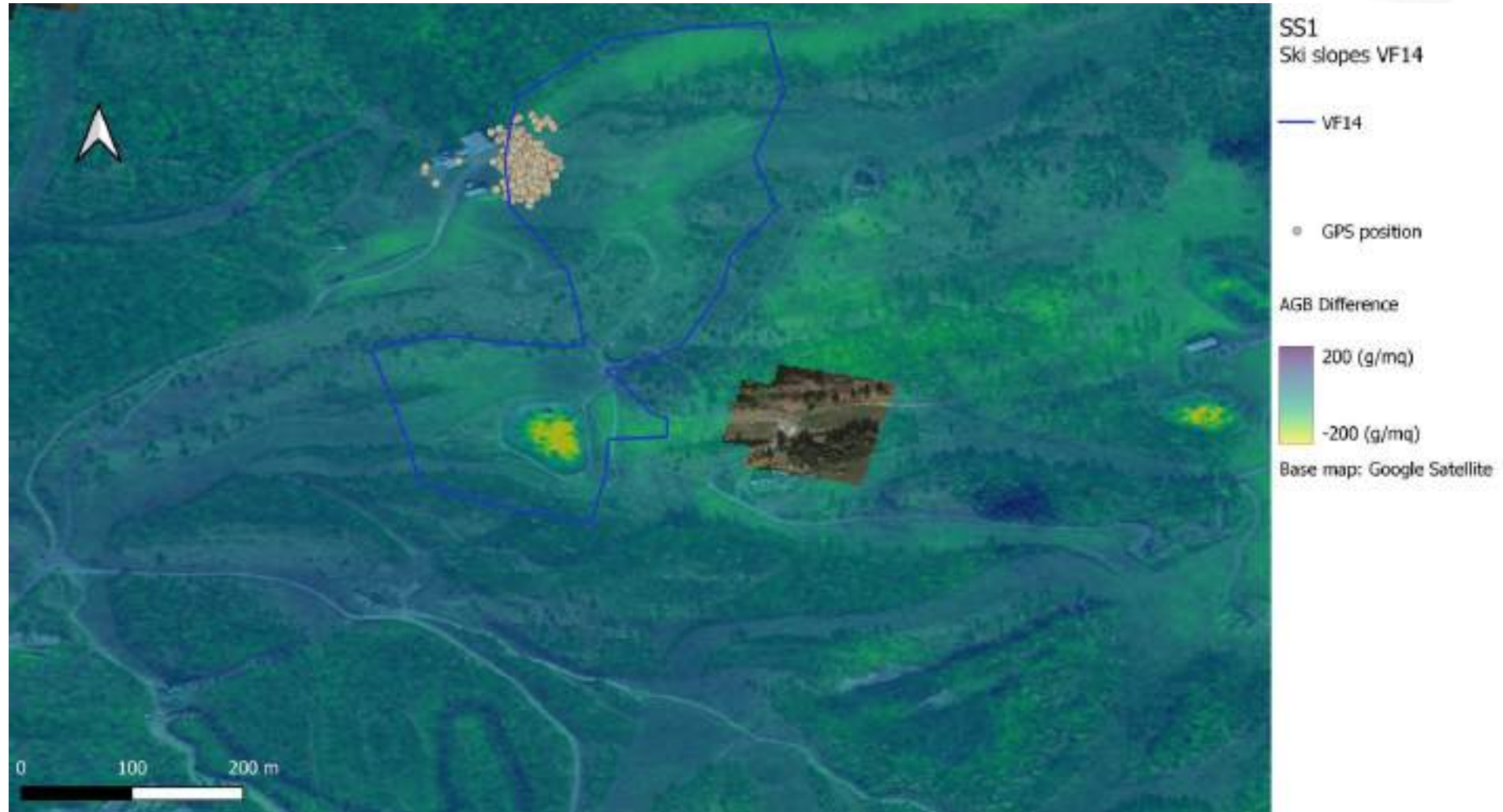
SS3 21/08/2023 to 26/08/23

Estimation of animal's feed uptake from satellite images SS1



Results and discussion

Estimation of animal's feed uptake from satellite images SS1



Results and discussion

SS2 16/08/2023 to 21/08/23

SS1 7/08/2023 to 16/08/23

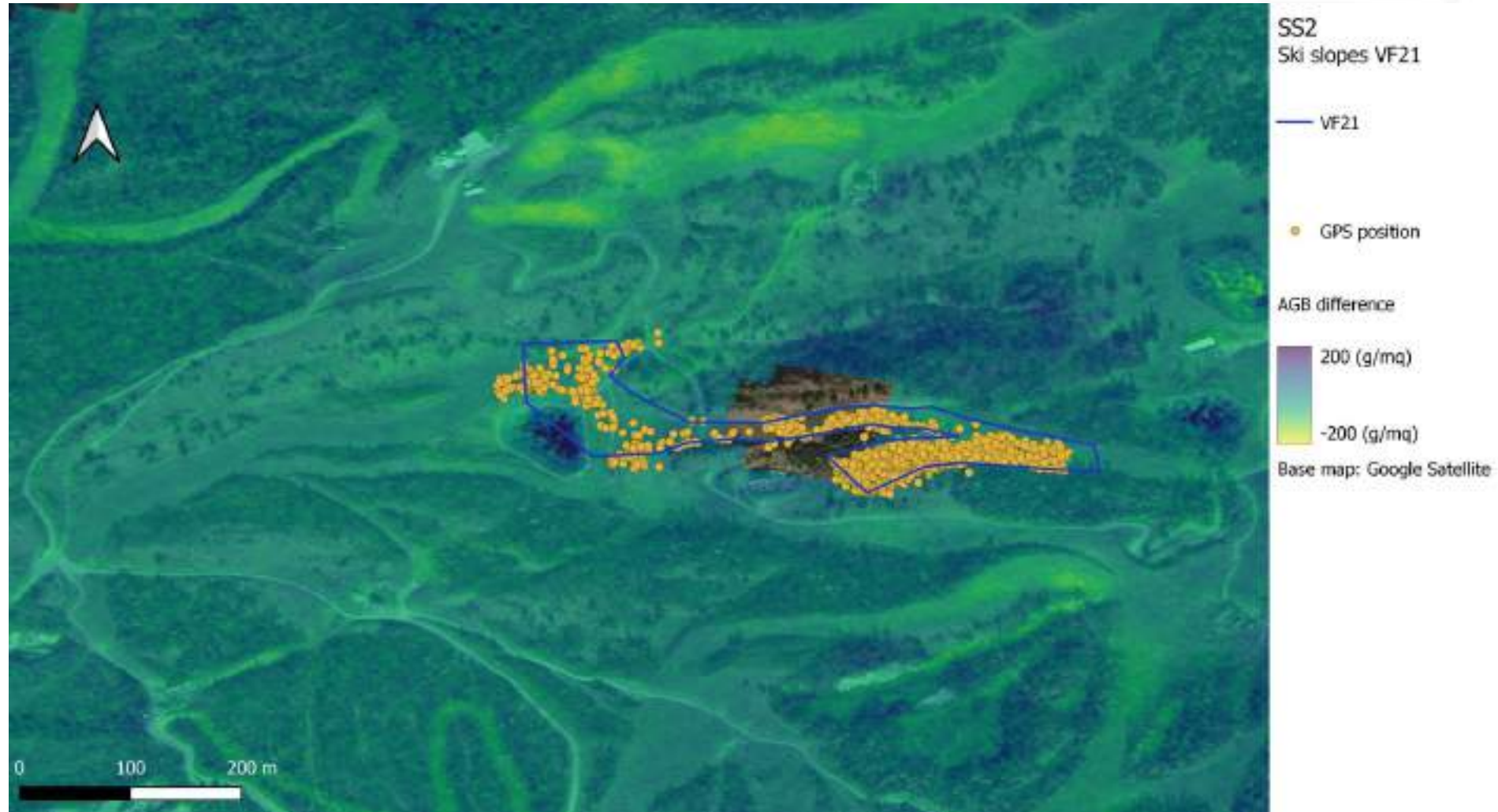
SS3 21/08/2023 to 26/08/23

Estimation of animal's feed uptake from satellite images SS2



Results and discussion

Estimation of animal's feed uptake from satellite images SS2



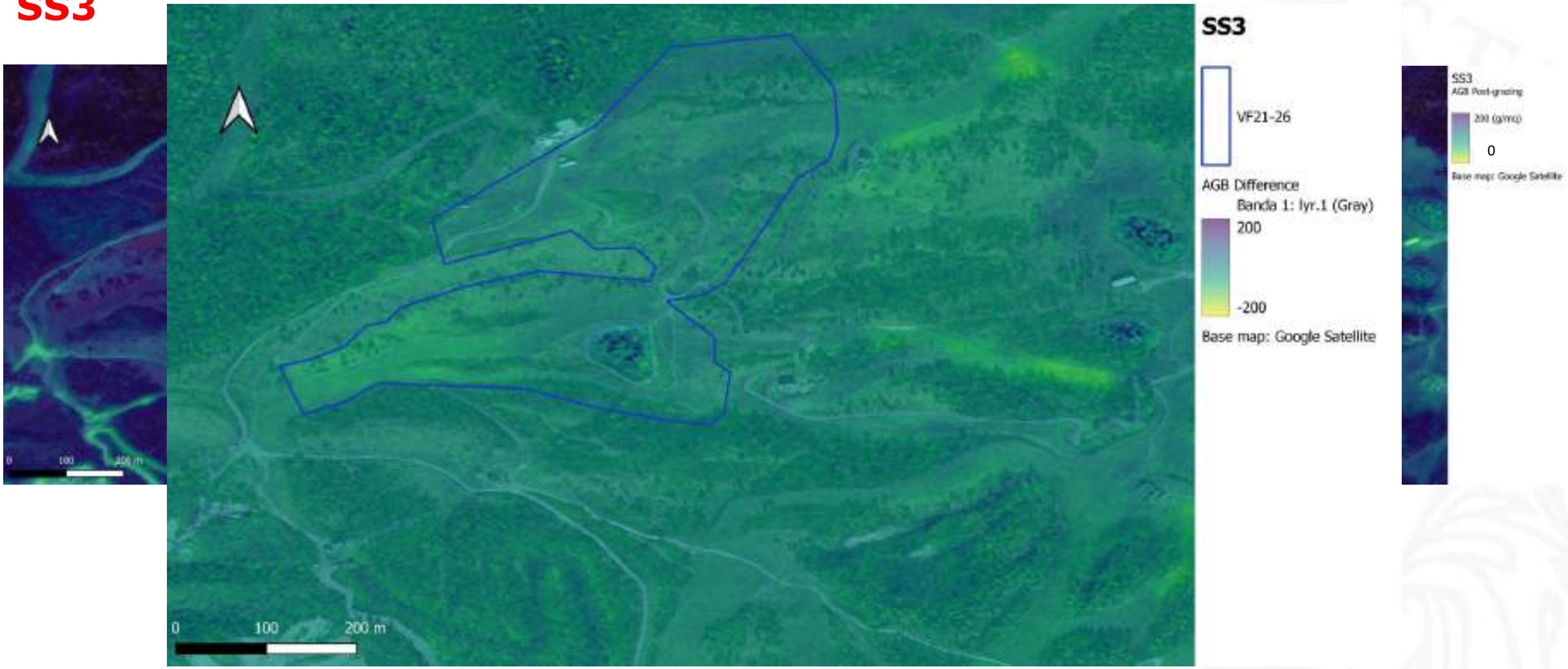
Results and discussion

SS2 16/08/2023 to 21/08/23

SS1 7/08/2023 to 16/08/23

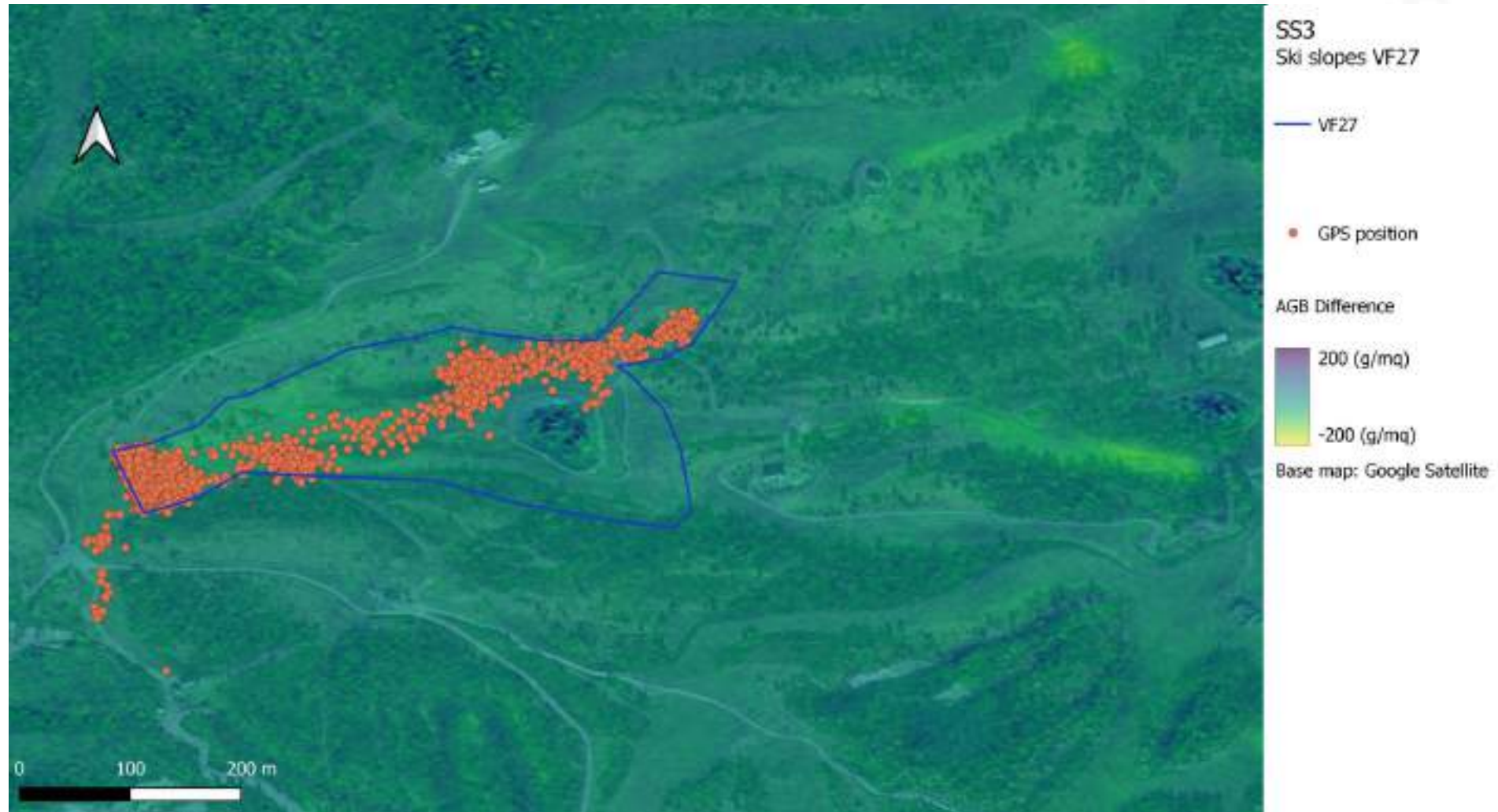
SS3 21/08/2023 to 26/08/23

Estimation of animal's feed uptake from satellite images SS3



Results and discussion

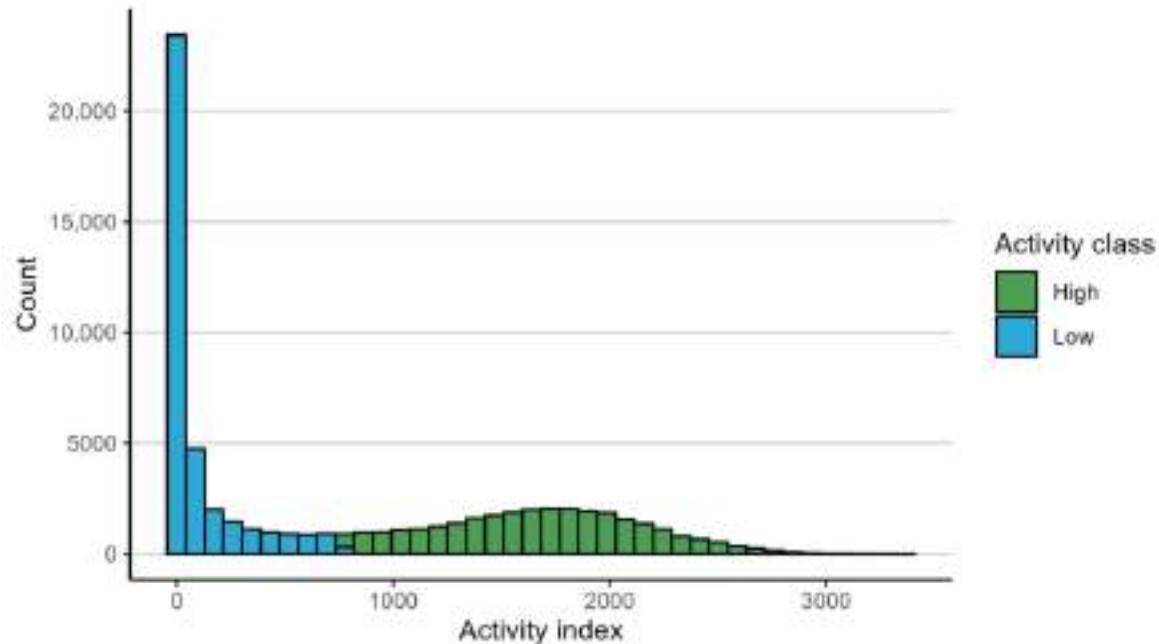
Estimation of animal's feed uptake from satellite images SS3



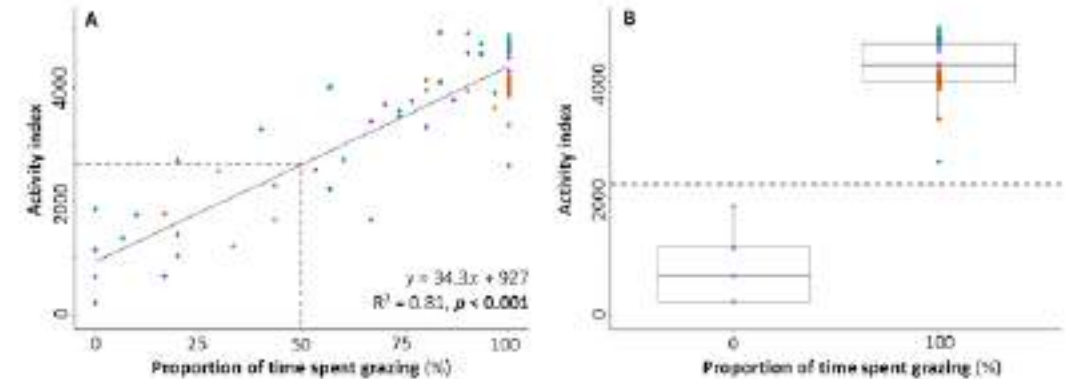
Results and discussion

Spatial analysis of activity behaviours

Activity Index from internal accelerometers of VF collars (0 to n)



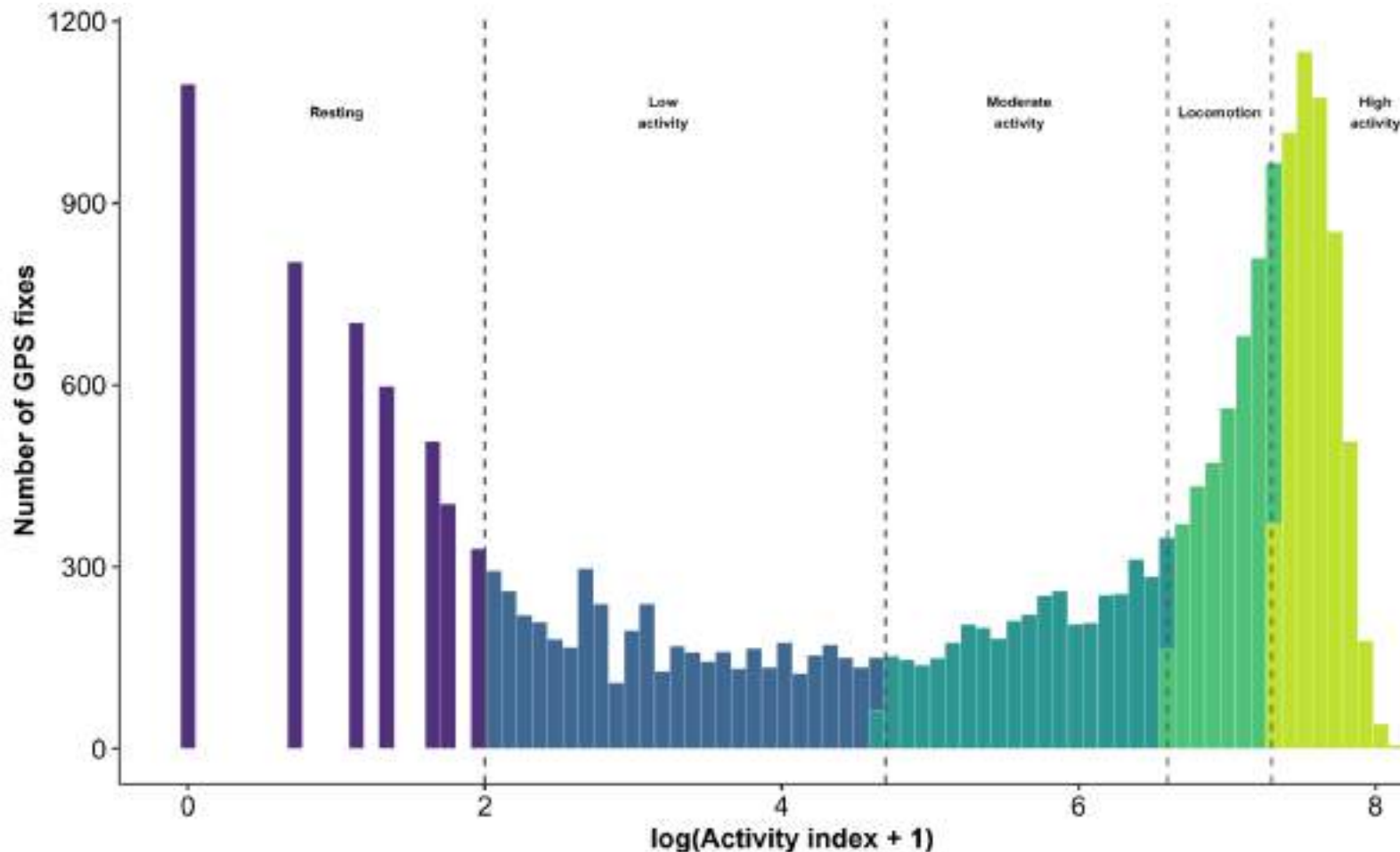
Aaser, M. F. et al., 2024



Chopra, K. et al., 2025

Results and discussion

Spatial analysis of activity behaviors

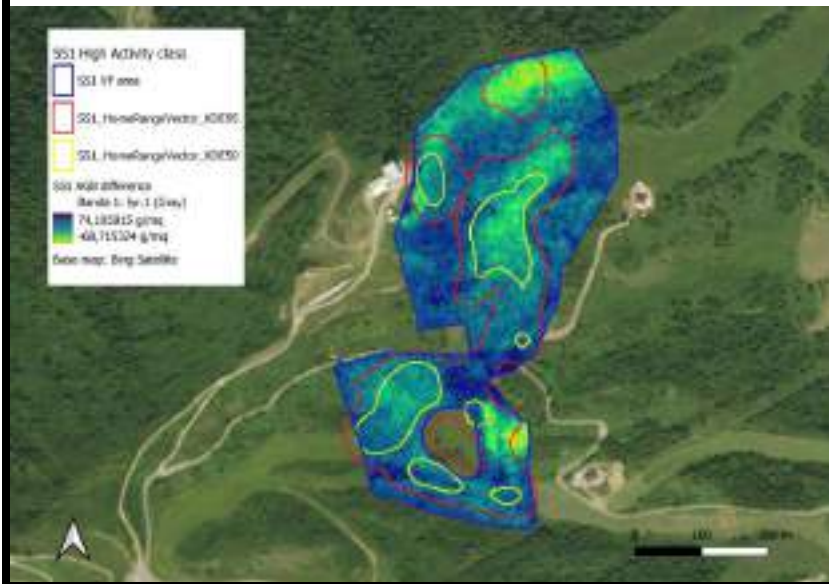


Activity Class Interval	Activity index	Median Speed (m/min)	Median Step Length (m)
Resting	0-2	0.24	0.0
Low Activity	2-6.6	0.26	6.5
Moderate Activity	6.6-7.3	1.60	48.2
Locomotion	7.3-7.7	1.87	57.9
High Activity	7.7-8.0	1.59	49.3

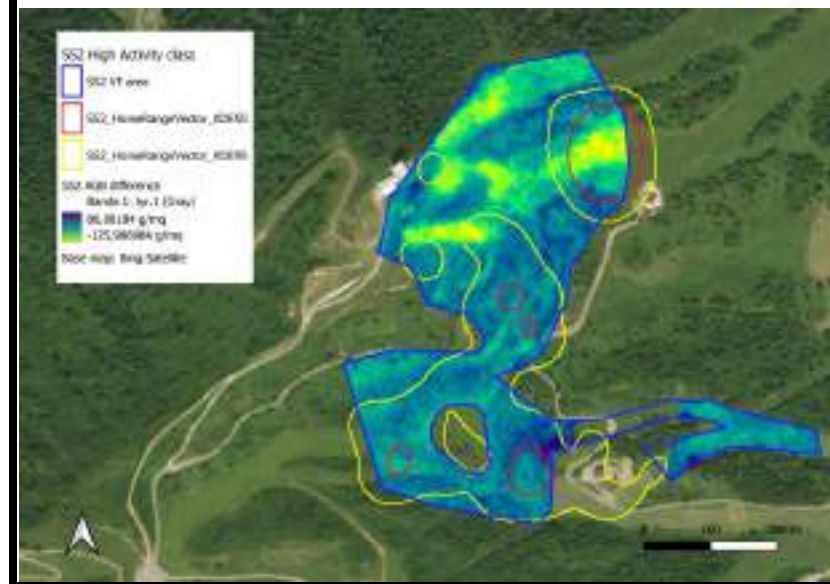
Results and discussion

Relationship between Activity Behaviour and NDRE dynamics

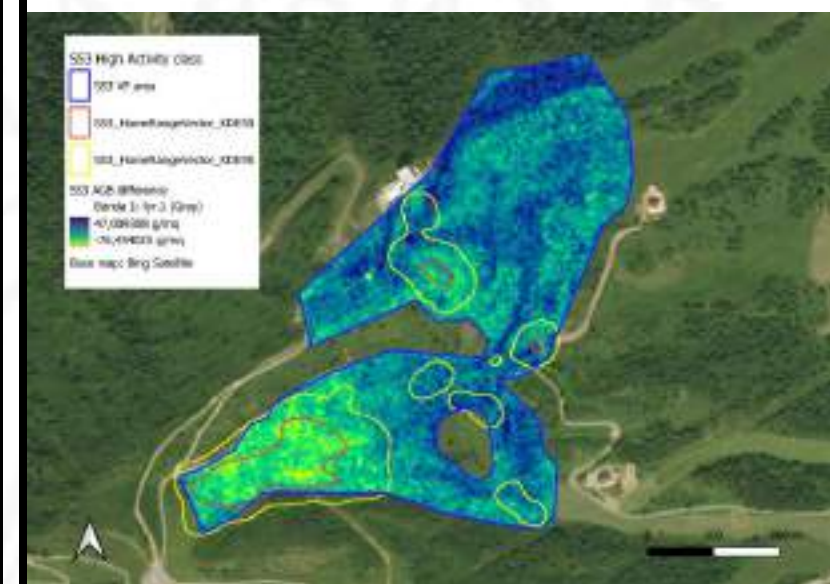
SS1



SS2



SS3



Sub- Period	$\rho(N.fix, NDRE)$	p-value	$\rho(High\ Activity, NDRE)$	p-value
SS1	-0.117	<0.001	-0.134	<0.001
SS2	-0.146	<0.001	-0.080	0.027
SS3	-0.295	<0.001	-0.340	<0.001

Spearman correlation coefficients between vegetation dynamics (AGB-NDRE difference) and animal spatial use intensity (N.fix) or High Activity locations identified through Gaussian Mixture Modelling (GMM) across the three study periods (SS1–SS3).

Conclusions

- Cows responded well to VF in all the pasture areas (two malga pastures and ski slopes)
 - VF kept animals within the assigned virtual grazing area
 - Remote sensing images could be a potential tool to estimate animal's feed uptake
 - Integrating Virtual Fencing system data with remote sensing provides a promising approach for monitoring animal–vegetation interactions in alpine grazing systems
 - Coupling both systems could improve the management of livestock alpine pasture-based system, enhancing environmental conservation
-

Limitation of the study

- Poor real temporal resolution of planet scope images
- Small interval of GPS fixes
- Few field measurements
- No other type of sensors to collect animal behaviours
- High length of the feed uptake estimation period



Thanks to...



the all Team!

Thanks for the attention!

