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A Study on the Classification of Arctic Tundra Vegetation using UAV Hyperspectral imagery

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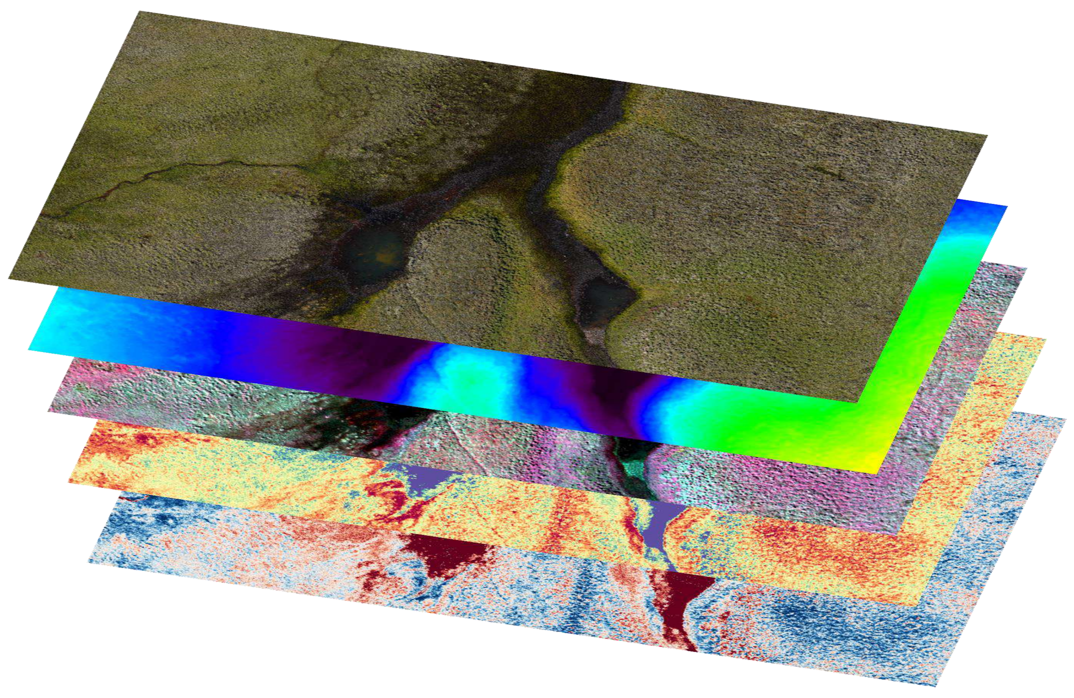

Summary

Hyperspectral sensors, compared to multispectral sensors, provide continuous spectral information, allowing for more detailed recording of the spectral characteristics of objects. This enables more quantitative analysis of the physical and chemical properties of various targets. Recent advances in UAV and sensor technology have made it possible to deploy miniaturized hyperspectral sensors on drones, facilitating low-cost, high-efficiency data acquisition. In this study, we classified ten dominant vegetation species in the tundra region of Adventdalen, Svalbard, using hyperspectral, LiDAR, and RGB imagery simultaneously acquired from UAVs, along with ground survey data. The results showed that vegetation classification using hyperspectral imagery in the 400–1000 nm wavelength range achieved relatively high accuracy, and visual comparison with field photographs and high-resolution UAV RGB images demonstrated strong agreement. However, due to the high-latitude conditions near 80°N, misclassification occurred as a result of vegetation shadows caused by the low solar elevation angle. This issue may potentially be addressed in future studies by integrating height information obtained from LiDAR data.

Study Area and UAV Multi-Sensor System

Study Area:

Adventdalen, Svalbard (Latitude: 78°09'56.0"N; Longitude: 16°00'52.8"E)

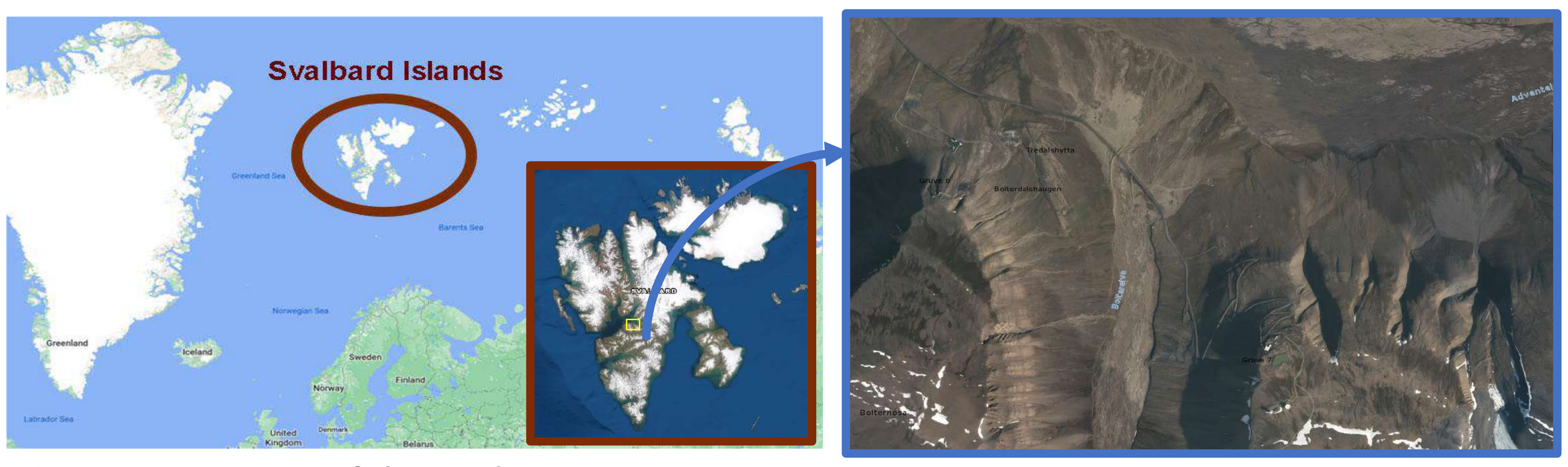

Figure 1. Overview of the study area

- UAV Multi-Sensor System
  - UAV: DJI Matrice 600 Pro
  - Hyperspectral: Headwall Nano-Hyperspec®
    (400 – 1000 nm; 270 bands)
  - LiDAR: Velodyne Puck Hi-Res
    (16 channels; range: ~100 m;
    range accuracy: ±3 cm)
  - RGB sensor: Sony A7R3 (35 mm lens)
  - GNSS/IMU: Trimble APX-15

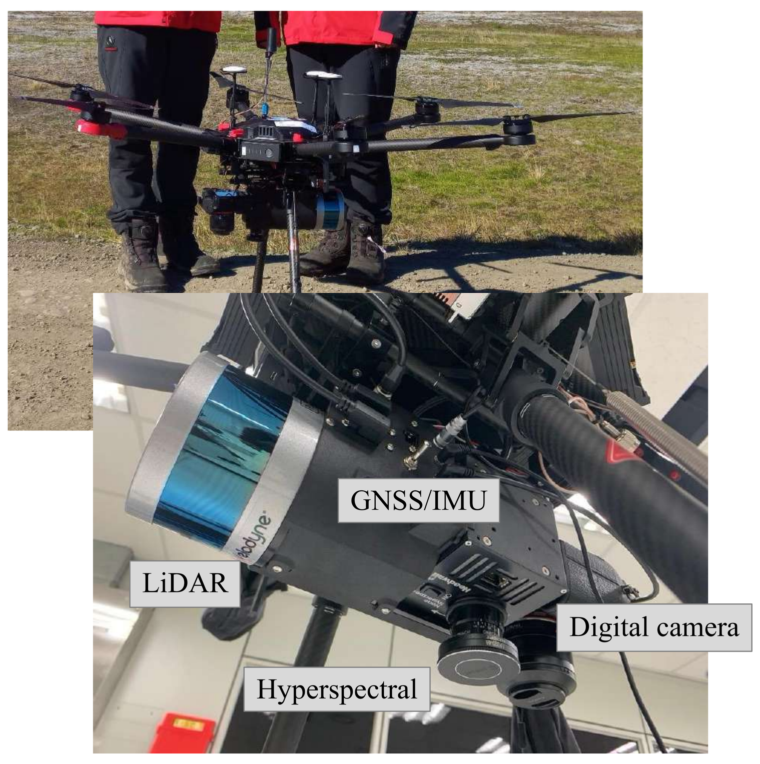

Figure 2. UAV multi-sensor system (RGB, hyperspectral, LiDAR)

Table 1. Resolution and Expected Accuracy of UAV Multi-Sensor Data

	Resolution (at 44 m altitude)	Expected Accuracy
RGB	0.6 cm	2 – 3 cm (Horizontal position)
Hyper	4 cm	5 – 6 cm (Horizontal position) 1.5 % (Spectral reflectance)
LiDAR	2.48 cm x 1.61 cm (Laser spot footprint) 316 points/m^2 (Single flight line) 5 – 6 cm (DSM)	2 – 3 cm (Vertical position)

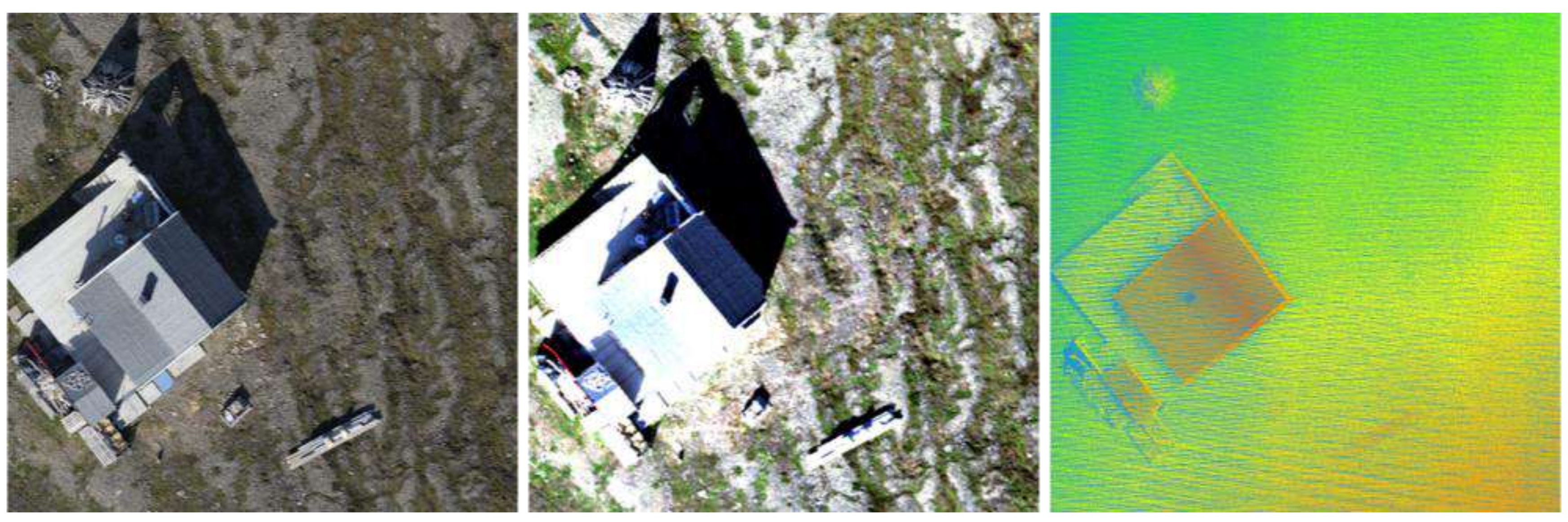

Figure 3. Multi-sensor data from the UAV (left: RGB; center: hyperspectral; right: LiDAR)

Research Methods

- Classifier: Random Forest
- Training and Validation Labels: 250–1250 pixels per class
- Input Data:

  Hyperspectral imagery;(400–950 nm, excluding low SNR bands; spectral band binning applied for noise reduction, resulting in 126 bands)

  LiDAR;Canopy height = Digital Surface Model (DSM) – Digital Elevation Model (DEM)

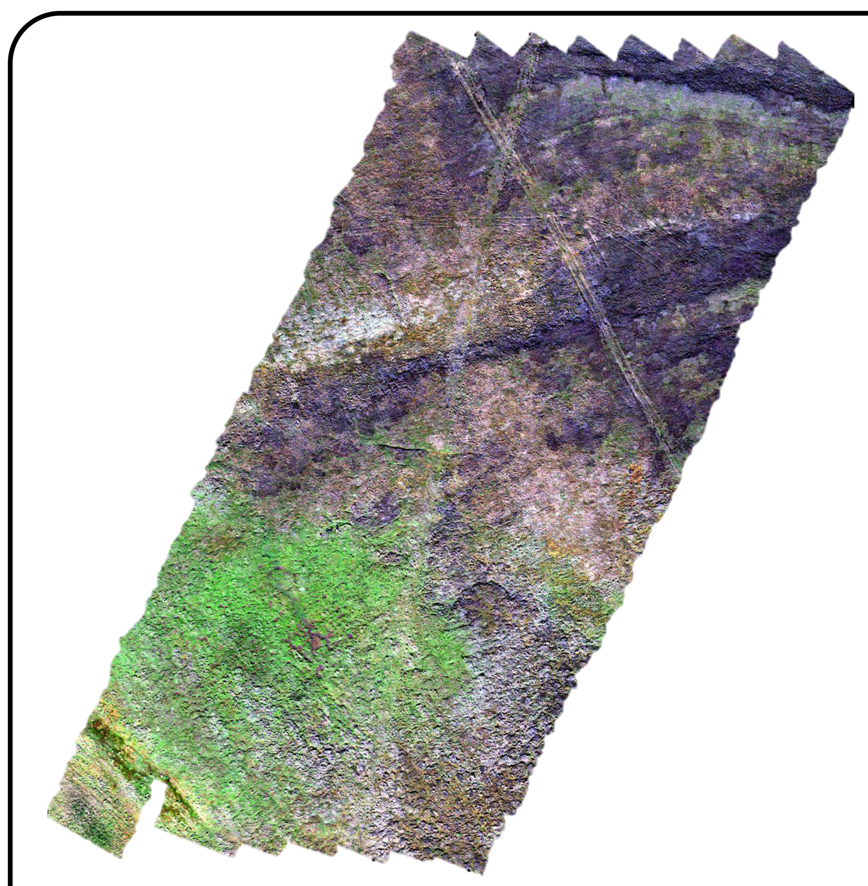

Figure 4. UAV hyperspectral image of the study area (R: 638 nm; G: 550 nm; B: 470 nm)

Table 2. Vegetation Class Information in the Study Area

ID	Class name
V1	Background
V2	*C. tetragona* (dead)
V3	*C. tetragona* (greening) & *D. octopetala*
V4	*Equisetum sp.* & *S. polaris*
V5	Granoid (dead) & *L. confusa*
V6	Bareground
V7	Moss (dry)
V8	Moss (wet)
V9	*S. acaulis*
V10	*S. polaris* & Moss
V11	Tussock
V12	Tussock (shadow)

Result

Table 3. Statistical Comparison of Classification Accuracy by Input Data (unit: %)

ID	Hyper		Hyper + LiDAR (Canopy height)	
	Recall	Precision	Recall	Precision
V1	100	100	100	100
V2	96	89	95	89
V3	88	77	89	83
V4	96	96	98	99
V5	98	94	98	93
V6	99	97	99	98
V7	99	100	98	98
V8	98	99	99	99
V9	92	98	88	96
V10	89	83	94	88
V11	50	76	66	87
V12	100	100	99	99
Accuracy	92		94	

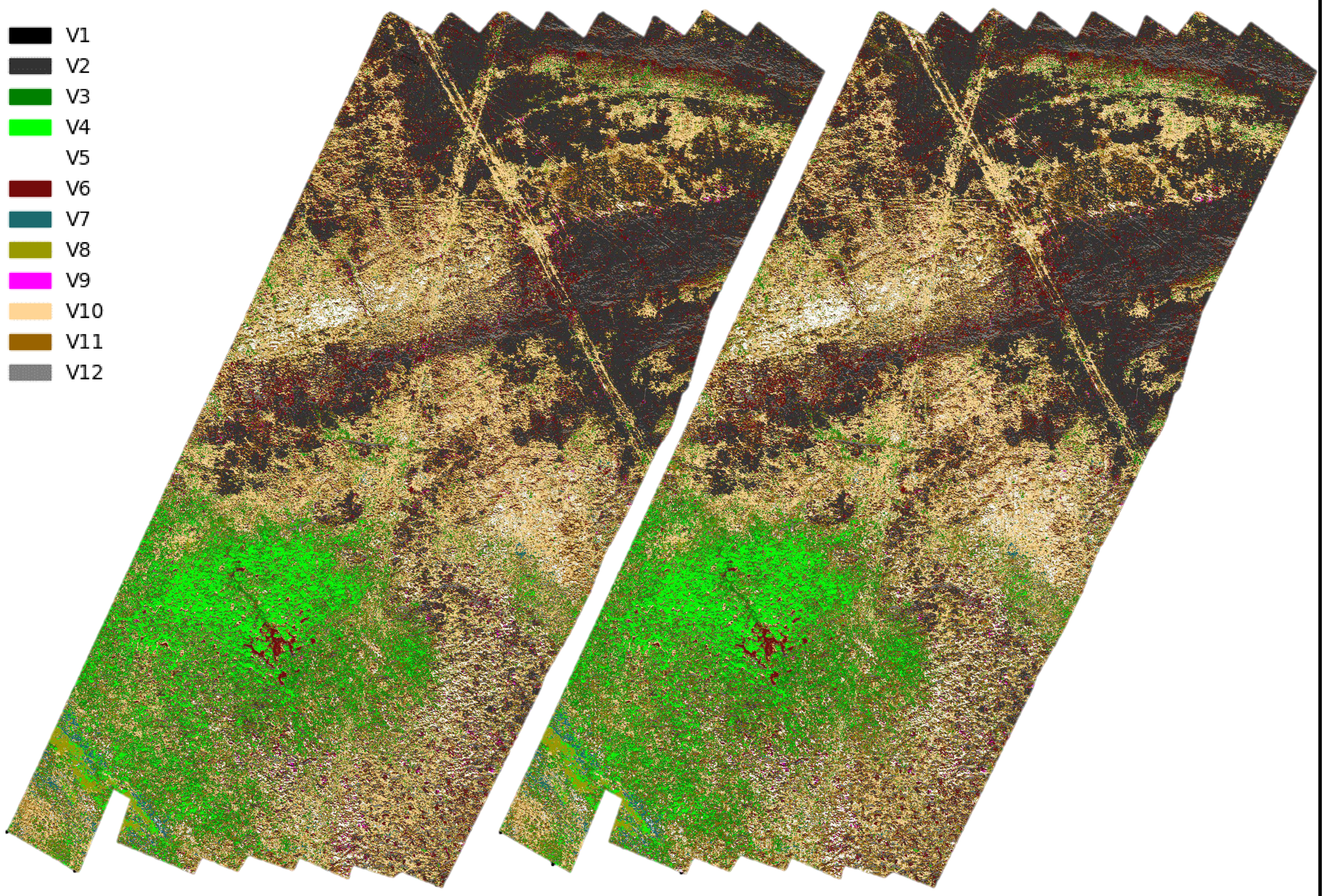

Figure 5. Classification results by input data (left: hyperspectral image; right: hyperspectral + LiDAR canopy height)

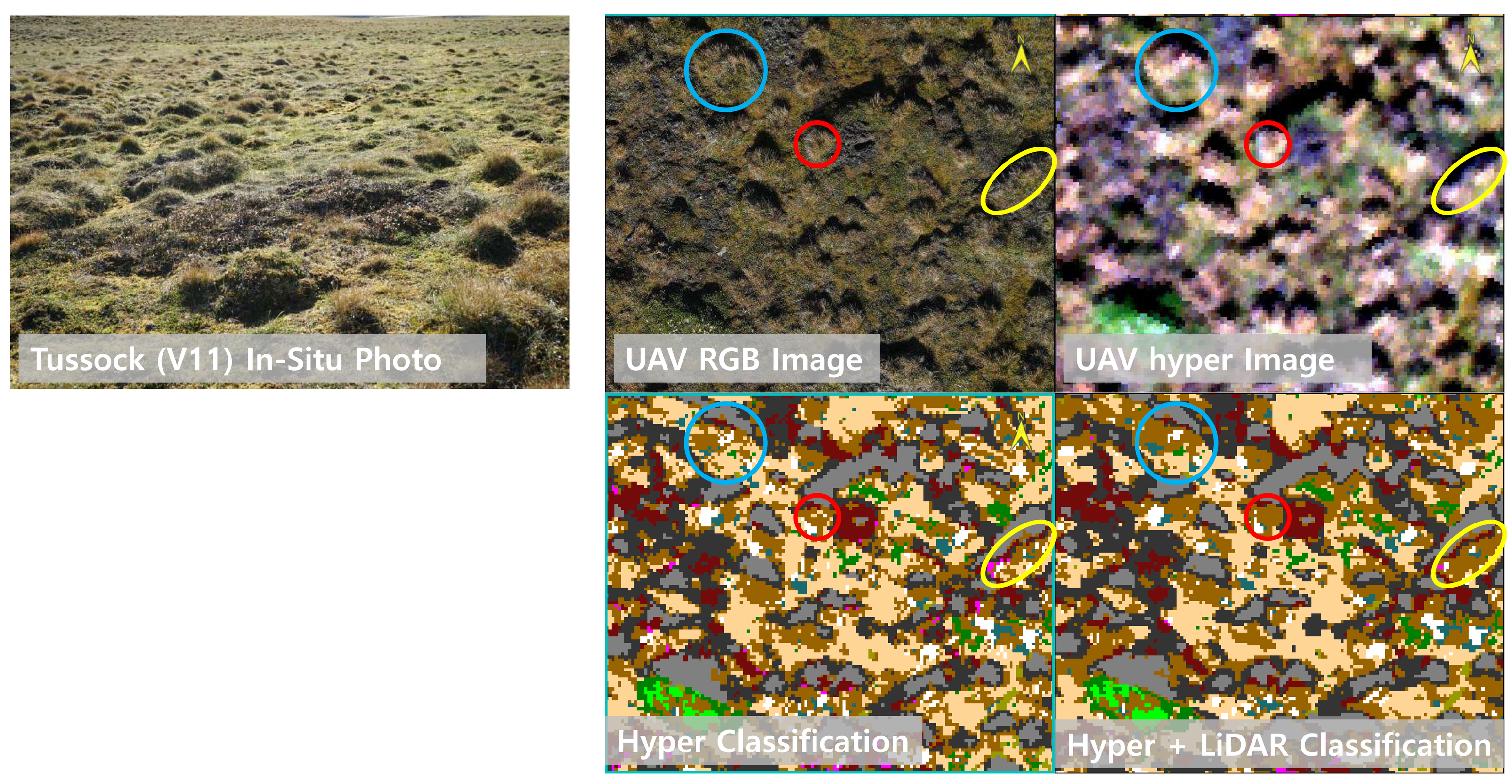

Figure 6. Qualitative improvement in classification performance. Tussock, where several vegetation types are clustered together, has greater individual plant height compared to other classes. Adding canopy height information from LiDAR, in addition to hyperspectral imagery, not only improved quantitative classification accuracy but also reduced the number of qualitatively misclassified pixels.

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