DETECTION OF EXPLOSIVE REMNANTS OF WAR WITH UAV-BASED HYPERSPECTRAL IMAGING

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Introduction

- Remnant landmines, unexploded ordinances (UXOs), & other explosive remnants of war (ERW) represent a significant detriment to social & economic recovery in post-conflict nations worldwide
- ERWs killed or injured 7,073 people worldwide in 2020[2]
- Current standard geophysical methodology for detection:
  - Terrestrial time-domain electromagnetic-induction (EMI)
- Unpiloted aerial vehicles (UAV) → a rapidly emerging tool for remote detection of ERW-contaminated areas
- Recent hardware design has significantly decreased the size, weight, & power (SWaP) consumption
  - Allows for much smaller & less expensive remote sensors, such as hyperspectral imaging (HSI)
- Our Primary goal: to better understand the strengths & weaknesses of UAV-based HSI to detect & spectrally quantify ERW of various sizes & material compositions

Methods

Airborne HSI

- Oklahoma State University Center for Fire & Explosives (CENFEX) hosts a large collection of inert ERWs
- Emplaced multiple ERWs, including anti-personnel mines, anti-vehicle mines, rockets, missiles, & grenades

Figure 1. Corning microHSI 410 SHARK

- Airborne hyperspectral data was collected over three types of inert minefields from June 7, 2022 through June 10, 2022
- The three different environments consisted of bare-ground with minimal vegetation, short grasses, & tall grasses
- 3 types of datasets, DJI Phantom 4 Pro 20-megapixel visible light camera, Phantom 3 with multispectral camera, Matrice 600 with Corning microHSI 410 SHARK

Results

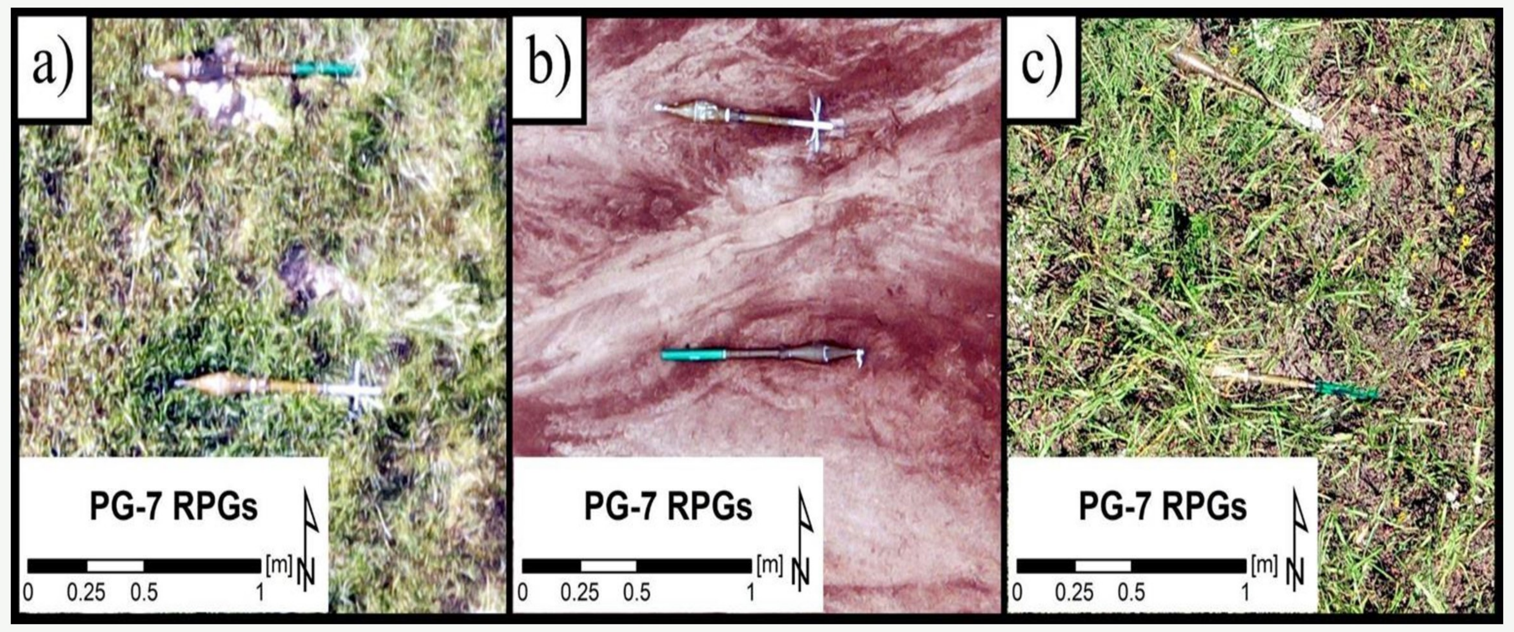

Figure 2. PG-7 rocket propelled grenade (RPG) in (a) short grass, (b) bare ground, (c) & tall grass environments.

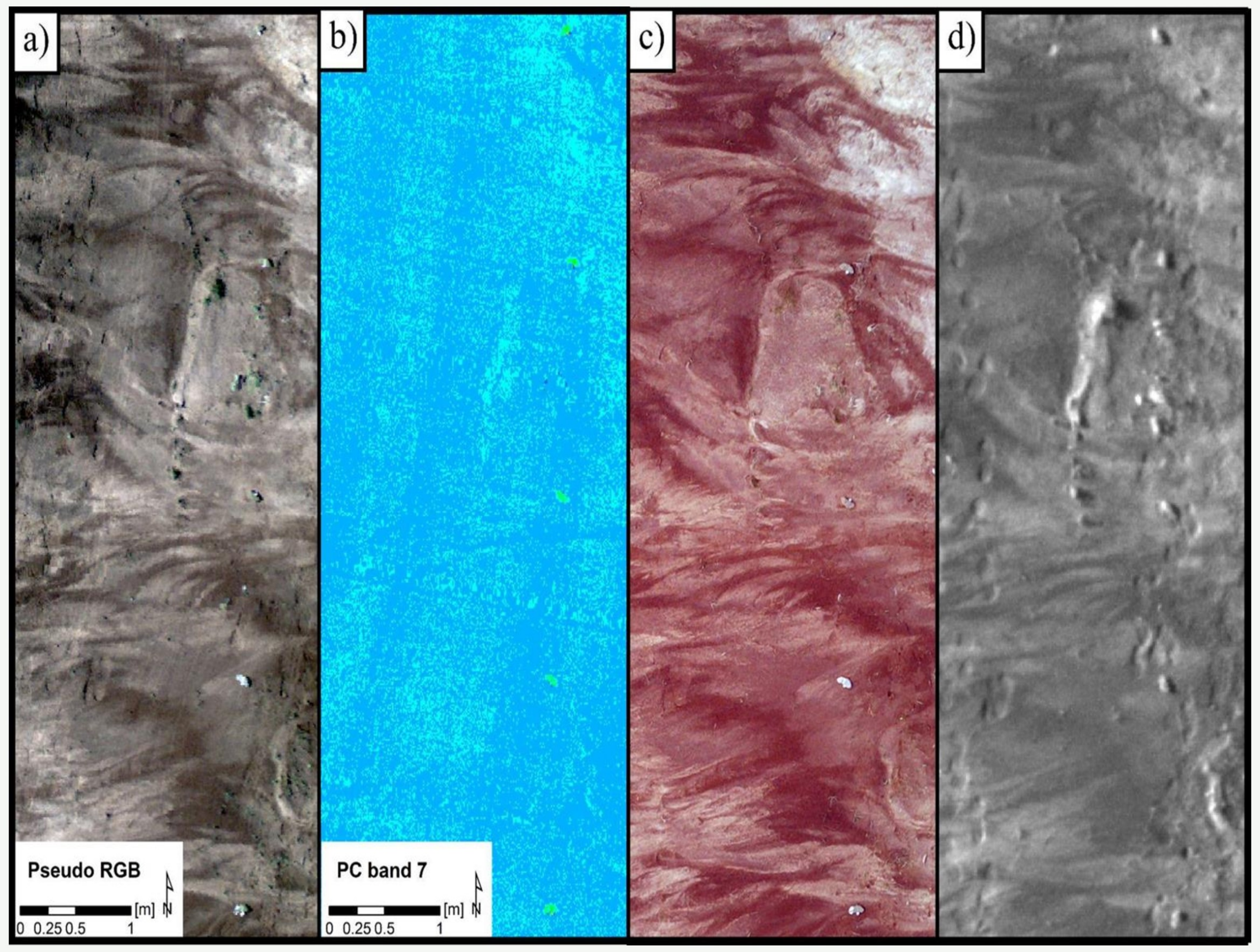

Figure 3. PFM-1 antipersonnel landmines data from three optical sensors & a derivative data product.

(a)Pseudo RGB from three hyperspectral imaging bands in the red, green, & blue with five PFM-1s. (b) Band 7 of a principal component analysis clearly showing PFM-1 landmines. (c) Visible light orthophoto from a DJI Mavic 2 Enterprise Dual demonstrating quality contrasts between HSI. (d) NIR from a Parrot Sequoia multispectral camera emphasizing quality contrasts between sensors.

Discussion

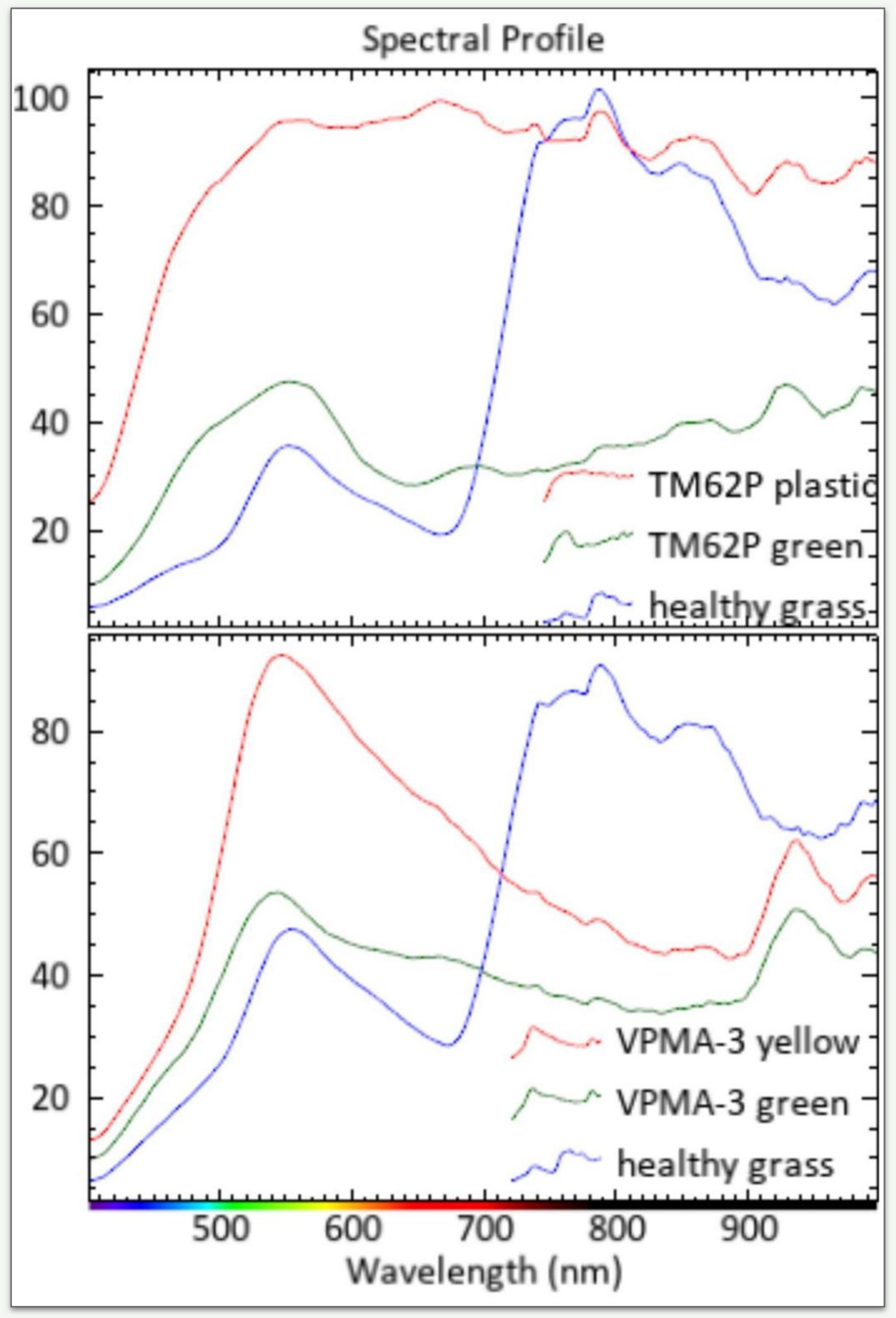

Figure 4. (a) Spectral profile of TM-62P antitank & (b) VPMA-3 antipersonnel mines.

- Principal Component band 7 from the bare-ground environment was successful in identifying PFM-1 anti-personnel landmines
- HSI strengths:
  - The ability to differentiate between ERW & host geology & vegetation environments based on their reflectance
- HSI limitations:
  - Larger ground sampling distance (GSD) resolution
  - Windowing
  - Possibility of line of sight obstruction

Future Work

- Future integration of HSI datasets into a convolutional neural network (CNN) currency being developed for rapid analysis of remote sensing datasets for presence of ERW objects
- Add the PCA of the PFM-1 landmines as a new channel to the CNN to further increase the accuracy of the network

Acknowledgements

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References

(1) de Smet, Timothy S., and Alex Nikulin. "Catching "butterflies" in the morning: A new methodology for rapid detection of aerially deployed plastic landmines from UAVs." The Leading Edge 37, no. 5 (2018): 367-371.
(2) "Landmine Monitor 2021." Monitor, http://www.the-monitor.org/en-gb/reports/2021/landmine-monitor-2021.aspx.