The frequency of droughts is expected to increase with climate change (Yu et al., 2019) and have a material impact on the agricultural industry and the demand for fresh water as such, our ability to detect water stress in crops is a timely and critical for crop preservation, efficient water management and maintenance of the global food supply.

Remote sensing offers a non-invasive and timely analysis of agricultural vegetation compared to most traditional methods (Díaz et al., 2015). Using tools such as spectrometers (AIS in this study) allows detection of changes is reflectance from a leaf and construction of spectral reflectance curves across a much wider range of wavelengths (Hyperspectral) compared to other methods. Each plant has its own unique spectral curve (i.e., spectral signature) and the analysis of changes in these curves through time (both visual and vs vegetation indices) are known to reveal such problems as nutritional deficiencies (Welzhar & Drax, 2016), diseases (Martins et al., 2017) and water stress (Zheng & Zhao, 2019). Given the high cost of spectrometers, a relatively small number of studies have been conducted on the subject to date, and especially on the impact of intercropping and ground cover facilitation treatments (e.g., sedum on our satellite) on water stress, which is covered in this study.

Lastly, green roofs take advantage of the stormwater and bees require less fresh water; building energy costs, and obviates the heat island effect. Furthermore, rooftop studies such as these are necessary in the development of technologies that could be deployed on satellites capable of surveying substantially larger agricultural landscapes than a hyperspectral sensor used in this study.

**Objective:** Identify water-stress sensitive wavelengths regions and vegetation indices using hyperspectral data in a rooftop experiment.

**Methodology**

**Experimental Design:**
The study was conducted on a highlighted flat rooftop at UTSC led by Prof. Isaac's team during July and August 2021.

Two water-stress treatments were implemented:
- **High SS:** soil moisture target of 12%–30%
- **Low (L):** soil moisture target of 12%–30%

In addition, the following four treatments were also conducted:
- **Sedum vs No Sedum:** 2.5cm and 1.5cm respectively covered the ground of some module while others
- **Intercrop vs Monocrop:** some modules had only bus beans (Phaseolus vulgaris) growing (i.e., Monocrop), while in others— in addition to beans had Russian red kale (Brassica napus subsp. Orientalis) and Italian parsley (Petroselinum crispum) also growing (i.e., Intercrop)

Out of the total number of 288 modules only a sample of each treatment was collected on July 25, 2021 (20 samples), August 3, 2021 (140 samples), and August 29, 2021 (79 samples).

**Results: Hyperspectral Curves**

**Monocrop treatment**

**Intercrop treatment**

**Sedum treatment**

**No Sedum treatment**

**Results: Vegetation Indices and Reflectance at 700 nm**

**Discussion**

1. The results of this study suggest that water stress can be detected in bush beans growing on a rooftop by investigating the changes in reflectance of the vegetation indices within the 330-370 nm region and the visible part of the spectrum (500-700 nm), which is in line with the previous work (Yu et al., 2019) and the current study.

2. The largest difference in reflectance treatment had in the red edge part of the spectral curve, particularly at a wavelength of 718 nm, where an increase in reflectance (i.e., water-stressed treatment) had higher reflectance at 718 nm than 8 treatments early July 26 and mid-July (August 2) resulting in the negative difference between L and H, with the visible regions— the white square regions. Treatments showed no difference in the visible part of the spectrum.

3. The end of the growing season (August 26), this trend seems to have reversed. Even though there was no vegetation in modules used in the treatment, presented here, a water in depth analysis is necessary to confirm these results.

4. Early in the growing season, the presence of other species in the modules (Intercrop treatment) were more detrimental in the growth of bush beans from water stress, suggesting that proper combination for maximum yield from other species was more important than water deficit. This was particularly evident in the visible range of 685 nm (red edge) and lower reflectance in the near infrared region (720–900 nm).

5. Lastly, the study has confirmed the potential utility of sedum, and combined Zheng & Zhao’s (2019) studies that (1) green and MS1 modules are among the most sensitive vegetation indices to identify water stress in plants. These markers were generally able to detect changes observed in the hyperspectral curves. This finding is evident in the study by Yu et al. 2019. The curves show a significant difference across the treatments (Figure 2) and therefore a suitable candidate for future research.

**Conclusions and Future Directions**

The study shows that remote sensing instruments can detect water stress in crops, which is a timely and critical for crop preservation, efficient water management and maintenance of the global food supply. The study also shows that green roofs can be used to reduce water stress and obviate the heat island effect. Furthermore, rooftop studies such as these are necessary in the development of technologies that could be deployed on satellites capable of surveying substantially larger agricultural landscapes than a hyperspectral sensor used in this study.

**Acknowledgements**

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- Prof. Minna E. Isaac team: especially Adriano Roberto and Chelsea

**Table 1.**

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Monocrop</th>
<th>Intercrop</th>
<th>Sedum</th>
<th>No Sedum</th>
</tr>
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<td>350</td>
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<td>-0.02</td>
<td>-0.06</td>
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</tbody>
</table>

**Figure 1.**

(A) Temperature and Rainfall during July and August 2021 at UTSC.

(B) No Sedum in the rooftop modules used in this study during each period.

**Figures 2.**

(A) Water index (WI)

(B) Water reflectance at 700 nm

**References**


