Using **an unmanned aerial vehicle with multispectral with RGB sensors to analyze canola yield in the Canadian prairies**

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Abstract. In 2017 canola was planted on 9 million hectares in Canada surpassing wheat as the most widely planted crop in Canada. Saskatchewan is the dominant producer with nearly 5 million hectares planted in 2017. This crop, seen both as one of the highest-yielding and most profitable, is also one of most expensive and input-intensive for producers on the Canadian Prairies. In this study, the effect of natural and planted shelterbelts on canola yield was compared with canola yield from fields with no tree or other natural vegetation. Yield was measured in 15 canola fields, 5 of which had naturally occurring trees, 5 with a row of planted trees and 5 without any trees, along three, 350 m transects, near Indian Head, Saskatchewan. During the growing season RGB and radiometrically corrected multispectral data from an unmanned aerial vehicle were collected at least once at each site. A variety of vegetation indices, such as normalized difference vegetation index, enhanced vegetation index, soil adjusted vegetation index and other variables were correlated with ground based measurements to determine the impact tree rows have on yield. Preliminary results from one replicate site which includes the natural shelterbelt, planted shelterbelt and control site are described here. A weak and inconstant correlation was found between yield and distance from natural vegetation.

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Introduction

Canola (genus Brassica) is an economically important crop in the Prairies of Canada generating $19.3 billion CDN in economic activity and making up one quarter of all farm cash receipts (Canola Council of Canada, 2018). In 2017 it was the dominant crop in Canada, surpassing wheat, with 9.3 million hectares planted (Statistics Canada, 2018) and it is also among the most expensive crop to grow in Saskatchewan (Saskatchewan Crop Planning Guide, 2017). It is typically used for cooking oil, livestock feed and biofuel feedstock.

Canola in Saskatchewan is typically produced in the dark-brown and black soil zones and these landscapes often contain wetlands, naturally occurring trees and planted shelterbelts. Shelterbelts are trees or shrubs, typically planted in rows, designed to protect crops, livestock, and buildings from wind and snow, see Figure 1. Shelterbelts and other natural vegetation areas, such as wetlands, have been shown to provide a variety of benefits for agriculture production, including increased soil moisture, a reduction in wind erosion potential and habitat for pollinators and other beneficial insects (AAFC, 2018). Kevan and Eisikowitch (1990) found that pollinators can increase canola germination by up to 13%, Abrol (2007) showed that pollinators resulted in a more uniform and earlier pod-setting, while Duran *et al.* (2010) found that pollinators increased the number of seed pods, and Sabbahi *et al.* (2005) found pollinators increased individual seed weight resulting a higher yield.

Figure 1. Example of canola field and planted shelterbelt

A total of 15 canola fields, 5 of which had a naturally occurring shelterbelt, 5 with a planted shelterbelt and 5 without a shelterbelt were examined. The research presented here is a preliminary examination of the relationship of one replicate site (Figure 2), which includes the natural shelterbelt, planted shelterbelt and control site.

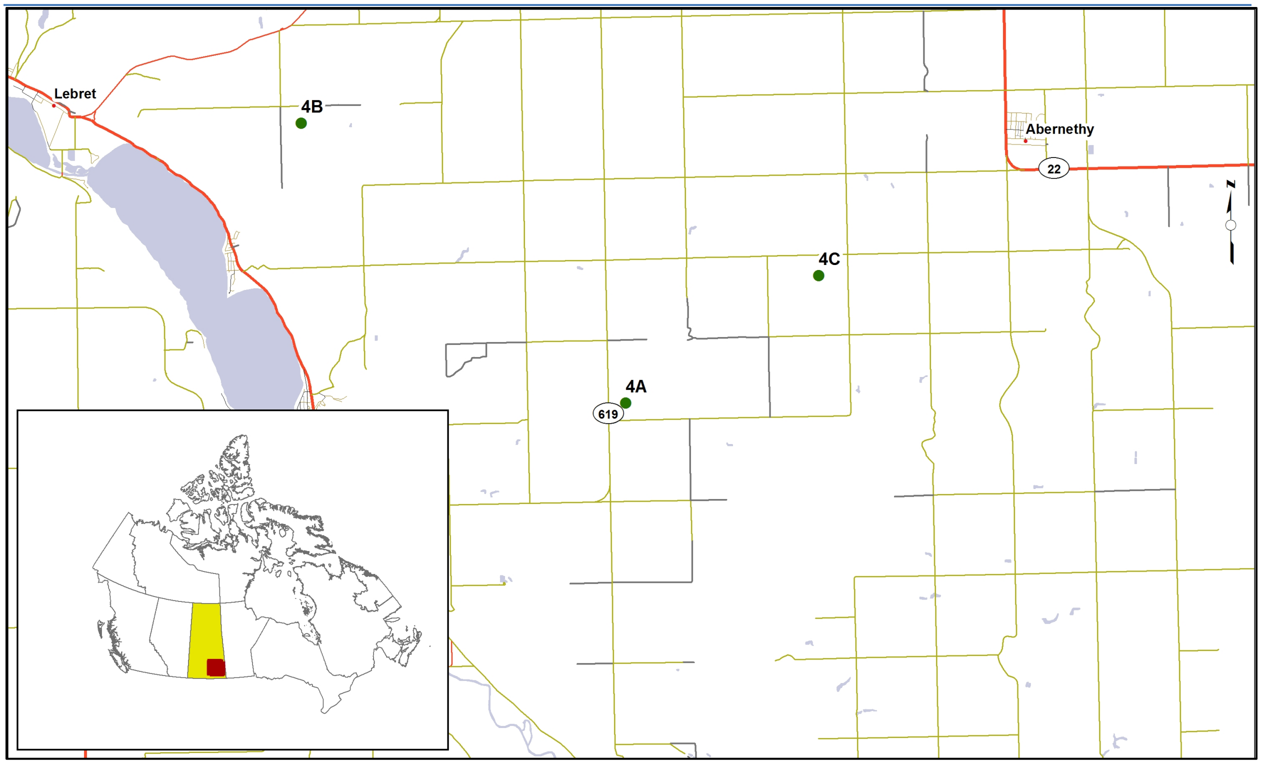


Figure 2., Study Area of one replicate site.

Materials and Methods

RGB and multispectral data were collected with an unmanned aerial vehicle (UAV) in July, 2018. Ground-based yield data were collected in 15 fields in August, 2017 near Indian Head, Saskatchewan Canada. RGB data from a DJI X3 sensor and radiometrically corrected multispectral data from a MicaSense RedEdge-3 sensor mounted on a UAV (DJI Matrice 100) were collected at each site. A total of 3,040, 3,595 and 4365 images multispectral images (Blue 475nm, Green 560nm, Red 668nm, Red Edge 717nm and Near-Infrared 840nm) from 4A, B and C were collected with a 80% front and side overlap, covering approximately 10.4ha, 21.5ha and 23.2 ha with a ground resolution of 39mm (Figures 3, 4 and 5). A variety of vegetation indices, such as normalized difference vegetation index, enhanced vegetation index, soil adjusted vegetation index and other variables were tested for correlation with ground based measurements to determine the impact tree rows have on yield. The sample fields consist of 5 replicate sites, each with 3 sites consisting of a canola crop with a natural, unplanted shelterbelt; a planted shelterbelt; and a site with no shelterbelt, as a control for a total of 15 fields. See Figure 3, 4 and 5 for their layout.

The images for each site were processed into a single mosaic, a digital surface model and vegetation indices with Pix4DMapper Pro 4.1 (Pix4D, Lausanne, Switzerland). Slope and surface elevation data were created with ArcGIS 10.4 (ESRI, Redlands, California). The image data was converted to polygon data, however, it was too detailed and a 2GB software limitation was reached in ArcGIS so the data was generalized into a 2m pixel in order to process the data. Yield point data were interpolated to the study area using the nearest neighbor algorithm in ArcGIS 10.4 (ESRI, Redlands, California).

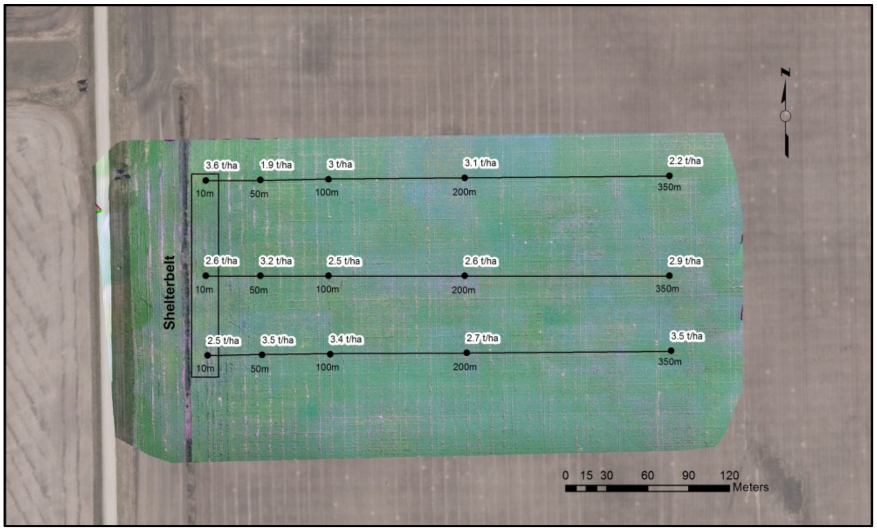


Figure 3. Site 4A. Planted Shelterbelt

Figure 4. Site 4B. Natural Shelterbelt

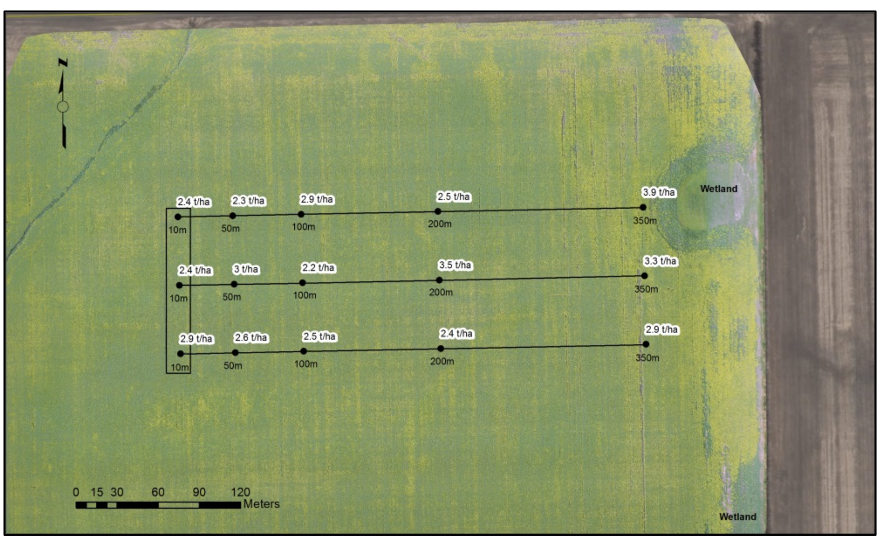


Figure 5. Site 4C. No Shelterbelt

A total of 16 vegetation indices plus slope, elevation and distance from natural vegetation (Table 1.) were checked for any correlation in R (R Core Team, 2018) with yield in order to determine the impact on yield of proximity to shelterbelts and wetlands. Pearson's correlation coefficient was used to measure correlation between the 20 variables.

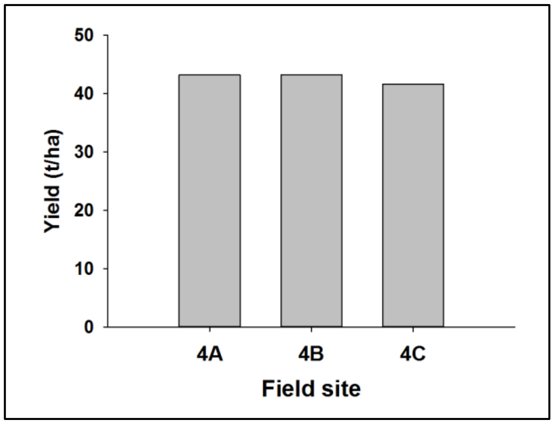
Results and Discussions

UAV data at sites 4A, B and C were collected at late flowering on July 26 and 27, 2017. The vegetation indices, slope, elevation and distance to natural vegetation were tested for correlation against yield (Table 1). No correlation between yield and any variables measured at site 4A was found. While at 4B, negative correlation between yield and BlueNDVI (r -0.80), NDVI (r -0.71), and NIR/Blue (r -0.81) and positive correlations between yield and Green/NDVI (r 0.73), and Green/NIR (r 0.76) were found. At 4B, additional negative correlations were also found between yield and Green/Blue (r -0.50), NDYI (r -0.52), and NIR/Red (r -0.63) and positive correlations between yield and Blue/green (r 0.53), and Red (r 0.60); however, the correlation coefficients were weaker than the vegetation indices mentioned before. At site 4C only distance to wetlands (r -0.78) and elevation (r 0.73) had any correlation with yield.

The results showed 4% increase in canola yield in the field boundary habitat sites (4A and 4B) compared to the site with no field boundary habitat (4C) (Figure 6). When plotted against the distance from the field boundary, site 4B showed a sharp decrease in yield after 10 m (Figure 7). No consistent pattern in yield was observed in site 4B between 50 to 350 m. At site 4A, crop yield remained the same along the distance from the field boundary habitat. At site 4C, yield remained the same until 200m after which there was a sharp increase at 350m which is adjacent to a wetland.

Table 1. r values of yield and metrics measured

	4A Yield	4B Yield	4C Yield
Yield	1.00	1.00	1.00
Blue/Green	-0.35	0.53	-0.40
BNDVI	0.31	-0.80	0.05
Elevation	-0.45	-0.07	0.73
EVI	0.26	-0.43	-0.36
Green/Blue	0.37	-0.50	0.41
Green	-0.08	0.34	0.45
Green/NDVI	-0.24	0.73	0.41
Green/NIR	-0.25	0.76	0.40
ModisEVI	-0.27	0.40	0.23
NDVI	0.24	-0.71	-0.39
NDYI	0.36	-0.52	0.40
NIR	0.27	-0.26	-0.12
NIR/Blue	0.36	-0.81	0.11
NIR/Red	0.27	-0.63	-0.40
Red Edge	-0.07	0.20	0.12
Red	-0.22	0.60	0.43
Slope	-0.19	0.16	0.40
Blue	-0.33	1.00	-0.20
Distance from Shelterbelt	-0.08	-0.20	N/A
Distance to Wetlands	N/A	0.17	-0.78



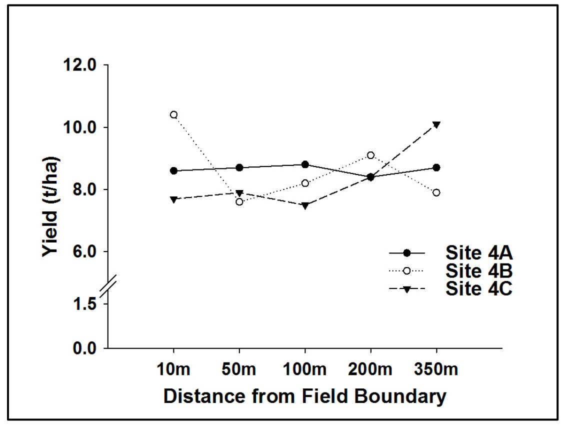


Figure 6. Total yield of sample plots at each site

Figure 7. Yield and distance from Shelterbelt

The vegetation indices examined here are inconsistent between sites and further analysis of these need to be completed. Basnyat et al. (2004) found that there is no single date consistently had high NDVI-yield correlation, however July 10 to Jul 30, which is generally the peak flowering, was the optimal range. Similarly, Behrens et al. (2006) found that NDVI steadily increased until flowering and then decreased due to radiation reflected by the flowers and overall found only weak correlations between canola growth characteristics and NDVI. NDVI is strongly related to chlorophyll absorption and is a commonly used spectral index to estimate in-season crop yield. Crops such as wheat and other cereals are typically green throughout their growing season and NDVI is a good index to measure in-season crop yield. However, canola has a distinctive yellow flowering stage (Figures 1 and 2) where green and red bands are reflected, causing the NDVI to be lower, and thereby lower yield estimates (Shen et al., 2009 and Behrens, et al., 2006). Other researchers have found alternatives to NDVI were better. For example, Shen at al.(2009) describe EVI was more sensitive to yellow flowers while Sulik and Long (2015), found that a band ratio of blue divided by green was strongly correlated ($r2 = 0.87$) to the number of yellow flowers, a proxy for yield. Sulik and Long (2016) found that variations in canola flower density affected NIR/Red and NDVI values suggesting that the stage of flowering is an important variable when considering when to collect images.

Conclusion or Summary

A variety of vegetation indices and landscape measurements were compared with canola yield and some correlation between yield and shelterbelts and wetlands were found. There is some indication that the areas closest to shelterbelts and wetlands have a higher yield, but that relationship is weak. Further analysis of the remaining sites, along with data to be collected in 2018, may find stronger correlations.

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