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## **Tree Counts from Satellite Imagery**

Tree Counts for Three Areas in the City of Regina

Prepared For:

City of Regina

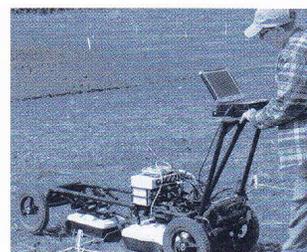
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## EXECUTIVE SUMMARY

The City of Regina asked WH Geomatics to count the trees in 3 areas in the City of Regina: Dewdney Tree Nursery, RCMP Training Ground, and the Tor Hill Golf Course. Two archival leaf-on 50 cm satellite images (June 2, 2019, and July 13, 2019) were ordered and a local maxima calculation was applied.

In order to understand how the local maxima method was performing, ground data was originally collected from the City of Saskatoon. The ground information revealed that his methodology worked best with coniferous trees and also that there was a weak correlation between the near infrared band and the number of deciduous trees.

Additional ground data from Dewdney Tree nursery revealed the filtering process was too aggressive in for these area. A filter size more appropriate for the tree nursery was selected and the counts were revised. Tree counts for the three areas are as follows: RCMP Training Grounds: 2592, Tor Hill 10,923 and Dewdney Tree Nursery: 9568.

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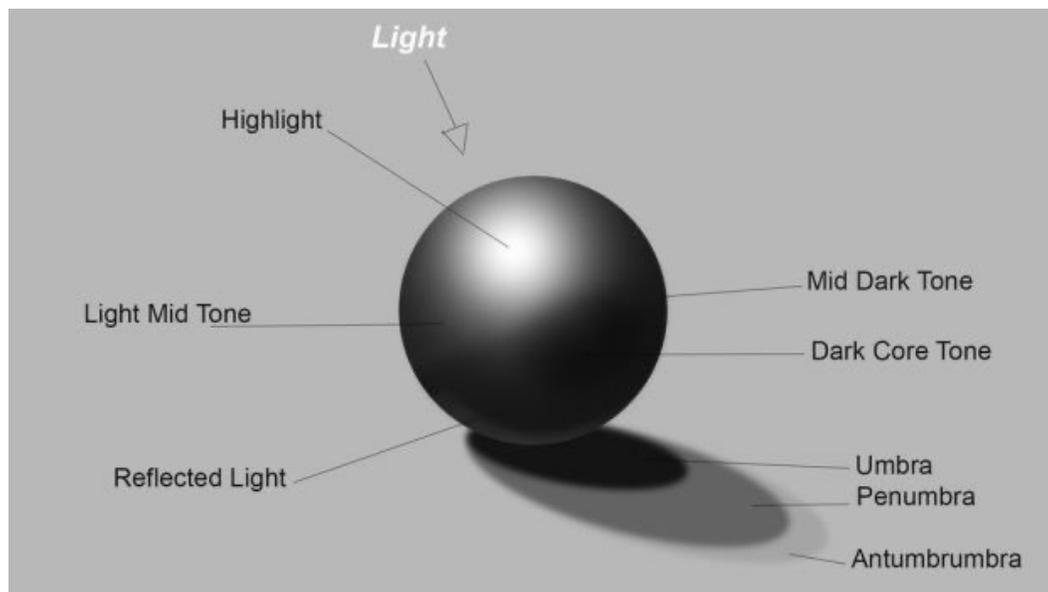


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## 1.0 BACKGROUND

Counting trees with high resolution satellite imagery at first glance seems straightforward. The pixel resolution of the imagery is sufficient to resolve individual trees, even very small ones. The trees can be counted by hand or through image classification techniques. However, not even in urban environments, are trees so obliging to keep their crowns separate for counting. In some neighbourhoods tree crowns are so expansive that they occlude even the road running between them. They appear to the satellite as one green mass.

In order to count these trees Western Heritage borrowed a technique from surface modelling used to calculate the local maximum. This calculation returns the highest point in the local area of pixels. When this calculation is used on satellite imagery, it is returning the brightest pixel in the local area rather than the highest elevation point but. Figure one illustrates why the brightest local pixel is significant using this art tutorial by Deviant Art user Phoenix-Fire-Soul.



*Figure 1: Lighting a sphere*

The area direct under the light source has the brightest reflection as the local incident angle is smallest here. As the local incident angle becomes larger the lighting becomes more

diffuse and the reflected light is not as bright. A local maxima calculation on the idealized object will return a point on the brightest part of the sphere. Trees are of course not sphere and they won't have one local maxima but many. Our methodology was mostly concerned with eliminating those spurious local maxima.

## 2.0 METHODS

### 2.1 Filter

The local maxima calculation is best suited for simpler objects, recall it is designed to work with elevation data. A tree can be made up of hundreds of pixels that add noise to our analysis. To smooth out the image a modal filter was used. This filter replaces all pixel values within a moving window with the most frequently occurring value. This filter is passed over the image twice.

The image was subjected to one more filter before the local maxima calculation. The remote sensing software used by Western Heritage has a "Fill Depressions" filter as part of its' Watershed Analysis. This filter removes small and spurious under or overestimations in a elevation model and in this case it further smooths out the image.

### 2.2 Classification

The local maxima calculation only needs only to be done on the trees and no other landcover type. To eliminate other landcover types the image was quickly classified into trees, grass, built up areas, and water. The tree class was separated out and used as a mask for the local maxima calculation.

### 2.3 Point thinning

The local maxima calculation still returned too many spurious points even with the filtering. These points are too close to one another to represent separate trees. To eliminate these too close points, buffers were applied. Each point was buffered and if the buffers touched the two points were collapsed into one point. This was a computational intensive task but, that methodology was successful in eliminating the majority of the spurious points. However, we believed our methodology was over estimating the trees.

### 2.4 Initial Ground Data

Due to the COVID-19 pandemic it became very difficult to travel to collect ground data. Western Heritage had archival images for Saskatoon and since the goal was to find out how the methods could be improved, ground data from Saskatoon was used.

Saskatoon is further north than Regina but urban trees are quite similar. Tree counts were collected from three different areas in Saskatoon. Unfortunately none of the area included tree farms as the Saskatoon city's farm is not open to the public. Stands identified on the image were located and the number of trees within them were counted.

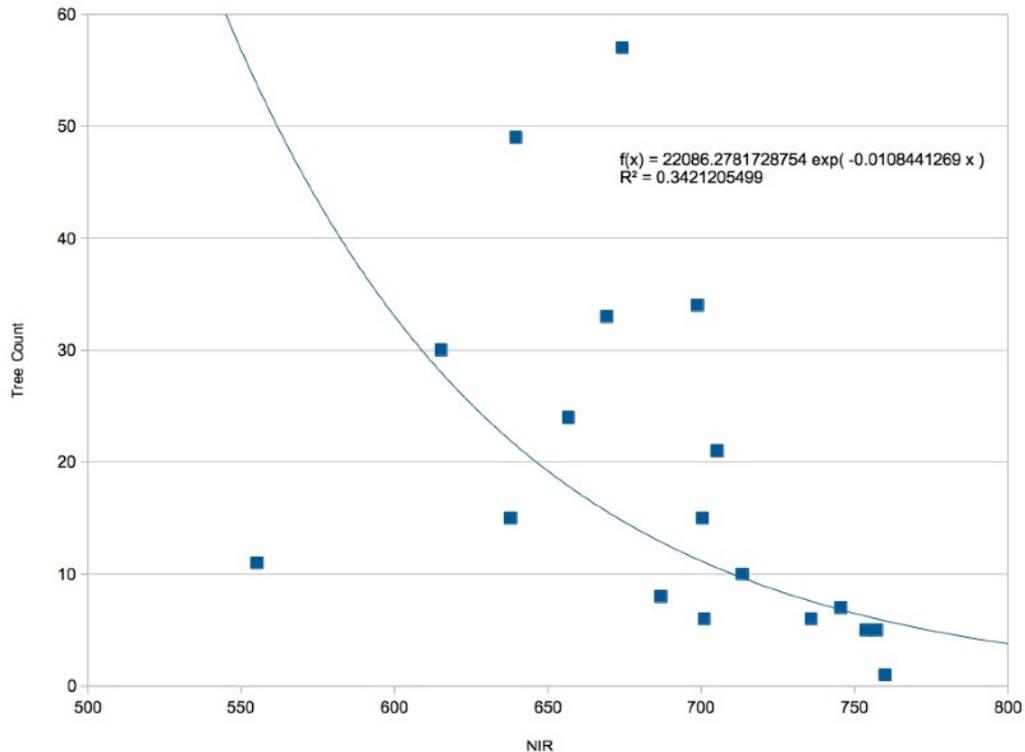


*Figure 2: Ground data Sampling Plots from the City of Saskatoon*

### **3.0 INITIAL ANALYSIS**

Applying the methodology to the Saskatoon imagery demonstrated that our methodology produced good estimates for coniferous trees. However, the method overestimated the counts for deciduous trees, by an average of three times.

The next question was whether there was a way to more accurately count the number of deciduous trees in the stand using either texture or tone. Tree counts were compared to different bands and texture. There were some weak correlations but only one was significant. That was the NIR band.



*Figure 3: Weak correlation between NIR and Deciduous tree counts*

The correlation is likely weak as the samples were chosen with no regard for age, tree species or environment. A possible explanation for the difference in NIR is that in stands where counts are higher the trees are smaller. This sample is not powered to make that determination. Using this observation we split the Deciduous trees into two broad classes: high and low NIR. The higher NIR areas were assumed to contain less trees and were filtered more heavily. This new knowledge was applied to the Regina areas to create the initial tree counts.

#### 4.0 INITIAL REGINA TREE COUNT

The three areas were given names from the prominent areas or landmarks found within. These were the Dewdney Tree Nursery, RCMP Training Ground, and the Tor Hill Golf Course. The final counts are as follows:

*Table 1: Initial Tree Count*

Area	Count
Dewdney Tree Nursery	9568
RCMP Training Ground	2592
Tor Hill Golf Course	10,923

## 5.0 DISCUSSION

The local maxima filter method that we used here appears to best suited for coniferous trees. This method overestimated the number of deciduous trees by several times. It would be worth exploring other methods that would be better suited for deciduous trees. Object-orientated analysis is extremely promising but beyond Western Heritage's capabilities at the time.

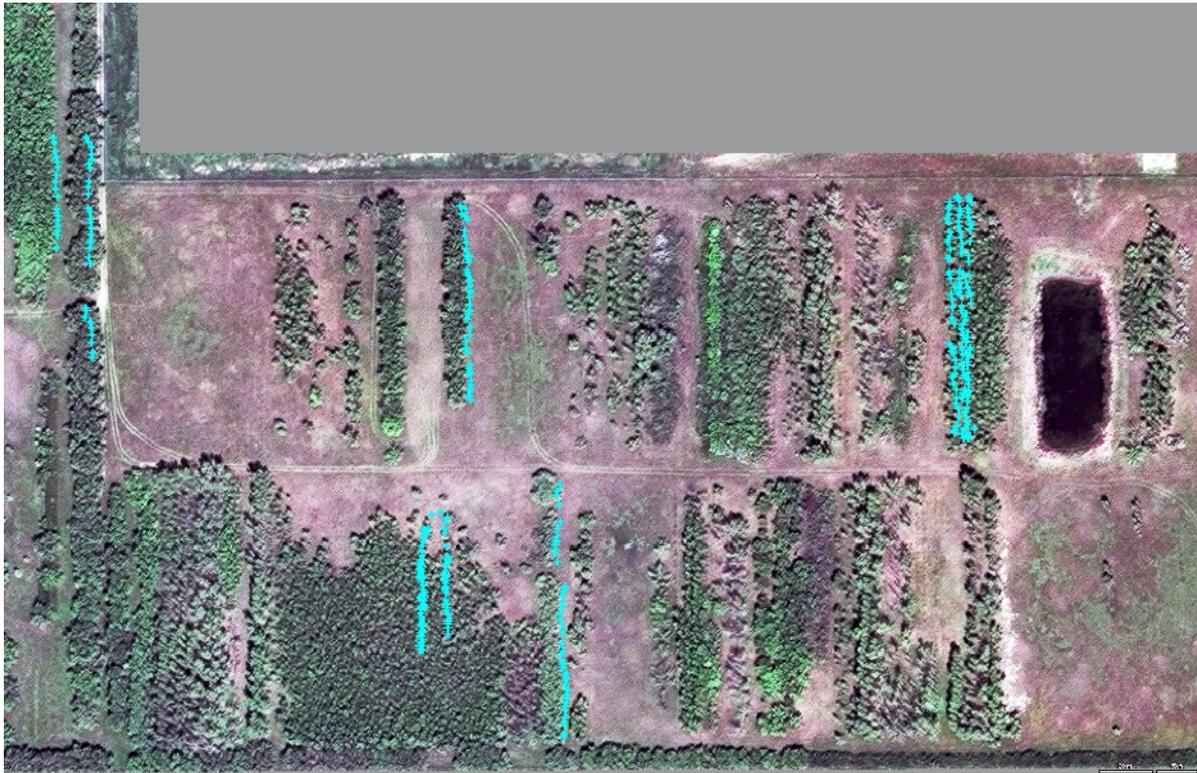
The most uncertain area is the Dewdney Tree Nursery. Much of the woody vegetation looked very short and it is quite possible that woody shrubs are being mixed in with the trees. If high accuracy digital surface models were available shrubs could be quickly eliminated from the tree counts. Also a digital terrain model would greatly improve the count. The local maxima calculation is designed to work with elevation data not imagery.

Exact numbers on how successful the local maxima analysis was are unavailable due to the lack of ground information. Sampling these three areas would give us a greater understanding of the accuracy and perhaps more knowledge on how to improve our methods.

## 6.0 DEWDNEY TREE NURSERY SAMPLING

After reviewing the initial draft of this report was submitted, the City of Regina thought there was value in improving our methodology by collecting some ground data. Western Heritage received ground information in the form of tagged trees and videos.

The Dewdney Tree Nursery had been closed for a number of years and as a consequence the trees are overgrown. One stand was so tight the ground crew could not even enter and the points were all acquired along the edge. The ground data made reference to rows however due to the tight packing it is unclear from imagery where one row ended and another began.



*Figure 4 : Dewdney Tree Nursery and location of ground data points*

As the tree stands were counted for the edge, some judgement was used in comparing the ground counts to the count extracted from Satellite Imagery. The results are tabulated below.

*Table 2 : A comparison of ground count and satellite counts*

<b>Rows</b>	<b>Ground Count</b>	<b>Satellite Estimates</b>	<b>Error</b>
<b>Elm Row 1</b>	21	47	124%
<b>Elm Row 2</b>	17	29	71%
<b>Elm Row 3</b>	10	18	80%
<b>Elm Row 4</b>	43	45	5%
<b>Ash Row 1</b>	123	123	0%
<b>Ash Row 2</b>	82	54	-34%
<b>Willow</b>	42	60	43%
		Average Error	41%

*Table 3 Revised Tree Counts*

Area	Initial Count	Final Count
Dewdney Tree Nursery	3069	9568
RCMP Training Ground	2592	2592
Tor Hill Golf Course	10,923	10923

## 7.0 SUMMARY DISCUSSION

The comparison of the ground counts and the satellite image analysis suggest that the methodology is still over counting trees, however, the error has been reduced. With the ground information that was provided Western Heritage is more confident in the estimations for the Dewdney Tree Nursery.

There are a couple of avenue that could be explored to improve the methodology. One approach that is unlikely to help is improved resolution. The trees are so tightly packed that imagery with higher spatial resolutions is more likely to add more noise to the analysis.

Digital surface models would greatly aid the tree count. DSM's are a 3D model of objects such as trees and buildings. The 3D model would help in determining where the local maxima truly lies as opposed to inferring that information from the image.

Another route that other researchers have used is object orientated analysis. An image is segmented to object and subsequent analysis is performed on the objects instead of individual pixel. This greatly reduces the noise and it also for shape, proximity, texture variables to enter the analysis.