Williston Drainage DTM Comparisons

March 10, 2021

Abstract

This report summarizes several digital terrain models (DTM) comparisons made within the Williston Drainage, British Columbia. For the first comparison, both the TRIM and CDED DTM are compared to ICESat-2 LiDAR observations within the Williston Drainage. The bias between these two data products is summarized, and the differences are plotted with respect to first order terrain derivatives slope as well as aspect. For the second comparison, a random forest model is used to predict the 10-category riparian areas and wetlands using the *wetlandmapR* R package and training points from the Ecological Reports Catalogue Predictive Wetland Mapping of the Williston Drainage. The model is fit on terrain derivatives from both an ensemble DTM (eDTM) and TRIM, model results and maps are compared between datasets.

Chapter 2

ICESat-2 DTM Comparisons in Williston Drainage

LiDAR observation of the surface elevation derived from ICESat-2 throughout the Williston Drainage were compared to both the TRIM and CDED DTM models at a resolution of 25 meters. Bias present in both of the DTMs was summarized, and residuals were plotted by first order terrain derivatives including slope and aspects to reveal any systematic trends in the errors related to the DTMs themselves.

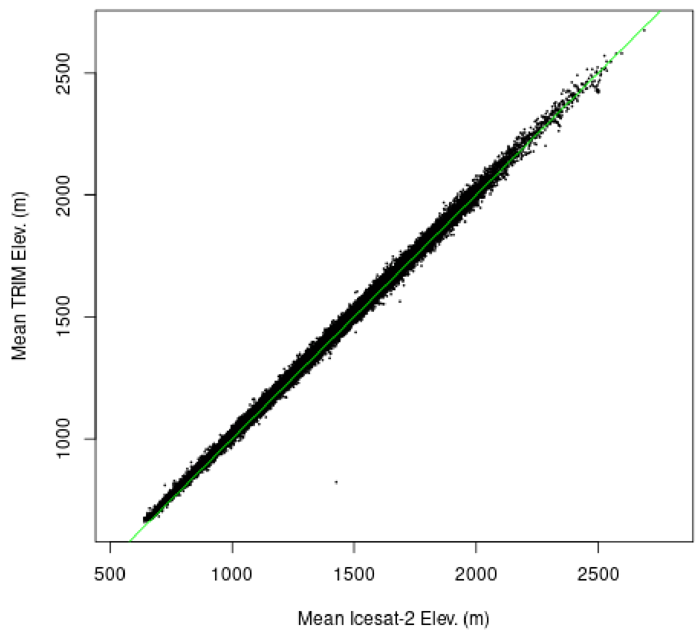
2.1 TRIM vs. ICESat-2

In this section the difference between ICESat-2 and TRIM surface elevations within the Williston Drainage is summarized. Both the ICESat-2 LiDAR observations and TRIM DTM were intersected with the Williston Drainage defining the area of interest. The TRIM DTM was resampled to BC Albers using cubic resampling at 25 meter resolution via gdalwarp. Slope and aspect were computed using the *raster* package in R and 8 neighbouring cells. After resampling the TRIM DTM was intersected with the ICESat-2 points using the *raster* package in R. The TRIM elevation data is plotted against the mean ICESat-2 surface elvation in Figure 2.1(a). Quantiles for the distribution defined by the ICESat-2 elevations minus the TRIM elevations are summarized in Table 2.1.

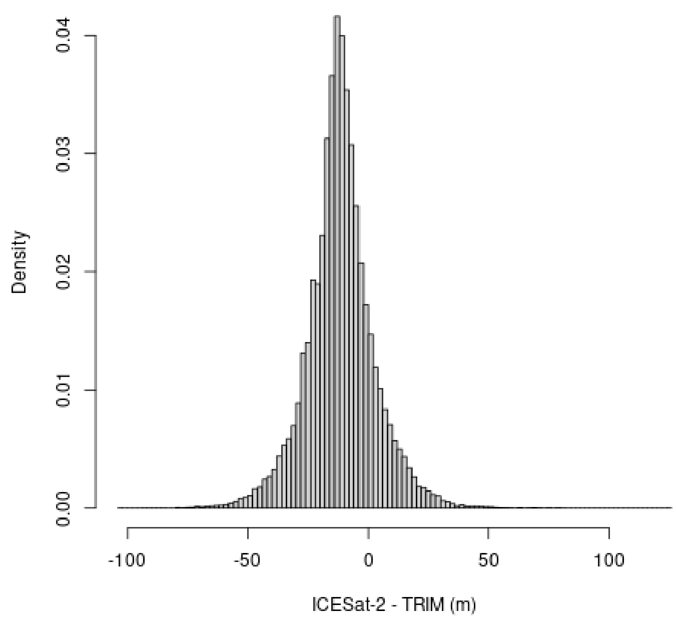
0%	25%	50%	75%	100%
-102.5	-19.0	-11.8	-4.3	604.5

Table 2.1: ICESat-2 - TRIM Elevation Quantiles

A median bias of -11.8 m was found for TRIM. Notice that one point has an exceptionally large discrepancy of 604 meters. The ICESat-2 elevation for the point at 1145953 E, 1233352 N is 1462.1±27.5 m where the intersected TRIM elevation is 821.7 m. The cause of this large outlier is not clear.



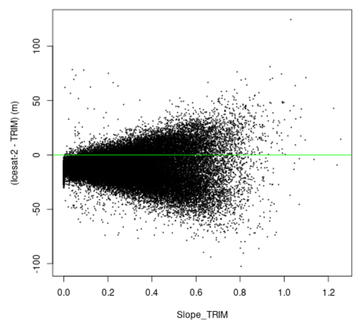
(a) TRIM surface elevation plotted against the mean ICESat-2 surface elevation for points within the Williston Drainage.



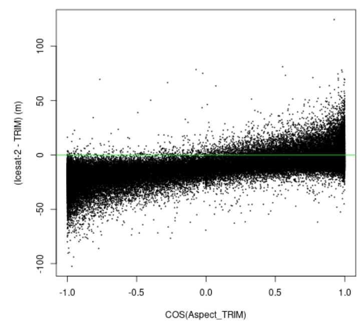
(b) Histogram of ICESat-2 minus TRIM surface elevation for points within Williston Drainage (Excluding outlier).

Figure 2.1: ICESat-2 vs. TRIM Surface Elevation

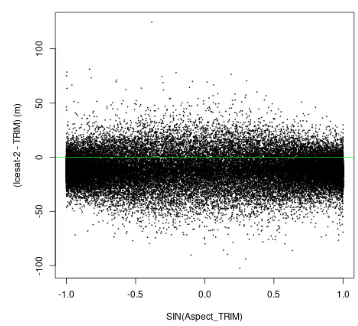
The difference between ICESat-2 and TRIM is plotted against TRIM derivatives slope, northness (cos(aspect)) and eastness (sin(aspect)) in Figure 2.2.



(a) Difference between ICESat-2 and TRIM as a function of TRIM slope.



(b) Difference between ICESat-2 and TRIM as a function of TRIM northness.



(c) Difference between ICESat-2 and TRIM as a function of TRIM eastness.

Figure 2.2: Diffrence between ICESat-2 and TRIM and TRIM first order derivatives.

Figure 2.2(a) shows that there is a increase in the absolute value in the TRIM errors at higher slopes. There is a linear relationship between the TRIM errors and northness (Fig. 2.2(b)). TRIM over estimates elevation on southerly aspects and underestimates elevation on northerly aspects. However, there appears to be slight overestimation occurring even at neutral north-south aspects. No obvious relationship between TRIM errors and eastness is visible.

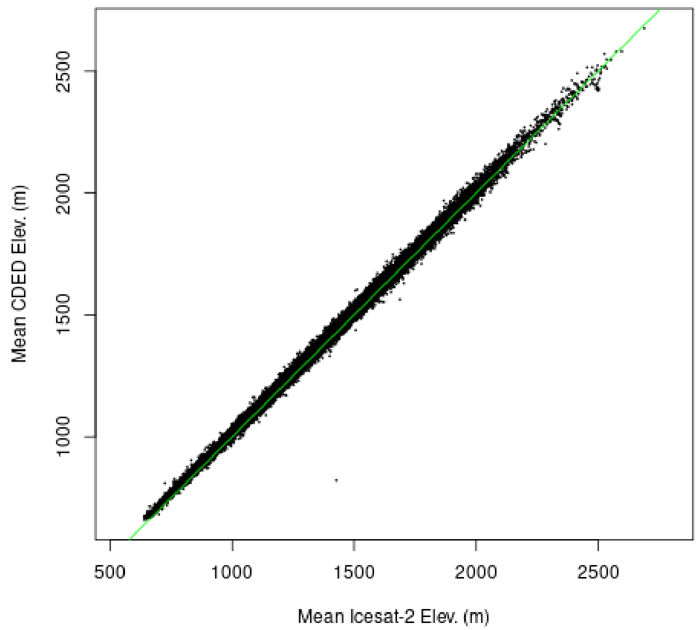
2.2 CDED vs. ICESat-2

The difference between ICESat-2 and CDED surface elevations within the Williston Drainage were determined using the same workflow outlined in Section 2.1. The CDED elevation data is plotted against the mean ICESat-2 surface elevation in Figure 2.3(a). Quantiles for the distribution defined by the ICESat-2 elevations minus the CDED elevations are summarized in Table 2.2.

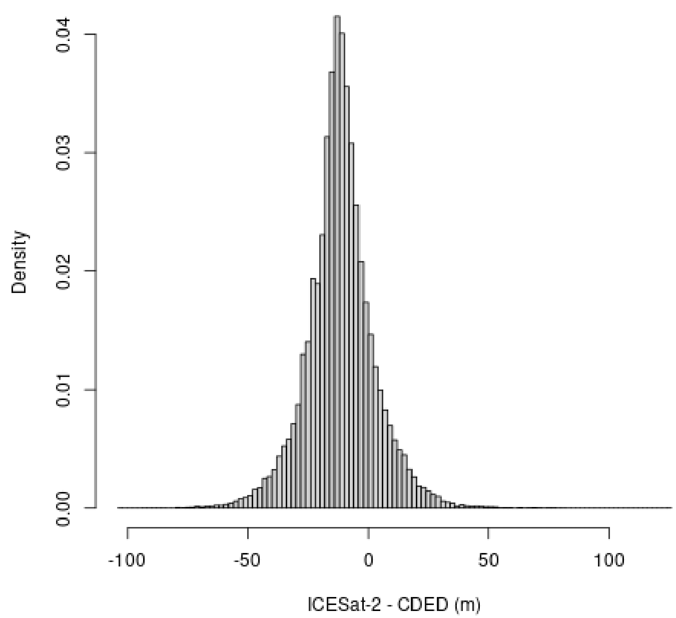
0%	25%	50%	75%	100%
-102.5	-19.0	-11.8	-4.3	604.7

Table 2.2: ICESat-2 - CDED Elevation Quantiles

A median bias of -11.8 m was found for CDED as well. The single large discrepancy is also present in the CDED DTM.

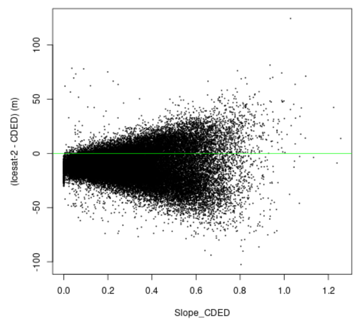


(a) CDED surface elevation plotted against the mean ICESat-2 surface elevation for points within the Williston Drainage.

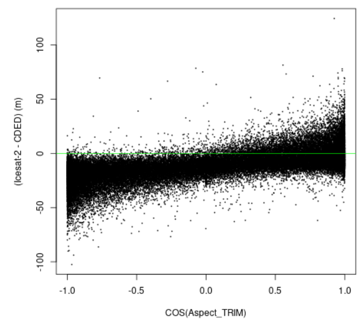


(b) Histogram of ICESat-2 minus CDED surface elevation for points within Williston Drainage (Excluding outlier).

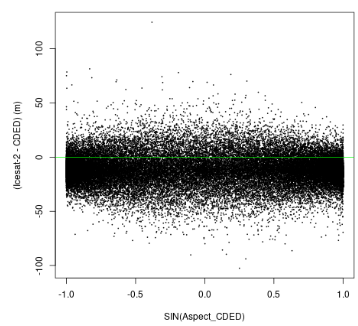
Figure 2.3: ICESat-2 vs. CDED Surface Elevation



(a) Difference between ICESat-2 and CDED as a function of CDED slope.



(b) Difference between ICESat-2 and CDED as a function of CDED northness.



(c) Difference between ICESat-2 and CDED as a function of CDED eastness.

Figure 2.4: Diffrence between ICESat-2 and CDED and CDED first order derivatives.

Chapter 3

wetlandmapR DTM Comparison Results

To explore the influence of the DTM on the prediction quality of a random forest model, both the TRIM and eDTM where used as inputs to the *wetlandmapR* R package. The area on interest was again defined by the Williston Drainage, and training points from the Ecological Reports Catalogue Predictive Wetland Mapping archive where used to predict the 10-category riparian areas and wetlands. A random subset of points was selected to balance the wetland classes, dictated by the class with the fewest observations. While in prior runs of the *wetlandmapR* package in the Williston other inputs such as Sentinel-2 optical imagery are incorporated into the prediction, for this comparison only the DTMs and their first and second order derivatives where used for predicting the riparian categories. This choice was made because this exercise focuses on the influence of DTM choice on the random forest prediction results.
The TRIM and eDTM datasets were first resampled to NAD83(CSRS) / BC Albers at 25 meter resolution using *gdalwarp* using the cubic resampling method, and clipped to the Williston Drainage. From these layers, first and second order terrain derivatives where computed using *wetlandmapR::create dem products*. For aspect, only the cos(aspect) and sin(aspect) where used at inputs into the models. All of the derivative layers were stacked using the *wetlandmapR::stack rasters* function. The training points where attributed with the raster stack values using the *wetlandmapR::grid values at sp*. A random forest classifier was fit to the training data using *wetlandmapR::wetland model*. The input layer representing the binary presence of sinks was input as a factor input. Finally model diagnostics and maps where produced using *wetlandmapR::wetland map*. These results are summarized below.

3.1 Out-of-bag error rate and *ntree*

Shown in Figure 3.1 and 3.2 is the out-of-bag (OOB) error rate as a function of the number of random decision trees 'ntree' for both the TRIM and eDTM based random forest models.

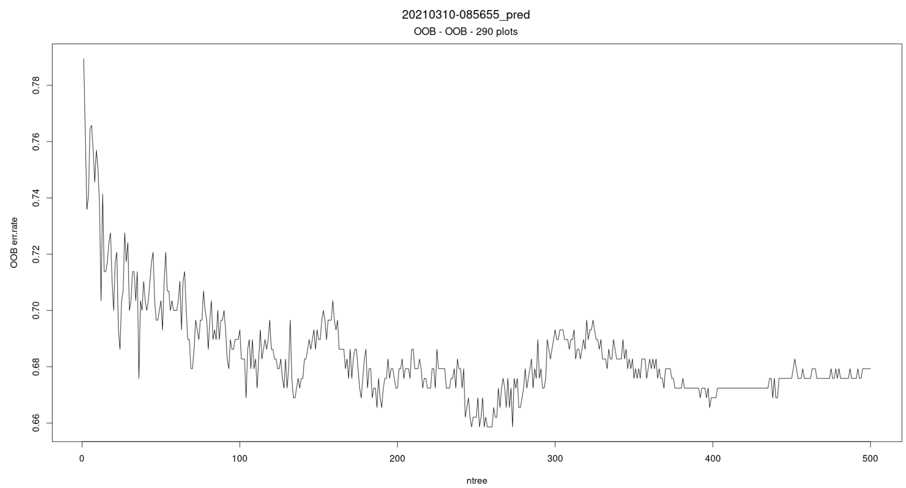


Figure 3.1: Out-of-bag (OOB) error rate as a function of the total number of random decision trees 'ntree' for TRIM.

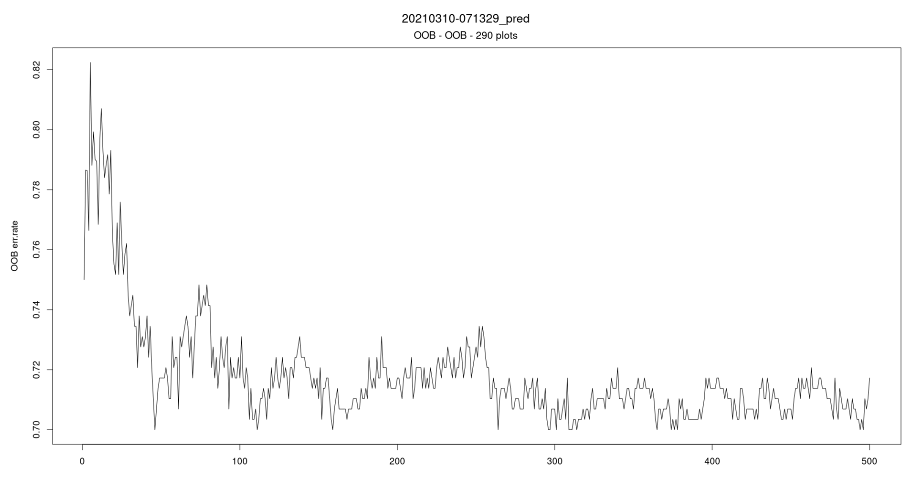


Figure 3.2: Out-of-bag (OOB) error rate as a function of the total number of random decision trees 'ntree' for eDTM.

From this plot it is evident that $ntree = 500$ (the default) is an adequate value for *ntree* as the OOB error has stabilized for both the TRIM and eDTM

DTMs. At $ntree = 500$, the OOB error rate appears lower for TRIM (0.68) the for the eDTM (0.71).

3.2 Correlation plots

The correlations among DTM derivative input variables are illustrated in Figure 3.3 for TRIM and 3.4 for the eDTM.

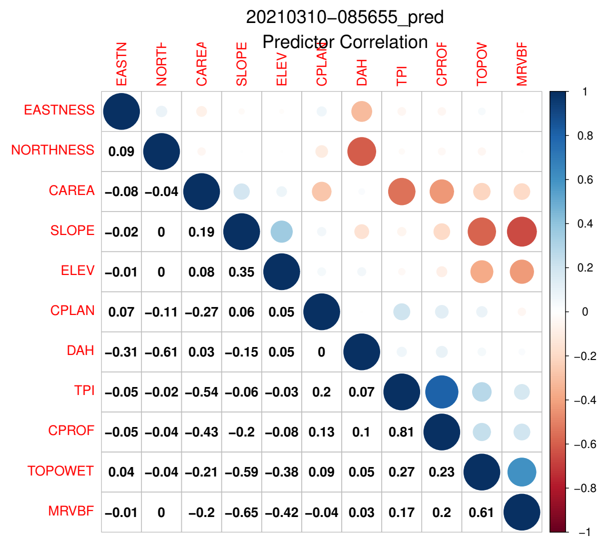


Figure 3.3: Correlation plot among input TRIM derivatives.

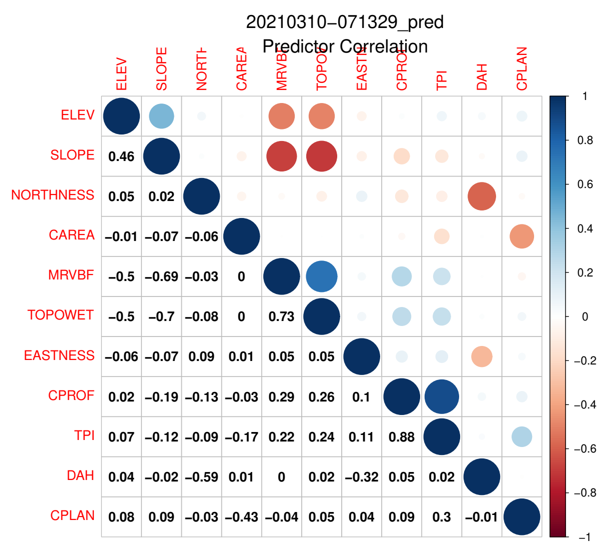


Figure 3.4: Correlation plot among input eDTM derivatives.

It appears there are relativity strong correlation among some of the input variables (DTM derivatives), both positive and negative. This suggest that some improvement in predictive performance could be obtained through decomposition (principle component analysis), which would remove any issues of multicollinearity between inputs, but may make variable importance more difficult to interpret. Interestingly, some of the correlations among input variables are not consistent between the eDTM and TRIM. For instance while the correlation between slope and topographic wetness are similar between DTMs, the correlation between the topographic position index and MDF flow accumulation is strongly negative for TRIM ($\rho = -.54$), and is only moderately negatively correlated when derived from the eDTM ($\rho = -.17$).

3.3 Model accuracy

The riparian category integer keys are defined in Table 3.1, they are the same for TRIM and the eDTM.

Category Code	Description
1	(Fh) High-bench Floodplain
2	(Fl) Low-bench Floodplain
3	(Fm) Mid-bench Floodplain
4	Upland
5	Water
6	(Wb) Bog
7	(Wf) Fen
8	(Wm) Marsh
9	(Ws) Swamp
10	(Ww) Shallow Water Wetland

Table 3.1: Riparian category key code.

The TRIM contingency matrix is outlined in Table 3.2, and the eDTM contingency matrix is shown in Table 3.3.

Category	1	10	2	3	4	5	6	7	8	9	**total**	**Commission**
1	10	0	2	11	2	0	5	3	1	3	37	0.73
10	2	14	3	1	0	1	2	4	6	1	34	0.59
2	1	2	12	5	2	1	3	1	2	2	31	0.61
3	9	0	4	2	0	1	2	2	2	2	24	0.92
4	1	1	1	3	17	0	4	5	1	6	39	0.56
5	0	3	1	0	0	14	0	0	0	2	20	0.30
6	2	2	1	1	1	1	6	2	4	2	22	0.73
7	0	1	1	0	1	3	2	7	2	3	20	0.65
8	1	5	1	3	0	3	2	3	6	3	27	0.78
9	3	1	3	3	6	5	3	2	5	5	36	0.86
total	29	29	29	29	29	29	29	29	29	29	290	**PCC**
Omission	0.66	0.52	0.59	0.93	0.41	0.52	0.79	0.76	0.79	0.83	**PCC**	0.32

Table 3.2: TRIM contingency matrix.

Category	1	10	2	3	4	5	6	7	8	9	**total**	**Commission**
1	5	3	2	7	0	3	0	2	2	4	28	0.82
10	0	10	3	2	0	0	2	5	2	0	24	0.58
2	1	5	12	5	1	4	4	2	2	3	39	0.69
3	9	1	4	4	2	1	5	2	0	3	31	0.87
4	2	1	1	1	18	0	2	3	0	8	36	0.50
5	2	1	1	1	0	11	4	2	3	0	25	0.56
6	4	2	3	5	0	5	1	4	2	3	29	0.97
7	2	3	0	1	3	1	4	4	2	0	20	0.80
8	3	2	0	2	4	3	3	4	14	5	40	0.65
9	1	1	3	1	1	1	4	1	2	3	18	0.83
total	29	29	29	29	29	29	29	29	29	29	290	**PCC**
Omission	0.83	0.66	0.59	0.86	0.38	0.62	0.97	0.86	0.52	0.90	**PCC**	0.28

Table 3.3: eDTM contingency matrix.

When based solely on the DTMs the random forest models appears to be mediocre at predicting the riparian categories with a percent correctly classified of 32%, and $\kappa = 0.25$ for TRIM, and 28% and $\kappa = 0.20$ for the eDTM. For TRIM, the category 4 riparian areas appear to have the lowest rate of omission, while category 5 riparian areas have the lowest commission errors. Category 3 riparian areas appear to have the highest rate of omission and commission errors, often being predicted at category 1 riparian areas. For the eDTM the category 4 riparian areas also have the lowest rate of omission, but also the lowest commission rate, followed by category 5 riparian areas. However category 6 riparian areas have the highest omissions and commission error rates for the eDTM. The results suggest that the choice of DTM does influence the classification accuracy manifesting primarily as differences in the individual riparian category performances, and less so the overall accuracy. Therefore, one could choose a DTM based on the desire to maximize classification accuracy for a given category, at the expense of accuracy in another category. For instance if one was most intersected in predicting bogs accurately the TRIM DTM would be the best choice, however if mid-bench flood-planes where the primary interest, one would most likely choose the eDTM.

3.4 Variable importance

The overall variable importance plots captured by the mean decrease in accuracy (MDA) and mean decrease Gini index (MDG) for random forest models derived from both TRIM and the eDTM derivatives inputs are found in Figures 3.5 and 3.6.

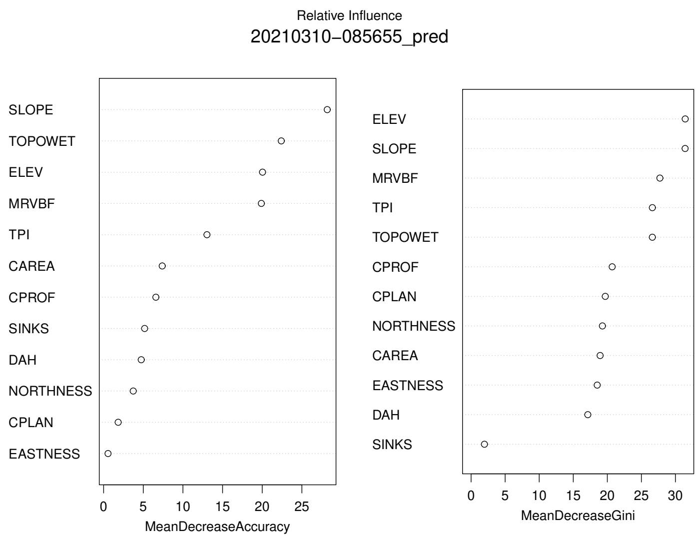


Figure 3.5: Random forest importance metrics for TRIM derivatives.

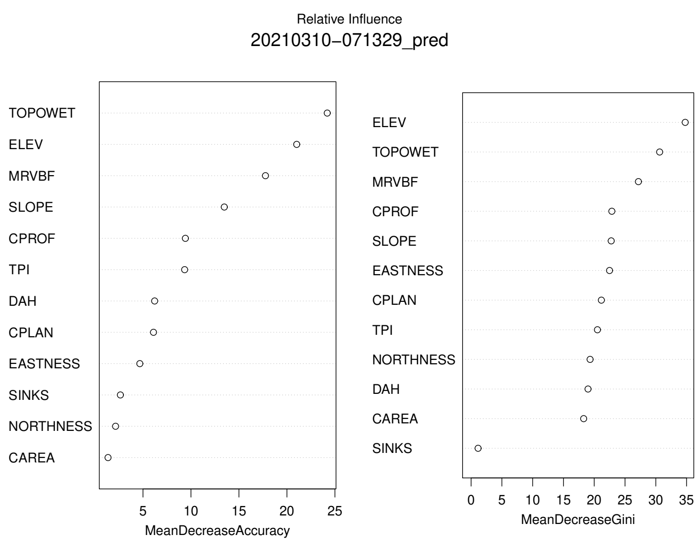
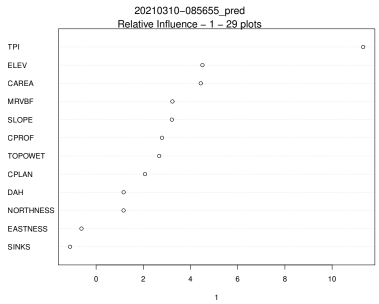


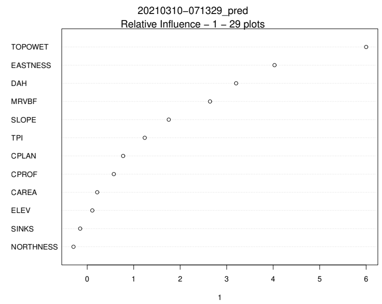
Figure 3.6: Random forest importance metrics for eDTM derivatives.

Looking at differences in variable importance for the TRIM and eDTM DTMs, there appears to be some level of agreement, but not perfect agreement. For TRIM slope is found to be the most import input with respect MDA, and elevation with respect to MDG. While when derived from the eDTM, slope is the 4^{th} most important variable with respect to MDA, however, there is agreement with respect ot MDG. Looking at variables of least importance, for TRIM eastness was deemed least important with respect to MDA, while MFD flow accumulation was found least import for eDTM. There was agreement with respect to MDG, sinks, a factor variable, was found least import for both TRIM and the eDTM.

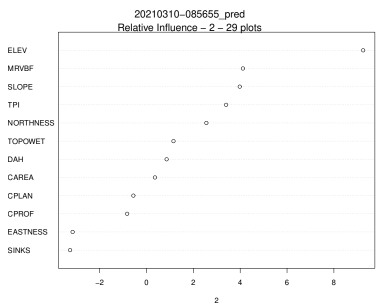
Variable importance by riparian category is summarized in Figures 3.7–3.10 for both TRIM and eDTM derived random forest classification models.



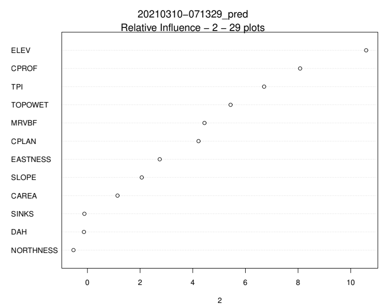
(a) TRIM category 1 variable importance.



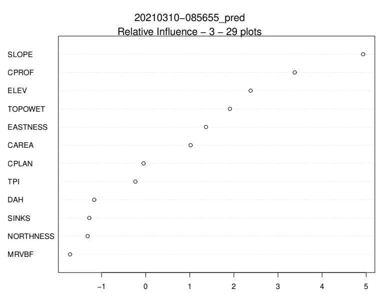
(b) eDTM category 1 variable importance.



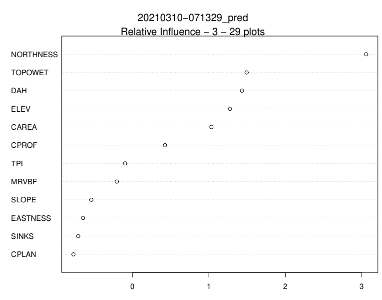
(c) TRIM category 2 variable importance.



(d) eDTM category 2 variable importance.

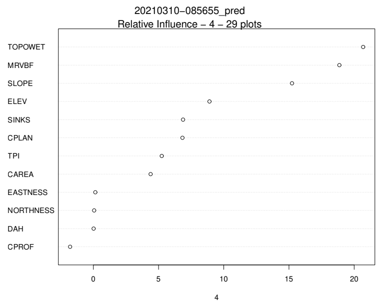


(e) TRIM category 3 variable importance.

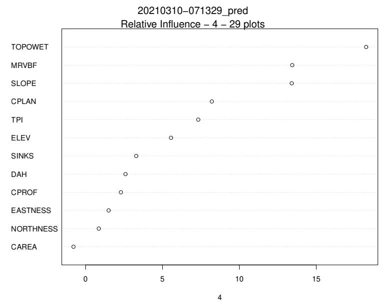


(f) eDTM category 3 variable importance.

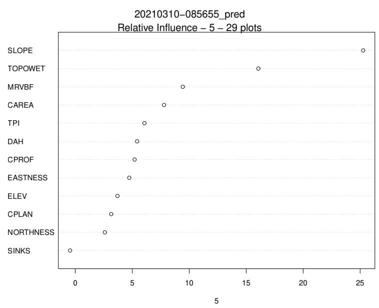
Figure 3.7: Random forest variable importance for riparian categories 1–3 derived from both TRIM and eDTM.



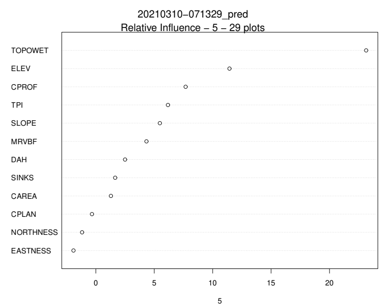
(a) TRIM category 4 variable importance.



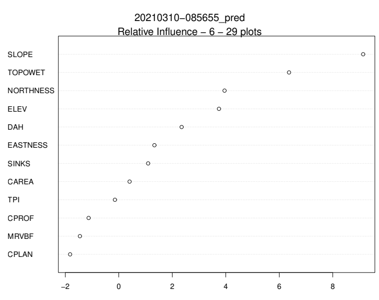
(b) eDTM category 4 variable importance.



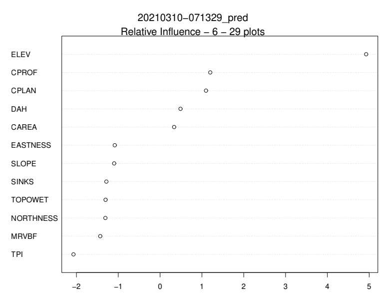
(c) TRIM category 5 variable importance.



(d) eDTM category 5 variable importance.

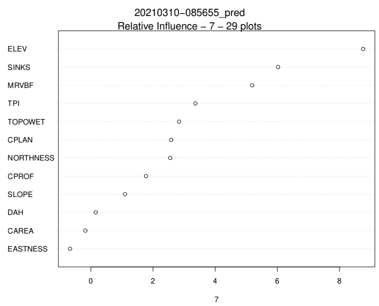


(e) TRIM category 6 variable importance.

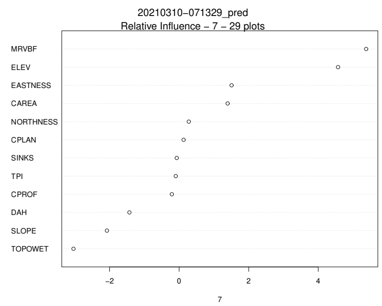


(f) eDTM category 6 variable importance.

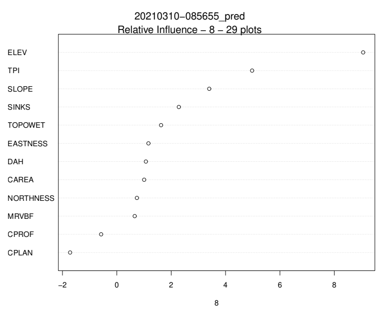
Figure 3.8: Random forest variable importance for riparian categories 4–6 derived from both TRIM and eDTM.



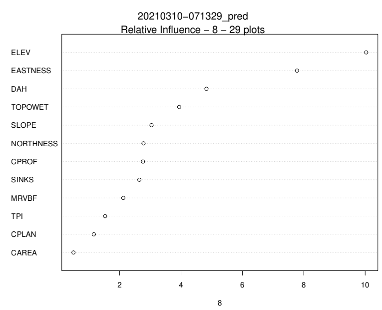
(a) TRIM category 7 variable importance.



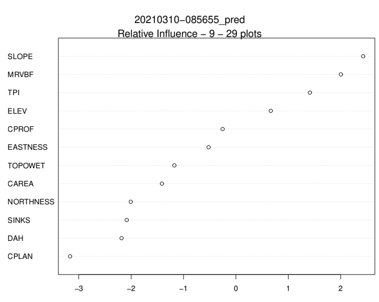
(b) eDTM category 7 variable importance.



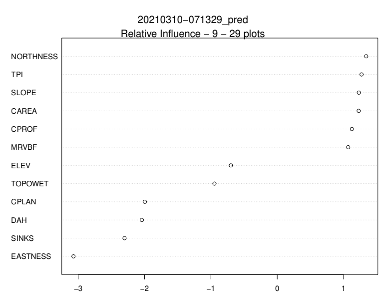
(c) TRIM category 8 variable importance.



(d) eDTM category 8 variable importance.

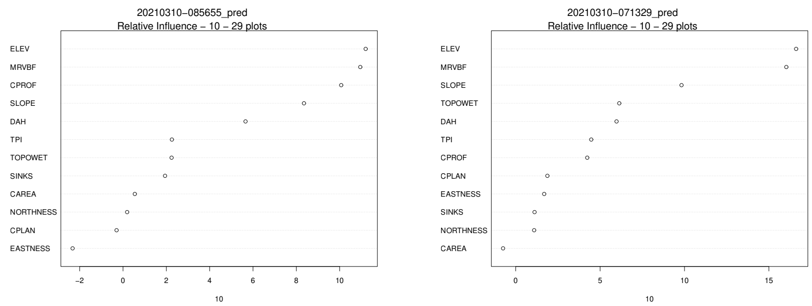


(e) TRIM category 9 variable importance.



(f) eDTM category 9 variable importance.

Figure 3.9: Random forest variable importance for riparian categories 7–9 derived from both TRIM and eDTM.



(a) TRIM category 10 variable importance.

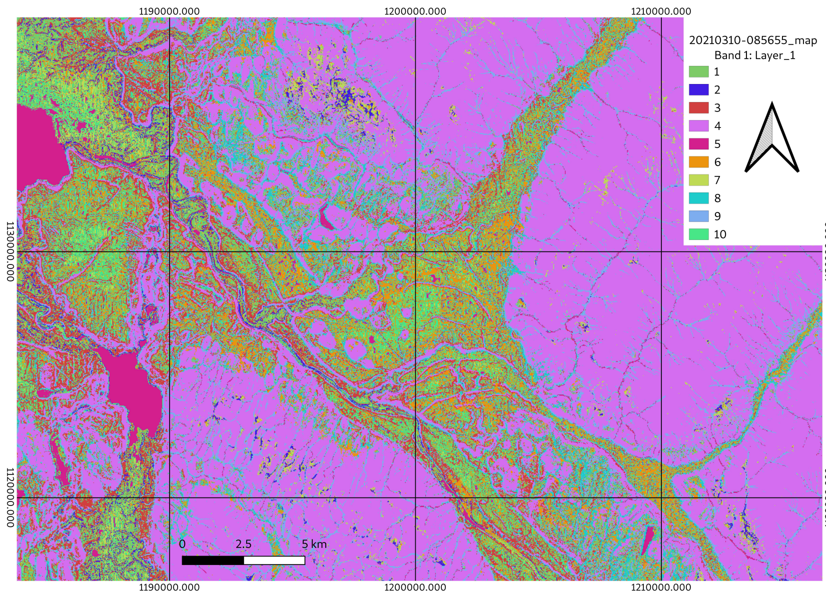
(b) eDTM category 10 variable importance.

Figure 3.10: Random forest variable importance for riparian categorie 10 derived from both TRIM and eDTM.

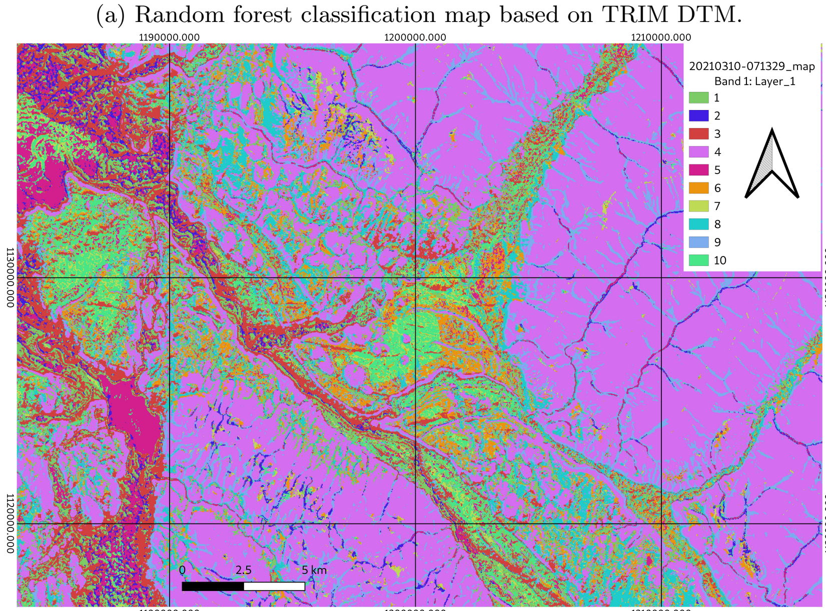
Similar to overall variable importance, when comparing random forest variable importance by riparian category, there is both some degree of agreement and disagreement between TRIM and the eDTM, depending on the category.

3.5 Map comparisons

The final random forest classification maps are illustrated in Figure 3.11 for a subsection of the Williston Drainage to help visualize the subtle differences in the classification results.



(a) Random forest classification map based on TRIM DTM.



(b) Random forest classification map based on eDTM DTM.

Figure 3.11: Random forest classification maps.

A visual inspection does reveal qualitative differences in the classification results derived from TRIM versus the eDTM. Generally, the discrepancies between the two DTM classification results appear to occur mostly for the wetland categories, and tend to agree for the lakes and upland categories, this was also evident in the contingency matrices. The TRIM classification appears more 'noisy' where the eDTM classifications appear to be spatially broader and more contiguous.

Chapter 4

Concluding remarks

This exercise has revealed some important differences between the TRIM, CDED and eDTM DTMs with regard to their specific inaccuracies and influence on identifying riparian areas in the Williston Drainage. Comparing TRIM and CDED to the ICESat-2 LiDAR points revealed that confined to the Williston Drainage there is positive median bias of 11.8 meters for both TRIM and CDED. This exercise also confirmed there are no substantial differences between TRIM and CDED DTMs within the Williston. Positive relationships between the TRIM and CDED differences with ICESat-2 where identified with the cos(aspect) (northness). An increase in the magnitude of the ICESat-2-TRIM difference was also observed. Relationships between ICESat-2 errors and second derivatives where not explored, but may also be present.

There appears to be important implications regarding the random forest classification results and the choice of DTM in the Williston Draniage. It was found that not all of the correlations among DTM derivatives input variables are consistent between the TRIM and eDTM DTMs, with important implications for the classifications results. Overall random forest model accuracy was found to be higher ($PCC = 32\%, \kappa = 0.25$) for TRIM than the eDTM ($PCC = 28\%, \kappa = 0.20$), but not substantially. More importantly, the contingency matrices revealed that the primary difference in accuracy was with respect to which categories performed well, and which categories were classified poorly. Therefore, the desire to maximize accuracy in a specific riparian category might guide the choice of DTM, TRIM or the eDTM. What input variables where deemed most and least important based on the mean decrease in accuracy and the mean decrease in the Gini index where also found to be dependent on the choice of DTM. While there was agreement for the importance of some variable, such as elevation, this was not true for all input variables (DTM derivatives). Finally, qualitative differences are evident between the random forest prediction map generated from TRIM and the classification map derived from the eDTM, and reflect the differences found in the contingency matrices.