Monitoring beaver induced flooding disturbances in forest land using Sentinel-2 data

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Introduction

Beavers are the biggest natural ecosystem engineers present in Estonia. Our numerous small streams connected to ditch network and large forest cover is suited well for beaver habitats. Beavers build dams across rivers, ditches and streams thus impeding natural water flow, which causes flooding. The forests and vegetation on and around the flooded area changes due to the new conditions.

The beaver habitat impact is often large enough to be detected from space using medium spatial resolution optical Earth observing satellites such as Sentinel-2 (from ESA) or Landsat-8 (From NASA). Changes in the vegetation spectral reflectance signature, measured by these satellites, can give us information about beaver activity on the ground. Using remote sensing methods, we can detect and map beaver habitat locations and monitor their conditions efficiently over large areas.

Materials

Ground truth data

The data about beaver habitat locations was provided by the Estonian Environment Agency. For this pilot study only beaver habitats in the Military Grid Reference System tile T35VME cut by the Estonian state border with Latvia were used (*Figure 1*). This tile had the highest density of beavers discovered in Estonia during the 2015 beaver survey.

The beaver habitats were then manually digitized as polygons based on visual interpretation using aerial photographs provided by the Estonian Land Board.

In order to have information about the tree species composition for the selected habitat areas, the database of Estonian forest registry from year 2013 was used.

Satellite data

Several cloud free (or almost cloud free) Sentinel-2 MSI images were selected from different years and times of year.

Methodology

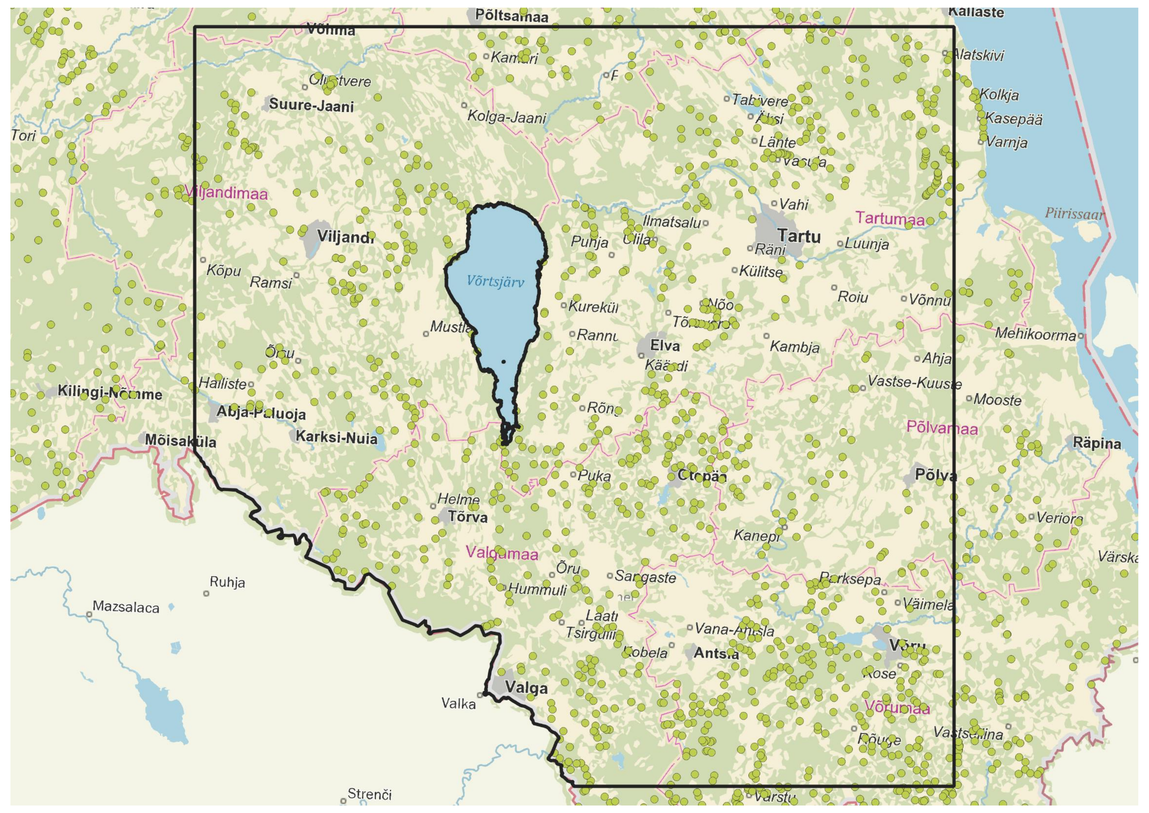

Figure 1. Study area and 2015 beaver survey points

The forest stand with visible beaver damage within them were split up into two classes:

- affected by beavers (ABB), and
- not affected by beavers (NABB).

Forests stands that didn't have any signs of beaver induced damage were excluded from the analysis to keep the ABB and NABB samples as similar as possible considering the tree species and the age of the forest stands growing there (*Figure 2*).

The average pixel values of each band, and calculated indexes (EVI, MSI, NDVI, NDMI, and NDWI) for each image, over the beaver and non-beaver areas were extracted using the raster layer zonal statistics processor in QGIS.

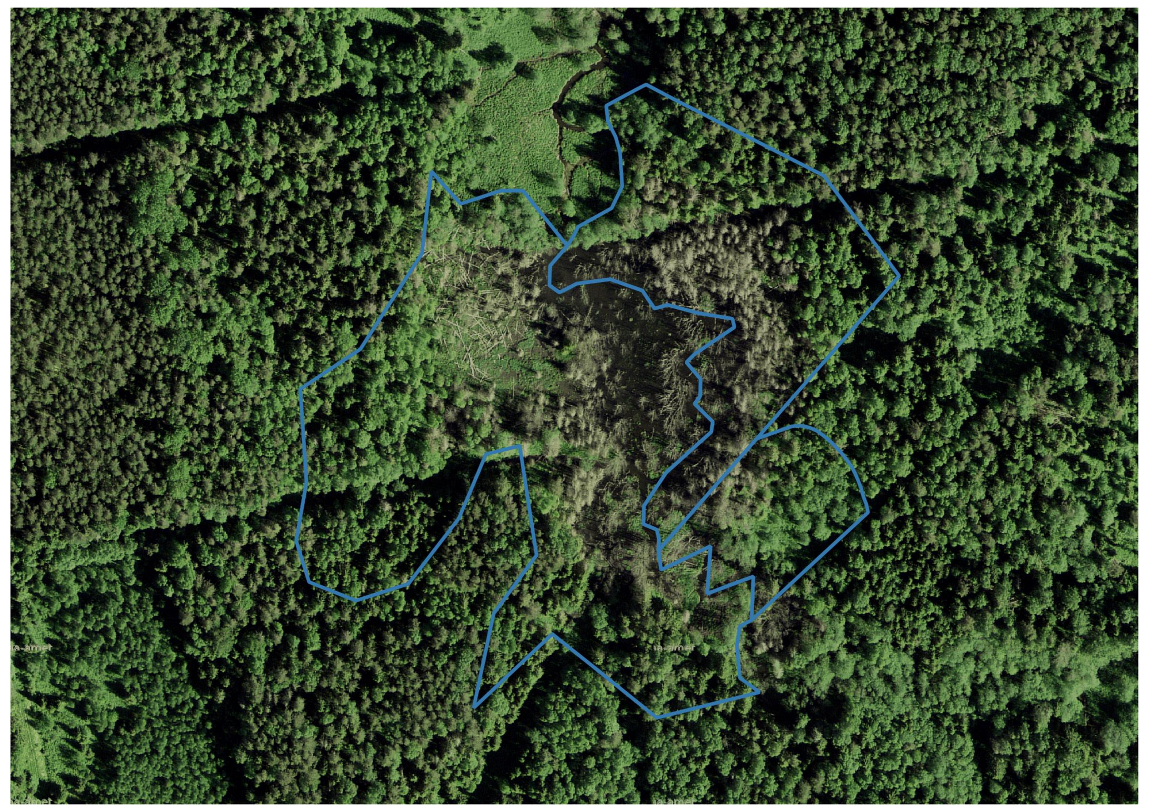

Figure 2. An example of beaver induced flooding in forest viewed from orthophoto (Maa-amet, 2015) The lines correspond to the borders of disturbed forest stands (data from the Estonian forest registry, 2013).

Results

Spectral analysis

In *Figure 3* we can see a significantly smaller reflectance in the visible and the first red edge band for the areas that are not affected by the beaver population. In the near infrared the NABB areas are quite similar to the ABB areas with a slight deviation towards higher values and the variation of the signal across near infrared bands are more spread out in both NABB and ABB forests. In the short wave infrared the NABB areas have again a clearly lower reflectance then the ABB areas.

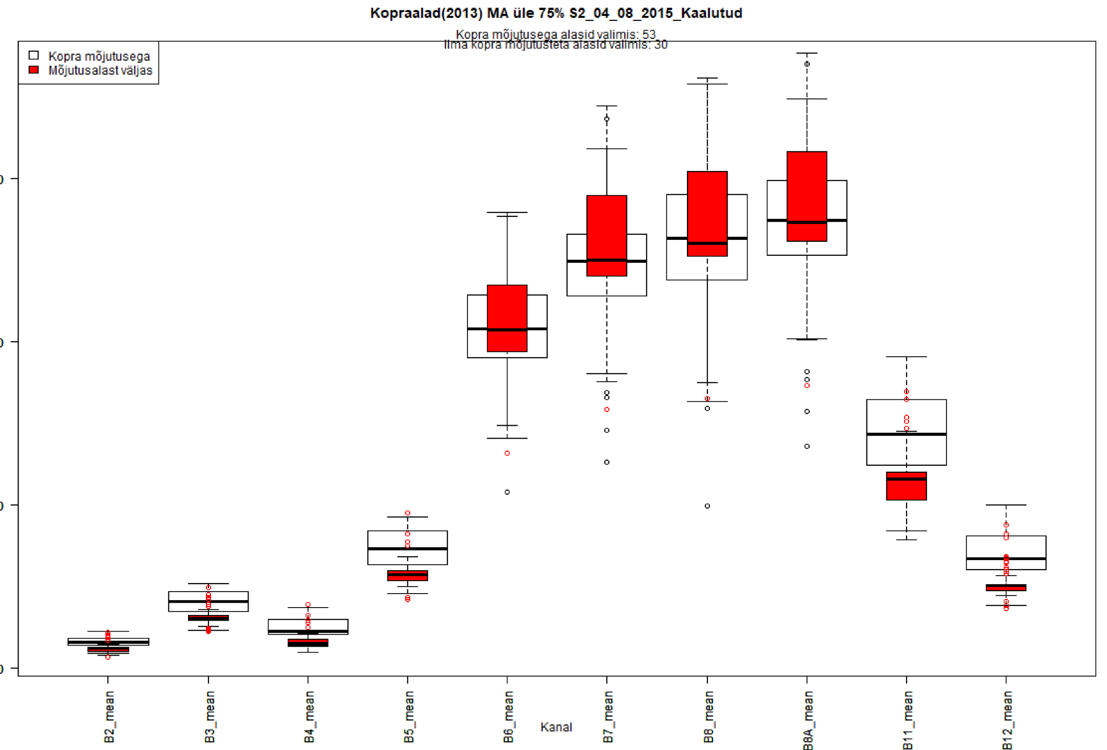

Figure 3. The average reflectance in different Senintinel-2 bands over ABB (white) and NABB (red) forests.

Indices

By using indices (EVI, MSI, NDVI, NDMI, and NDWI) to compare the beaver and non-beaver affected habitats we can see a very strong difference between them. For example EVI shows a significantly higher values over NABB areas compared to ABB areas (*Figure 4*). This difference is present in any time of the year that this study looked at. Also other indices like NDVI, MSI, NDMI, and NDWI indicate disturbance in them as well in every sentinel-2 image analyzed.

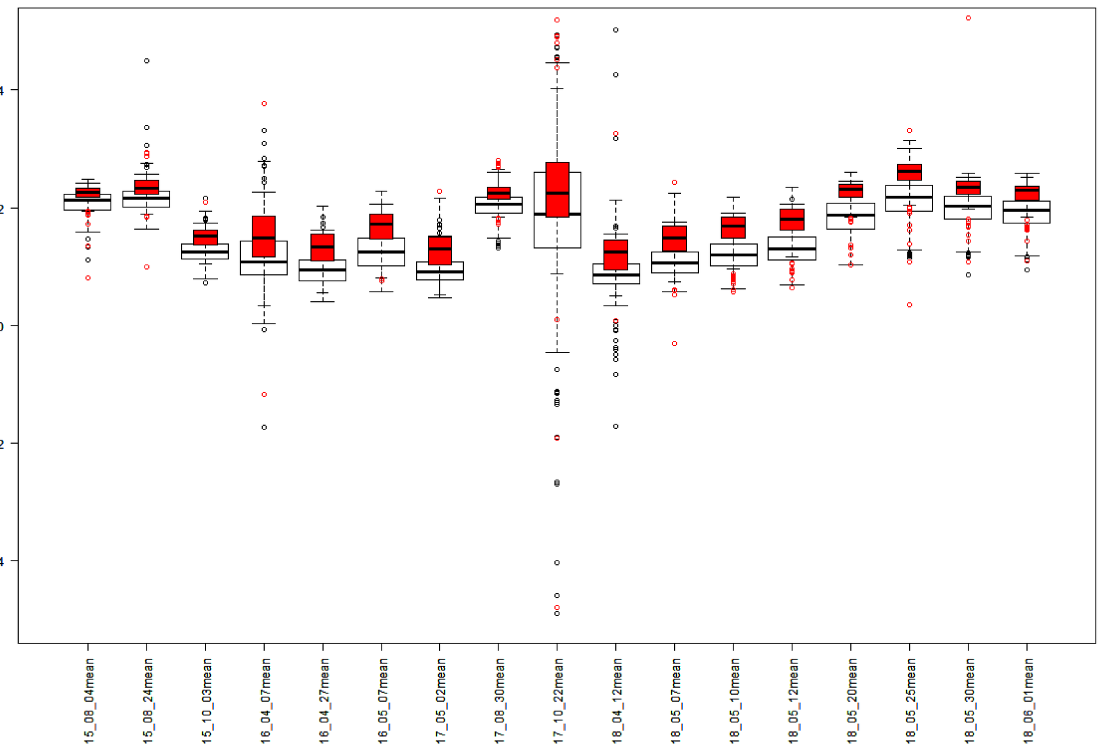

Figure 4. Boxplot of average EVI values over ABB (white) and NABB (red) over all sample plots. Each column represents a different Sentinel-2 image.

Looking at the NDVI image (*Figure 5*) we can see a clear drop in NDVI values over ABB area, but we can also notice that the area is quite heterogeneous.

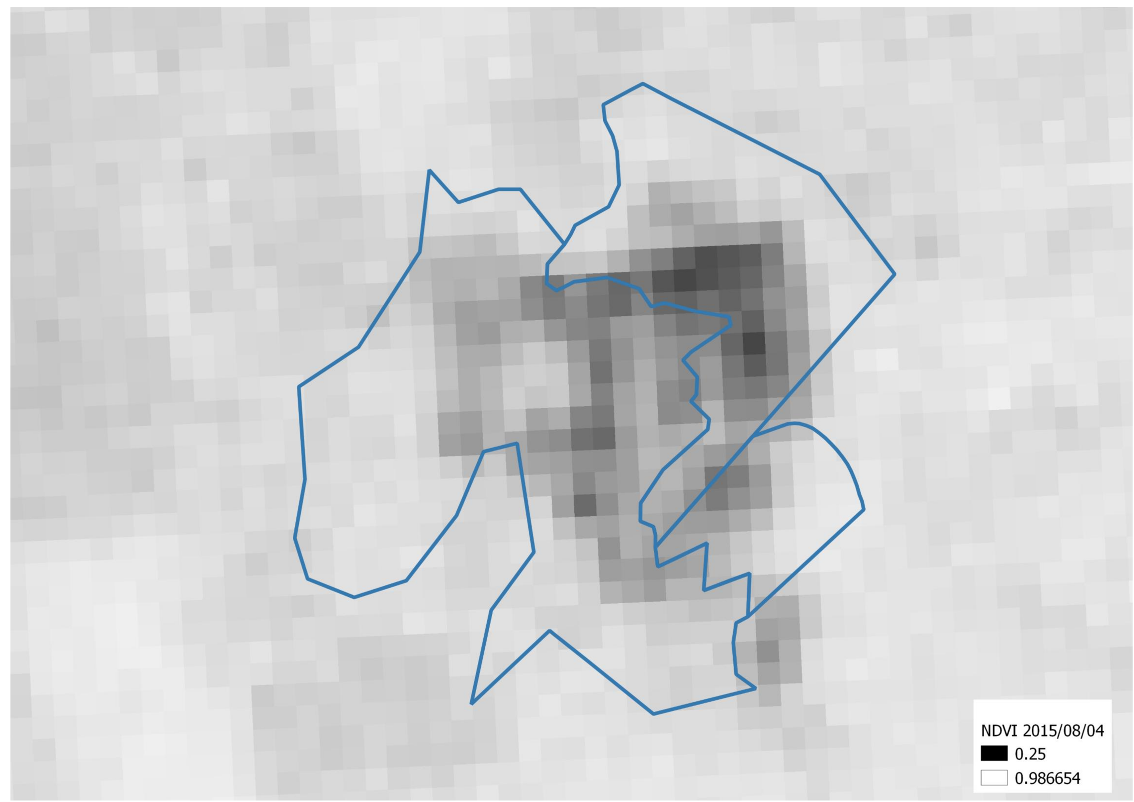

Figure 5. NDVI map from same example area as in Figure 2 calculated from Sentinel-2 image from 2015/08/04.

Conclusion

Beavers create complex earthworks for their habitats. With the dams, lodges, flooding, felling of trees, tunnels and canals the effects on the landscape varies in different areas of the beaver habitat. Looking from above it is clear that the beaver affected area is very heterogeneous, thus the spectral signatures detected from them vary greatly even within flooded area around one beaver colony. But the average values of ABB and NABB areas show great differences. Furthermore, the differences in forests with different dominant tree species are quite small.

These differences in the average values can be very useful for detecting beavers. Machine learning could be used to detect beavers over large areas quite effectively. Using the spectral signature, as well as the indices, a good predictive model can be constructed. It seems that the calculated indices are useful to detect the differences between ABB and NABB forested areas.

Acknowledgements

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