Towards a Map of the European Tree Cover based on Sentinel-2

Thor-Bjørn Ottosen, Geoffrey Petch, Mary Hanson and Carsten Ambelas Skjøth

Institute of Science and the Environment, University of Worcester, Worcester, UK

Context and Aim:

The European tree cover is important for many areas of science and planning such as climate (Bonan, 2008), atmospheric composition (Kesselmeier and Staudt, 1999; Pauling et al., 2012) and socio-economic values (FAO, 2015). Until recently, the best estimate of the European tree cover has been $\mathbf{1.47 \cdot 10^6}$ km^2 $\pm$ $\mathbf{0.02 \cdot 10^6}$ km^2 based on either a combination of MODIS images and LISS-3 images (Kempeneers et al., 2011) or Landsat images (Hansen et al., 2013) with a spatial resolution of 25 m to 30 m. In old cultural landscapes, like the UK and other European countries, trees are often located in small linear features or groups, thus making them difficult to detect using satellites such as Landsat or MODIS. It is thus likely that woodland is more widely distributed. With the launch of Sentinel-2, a new tool has become available with a high spatial resolution and a band combination specifically designed for vegetation studies. In this paper we explore a methodology for tree cover mapping from Sentinel-2 and assess the accuracy of the methodology.

Tree mapping

Main steps in the tree mapping algorithm:

1. All bands are normalized by mean centering and division with the standard deviation. This is done to normalize the weight of the individual bands.
2. A K-means unsupervised classification is done using Intel Data Analytics Abstraction Library (DAAL) with the number of classes set to 25.
3. The NDVI values of the pixels corresponding to forests in Corine Land Cover (CLC) (*CORINE Land Cover. Technical Guide.* 1994) are extracted from the image. Non-vegetation pixels are subsequently removed.
4. The dominating classes for respectively broadleaved and coniferous forests are labelled using CLC by K-means clustering the clusters from the first clustering into two classes (dominating and non-dominating). This is done iteratively starting from the largest polygons within the Sentinel-2 tile proceeding to the smallest polygon until convergence. Convergence is defined when the largest change in a class is smaller than 1%

Accuracy assessment

Sampling design: 1000 pixels were selected across the image using stratified random sampling (Stehman, 2009). The pixels were stratified into broadleaved trees, coniferous trees and no trees to prevent the non-forest category dominating the results.

Response design: The primary land use class of each pixel was subsequently manually determined using Google Earth. The interpreter did not have access to the classified map during the manual classification to avoid biasing the classification (blind interpretation). To enhance consistency among interpreters, a written guide to the classification procedure was produced and 99 points were classified by all interpreters. As well as broadleaved trees, coniferous trees and non-forest, the interpreter had opportunity to classify a pixel as unclassified and unclassified trees. Data points that were classified to be in the last two categories were subsequently excluded from the analysis

Analysis: A confusion matrix between the accuracy assessment dataset and the tree map based on Sentinel-2 was subsequently prepared for three classes (broadleaved trees, coniferous trees and non-trees). This allowed the calculation of overall, user's and producer's accuracy (Congalton and Green, 2009).

Results

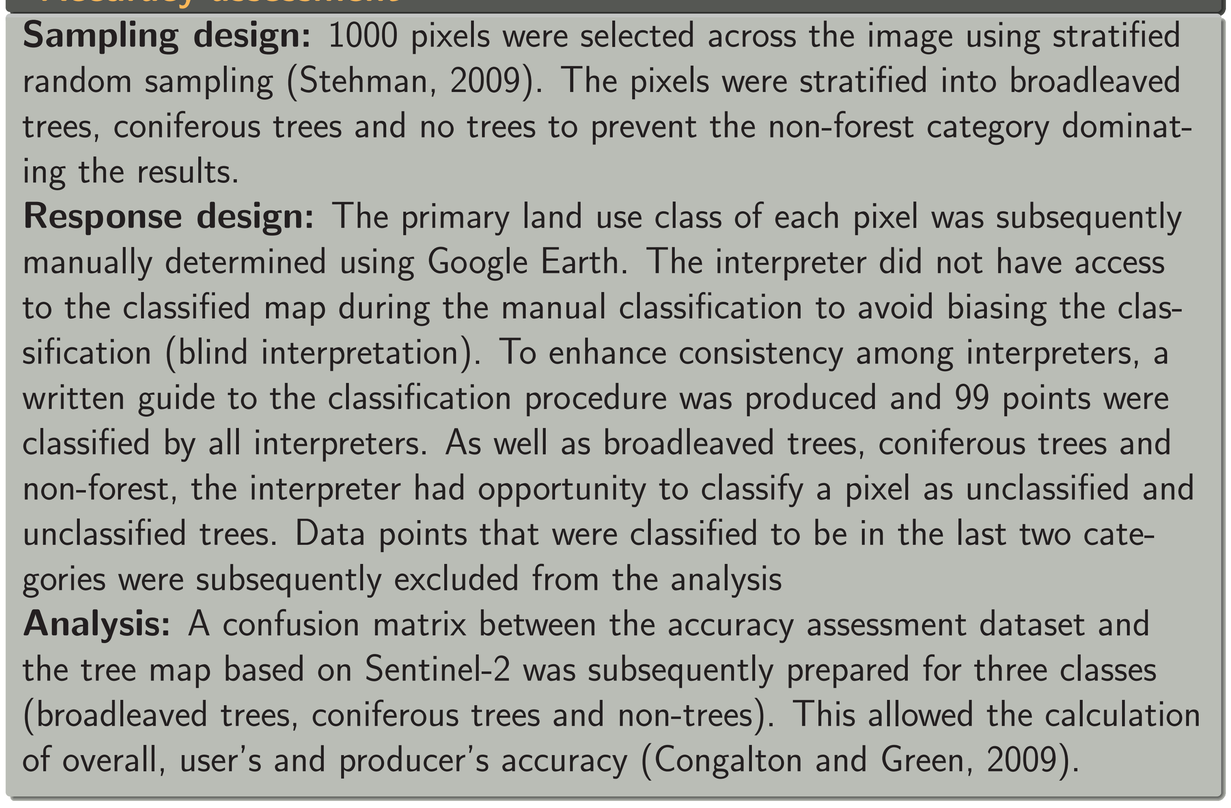

Figure 1. Excerpt of the tree map for tile 32VNH (Western Denmark)

Results – Continued:

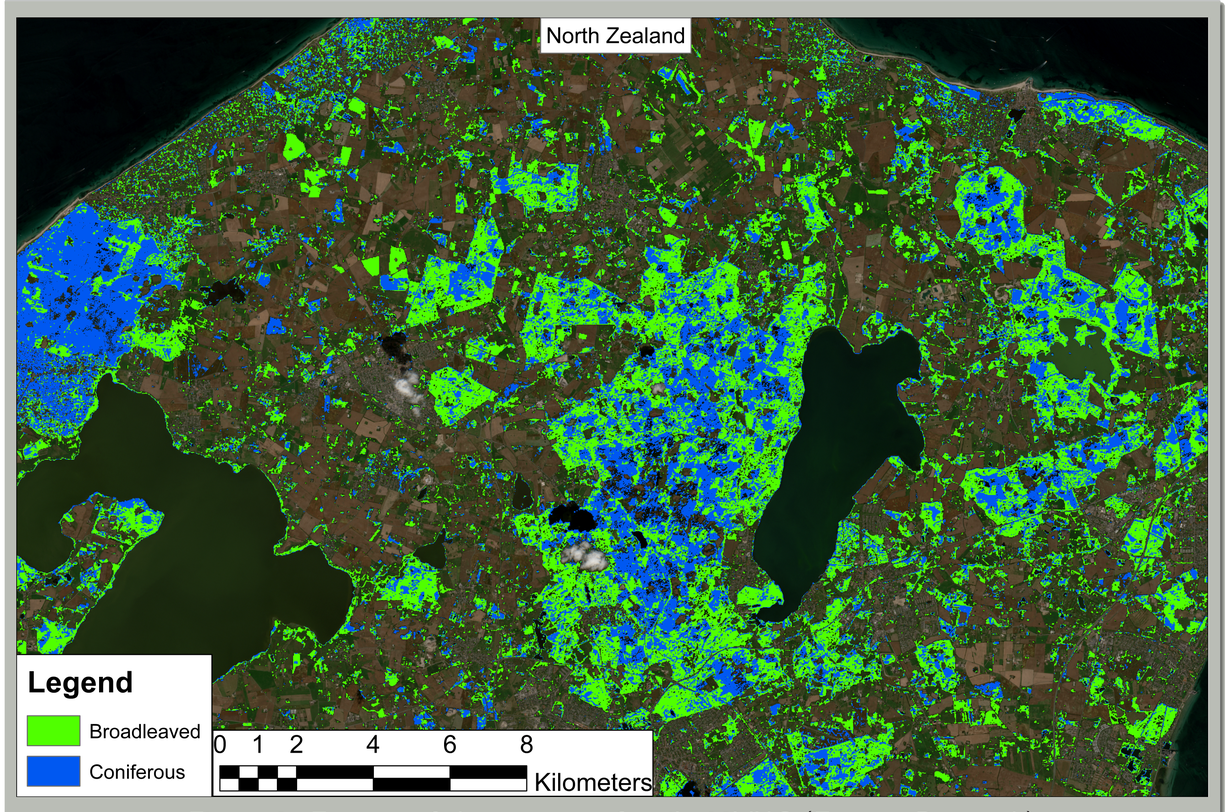

Figure 2. Excerpt of the tree map for tile 33VUC (Eastern Denmark)

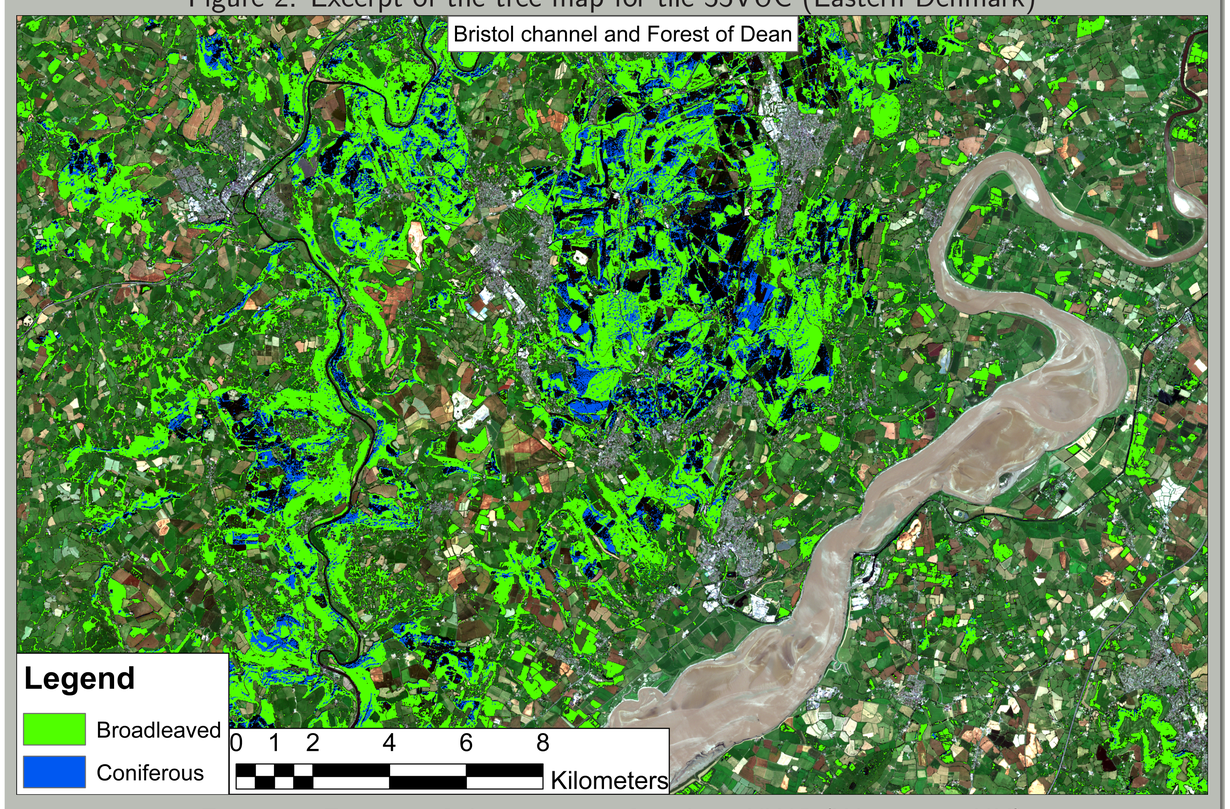

Figure 3. Excerpt of the tree map for tile 30UWC (Worcester, UK)

Table 1. Confusion matrix for tile 30UWC covering Worcester, UK

	Map (Worcester, UK), Overall accuracy= 68 %					
Reference	No trees	Broadleaved	Coniferous	Total:	Prod:	n
No trees	32.2	7.1	1.9	41.2	78.1	388
Broadleaved	2.4	24.2	19.3	46.0	52.7	433
Coniferous	0.3	1.1	11.4	12.8	89.2	120
Total	35.0	32.4	32.6	100.0		
User	92.1	74.8	34.9			
n	329	305	307			941

Conclusion:

- More accurate tree cover maps can be produced based on Sentinel-2
- The weighted thematic accuracy for this approach is up to 95 %
- The present tree map agrees well with previous studies and the corresponding national forest inventory

Contact info:

Dr. Thor-Bjørn Ottosen, Institute of Science and the Environment, University of Worcester, t.ottosen@worc.ac.uk, Phone: (+44)1905 54 2969

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