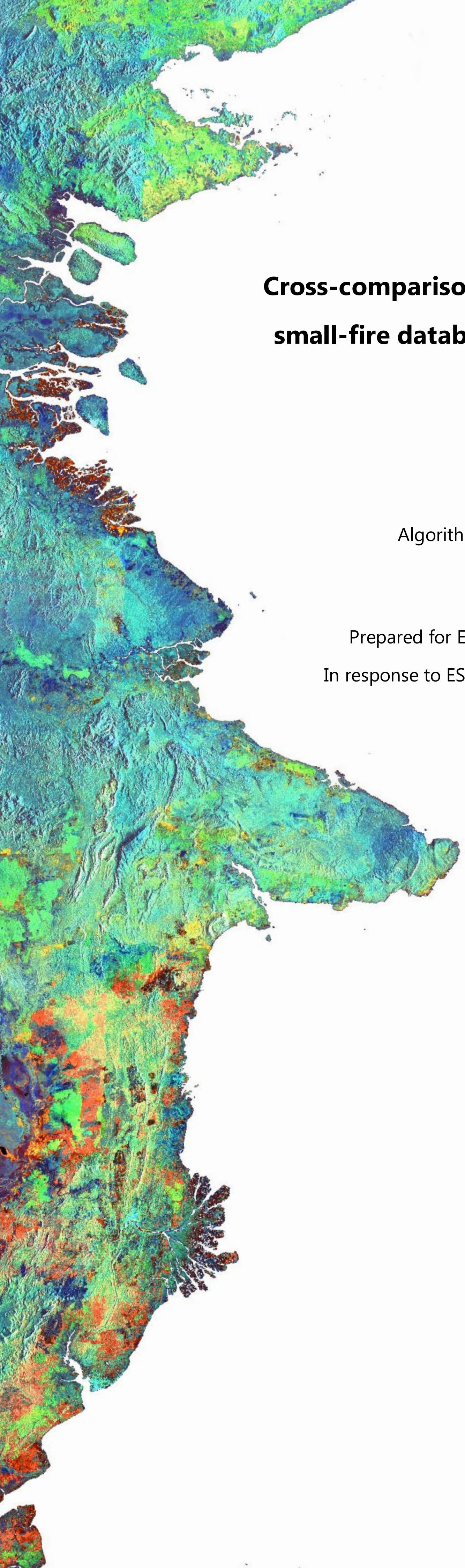

FIRE_CCI

Cross-comparison of methods developed under small-fire databases applied in Tropical Africa

D5

Algorithm Intercomparison Document

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1 Executive summary

The aim of this document is to compare the different burned area algorithms developed under fire_cci small-fire databases (SFD) using high resolution Sentinel-1 data in order to test the different algorithms performance outside of the confines of where it was developed. The different algorithms were applied to a test site in Tropical Africa which was specified in coordination within the fire_cci consortium. The characteristics of the different algorithms are shown and the different burned area results are compared in this Algorithm Intercomparison Document.

2 General description of the test site

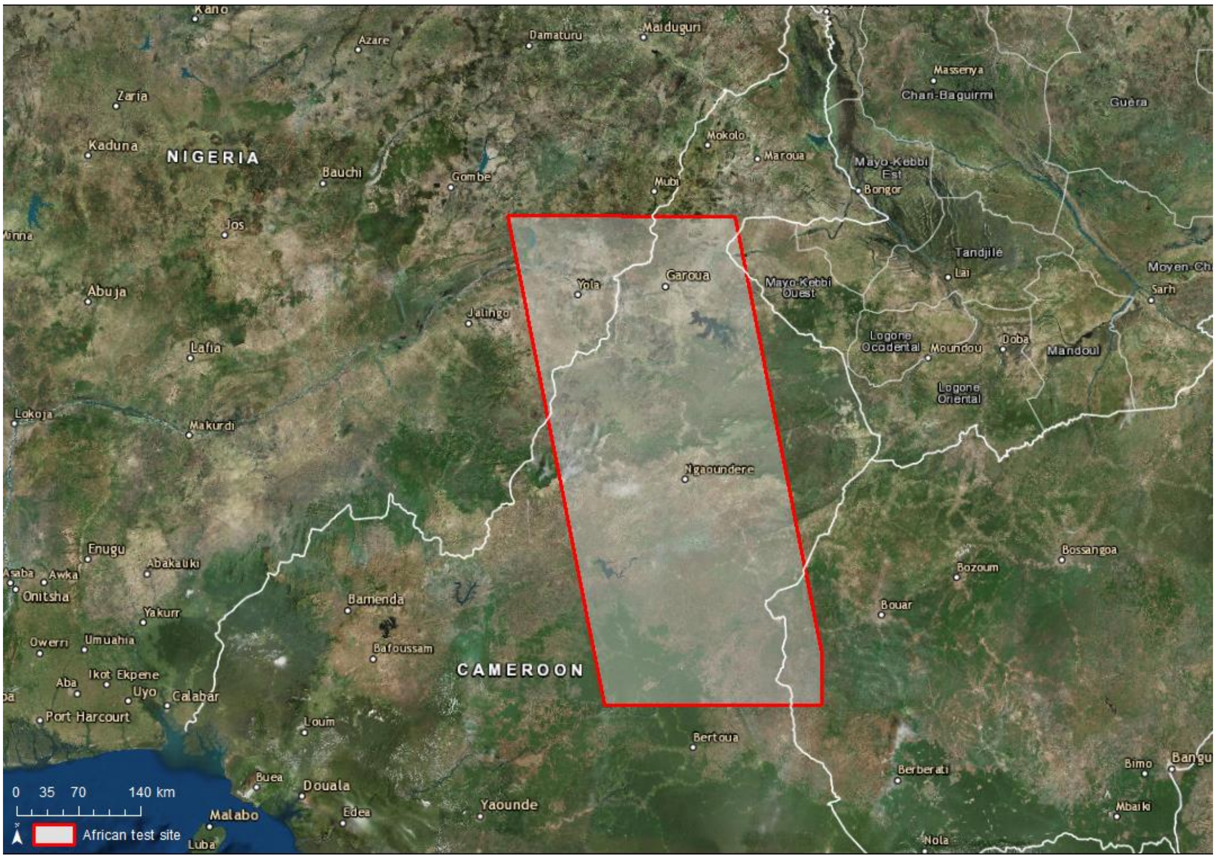

Figure 1: The African test site in north-east of Cameroon.

The African test site was specified in close cooperation with the fire_cci consortium and is shown in Figure 1. This test site was selected as it covers a variety of biomes with large burned areas as well as having plenty of Sentinel-1 data available in 2016. Furthermore, this site is one of the 16 test sites selected for the Sentinel-1 and Sentinel-2 intercomparison (see Fire_cci_D2.1.2_ATBD_SFD_v0.1.pdf).

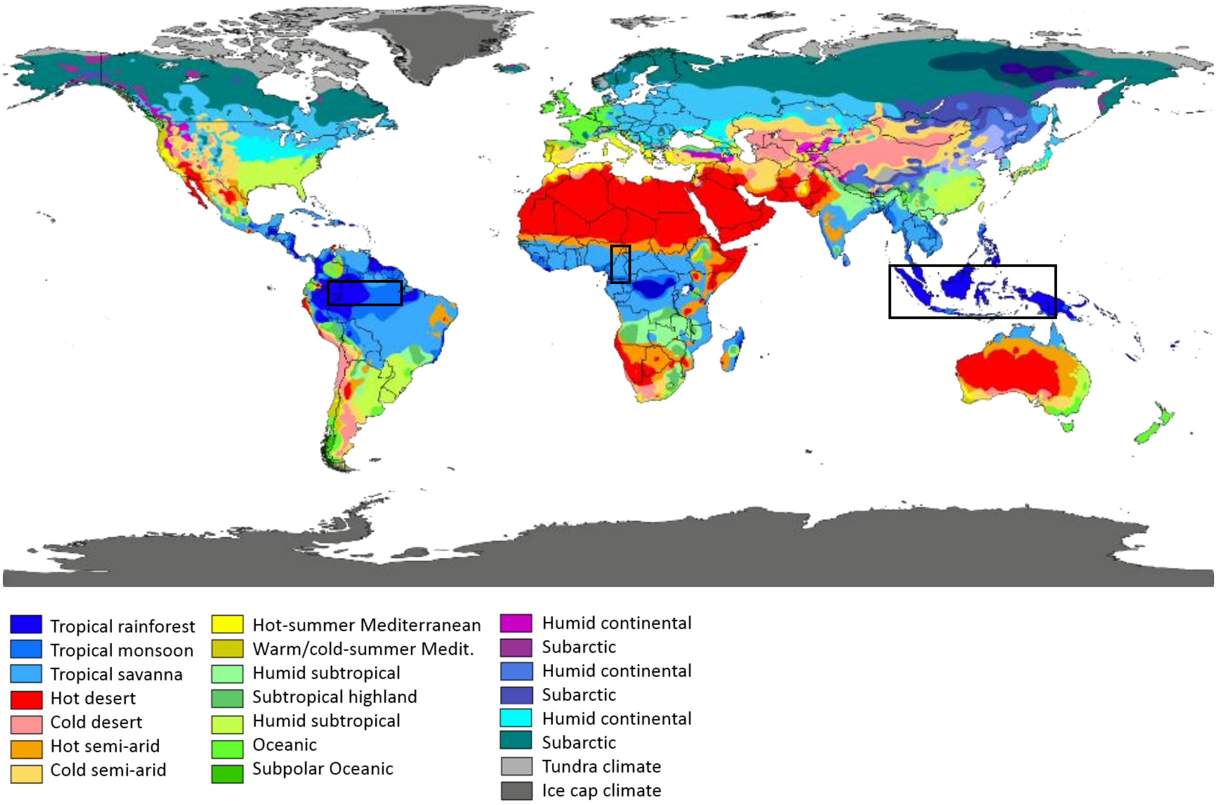

Figure 2: Köppen-Geiger climate classification outlining the three study areas.

In contrast to the Indonesian and the South American test sites, which are classified as a tropical rainforest ecological zone, the African test site is categorized as a tropical savannah ecological zone (Figure 2). The African test site comprises different dry forest and savannah ecosystems where mainly grassland and understory burns when fires occur. In contrast to Indonesia, where the fire has a severe impact on the forest.

The application of the algorithm to the whole study area showed that it did not performed very well, as the SAR signal of burned areas is very different from that in Indonesia. The signal of burned areas was party not visible in the SAR images (see Figure 3) and therefore not detected via the object based classification approach.

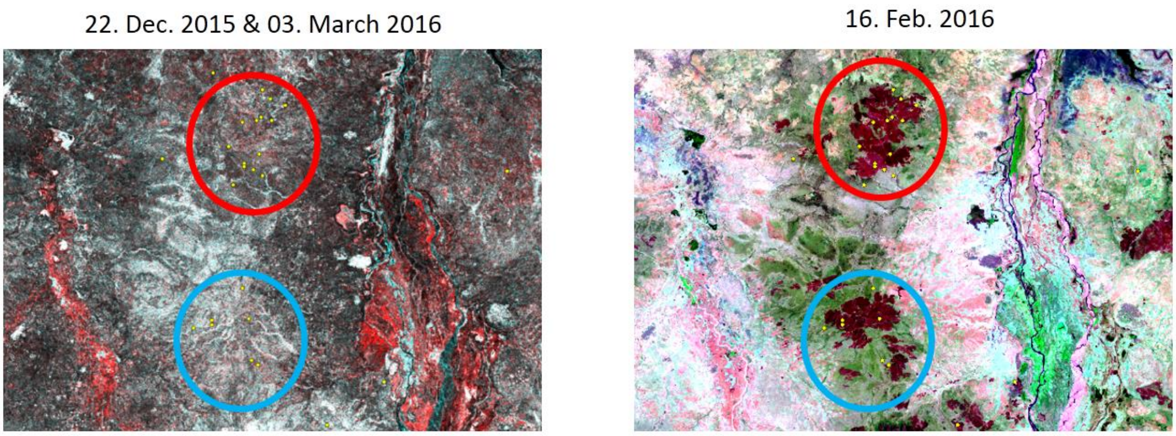

Figure 3: Sentinel-1 imagery (R: 22.12.15, G,B: 03.03.16) on the left and Sentinel-2 imagery on the right panel showing burned areas in the red and blue circle.

Therefore, the algorithm was adjusted to a subset of the study area covering 1.9 Mha where mainly broadleaved evergreen tree cover, shrub land and natural vegetation occurs. An overview of the African test site subset is given in Figure 4.

Figure 4: Overview of the African test site subset.

Figure 5 depicts the number of MODIS hotspots and TRMM precipitation data showing a fire season from beginning of November 2015 until end of March 2016.

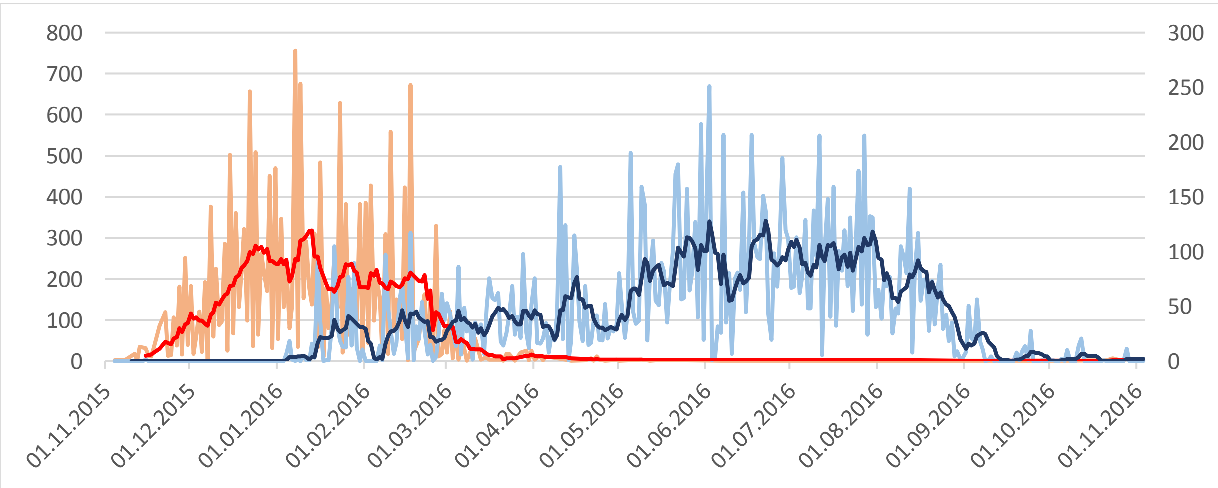

Figure 5: MODIS Hotspots (in red) and TRMM precipitation (in blue) from November 2015 until December 2016 for the African test site

3 Methods

Sentinel-1 products are released in two Level 1 formats, Ground Range Detected (GRD) and Single Look Complex (SLC). GRD products are projected, intensity images, radiometrically and terrain corrected. SLC data are designed for interferometric applications, containing both phase and intensity information. The most commonly available SLC and GRD data are released in interferometric wideswath (IW) mode, separated into three swaths captured using Terrain Observation with Progressive Scans SAR (TOPSAR).

The inter-comparison of burned area algorithms was carried out in the above shown subset area (Figure 4) for the months January-April. These months were selected as it is the fire prone season with less precipitation within one year's time frame. Furthermore, all three products were available for this time period. Table 1 shows the characteristics of analysed Sentinel-1 images.

Table 1: Sentinel-1 data used for burned area mapping of the African test site.

Area	Polarization	Relative Orbit	Pass	Acquisition date
African test site	VV/VH	161	ascending	03.01.2016
African test site	VV/VH	161	ascending	15.01.2016
African test site	VV/VH	161	ascending	27.01.2016
African test site	VV/VH	161	ascending	08.02.2016
African test site	VV/VH	161	ascending	20.02.2016
African test site	VV/VH	161	ascending	03.03.2016
African test site	VV/VH	161	ascending	15.03.2016
African test site	VV/VH	161	ascending	27.03.2016
African test site	VV/VH	161	ascending	08.04.2016
African test site	VV/VH	161	ascending	20.04.2016

The main characteristics of the compared Sentinel-1 burned area algorithm can be found in Table 2. University of Leicester (UL) developed the burned area algorithm originally for Africa. The algorithm developed by Remote Sensing Solutions GmbH (RSS) was originally intended for Indonesia and the algorithm of University of Alcala was originally developed for South America. For further details of the different algorithms can be found in the respective ATBDs.

Table 2: Characteristics of compared Sentinel-1 algorithms

Description	UL – Africa	UAH – South America	RSS – Indonesia
Type of data (GRD-SLC)	SLC IW	GRD IW	GRD IW
Sensor	Sentinel 1A (for now)	Sentinel 1A and 1B	Sentinel 1A (availability)
Polarization	VV	VV – VH (more important)	VV
Resolution	30 m	50 m	10 m
Method	Coherence – Pixel based thresholding	Backscatter – Statistical approach	Backscatter - Object based analysis (eCognition)
Pre-processing	SNAP	Gamma, Orfeotoolbox (OTB)	SNAP
Auxiliary data: active fires	No	MOD14MLC6, VIIRS 375m	No
Auxiliary data: other	CCI Land Cover v2.0.7 2015	Future possible development: CCI Land Cover	TRMM precipitation data; JRC Global Surface Water Layer [1]
Minimum mapping unit	9 pixels	1 ha (4 pixels with 50m resolution)	9 pixels
Speckle correction	Multi-temporal median filter (for noise, not speckle)	Multi-look and multi-temporal filter	Multi-temporal enhanced Lee filter
Maximum temporal threshold	24 maximum days between images	90 days at the moment	No threshold applied (but moisture analyses)
Confidence	Sum of distances from thresholds in burned area pixels (could be used for adjusting burned area in different biomes)	Calculated with a statistical distance between the object and the areas that are clearly burned.	Not calculated
No data code	In the monthly product, if there are no acquisitions in that month, they will be marked as -1. It will be blocks of information.	The not observed information outside the strip is marked with a not observed code, which can be translated to -1.	Not available (0 for not burned areas and number of the day of burned are detection). If there was rain in the image, the whole image was discarded due to moisture.
Known limitations	Thresholds are too restrictive for certain biomes (savannah) – algorithm does not account for differences between 12 and 24 day coherence.	Some lack of data in South America in some areas.	Does not perform well in other biomes apart from tropical forests (e.g. savannah ecosystems). Misclassifications in flooded areas.

For the comparison of these three products derived from the different methods a quantitative analysis was performed. Therefore the data was intersected monthly and for the total investigation period. This allows a spatial comparison of the detected burned areas between the different products. Furthermore, the amount of classified burned areas within each of the cci land cover classes was evaluated.

It will not be possible to validate the Sentinel-1 methodologies according to CEOS protocols because:

1. RSS cannot apply their algorithm outside of this subset area due to the different ecosystem.
2. UAH are in the first stages of their algorithm development.
3. None of the reference data that has been collected to validate the CCI product are available in this test area.

4. Optical data of the region (for example that used for the S-2 product, shows cloud cover at different times and locations so it is not possible to establish the extent of burning. Any attempt to do this would not be robust against CEOS protocols.
5. Sentinel-2 data will not be collected at the same time as Sentinel-1, which will further potentially invalidate any comparison.

To help understand algorithm performance, it is proposed that burned area products are derived for this test area and for a period 01 January to 30 April 2016. Further, not burned areas are defined and the date of detection is analysed monthly across the three products.

4 Results

Figure 6 shows mapped burned areas derived from Sentinel-1 and their inter-comparison between the products of all partners in the African test site subset (1,819,560 ha). Most burned areas were detected in the north-eastern part of the study site where savannah is the dominant land cover type. In total UL detected 30,685 ha, UAH 163,751 ha and RSS 10,895 ha burned areas for the investigation period. All combinations of burned and unburned areas of the different products can be found in Table 3.

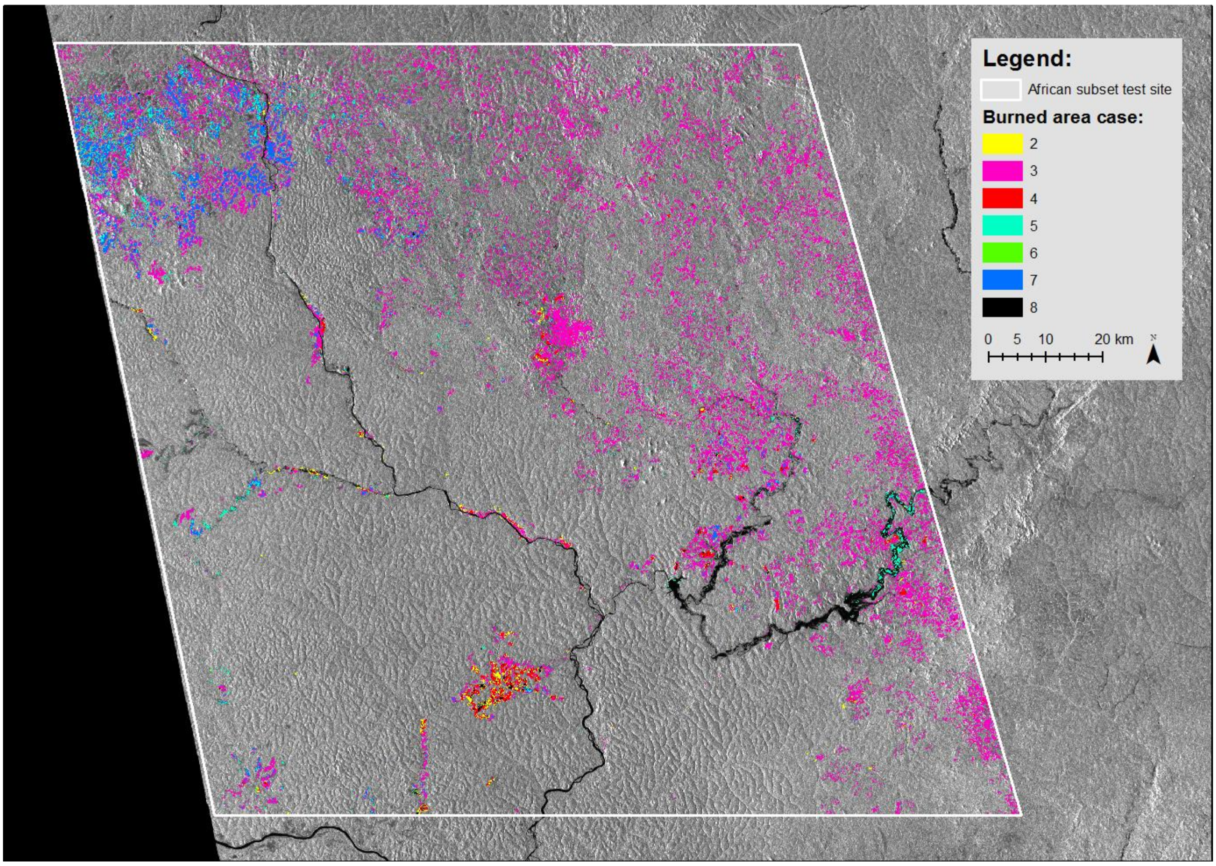

Figure 6: Spatial distribution of Sentinel-1 burned areas in the African test site subset from January to April 2016. The "burned area case" can decoded using Table 3.

Table 3: Spatial extent of Sentinel-1 burned areas of the different investigation methods in the African test site subset from January to April 2016. The matrix allows to compare burned areas of the different classifications in all possible combinations. The colour scheme on the right can be used for the interpretation of Figure 6.

Area [ha] Area [%]	Product			case
	UL	**UAH**	**RSS**	
1,642,781.09 90%	UNBURNED	UNBURNED	UNBURNED	1
3,192.81 0%	UNBURNED	UNBURNED	BURNED	2
136,385.54 7%	UNBURNED	BURNED	UNBURNED	3
6,515.15 0%	UNBURNED	BURNED	BURNED	4
9,608.24 1%	BURNED	UNBURNED	UNBURNED	5
227.25 0%	BURNED	UNBURNED	BURNED	6
19,890.41 1%	BURNED	BURNED	UNBURNED	7
959.51 0%	BURNED	BURNED	BURNED	8

The comparison of the different burned area products per CCI land cover class showed that the classification of UAH mainly detected the significant largest extent over all land cover classes. In forest classes classified RSS and in non-forest classes UL mainly the least burned areas. Regardless of land cover classes RSS classified the least (10,891 ha) and UAH most (163,726 ha) burned areas (Figure 7). Also Figure 6 underlines this calculations with an extensive pink visual impression on the map.

The average extent of burned areas was classified by UL with 30,682 ha (Table 4). Since only this methodology was developed for the African ecosystem, this could argue for the possibility that the other two algorithms may over- or underestimate burned areas.

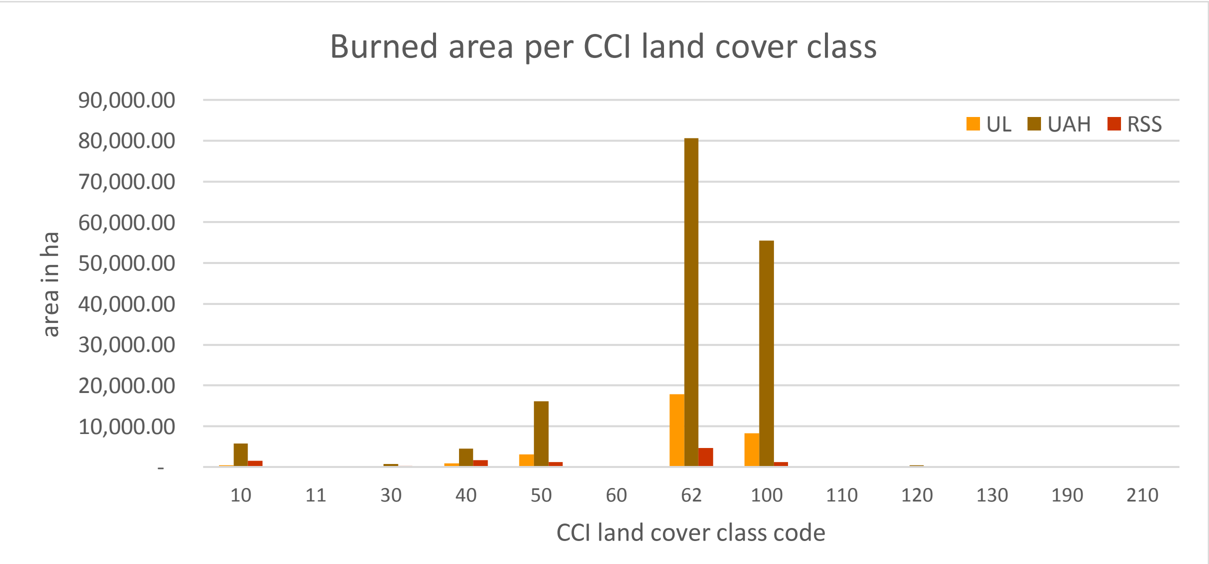

Figure 7: Comparison between the spatial extents of burned areas per CCI Land cover class. The class code can be found in Table 4.

Table 4: Spatial extent of burned areas per CCI Land cover class.

		Area in ha		
LC Code	**LC class**	**UL**	**UAH**	**RSS**
10	Cropland, rainfed	366.05	5,736.45	1,533.80
11	Herbaceous cover	0.41	41.5	-
30	Mosaic cropland (>50%) / natural vegetation (tree, shrub, herbaceous cover) (<50%)	121.88	792.87	317.89
40	Mosaic natural vegetation (tree, shrub, herbaceous cover) (>50%) / cropland (<50%)	871.88	4,442.94	1,683.36
50	Tree cover, broadleaved, evergreen, closed to open (>15%)	3,117.91	16,047.82	1,208.62
60	Tree cover, broadleaved, deciduous, closed to open (>15%)	0.22	5.7	3.04
62	Tree cover, broadleaved, deciduous, open (15-40%)	17,835.97	80,595.58	4,725.70
100	Mosaic tree and shrub (>50%) / herbaceous cover (<50%)	8,308.47	55,505.10	1,266.95
110	Mosaic herbaceous cover (>50%) / tree and shrub (<50%)	3.26	1.6	-
120	Shrubland	52.88	351.11	96.2
130	Tree cover, flooded, saline water	-	28.25	23.47
190	Urban areas	-	1.5	-
210	Water bodies	3.27	175.68	31.97
	total	**30,682.21**	**163,726.10**	**10,891.00**

5 Conclusion

To conclude this intercomparison, it turned out that UAH most likely overestimates and RSS most likely underestimates burned area in the African test site subset area. It is assumed that UL has the most appropriate algorithm for application in this area as it has been developed specifically for this ecosystem. For the reasons mentioned, a validation was unfortunately not possible.

6 References

[1] J.-F. Pekel, A. Cottam, N. Gorelick, and A. S. Belward, "High-resolution mapping of global surface water and its long-term changes," *Nature*, vol. 540, no. 7633, pp. 418–422, Dec. 2016.