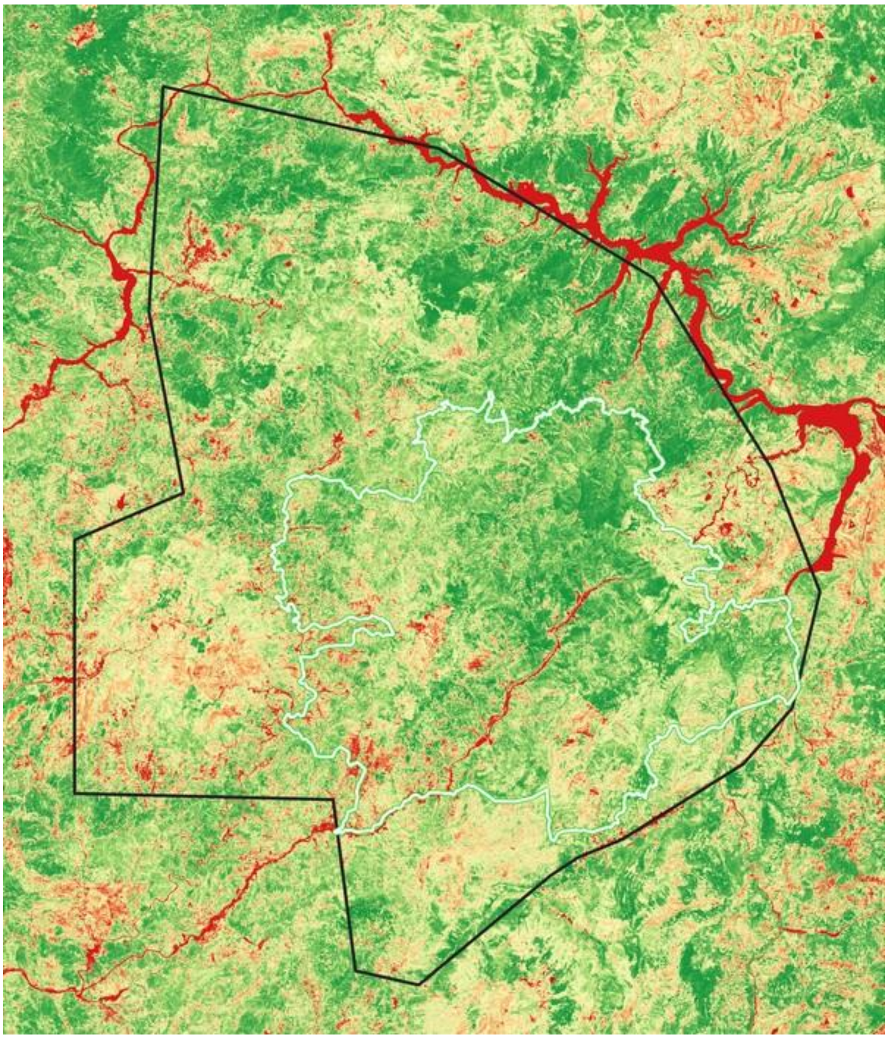
Creation of a methodology for verification of logging in the Wider Munella Mountain Region

A report on the creation of a methodology



to verify the effectiveness of the logging ban via remote sensing

Ronny Dobbelsteijn for PPNEA

April 2019

Table of contents

Abbreviations

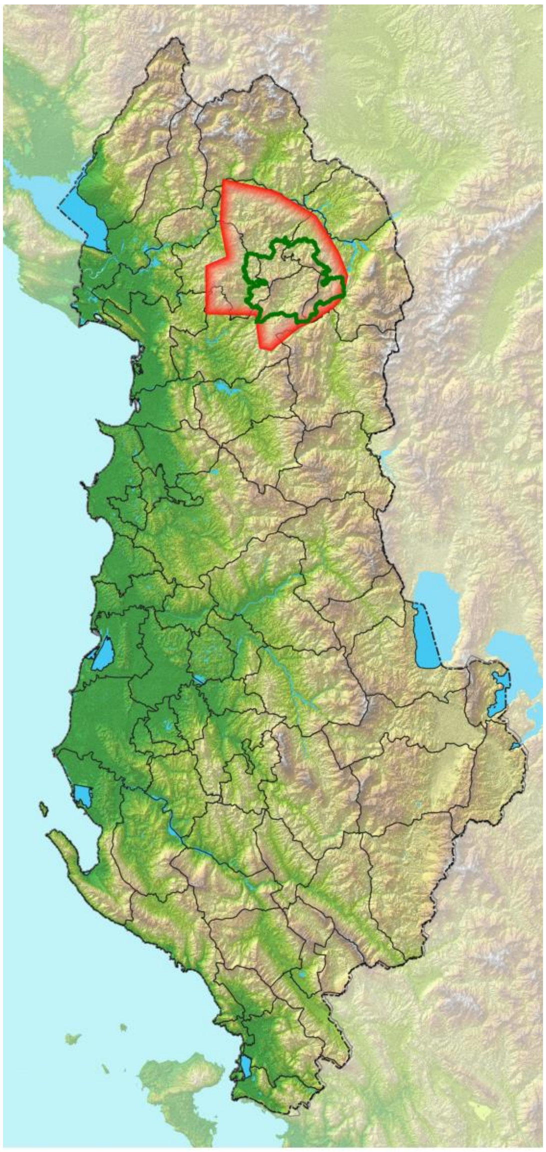
GIS	Geographical Information System
F-TEP	Forestry Thematic Exploitation Platform
NBR	Normalized Burn Ration
NDVI	Normalized Difference Vegetation Index
NIR	Near InfraRed
PPNEA	Protection and Preservation of Natural Environment in Albania
REDD+	Reducing Emissions from Deforestation en forest Degradation
RS	Remote Sensing
SWIR	Short Wave InfraRed

1) Introduction

The government of Albania installed a logging ban in 2016 in an attempt to stop further uncontrolled deforestation. PPNEA committed to verify the results in the Munella Mountain Region, a proposed protected area, and check the impact of this logging ban with regards to legal and illegal logging. To be able to verify forest loss within the proposed area over a logging season via Remote Sensing (RS), a methodology needs to be developed, also with a view to monitor the effectiveness of forest moratorium in the Munella region. The prepared methodology will assist institutions to assess the impact of the moratorium until its completion in 2026.

To verify if the methodology by RS is an effective tool, it was tested for the wider Munella region and this report is the summary result of this effort. To highlight the results, maps and measurements are included whereby the accuracy on the ground still needs to be verified.

Image 1: Munella proposed park and extended region in Albania



To be able to make an assessment of logging in the Munella mountain region, the process of finding anomalies in Remote Sensing Data has to deal with the fact that many areas have had human interventions over time. This has resulted in a mixed landscape from fertile valleys to rugged mountain tops with a varied land cover strongly impacted by fire, logging, hunting, livestock rearing and farming. A second issue is the climate as the seasons and water availability impacts the visible results that are captured by remote sensing.

To assess the impact of the logging ban, different steps have to be taken to create a clear understanding of the impact of the ban and other factors like fires but also legal logging areas in different years. It will be tested if it will be possible to indicate logging and changes in forest areas in relation to forest density, a process when selective logging is happening.

2) Methodology development

The process to detect areas that have been logged in a specific time frame is a step-by-step process, whereby the results regularly have to be reviewed and methods adapted.

In general the process is as follows:

i. Establishing the project boundaries
ii. Selection of the imagery source for Remote Sensing of (preferably) the same source
iii. Selection of the best imagery for classification without cloud cover over target area
iv. Classification of the imagery of the different years to have a land cover baseline, specifically to find the forest areas and 'wooded areas'
v. Create and test different methodologies on verification of vegetation/land cover change between the time frames
vi. Review the resulting change areas with the forest cover baseline and legal logging areas
vii. Finally, visually verify if changes have other causes than logging (e.g. fire)

The process is as mentioned re-iterative and the final products per step are individually tailored. This means each assessment will require some technical expertise and knowledge or verification of the actual situation on the ground.

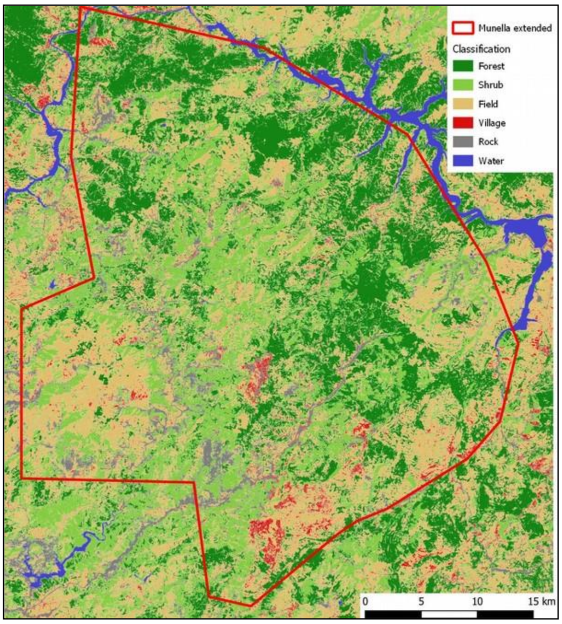
The process has been followed as indicated above while doing the analysis. However for the purpose of this research to develop and test different methodologies, the order is not followed in this document.

First, the different technical methodologies are explained after which the results of the different methods are given for the project area. Especially on the subject of forest recognition and what to include as forest some extra information is provided. Based on the results the best methodology and conclusions are provided.

3) Technical assessment of methodologies

The selection of the RS imagery was based on the availability of imagery from the region and the possible usage for this research. Sentinel 2 imagery was selected as this open data source has a high resolution of 10 x 10 meters in different visual bands and for vegetation (Infra Red) 20 x 20 meters. Also the EU based website provides different opportunities to verify the imagery on the cloud with specific research protocols.

Image 2: Macro classification of 21 July 2018



First of all it is necessary to find areas covered with trees. The purpose of this is to verify if the actual changes visible between the years are in forest or wooded areas rather than changes in other areas. This is necessary to reduce the total areas where 'a change' has been found. Finding vegetation with RS is not too difficult, however the landscape is dominated by meadows, shrub and forests of different composition but also mines, roads and villages and anything in between. It is therefore necessary to make an analysis of the best way of creating a base layer for forests and/or wooded areas (shrub).

To recognize forests or shrub areas one needs to understand that so called 'open' forests of only 30% forest cover are also considered as forests. So while some areas might seem to be shrubs and individual trees, these areas may be called forests.

For the first classification a semi-automated classification was done using Sentinel 2MSIL1C Imagery of 21 July 2018.

Due to the elevation the area around Munella is regularly covered with clouds so after verification the cloud free image of 21 July 2018 was selected. The classification was done with the bands 2,3,4,5,6,7,8 and 8A whereby the bands were first corrected for the reflectance and then clipped to the correct region. For the creation of the training input file with which the semi-automated classification program can run, manually areas are selected from high resolution orthophoto images with a clear visual image to recognise the different macro classes; water, forest, rocks/bare land, fields/grass, village/buildings and shrubs. The orthophotos with a 20 cm pixel size from the ASIG database provided by the Albanian government from 2015 were used of this purpose. The resulting division into the macro classes is given in image 2. A second image of 15 August 2016 was put through the same procedure and resulted in a very similar distribution of the different classes.

A second way of finding forested areas is done via the NDVI (Normalized Difference Vegetation Index). With the Sentinel 2 imagery this means the bands 8-4/8+4. This well known way of verifying vegetation conditions allows a more precise way of finding the 'cut-off' is between forests or wooded areas and grasslands.

To verify more closely the area with forests in the region and rectify influences of climate, drought or inclination of the sun and satellite a combination of 4 Vegetation Index files was created where in all 4 images the cut-off point was established for forests compared to grassland.

After the classification the results need to be compared with reality. For this purpose PPNEA gathered georeferenced data on types of vegetations along trails captured during other activities in the Munella region. The difference between the land use classes 'Forest', 'Shrub' and 'Grassland' is in many areas difficult to agree upon. Based on the results, both Forest and Shrub areas are to be considered as ‘wooded areas‘ where impact of logging is likely to happen and thus to be reviewed year by year. The results will be given for forests and shrub areas together.

The next step to review which areas have been logged can be done in 4 different ways. The logging can be reviewed by assessing the difference between images of different times even when the images are seemingly very different.

The first two manual methods are as follows;

1) by comparing the different Vegetation Indexes between years (NDVI date X – NDVI date Y). The result will indicate areas with minimal differences in vegetation cover change and those with a lot of change, which is what we are looking for.

2) by comparing the visual bands (B2, B3, B4) between the years. This last comparison is done by calculating the squared difference of the images per band:

Difference between 2018 and 2017: $(B2_{2018} - B2_{2017})^2 + (B3_{2018} - B3_{2017})^2 + (B4_{2018} - B4_{2017})^2$

Besides these two manual systems there area several semi-automated systems in development.

A first semi-automated method is provided via the Forestry Thematic Exploitation Platform website: https://f-tep.com. This research facility enables easy access to satellite data from any global location. The platform offers on-line processing services and tools to generate value-added forest information products. Via the platform, the users can also create and share their own processing services, tools and products.

“When forest is converted to agricultural land or logged for other purposes, the measured reflectance in various parts of the visible and infrared spectrum changes a lot. This is evident when investigating the various spectral bands of the MSI instrument aboard Sentinel-2 satellites. Especially if bare ground is exposed in connection with the logging operation, red reflectance (and the infrared reflectance in the 1.6 µm band) rises. The ratio of red reflectance after vs. before can be used as a measure of detecting changes in forest cover. The Forestry TEP Sentinel-2 Forest Change service computes a red-reflectance ratio layer, which can then be further analysed“

A second methodology is via Planet maps and a process called Delta-rNBR (= the difference of corrected mean values for Normalized Burn Ration). Planet is supported by Google Earth Engine and is a paid service whereby use can be made of the ‘box satellites’ which provide coverage of a large part of the earth on a daily basis. This enables the verification of logging as it is taking place. The facility allows for analysis of imagery from different periods based on externally created algorithms. In this case the algorithm used is: Andi1974/Forest-degradation-monitoring v1.8.

“Basically, the NBR index is computed for two different periods, and the difference (time 2 - time 1) between both NBRs potentially show canopy cover disturbances. The delta between both periods should be:

- 0 for no disturbance event taking place between time 1 and time 2
- Negative values for any disturbance event taking place between time 1 and time 2

It is calclulated as follows: **NBR = (NIR - SWIR) / (NIR + SWIR)** where:

- NIR is the Near InfraRed band (Band 8 for Sentinel 2)
- SWIR is the Short Wave 2 InfraRed band (Band 12 for Sentinel 2)

These last 2 methodologies are both services created for the specific usage in wet tropical environments where the differences created by logging in the heat spectrum is high when a gap in the forest canopy is created due to logging or other removal of trees.

This means for this research that only when images are found that have very similar circumstances in relation to humidity and forest cover (foliage), these can be reliably used, which is particularly the case for the second semi-automated method. It is thus still a manual process of trial and error in finding the correct imagery to compare with each other. The trials with Delta-rNBR showed its limitations in the implementation for the Albanian territory by providing very little effective results. Therefore this method is not further pursued.

The effect of seasons becomes more difficult as one of the major obstacles is that the trees (especially in the higher altitudes) must have leaves to be recognisable for analysis. This means the time of the year that an image can be used will depend on the weather, humidity and growing season in that particular year and thus the images early in the year can be problematic for finding forested or logged areas for higher elevated areas in Albania.

As the logging seasons continues towards the end of winter the impact of logging can only be detected in late spring/summer the next year. E.g. to verify the data up to the 2018 logging season, the results can only be seen from imagery of June 2019. Verification is thus something that happens a few months after the year has finished as in winter the logging can not be verified. However if logging happens between July and October, if the images are cloud free the logging can be detected with just 16 day intervals.

The data of 2016 is verified with data as early as possible in 2016 as baseline, keeping in mind that logging continued after the ban on those areas where contracts were given before. However as the Sentinel 2 satellite was just operating in that time frame, not all imagery is usable for analysis. Only after October 2016 the imagery of Sentinel 2 has become more readily available and systematic.

To verify land cover changes over time in this research is done with the imagery from:

- September/October for comparing 2016 – 2017
- June to August for comparing 2017 – 2018
- June for comparing 2018 – 2019 (proposed)

The resulting areas of visible / significant change are overlaid with the areas that are recognized as wooded areas according to the different methods. The results then have to be analysed taking into account that legal logging still is taking place. The official data on logging concessions and the areas concerned (precise geographical location) is required to verify if forest cover change is within legal parameters.

The data regarding legal logging for 2016-17-18 by the respective municipalities only contained the IDs of the different concessions and other details like Cub meters, Ha logged, areas logged, effective result of logging, type of logging (clear-cut or not), tree types, etc. However this data was not linked to geographical related information and thus no clear boundaries of the concessions could be established.

For the purpose of verification it is necessary to know the exact locations of the logging concessions to compare this with the illegal areas of logging, the GIS file of the plots should be found and the link made between the logging concessions and the remote sensing land cover changes between the years.

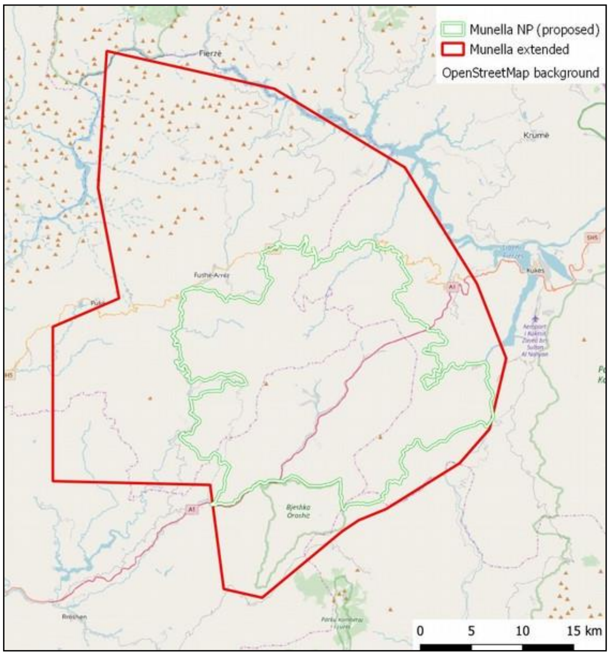
For the comparative analysis of the methodologies in recognition of forest losses between the years the following Sentinel 2 images were used:

- Sentinel 2A L1C of 14-10-2016
- Sentinel 2B L1C of 06-07-2017
- Sentinel 2A L1C of 19-09-2017
- Sentinel 2B L1C of 21-07-2018

4) Results in Munella

Establishment of the pilot area.

The image below indicates the area under investigation in this report. As the interest of PPNEA is specifically in the proposed protected area of Munella Mountain, it is also indicated. To ensure the methodology for verification of logging is not only limited to a (to be established) protected area but rather areas used by people, the Wider Munella area is the pilot area for this report.



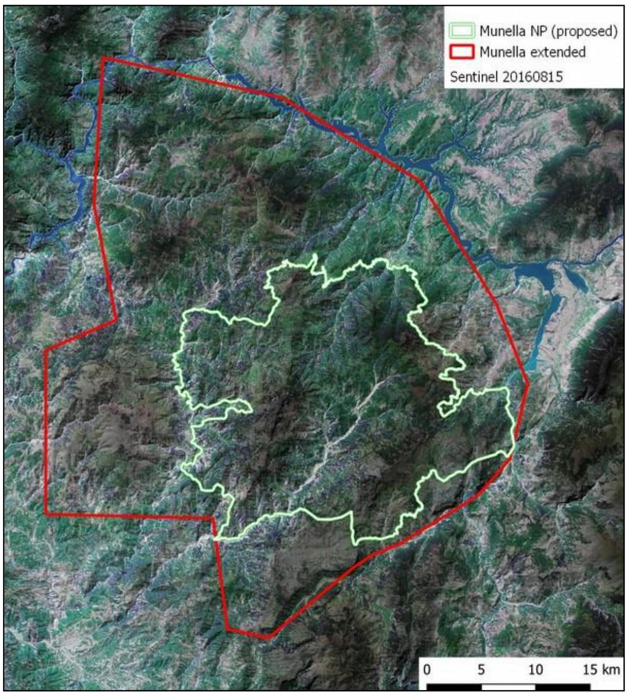


Image 3 & 4: Munella extended region as research area

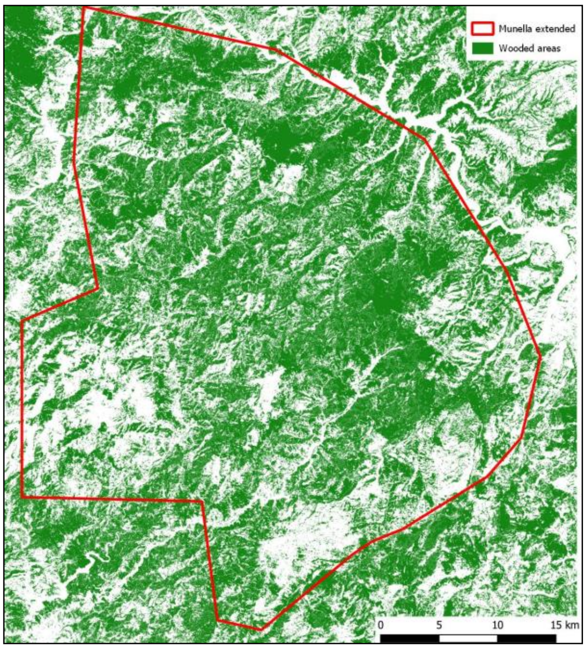
The recognition of forests & wooded areas

The image 5 indicates the wooded areas that were created with the semi-automated classification of the Sentinel imagery of 2016. In this image the classes of Forest and Shrub are combined as logging is taking place in forested and in more open and lower tree canopy areas as well.

The area under investigation (Munella extended) is about 152.000 Ha. The surface of wooded area within is about 86.000 Ha (Image 5). This was the result of the semi-automated classification of 2016.

To verify the results and to check more closely if forests in the region have been logged a combination of 4 Vegetation Index (VI) files is created where in all 4 images the cut-off point was established for forests including shrub. These cut-off points were established with visual verification of wooded areas

Image 5: 'Wooded' areas under investigation



and VI levels. A second parameter used was GPS recorded data of forests and open wooded landscapes in the area by PPNEA staff. The staff recorded the different forest and meadows while being on different trails in the area for their Lynx camera trapping work.

The cut-off points for the following Sentinel Images of the different years were found:

2018-07-21 S2B - NDVI	0.66 – 0.86
2018-07-16 S2A - NDVI	0.69 – 0.85
2017-08-25 S2A - NVDI	0.52 – 0.81
2016-08-15 S2A - NDVI	0.62 – 0.85

By combining the 4 results whereby only the overlapping positive results was taken into account a total area of some 56.100 ha was recognized as being under forest cover up to July 2018 (Image 6). Because this area is recognized as forest in all 4 images it can be concluded that this size indicates the area under full deciduous forest up to 2018.

By combining the 4 results through adding, an image that indicates better which areas are close to forests and shrub but in dry years do not seem to have a fully closed forest layer (Image 7), increasing the area to 97.876 ha. This is the wooded area size.

As the Image of 2018-07-21 is the only S2B image in the list and shows different results, the same combination was made with the 3 VI results taken with the same module. The results (below) show that the final results are quite similar in total forest area when combined and when for all 3 or 4 are positives only.

3 VI images combined	
Forest in no Images	Ha
No forest	55157
1	19429
2	20885
3	56675
Total Forested	**96.989 Ha**

4 VI images combined	
Forest in no Images	Ha
No forest	54270
1	17436
2	10734
3	13605
4	56101
Total Forested	**97.876 Ha**

The four different results for forested/wooded areas seen in images 6, 7, 8 and 9 shows how difficult it is to clearly determine the extend of wooded areas. In general forestry activities in Albania, a forest cover of 30% or more is seen as a forest, or in our case a wooded area. Secondly the cutting of shrub is also forbidden according to the logging ban. Therefore it is in the interest of this research that also the areas where only limited forest/shrubs are recognised are included in the wooded category.

This does have an impact on the size of areas that will be identified having a change in vegetation, i.e. resulting in a larger area being 'deforested'.

Image 6: Forest areas created by combining 4 Vegetation index images combining only positives

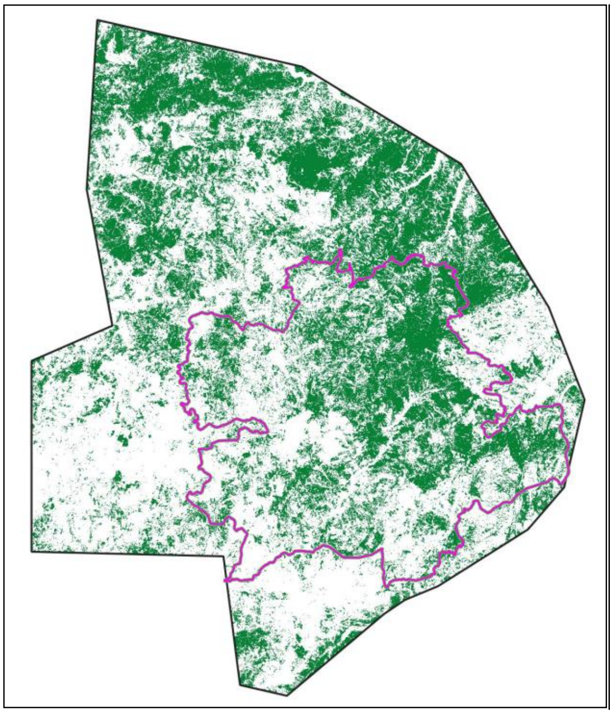


Image 7: Forest areas created by combining 4 Vegetation index images adding all positives

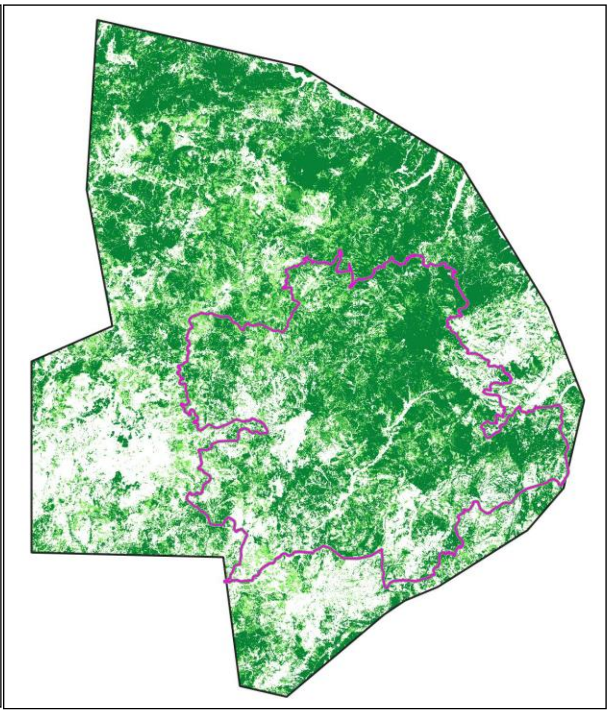


Image 8: Forest areas created by combining 3 Vegetation Index images only positives

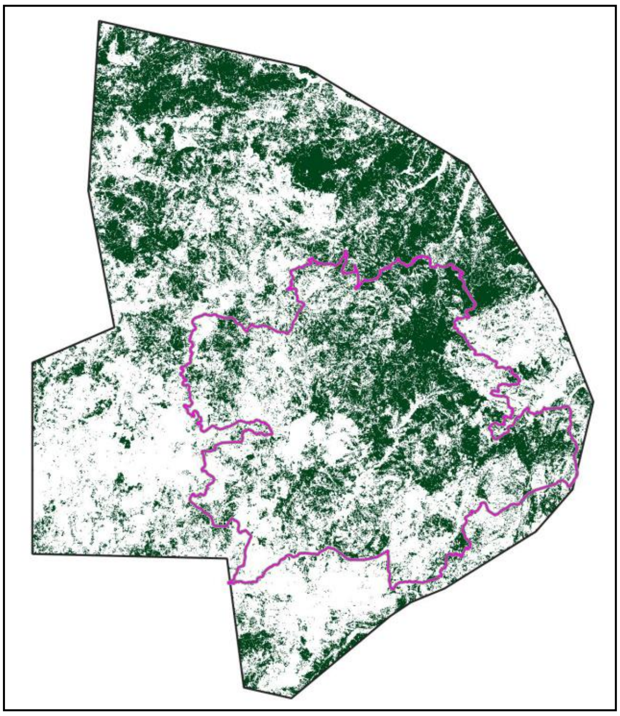
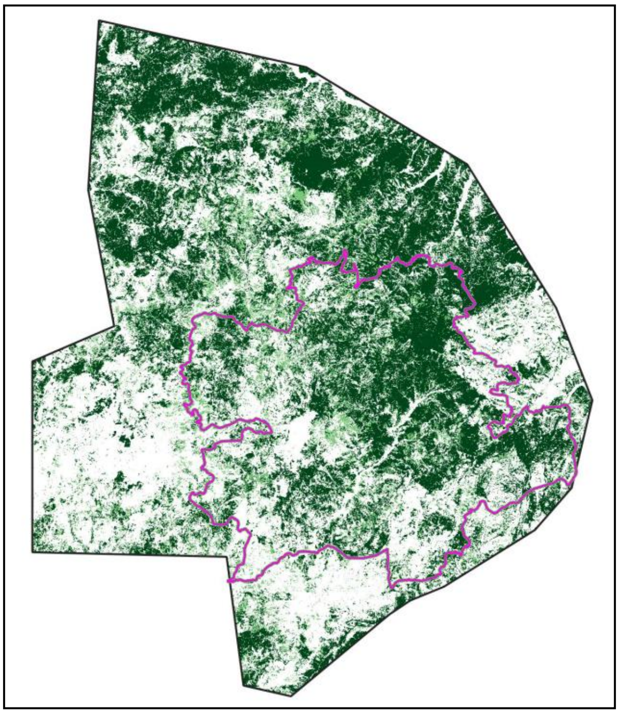


Image 9: Forest areas created by combining 3 Vegetation Index images adding all positives



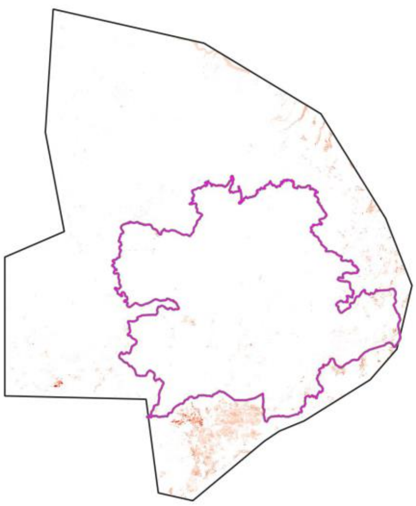
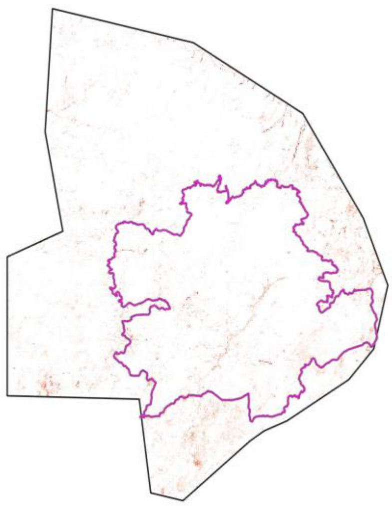
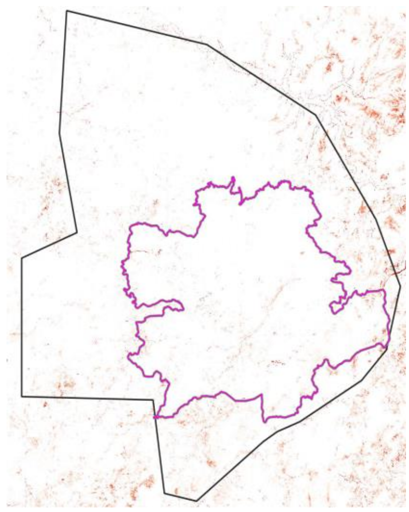
In conclusion based on the results of the different methodologies and verifications done, the estimated forested or wooded areas in the pilot area is about 97.000 ha over a 152.000 ha area.

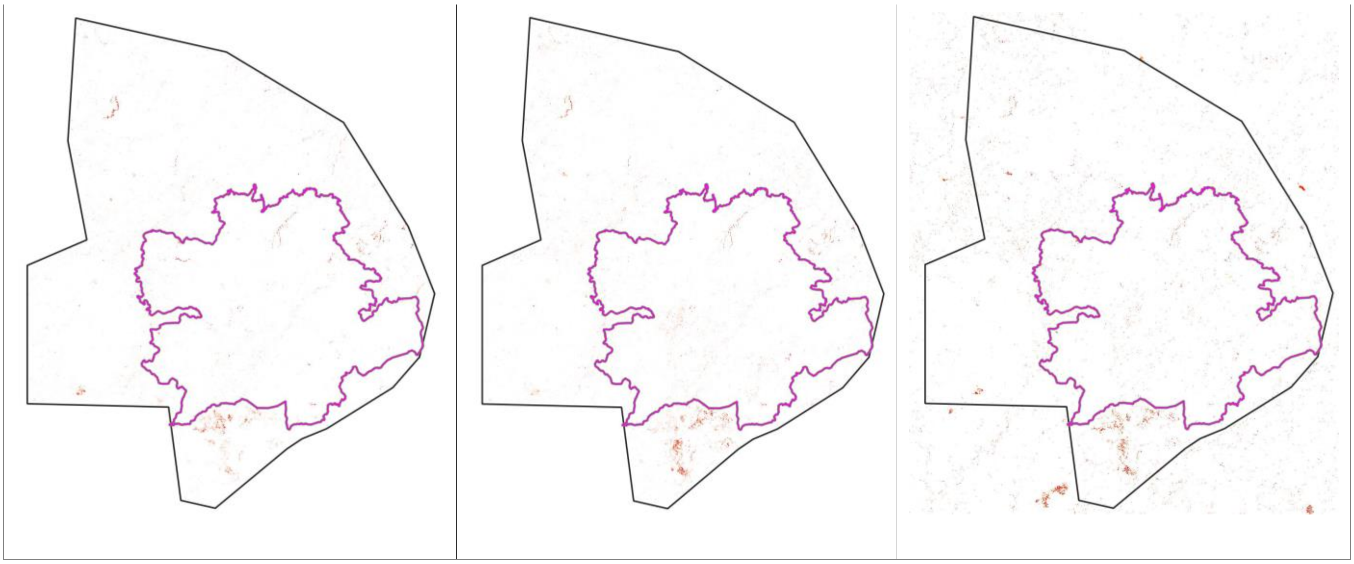
This result shows that it is possible to reasonably estimate forested areas even in topographical challenging areas. With verification of data from the field it has shown that one of the more difficult forest types to assess are pure pine forests located in the shade of a mountain in late summer as these tend to dry out and get Vegetation Index results similar to grassland areas.

Forest loss verification results

The next images indicate the forest changes between different years/logging seasons and with different methodologies. The colour RED is used to indicate the areas where a clear difference between the results was observed. This does not directly indicate that these areas have been subject to deforestation but rather that a clear change was detected.

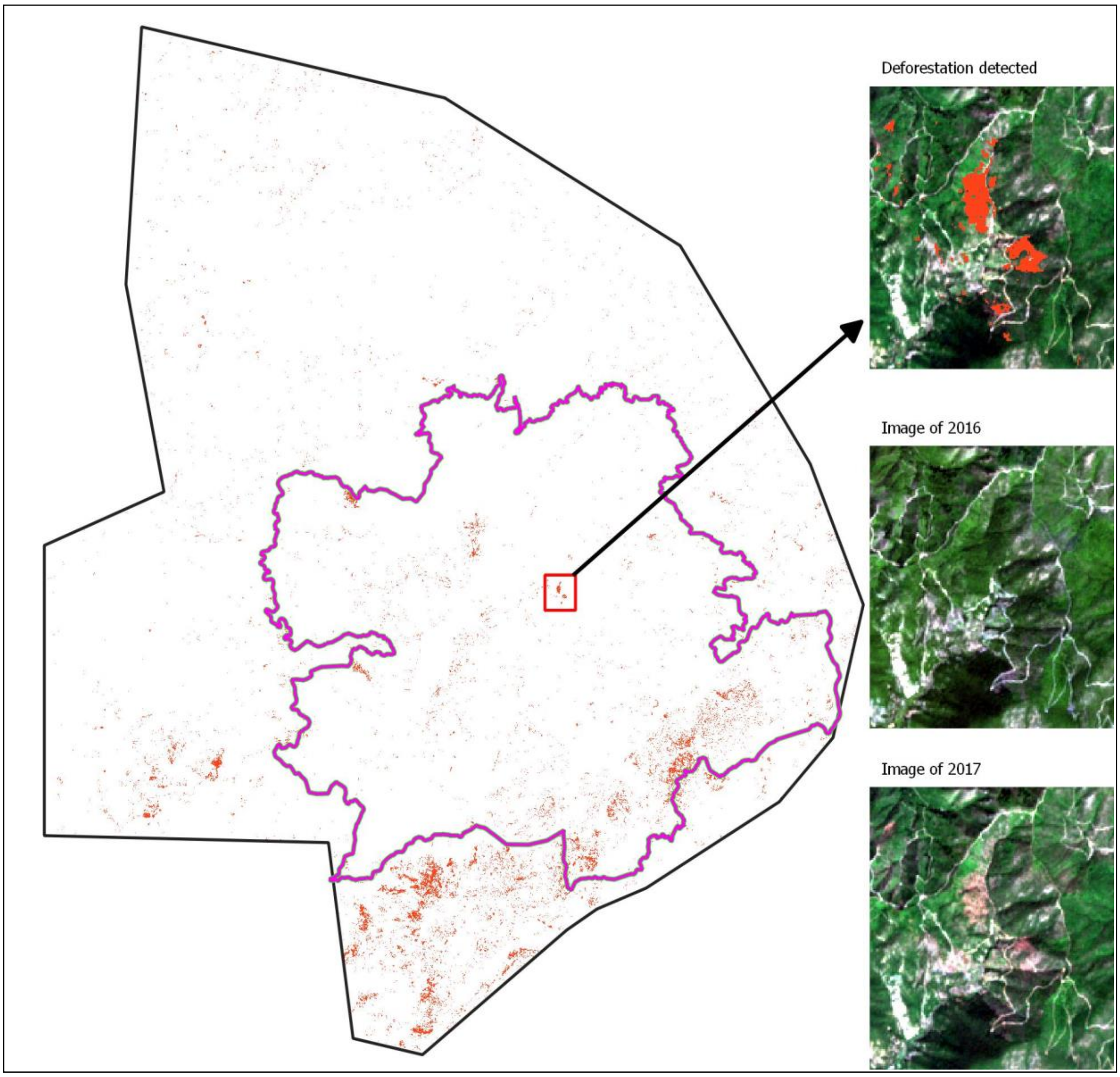
Image 10: Results of change detection in different methodologies and for the years 2016 – 2017 and 2017 – 2018

2016 – 2017 Changes detected		
Vegetation Index	Colour bands (B2,3,4)	F-TEP forest change analysis
		
2017 – 2018 Changes detected		
Vegetation Index	Colour bands (B2,3,4)	F-TEP forest change analysis



Although all three methods were used on the same satellite images, one can identify differences in detection of forest cover changes. In reality the changes identified by the different methods often have to do with drought which is grass and shrub drying out or earth movement which shows up as a clear indication of change. By closely reviewing the results with the colour imagery it is possible to determine which forest areas have been cut, lost to fire or other causes. This is why the next step in the process of checking the results needs to be done manually for the whole area. From the visual comparison of 2017-2018 it is clear that a lot of vegetation loss happened where economic activities/constructions were happening including road constructions. For the logging season of 2016 there is a lot of areas in the West and South-West that have been burned but in other areas clearly mature forests are logged. In comparison with the logging season of 2017 it is visible that the logging season of 2016 has had higher volumes of logging in many areas but in 2017-2018 there was more construction.

Image 11: Deforestation result between 2016 and 2017, from NDVI comparison overlaid with NDVI of 3 images forest cover (manual system)



The final step is to overlay the forest changes with the 'wooded areas' and verify the result with the Imagery of the different years to see if it is visible that actual logging has taken place.

For the final analysis of the forest change only the F-TEP and comparison of NDVI results are considered as the colour bands comparison seems to indicate a lot of false positives probably due to changes in the weather and humidity. The Delta-NBR method has already shown it's limitations and is thus no longer pursued.

From the visual verification of the results between different methods, the comparison of the change between 2016-17 works well with NDVI. Overlaying the result with the combined NDVI of 3 images for wooded areas the resulting sizes are:

No (forest) change: 150.211 Ha
Forest change: 1937 Ha

Image 11 has some clear areas where deforestation took place but also a lager area in the south where the depletion of the forest seems to be caused by a big fire. The 1937 Ha forest loss is thus not only from deforestation but also other causes.

With the same procedure for the comparison between 2017 and 2018 with NDVI comparison and the combined NVDI of 3 images for forest the result is:

No (forest) change: 150.389 Ha
Forest change: 1846 Ha

While this seems less than in 2016-17 there were some clear differences in 2017-2018 like roads being build where trees were cut, and the forested areas destroyed due to fire was not included in this logging season.

Interestingly the result from the F-TEP verification overlaid with the combined NDVI of 3 images for forest shows a higher decline of forest change.

F-TEP 2016-17 verification with 3 images forest areas:

No (forest) change: 150.133 Ha
Forest change: 2008 Ha

F-TEP 2017-18 verification with 3 images forest areas:

No (forest) change: 151.032 Ha
Forest change: 1110 Ha

This difference in results can be attributed to the different methods but also the levels at which the cut-off is manually set. Only via verification of forest change in the field even more precise cut-off points can be established.

Visibly the results are very similar but in the areas devastated from the forest fires in 2016-2017 the methods differ in recognition of trees which were dead/cut by 2018. The opposite can also be identified where deforestation on the same area is visible in both logging seasons. Although this is only in in a few small areas it is interesting that this is a result of the analysis.

It is thus possible to verify logging but it is difficult to give a precise number of hectares that has been logged within a larger area and. To be sure which areas are cut, which are burned or what change has happened one needs field verification of many different locations, which is labour intensive.

The legal and illegal forest activities are not further verified as the geographical data of the legal forest logging areas (parcels with precise location) under the municipal logging quota are not available. This could have helped to verify the accuracy of the comparison results between the years.

The results for the proposed Munella National Park with the NDVI change analysis overlaid onto the combined NDVI of 3 layers for wooded area, the logging season of 2016-2017 had 729 Ha forest loss and in 2017-2018 only 555 Ha within the boundaries of the park (area: 84.200 Ha of which 35.000 Ha wooded).

Although the numbers seem nice to have, not each area of suspected forest loss was verified by reviewing RS imagery as this requires much more detailed work and a final review in the field. These number should thus be used with caution.

5) Appropriate methodology

From the test done with the different methodologies both the 'manual' NDVI method and the F-TEP procedures complement each other. However as the semi-automated analysis are improving by the year, a close eye should be kept on these developments and regularly verified. In any case, the semi-automated system via F-TEP is so easy to perform that it is useful as a first verification before starting with the NDVI method which is labour intensive.

The comparison of the visual bands does not give very accurate indication of vegetation change and the Delta-rNBR methodology is focussed on tropical regions. When used on the territory of Albania it shows results picking up on differences that are created by drought rather than vegetation loss. Besides this, it is a paid service. This is only a viable method when the resulting forest loss is directly reacted upon by investigations and law enforcement.

When checking two images from the same year (2016 July and October) F-TEP already recognized logging areas. In this way relatively up-to-date information can be provided for the summer and autumn when logging activities have started. Provided imagery without cloud cover can be found, every 16 days the images can be checked for ongoing logging.

From the analysis it also is clear that at this moment the best method is still manually with the NDVI comparisons overlaid on a clear image with the forest coverage, or rather the forests and shrub areas that need to be protected.

6) Conclusion

The objective of this study was threefold; if it is possible to verify logging with Remote Sensing for a larger area; which methodology is best or easier to use and to verify if the logging ban is being upheld.

It is clear from the data that the logging ban has it's impact on logging (less and smaller areas) but it is also clear that logging continues, legally and/or illegally. Problematic are the sizes of logging areas for the analysis. The results show small scale logging is happening in many areas (indicative of illegal logging) but the results also show a lower total volume.

It is recommendable to continue the verification of the target area for at least one more year where the difference between 2018 and 2019 can be established as well as verifying if between the months from June to October in year 2019 logging can be identified correctly and verified in the field.

The results of the RS for both wooded areas and forest cover change needs also to be more precisely verified on the ground to have a better indication of the accuracy of logging indications. This verification of accuracy was not part of this study.

The geographical data related to legal logging (concessions agreed by Municipalities) was not available so a verification of the results with the known logging areas was not possible. This lack of data is important to rectify as otherwise legal and illegal logging can not be verified and acted upon.

Semi-automated methodologies for checking logging or deforestation are improving at a rapid rate as different conservation mechanisms are tried (like REDD+). At this moment the best methodology is a combination of F-TEP and manual NDVI comparison. The NDVI manual comparison is relatively precise and useful in the region. The F-TEP is useful due to its simplicity, minimal time consumption and repeatability also for non-expert GIS users. When these two methods are used in combination with each other it may help to limit the sites which need to be verified in the field.

The results have also shown to be difficult in two issues; size of the area to be covered and a precise distinction of wooded areas. To do an interpretation over a large area, especially in mountainous terrain where valleys may be in the shade on some images, will result in a massive job with many places to be verified in the field for accuracy. Also the detection of pine forests is difficult in dry spells as these reflect little with the NDVI and thus seem to be grassland areas. However this has no influence on the result of change detection.

If one was willing to monitor the whole country, at least one person should be made full time available for the GIS-RS work while field staff should be available to verify deforestation activities in the field in a timely manner and provide feedback to improve the detection of wooded areas. Much of the fieldwork should fall within standard operations (daily activities) of Forestry Authorities and thus require little extra time, limiting the costs.

The different results for wooded areas (vs. forests) show how difficult it can be to interpret what is under investigation. Especially shrub land and 'open' forest areas are difficult to recognize and therefore often need further assessment if these are actually deforested.