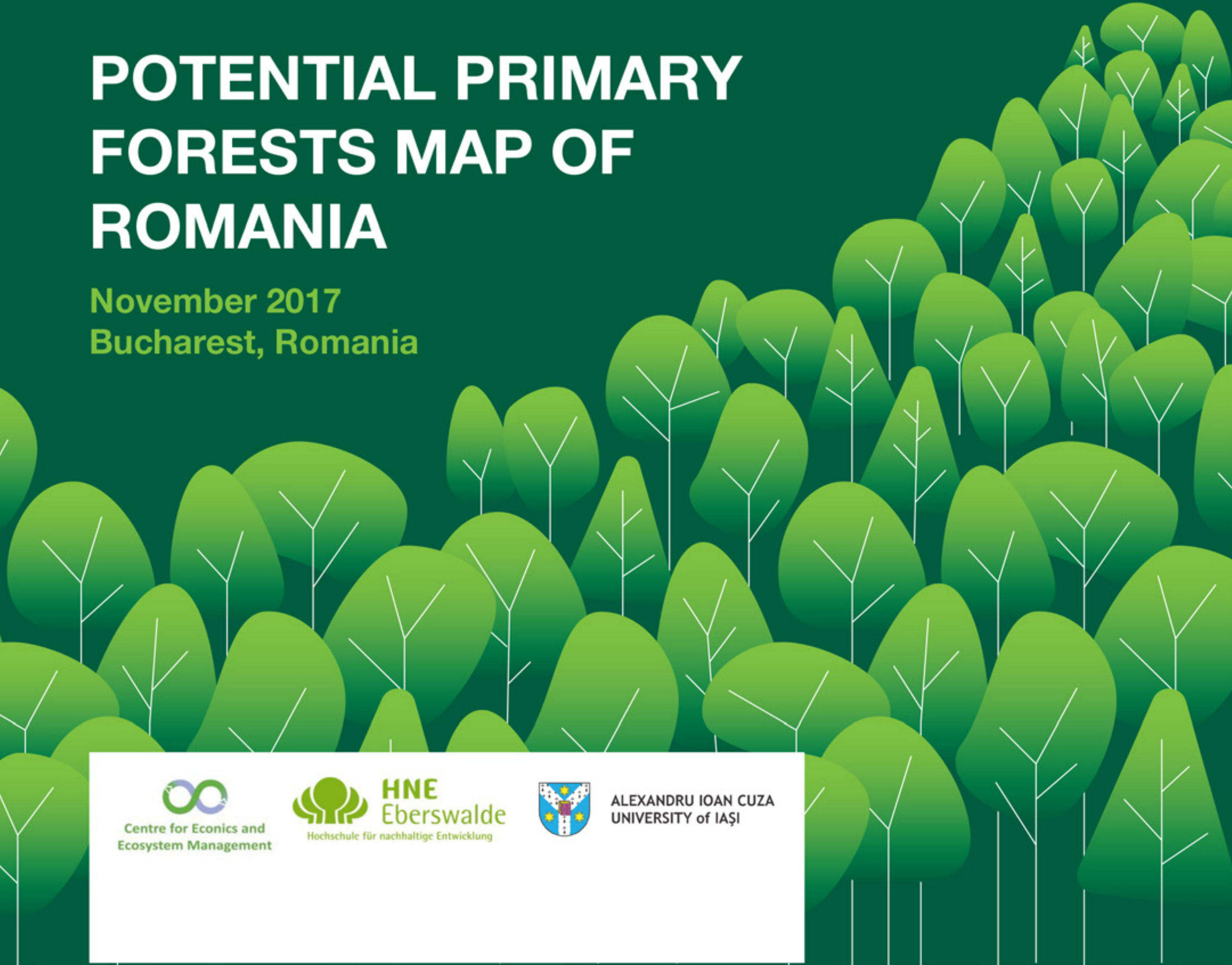
POTENTIAL PRIMARY FORESTS MAP OF ROMANIA

November 2017
Bucharest, Romania



Centre for Econics and Ecosystem Management

HNE Eberswalde
Hochschule für nachhaltige Entwicklung

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Contents

Primary forests protection in Romania

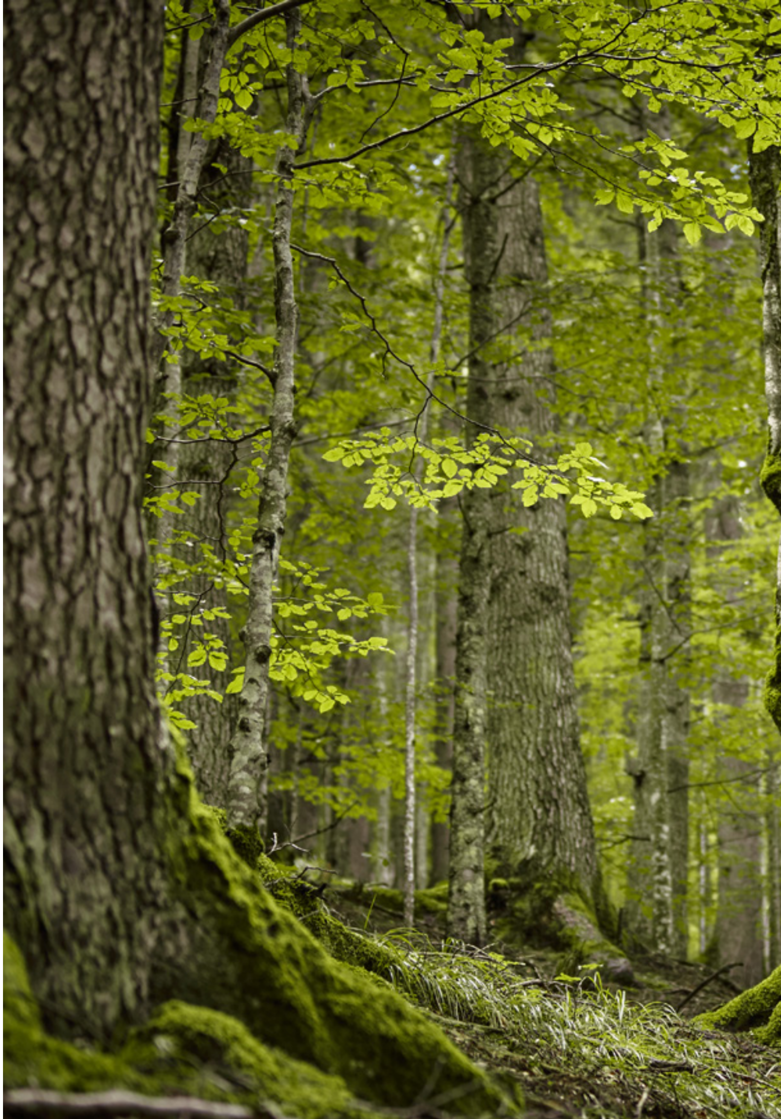
Iovu - Adrian Biriș

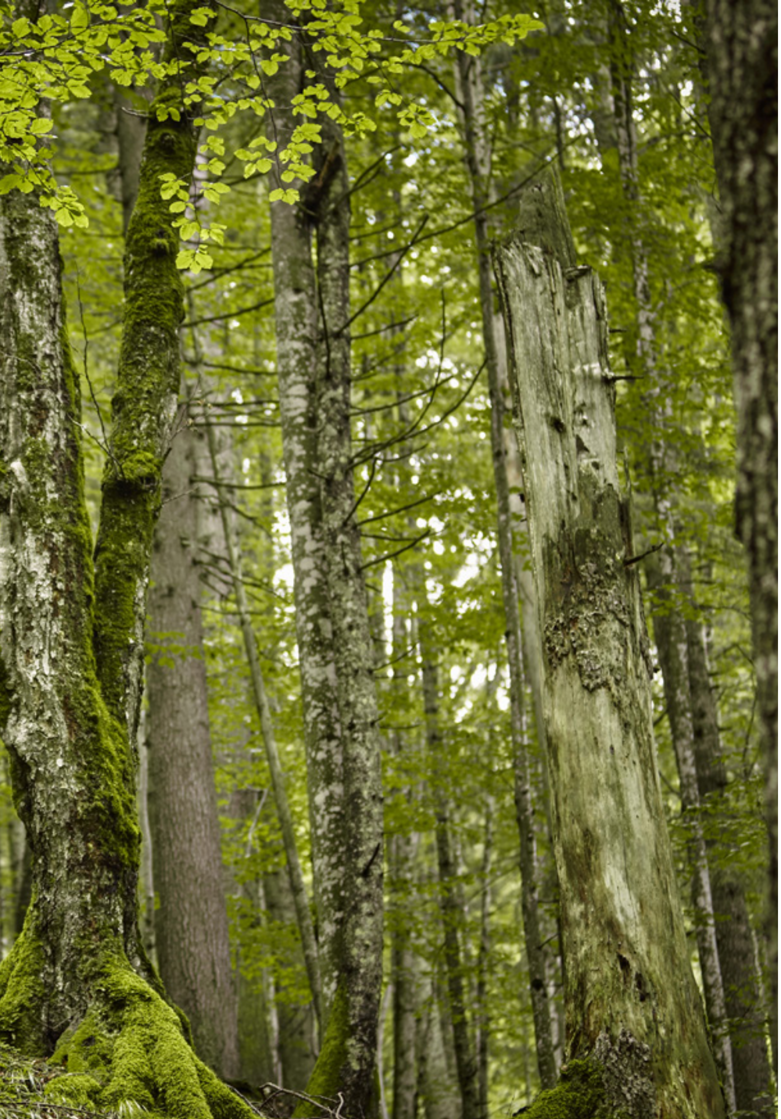
In the last century, the topic of protecting the virgin forests[1] has constantly/continuously been both on the agenda of the environment and forestry studies' scientific community and of the environmental organisations from Romania and the world. Not only the scientific arguments but also the perseverance in supporting the role and the importance of their protection have convinced the decision factors/powers from the forestry industry to give this objective the chance it needed. At first it was a rather vague idea – a matter of principle; but it has slowly become more and more achievable once the tools and the procedures for the protection of forests were implemented.

Between 2000 and 2008, a series of stipulations concerning the protection of virgin forests existed on paper as declarations without being taken to an operational level in order to produce concrete results. However, they were included in official or normative/bounding documents: e.g. The policy and the development strategy of the forest sector in Romania between 2001 – 2010 (MAPPM, 2000) , The technical standards/norms for forest administration, approved by the ministerial order 1672/2000 (MAPPM, 2000) , The Forest Code (law no. 46/2008).

Following a massive communication campaign – Save the Virgin Forests! – which received incredible support from the public, the forest legislation for

1. To be consistent with the Romanian legal terminology "virgin" is used below as an equivalent for primary.





the protection of the virgin forests was gradually approved between 2012 and 2016. Thus, in September 2012, the Forest and Environment Ministry passed the ministerial order no. 3397/2012 establishing the criteria and the identification indicators of Romania's virgin forests. In 2015, law no. 133/2015, which modified and completed law no. 46/2008 – The Forest Code, stipulated the strict protection of the virgin and quasi-virgin forests and the creation of the «National Catalogue of Virgin and Quasi-virgin Forests» (art.26 line 3). Then, in 2016, by the order of the Environment, Water and Forests Ministry no. 1417/11.07.2016, the creation of the National Catalogue/Register of Virgin and Quasi-virgin Forests was approved as an instrument of cataloguing and managing Romania's virgin and quasi-virgin forests – just like they are defined in the annex of the Environment, Water and Forests Ministry's order no. 3397/2012 which established the criteria and the identification indicators of Romania's virgin and quasi-virgin forests.

Once the ministerial order no. 1417/11.07.2016 was applied/executed, it revealed a series of deficiencies which complicated the process of identifying and mapping the virgin forests. Therefore, it has been replaced by the Environment, Water and Forests Ministry's order no. 2525/31.12.2016.

Thus, the legal requirements and the tools for the identification and protection of the virgin and quasi-virgin forests in Romania were created between 2012-2016. However, the implementation of the legislation concerning the strict protection of the virgin forests proved to be quite difficult because the people who were in charge of performing it showed indifference, lack of involvement and even unwillingness to apply it. Although the ministerial order no. 3397/2012 offers the administrators the tool to identify the virgin and quasi-virgin forests for their inclusion in the appropriate forest classification to ensure their strict protection, the implementation of the legislative requirements was completely ignored by them. Relatively only small areas have been classified as virgin or quasi-virgin forests, often as a result of the evidence provided by the public. At the same time, although the order no. 2525/2016 foresees the obligation of the administrator / provider of forest services to 'communicate to the specialised territorial structure of the central public authority in charge of forest management the information regarding the placement and the surface of the identified forest and to stop any forest works in the area' if 'he/she identifies in his/her administrative area a forest that meets the criteria and the indicators specified by the Environment, Water and Forests Ministry's order no. 3397/2012', even this provision has been ignored by those people in charge.

Although there is a coherent and an adequate legal structure for the identification and the protection of the virgin forests and both the state owned and private forests administrations, including the certified operators, are in possession of all the necessary information required to establish if a forest meets the criteria and the indicators to be declared a virgin or quasi-virgin forest, the responsible parties haven't fulfilled their obligations required by the law. What is more, some owners or administrators / forest service providers procrastinate on purpose to protect them or even 'force' forest work so that the forest wouldn't correspond to the requirements that would classify them as virgin or quasi-virgin forests. All these happen under the 'supervision' of the territorial structures that belong to the central public authority who is in charge of forest management and who watch helplessly or even pretend not to see/notice when the virgin forest protection legislation is being ignored.

The information presented above shows without a doubt that the bottom-up approach regarding the identification and protection of virgin and quasi-virgin forests, which is the main type of approach suggested by the law, hasn't led to the expected results/ hasn't worked, of course with some exceptions, because of the lack of interest or lack of involvement of the people and institutions in charge.

The environmental non-governmental organisations (NGOs) have demanded a speedy/an urgent implementation of the law regarding the protection of virgin and quasi-virgin forests; therefore, at the end of 2016, the central public authority responsible with forestry initiated a governmental decision that would use the Environmental Fund to finance a study for the identification of Romania's virgin and quasi-virgin forests in order to enlist them in the "National Catalogue of Virgin and Quasi-virgin Forests". The budget allocated to this project was 2.58 million lei/RON.

This kind of a top-down approach would have accelerated the process if a general enforcement of the legal requirements regarding the protection of the virgin and quasi-virgin forests had been implemented in the entire country. The necessity of a project for the identification and mapping of these forests, rolled out on a national level, has been acknowledged by all the parties involved. Unfortunately, this initiative has been abandoned / postponed by the new decisional board of the Environment, Water and Forests Ministry assembled at the beginning of 2017. Thus, no steps have been taken towards this until the present moment. Any delay in the implementation of such a project, whether deliberate or caused by incompetence/irresponsibility/idleness on behalf of the authorities, means

the irreversible loss of large areas of virgin forests.

More than a year after the legislation concerning the protection of virgin and quasi-virgin forests has been adopted, we sadly ascertain that quite a small surface of forests has been included in the National Catalogue. On the other hand, concern rises at the alarming rate of their destruction.

The facts presented above clearly illustrate why the mapping of the virgin and quasi-virgin forests is essential for their protection. The forest surfaces which are to be protected must be identified and located with precision, so they can be included in foundation studies and added to the National Catalogue.

Such an action is especially necessary and urgent as the last time these forests were catalogued was between 2001-2004, approximately 15 years ago. Meanwhile, Romania's forests have gone through quit a tumultuous period: their restitution to the ex-owners, the diversification of the property's structure and the fragmentation of forest property, the roads created to access the virgin forests' basinets to explore them, illegal deforestation etc. All of these have affected the virgin forest areas, which had already been catalogued, to such an extent that they no longer correspond to the selection criteria anymore.

In fact, the work methodology regarding the identification of the virgin and quasi-virgin forests (Annex 3, ministerial order no. 2525/2016) mentions as a preliminary analysis stage a screening / and investigation that must be performed using satellite information or orthophoto-plans for the configuration of forest surfaces which have the potential to meet the identification criteria of virgin and quasi-virgin forests. (Ministerial order no.

2525/2016, Annex 3, Stage 2. The preliminary analysis: “At this stage we use specific office methods to identify the surfaces affected by human intervention which do not meet the natural criteria and, as such, are to be excluded from the documentation required for the next stage. The areas constituted in stage 1 are to be analysed with the help of satellite images or orthophoto-plans provided by the executor of the foundation studies, e.g. Google Maps, Bing Maps etc.).

Currently, the main challenge regarding the protection of the virgin forests is the development of concrete activities that should focus on the identification and localization of areas which have a high potential of fostering virgin and quasi-virgin forests throughout the country or in the Carpathian Mountains. The creation of such a map / geo-spatial database would allow the focus of resources and efforts of all the parties involved on a smaller surface which has a higher probability of accommodating forests with a high degree of naturalness.

The initiative of Greenpeace Romania to create a complete / comprehensive map of the areas that have high potential to house virgin and quasi-virgin forests comes as an answer to the urgent and concrete need regarding their protection, and represents an extremely useful tool in the identification of those areas / surfaces with forests which appear to meet the naturalness criteria.

The aim of the study is represented by the creation of a geo-spatial database/maps of potential primary forests / old-growth forests, which have a high degree of naturalness and the potential to present a primary / virgin or quasi-virgin characteristic, specified in Romania’s Carpathian Convention.

The methodology used for the development of this map / geo-spatial database has a scientific foundation both from the point of view of the sets of data used and also the methods used for its processing, analysis and interpretation. All the data used in the study such as: Sentinel 2 satellite images, the digital rendering of the ground, high-resolution images from Google Earth, the limits of the area falling under the Carpathian Convention, comes from open sources, verifiable, official or scientifically validated at an international level, available on request or freely. The methods used for the processing, analysis and interpretation of data are enlisted with all the required information, so they can be verified and reproduced. From the practical point of view, the methodology used combines the supervised classification with the assisted one which has allowed for the delimitation of areas / surfaces occupied by old-growth forests. They have a high probability of accommodating forests with a high degree of naturalness / virgin or quasi-virgin.

The result of the study should be followed-up by a ground analysis in order to analyse the meeting of the tools and criteria for the identification of virgin and quasi-virgin forests and to exclude the surfaces that might not qualify. The limitation of the study is mainly caused by the lack of information from the forest administration regarding the human interference that happened in the past as well as the forest division layer required to cut out the identified areas / polygons on the surface lines or surface parts. The lack of information from the forest administration has partially been compensated by using some data or algorithms for the exclusion of the forests which seem not to meet the naturalness criteria, such as coniferous plantations outside their natural areas, pure coniferous plantations growing in the subfloor of forests which mix beech and softwood, the surfaces that have been affected by forest loss in the last 15 years, and the surfaces that include transportation routes / roads / cableways. However, it is important to specify that the use of the data and algorithms mentioned before does not guarantee the total exclusion of areas which do not meet the naturalness criteria from old-growth forests which present the potential of being primary / virgin or quasi-virgin.

In spite of the limitations already mentioned, which are to be expected in such a large study aimed to cover the entire area of the Carpathian Convention, which hasn't benefitted from the information regarding human intervention noted by the forest administrations, the obtained results can be considered quite consistent and especially useful to all the parties that have the responsibility to implement the legal requirements regarding virgin forests as well as those interested to get involved in their identification and protection.

In the last decade, the identification and protection of forests with a high degree of naturalness has become a regional and European interest.

From the point of view of the Carpathian Region, the Protocol related to the durable management of forests, which was adopted on the 27th May 2011 and was part of the Convention regarding the protection and durable development of the Carpathian Mountains, stipulates in art. 10 line 1 that "each Party is to pass their own legislation at a national level for the identification and protection of natural forests, especially the virgin ones from the Carpathians, by assigning natural areas that are sufficiently protected from the perspective of numbers and surface and by implementing other specific measures of protection".

Quite recently, the Wild Europe organisation has initiated and coordinated the elaboration of a "Strategy for the protection of Europe's old-growth forests", aiming to save the last areas of virgin forests from the European continent. One of the goals of this strategy is to create a geo-spatial database / interactive map of forests with a high degree of naturalness. This platform, known as "The Last European ancient Forest (LEAF)", will be the foundation for the development of an Early Warning System for the identification and the prevention of threats concerning these forests (https://www.wildeurope.org/index.php/wild-areas/old-growth-forest-protection-strategy).

By taking concrete actions for the protection of virgin forests such as: the creation of an adequate legislation, the implementation of practical measures of protection, the development of a mapping methodology and of interactive maps, providing compensation payments, Romania has demonstrated its dedication to accomplish this endeavour. Thus, Romania could become a best practice example to be adopted by the rest of Europe.

Romania's key role in the conservation of European primary forests

Pierre L. Ibisch

Centre for Econics and Ecosystem Management at Eberswalde University for Sustainable Development

European Beech Forest Network

For a long time, in the history of European nature conservation, forests and especially ancient and primary forests have been seriously neglected. In many regions, forests had been severely reduced and degraded in earlier centuries, before they were partly reestablished and/or managed. It seemed to be a given fact that Europe would have responsibility for mainly conserving cultural landscapes, severely modified by human action, reflecting more or less historical land uses and harbouring many species that would have come to Europe with or after the introduction of agriculture. The conservation of forests and wilderness areas was an issue to be delegated to tropical or boreal countries. Indeed, in most European countries, the ancient and primeval forests – originally and potentially representing the vastest and continuous ecosystem complex across the whole continent - have entirely vanished or been reduced to more or less small remnant patches.

The different ancient and primeval forests help us to understand that ancientness is somehow relative. Of course, many primeval forests in Europe are 'just' a few thousand years old, and developed in parallel to humans colonizing and changing the European land. Topography, political processes and special land tenure patterns contributed to their protection. Ancient and primeval forests are also a key component of the European heritage and identity. Therefore, it has been a great achievement that the serial UNESCO World Natural Heritage property dedicated to the Primeval Beech Forests of the Carpathians caused a steep increase of attention given to this ecosystem type. The extensions achieved in 2011 and 2017 that led to the establishment of the largest and most complex transnational World Heritage property, confirm the growing interest in and importance of preserving these ‚crown jewels' of European forests, now called Ancient and Primeval Beech Forests of the Carpathians and Other Regions of Europe stretching over 12 countries (Albania, Austria, Belgium, Bulgaria, Croatia, Germany, Italy, Romania, Slovakia, Slovenia, Spain, Ukraine). The Europe-wide screening process in search of appropriate sites to be included (Ibisch et al. 2017), inspired the foundation of a network that comprises scientists, protected area managers, organizations and citizens from all over the continent, the European Beech Forest Network.

The values of ancient and primeval forests, all too often, were recognized when it was (almost) too late. Today, many of them represent top priority areas, which receive much attention from conservationists, visitors and scientists. Beyond being unique and irreplaceable reserves for biodiversity that has been lost elsewhere, the values of ancient and primeval forests refer to their multiple cultural and regulating ecosystem services they provide to humans. Many of the first component parts of the World Heritage property to be established (in Ukraine, Slovak Republic and Germany) have already witnessed how the public attention and touristic relevance can contribute to local sustainable development. Amongst others, primeval forests also represent natural laboratories that can inform our ecosystem management; they are the baseline to our managed forests, and are likely to provide 'nature-based solutions' to future problems.

In many parts of Europe we have built our economic richness on the ruins of the natural ecosystems, and the loss of ecological functionality is compensated by the ongoing import of goods and services from others parts of the world, ever more externalizing environmental costs. Whilst this has to be stopped, and Europe has to learn to live wisely and sustainably from its own resources, as a region with a relatively high population density, it has to show to the World that the universal task of nature conservation must and can be achieved everywhere – without losing out economically and socially. For natural and historical reasons, the Carpathians are the core area of the current European ancient and primeval forests. The growing European Beech Forest Network appreciates that Romania became part of the joint pan-European endeavour adding precious and ecologically important Carpathian forests to the serial World Natural Heritage property. Romania is the country with the largest extent of old European beech forests; and it is also amongst the country with the highest loss rates. It seems to be a little unfair that the Carpathian countries that somehow did not damage their natural heritage in the past (as much as others did), now have a relatively higher responsibility for preserving the ancient forests. A business logic could be that Romania has the right to degrade its ecosystems for boosting socioeconomic development, as it was done in the past in Germany, the Netherlands, Belgium and many other countries. Indeed, Romania has the sovereign right to repeat the same mistakes committed by other nations. But it has also the opportunity to come up with a new approach and turn towards a more ecosystem-based model of sustainable development. Romania has a key role in the conservation of European forests – and a key opportunity to be Europe's sustainable forest country No. 1.

On our European continent, those countries that are responsible for a substantial share of past biodiversity loss and ongoing 'nature consumption' also outside their national territories, and therefore may have even gained some development advantages, have the duty to collaborate with others empowering them to develop in a truly sustainable way without further damaging our continental natural heritage. Clearly, in Europe we need new strategies and instruments for sharing short-term socioeconomic burdens related to preserving ecosystems and the services they provide and thereby investing in a sustainable future. The fundament for further building a coherent European conservation system that can also financially support states and regions with special challenges and responsibilities, will be a good and transparent knowledge of the distribution and extent of the natural treasures at stake. Therefore, we were very happy to support the current mapping exercise that will be another input for creating an informed discourse on the conservation of ancient and primeval forests in Romania.

Why a Primary Forests Potential Map?

Valentin Sălăgeanu
Greenpeace România

The completion of the National Catalogue of Virgin and Quas-virgin Forest could be easily achieved if the authority in charge truly accepted thieir responsibility. The process would begin with the evaluation of the data existent in forest administrations found either directly in the archives of the Ministry of Water and Forest, or in each Forest Area, followed by a proper ground analysis operated by the specially instructed staff of the Forest Guards, and would end up being validated by the Technical Committee of Forest Approvals (CTAS), the highest specialist commission.

The process would not have to start anew, since a partial classification has been already done between 2001 and 2004. The National Research and Development Forest Institute 'Marin Drăcea' (ICAS at that time) has undertaken, with external financial aids, a project for the identification of Romania's primary forests. Almost 220.000 ha have been mapped, without counting the surfaces smaller than 50 ha.

Today we have the benefit of a national legislation, which creates a norm for the processes of identification and protection of Romania's and Europe's invaluable natural patrimony, which also belongs to the world, as proven by the recent inclusion of over 24000 ha of Romanian virgin beech forests in the world patrimony of UNESCO.

However, the process of saving the virgin forests is being halted by the lack of interest from the authorities in charge. Unfortunately, the Water and Forest Ministry's lethargy justifies the inaction of the other involved parties when it comes to following the law. This evident lack of responsibility results in the huge loss of an important surface of one of nature's last refuges and an irreparable decline in its biodiversity.

The map of potential virgin forests that has been produced by Greenpeace Romania in partnership with the Centre for Econics and Ecosystem Management at Eberswalde University for Sustainable Development from Germany, and University Alexandru Ioan Cuza from Iași is the first stage in the protection process of these forests (ministerial order 2525/2016, Annex 3). The purpose of this first analysis based on satellite images is to evaluate the state of the forests, in order to eliminate the degraded areas, which do not correspond to the identification criteria and in order to define and create an hierarchy for the next stages of documentation and final ground evaluation.

We have to underline that the methodology developed for the Primary Forest Potential Map of Romania is perfectible and that, as such, this exercise can be continued.

We expect this exercise to be considered a call to action by the Ministry of Water and Forest, for fast and concrete decisions towards saving Romania's virgin forests.

Results

Bucharest Surface
22.800 ha

Potential Primary Forests
295.779 ha

19%
overlaps Pin-Matra forests

Top Protected Areas of Potential Primary Forests

59%
are found in SCI

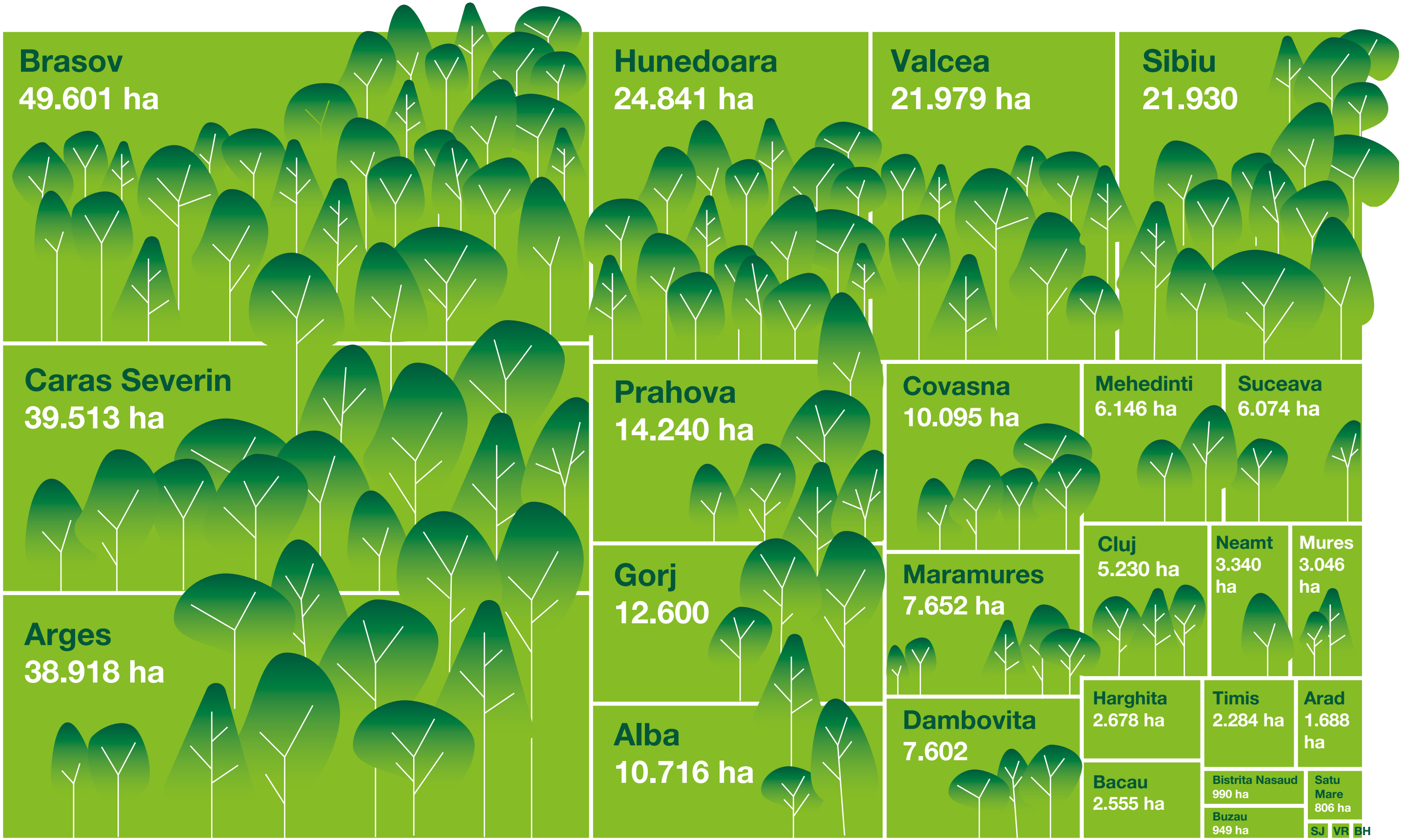
Făgăraș Mountains
61.423 ha

13%
are found in National Parks

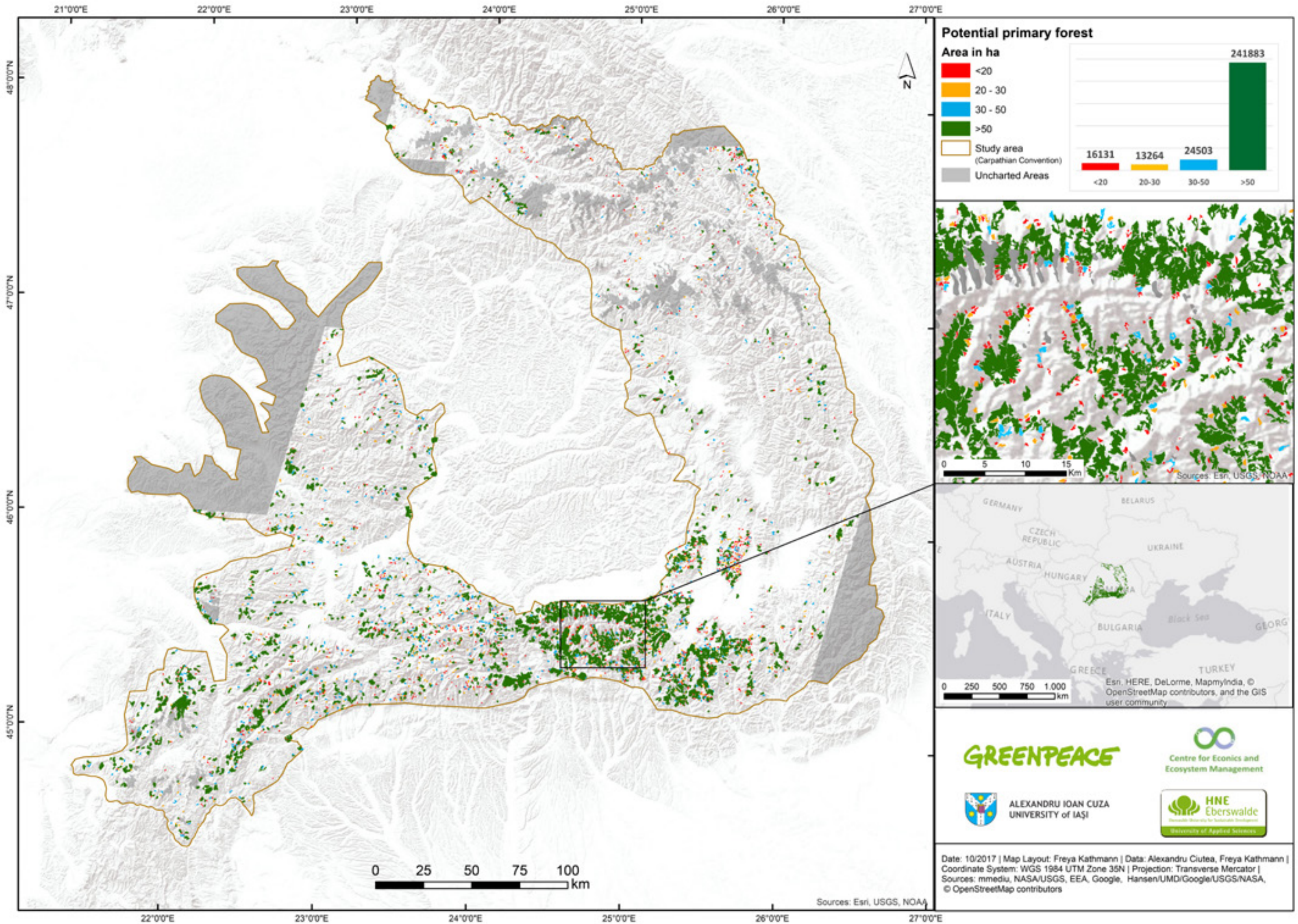
Domogled - Valea Cernei
11.555 ha

4% are Potential Primary Forests in UNESCO designated sites (ha)

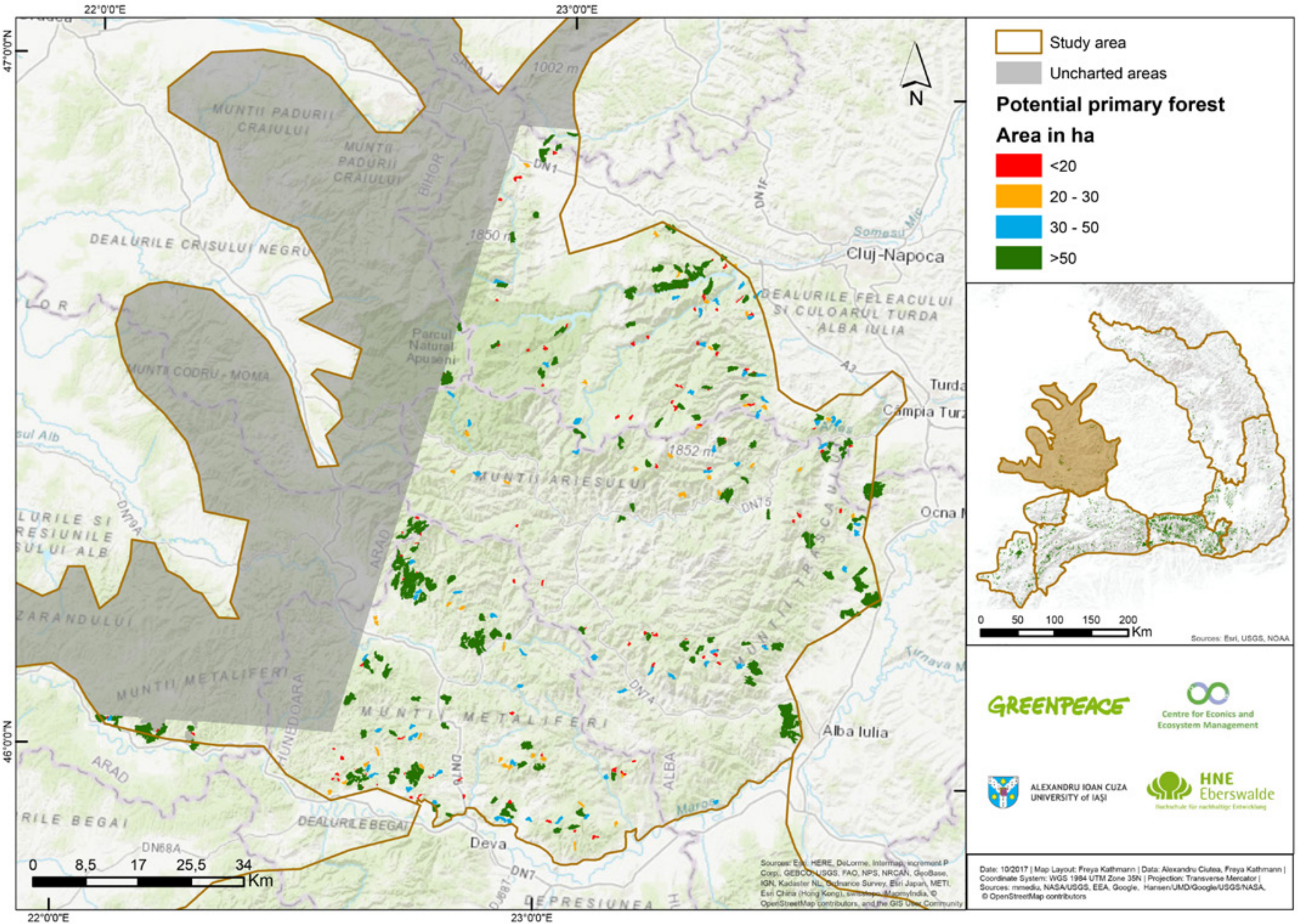
Top Counties with Potential Primary Forests



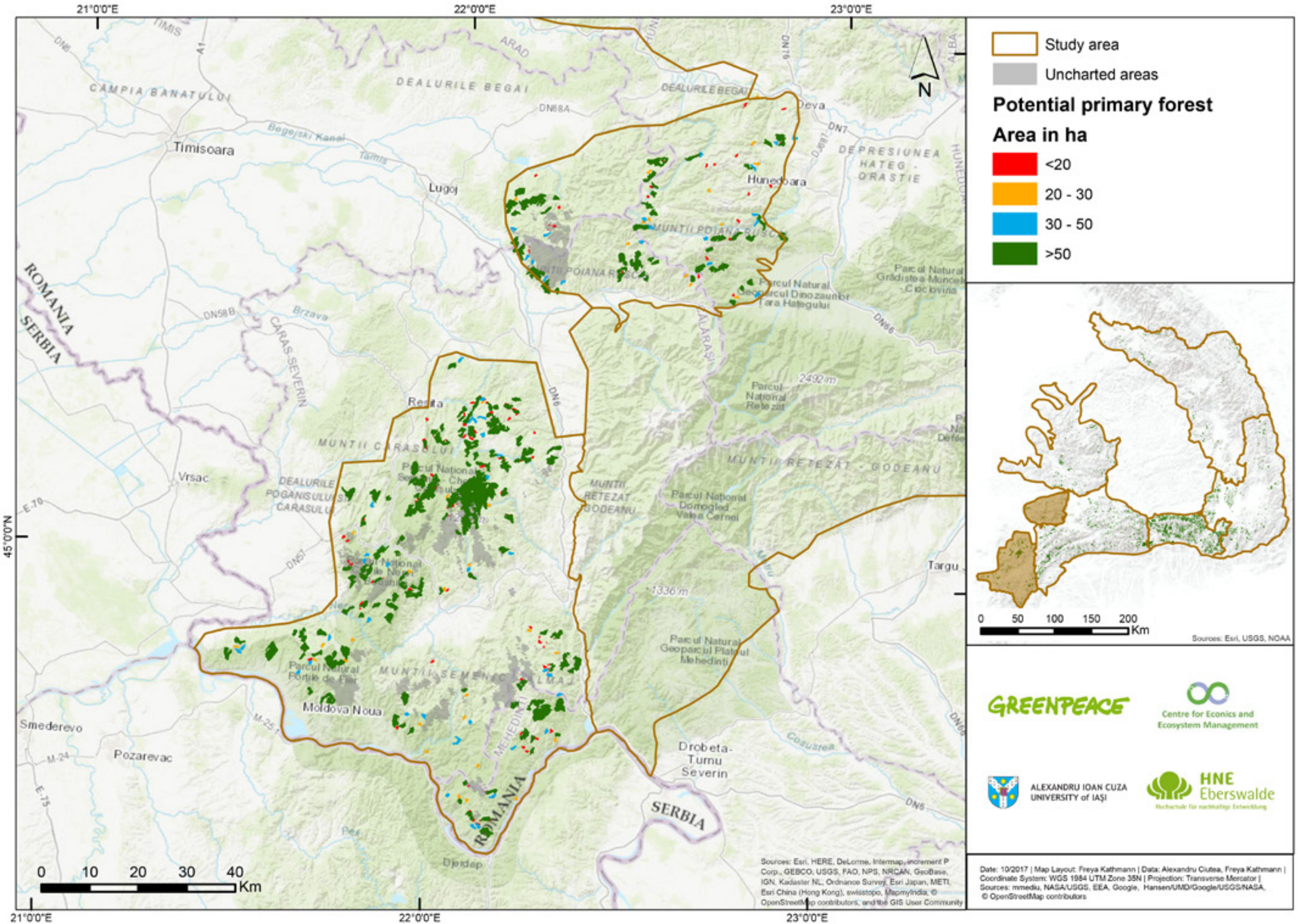
Potential primary forest map of the Romanian Carpathians



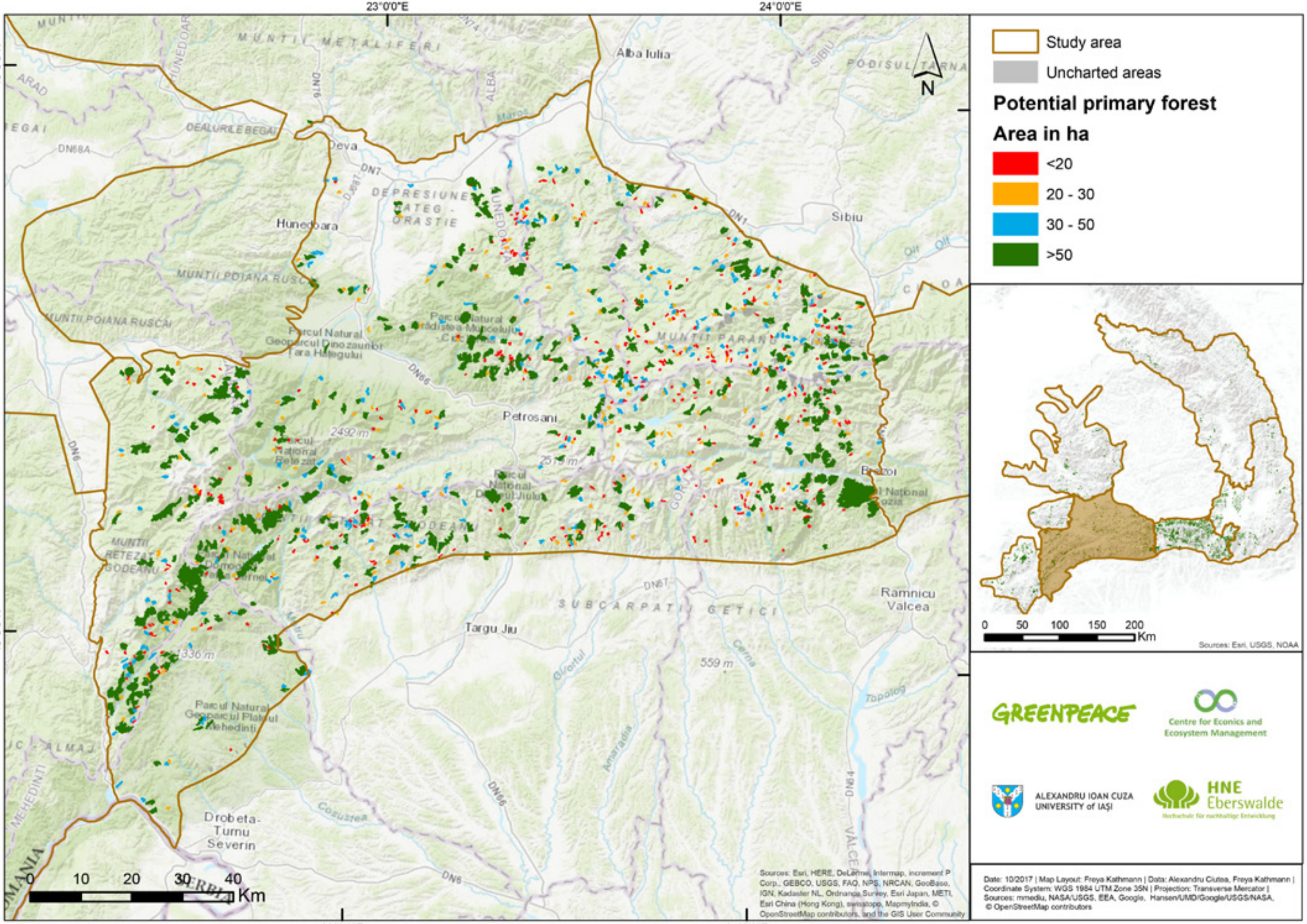
Potential primary forest map of the Western Carpathians



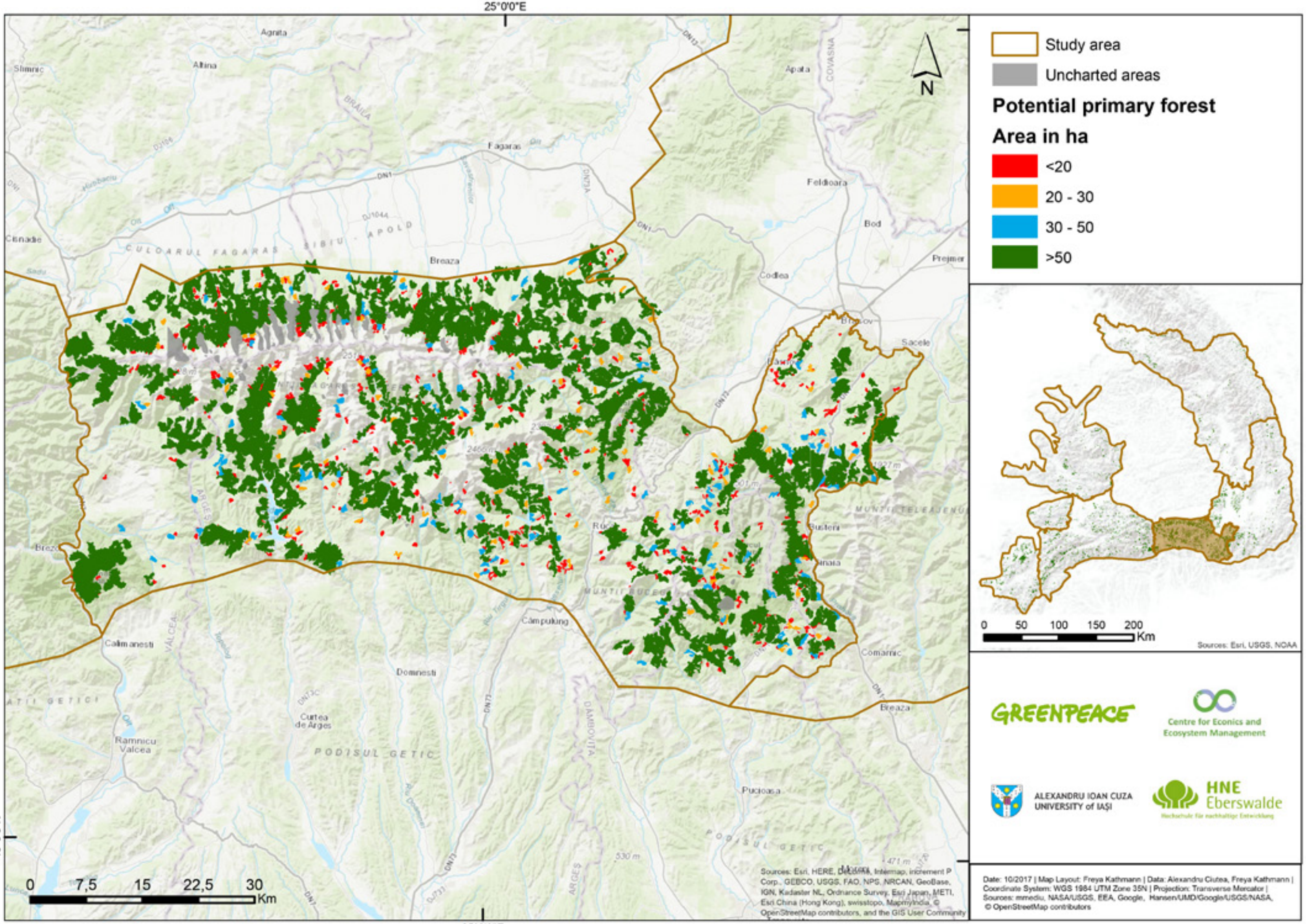
Potential primary forest map of South-Western Carpathians



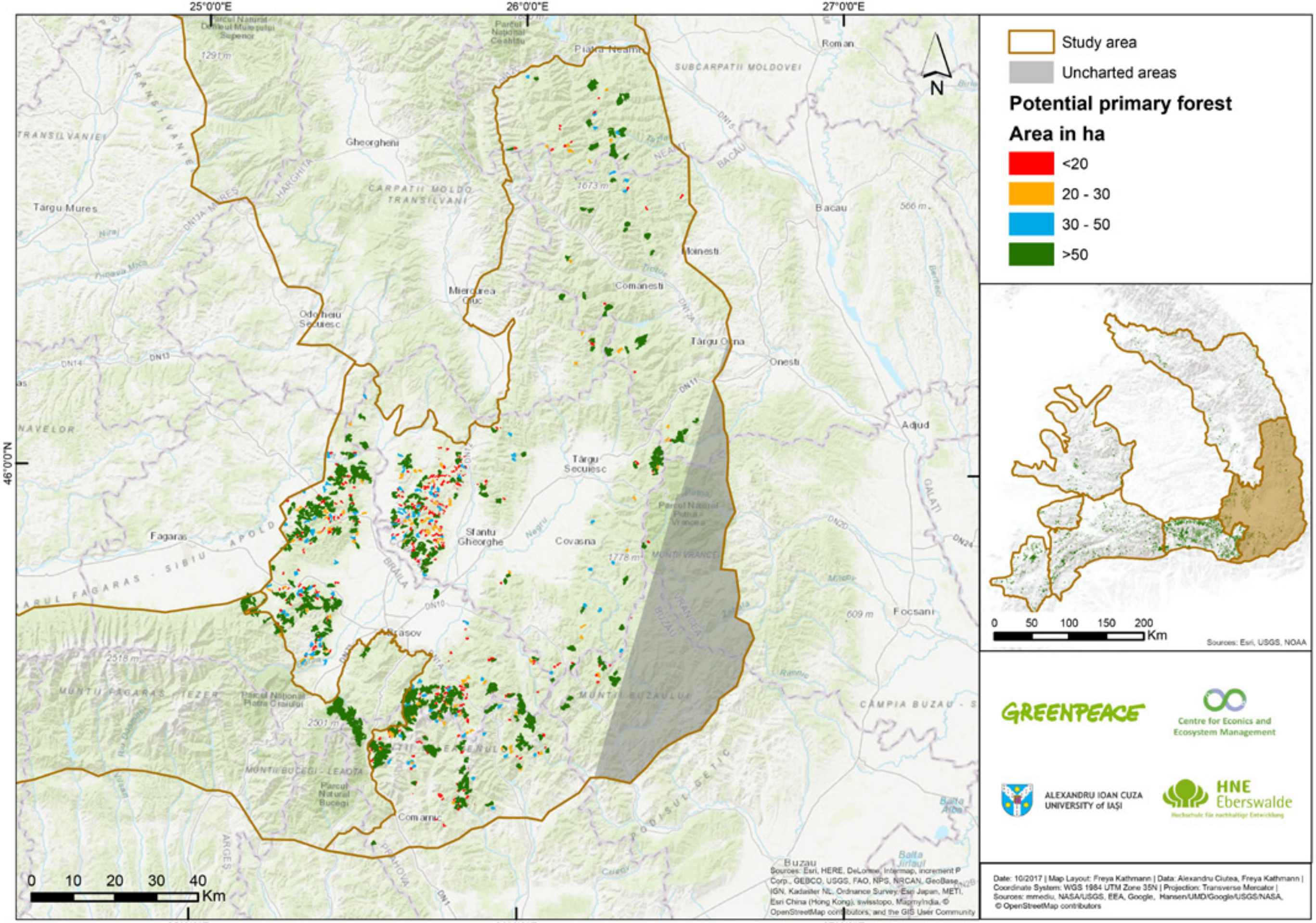
Potential primary forest map of the western half of the Southern Carpathians



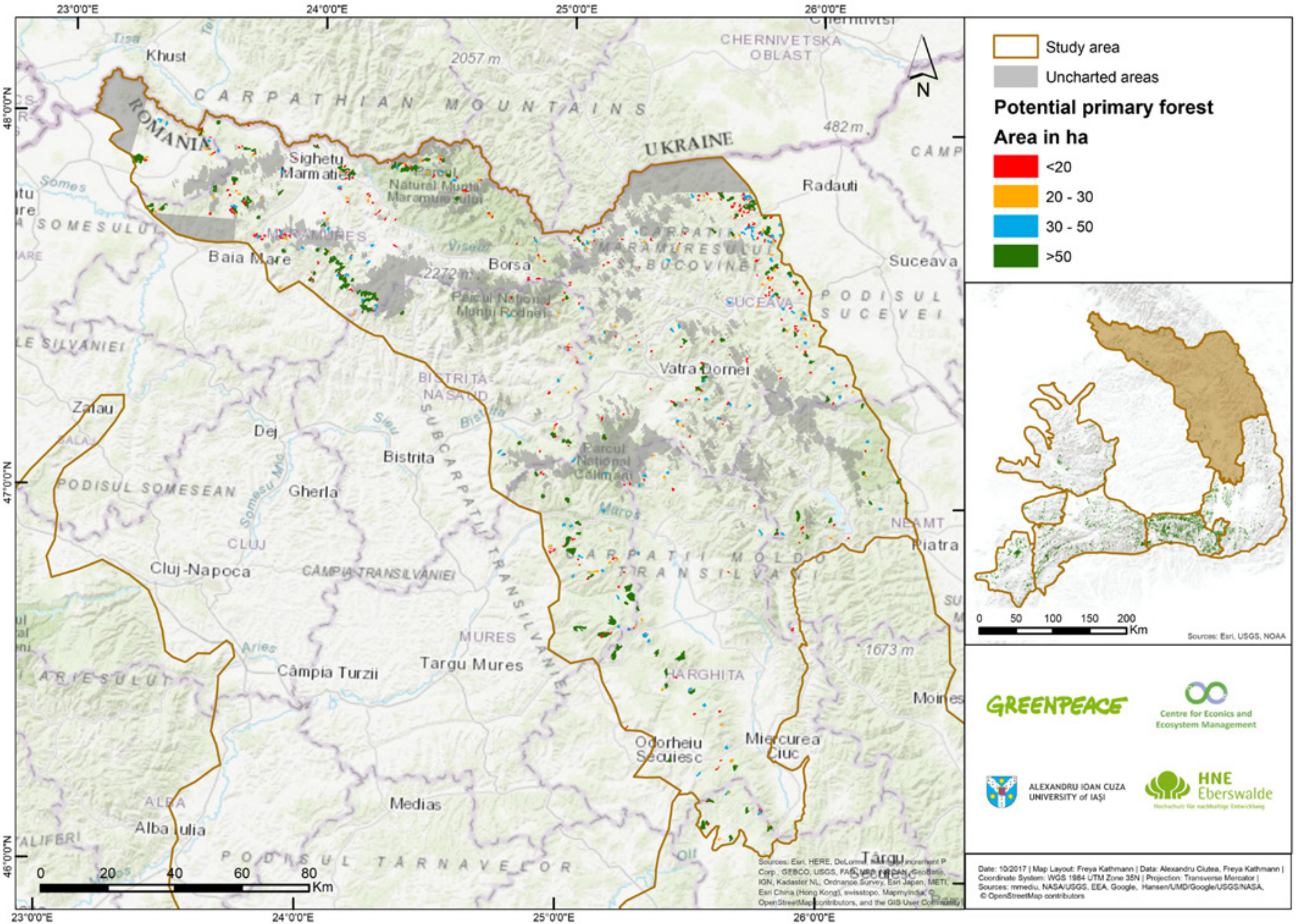
Potential primary forest map of the eastern part of the Southern Carpathians



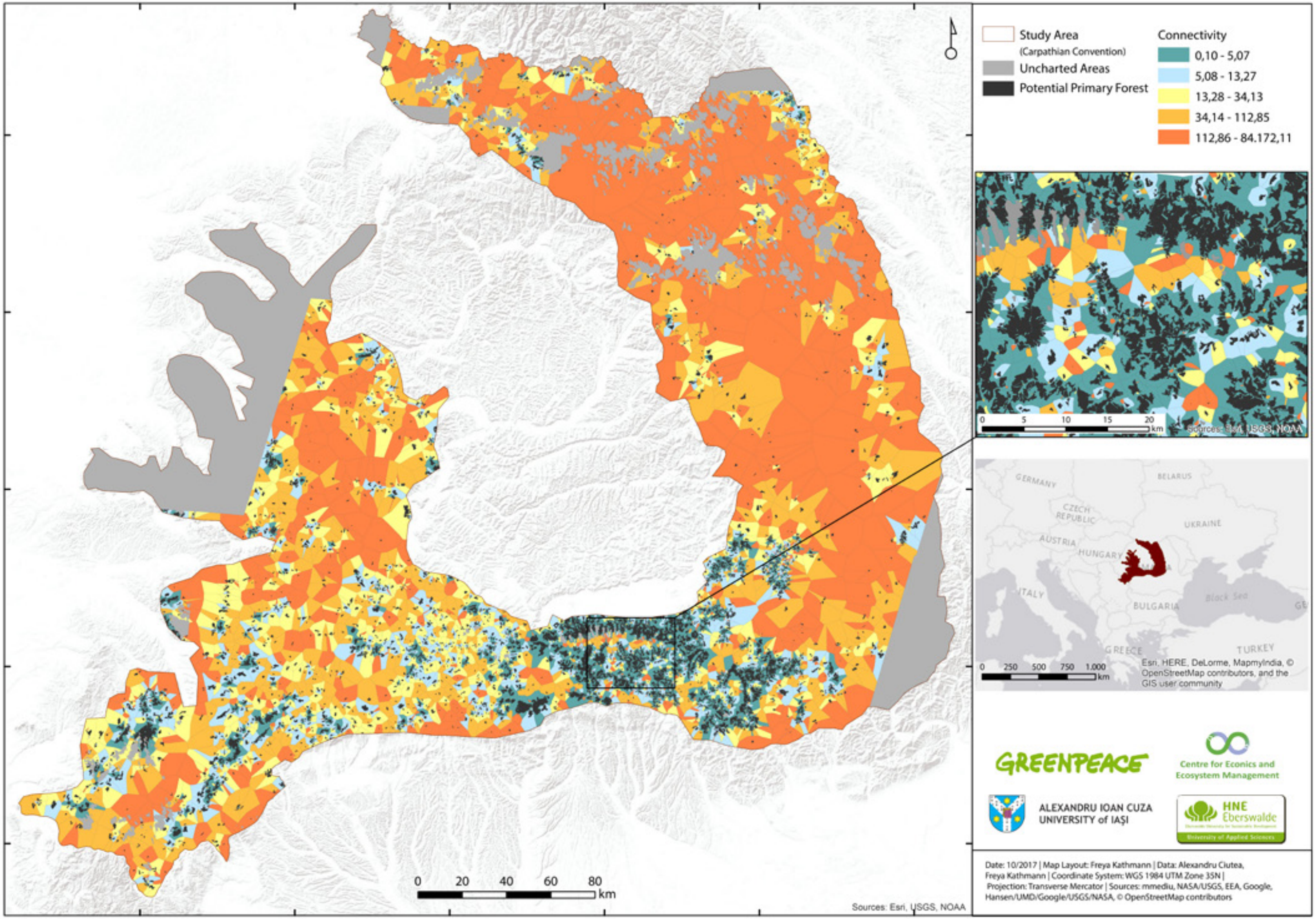
Potential primary forest map of the Curvature and south-eastern part of Carpathians



Potential primary forest map of the north-eastern part of the Carpathians



Connectivity into all Directions of the Potential Primary Forests in the Romanian Carpathians



Frequently asked questions on the Primary Forests Potential Map of Romania

1.Why did you focus on the Carpathian Convention area?

Because the protection of primary forests is clearly addressed by the Sustainable Forestry Protocol of the Carpathian Convention. As the national legal framework and its enforcement are weakened by political instability and corruption, it is of high relevance to highlight the multilateral obligations and call for international support. As a next step, the mapping and screening will cover all forests.

2.What does this map show?

This map presents a pre-assessment of potential primary forests. It represents a searching area where potentially primary forests are likely to be.

These forests represent the remaining parts of potential primary forests in Romania. Applying a precautionary principle, Greenpeace Romania will ask the Ministry of Waters and Forests for a moratorium on further logging these valuable forests.

3.What does it not show?

The presented map does not present an area that is for sure primary, virgin or quasi virgin forest. There might exist certain additional valuable ancient forest remnants that have been excluded due to the criteria described in the methodology. Still, ground-truthing might show that the area of ancient and primeval forests is even bigger.

4.How close does it come to reality?

An official inventory of virgin forests is lacking. This map is a first approach towards identification of primary forests, with the application of freely available data. The second step would then be a field verification of the sites. We invite everybody to contribute to the verification of the map. This way a comparison with reality and thus further improvement of the map can be achieved.

5.How much does the result differ from other/previous mapping exercises?

In 2005, the PIN-MATRA study identified about 218.500ha of virgin forest[1]. About 20% of the potential primary forest polygons intersect with the PIN-MATRA polygons. There are many reasons that could explain these differences. Firstly, the PIN-MATRA study was done using a totally different methodology, based on the field surveys and compared to our methodology which is based on remote sensing. PIN-MATRA polygons are based on the limit of the forest units, which include naturally occurred canopy gaps, while potential primary forest polygons are delineated only by the crown cover. This difference is visible especially in the high altitude coniferous forests situated at the contact with the alpine meadow. Also, some of the forests that were included in PIN-MATRA were logged. For example, in the Cumpăna and Cumpănița watersheds 38% of the PIN-MATRA forests were affected by logging activities [2]. PIN-MATRA

1. http://www.mmediu.ro/articol/proiect-pin-matra-padurile-virgine-din-romania/2068
2. http://www.greenpeace.org/romania/ro/campanii/paduri/tabara/tabara-padurii-la-final/

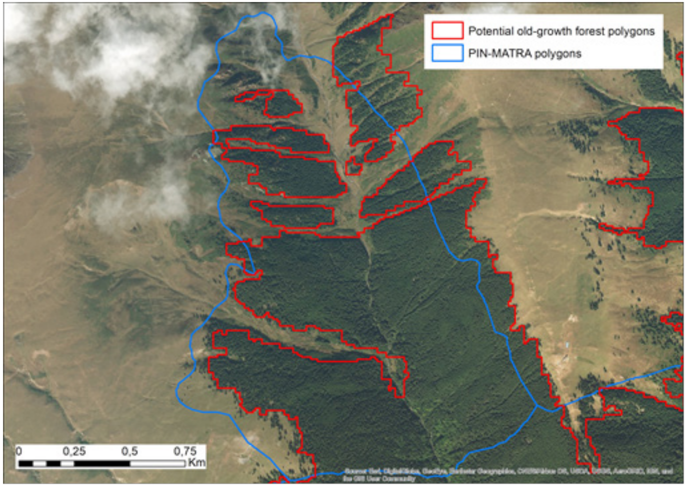


FIGURE 1. Comparison between potential primary forest polygons and the pin-matra polygons

polygons are shifted from their original position (Figure 1), this being another potential factor that could increase the differences between the two studies.

6. How transparent and replicable is the analysis?

A strong emphasis was given to the transparency of the methodology. Following the flowchart (Annex 1-3) the methodology is replicable. (In the manual differences in corrections may occur, due to potentially varying expertise of the operators; but they are of minor importance).

Methodology

The assessment of the potential primary forests is based on a mixed approach, automated and manual techniques being used in the process. It is a completely transparent procedure, which will be described step by step indicating potential shortcomings and challenges.

1 | Used data

The identification of the potentially primary forests of Romania was made using Sentinel 2 satellite images, which are freely available and have a 10m spatial resolution for the visible and near infrared bands. The images were downloaded from the Copernicus Data Hub[1].

Sentinel 2 images are composed from 12 bands, which cover the visible, near-infrared (NIR) and mid-infrared (SWIR) wavelengths. Four bands have a spatial resolution of 10m (2, 3, 4, 8), the rest of them having a resolution of 20m and 60m.

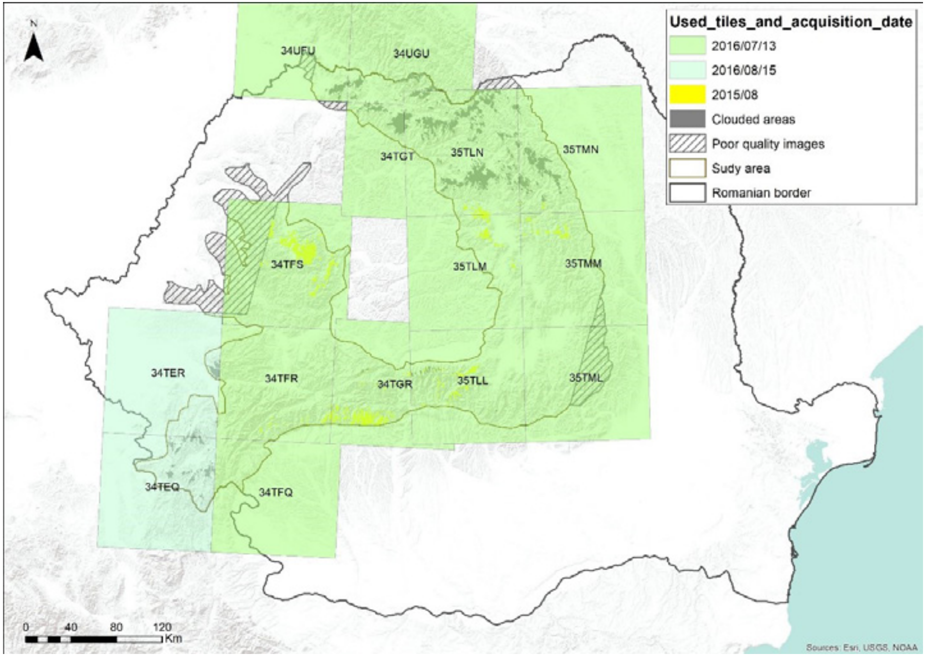


FIGURE 2. Pairs of Sentinel 2 images used in the identification of the potentially old growth forests

Images from 2016 were mostly used, except for the clouded areas where images from 2015 were used, if available (Figure 2). Also in some areas, like the extreme west of the Romanian Carpathians (west of the Apuseni Mountains) images with a quality suitable for our analysis were not available, thus those areas were excluded from the analysis (11,1% of the study area).

Sentinel 2 images were used in detriment of Landsat images, mainly because of the better

1. https://scihub.copernicus.eu/dhus/#/home

spatial resolution. For the visible, NIR and SWIR bands, Landsat 8 images have a spatial resolution of 30m, which is lower than Sentinel's 2 10m and 20m resolution. The disadvantage of using sentinel 2 images is the short temporal coverage, because the Sentinel 2 mission started in 2015. Thus, cloud free images that could be used in the analysis are scarce.

The Carpathian convention area for Romania[2] was used as study area. The Convention covers 68913,2 km2 and includes the mountainous areas of Romania.

SRTM (Shuttle Radar Topography Mission)[3] digital elevation model (DEM) with a 30m spatial resolution was used.

Google earth[4] images (CNES, Airbus, DigitalGlobe) were used for a visual verification of the results. Google images have a higher spatial resolution, but recent images are not widely available.

Global forest change data set up by Hansen et al. (2013)[5] is used in this study in the version 1.3 indicating forest loss from 2000 – 2015.) From the dataset only the forest loss data was utilized.

OpenStreetMap (OSM)[6] data is a global voluntary based and user generated infrastructure map. It was downloaded at. From this dataset roads and railways were utilized.

The forest layers from the Corine Land Cover (CLC)[7] data from 2012 were used as reference in the supervised classification of the tree species.

2. http://www.carpathianconvention.org/

3. https://www2.jpl.nasa.gov/srtm/

4. https://www.google.com/earth/

5. https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.3.html

6. https://www.openstreetmap.org

7. https://www.eea.europa.eu/publications/COR0-landcover

2 | Spectral characteristics of the forests

Vegetation in general has a low reflectance in the visible region of the electromagnetic spectrum. Higher values are specific to the infrared region, especially near infrared.

The spectral signature of a forest is mostly dependent on the interaction between the electromagnetic radiation and the crown cover. In our case, the electromagnetic radiation reflected by the forests was analysed using Sentinel 2 satellite images. Therefore, the level of processing and the quality of the images influences the perceived appearance of the forests, the values being more or less accurate. For example, after the topographic correction the reflectance values of the forests situated on the shaded slopes are more realistic.

Crown cover reflectance depends on a series of factors, such as species composition, vegetation period (growing season) or age. In the case of a satellite image the reflectance values are also influenced by the gaps in the crown cover, shadows created by different

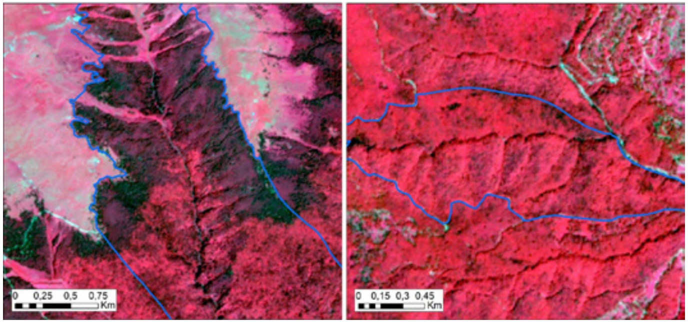


FIGURE3. Old growth forests as seen on sentinel 2 false color infrared composites

FIGURE 4. Comparison between a L1A and a L2C corrected image

tree heights, slope exposition and gradient or atmospheric conditions.

Because of the complex appearance of the forests, an implementation of a fully automatic identification algorithm was considered to be impractical. In addition, old growth / primary forests that could be used as samples in an automated classification are few. Considering these aspects, we chose to use a semi-automatic algorithm, thus combining visual interpretation of the satellite images with automated methods.

3 | Image preparation

3.1 Radiometric correction

In order to reduce classification errors due to different illumination conditions or atmospheric effects, Sentinel images were corrected using a dedicated Sentinel 2 processor called Sen2Cor, which is capable of atmospheric and topographic correction.

One of the most important steps was the topographic correction, which was useful in minimalizing the shadow effect that appears due to different illumination conditions (Figure 4).

Because of the strongly fragmented terrain in the mountain areas, shadow effects can be very pronounced. Atmospheric correction was useful in converting the top of the atmosphere (TOA) reflectance values in bottom of the atmosphere (BOA) ones. Sentinel 2 images were downloaded as L1C processing level products. With the Sen2Cor software the images were converted to L2A. Only the 10 and 20m bands were processed.

An SRTM 30m resolution digital elevation model was used in the process. The lower spatial resolution of the SRTM (30m) could influence the quality of the topographic correction

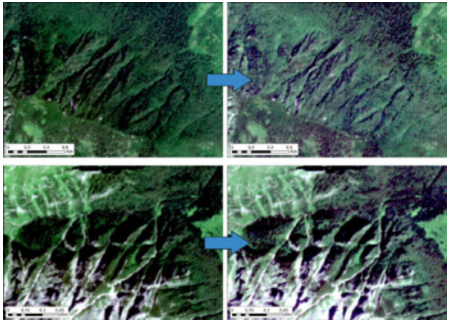


FIGURE 5. Examples of topographic correction limitation

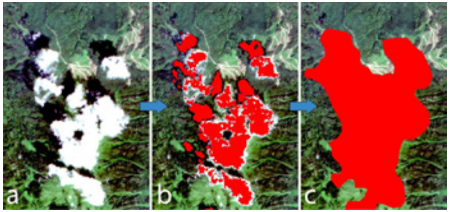


FIGURE 6. Clouds and cloud shadows (a) automatically identified using Sen2Cor (b) and manually mapped (c)

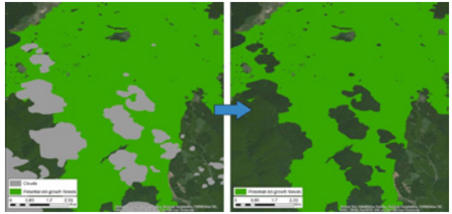


FIGURE 7. Errors due to the cloud coverage

process. Thus, using a higher resolution DEM may have resulted in a more accurate correction of the pixels belonging to the shadowed slopes. In addition, the topographic correction algorithm has its limitations, the shadow effect from the slope with very high inclination values being difficult to remove (Figure 5).

3.2 Cloud identification

Clouds are one of the biggest problems of the multispectral satellite images, in the case of Sentinel 2 the availability of images with a low level of nebulosity being limited, because of the short temporal coverage (2015 and above). Satellite images with a cloud coverage between 0 and 2% were utilized.

Clouds and cloud shadows were extracted manually. Sen2Cor software is capable of automatic identification of clouds and cloud shadows, but the accuracy is not ideal for our analysis (Figure 6). From the 68913km2 of the study area, 4.,1% is covered by clouds.

Because of the cloud coverage, some primary forests could appear fragmented or shrunk (Figure 7). Where available, 2015 images were used for the areas affected by nebulosity on the 2016 images. Thus, the areas analysed using older images could contain fresh loggings that were not charted.

4 | Forest area derivation

4.1 Segmentation

An object based image analysis was utilized for the identification of the potentially primary forests of Romania. The first procedure in an object based analysis is the segmentation process. First, the forest cover was extracted, in order to have an area to work with.

Segmentation can be defined as the object (polygon) creation based on neighbouring pixels and their spectral and spatial properties[1]. The multi-resolution segmentation algorithm was used with the bands 2, 3, 4, 5, 8 and 11, corresponding to the visible, NIR and SWIR. Multiresolution segmentation is a "bottom-up segmentation strategy assembling objects to create larger objects" [2]. The best values for the scale parameter, shape and compactness were found using an iterative process. The used values are 80, 0.8, and respectively 0.4. The scale parameter defines the size and respectively the number of objects that are being created, a higher value resulting in larger polygons. The value of the scale parameter was chosen in order to obtain polygons with an area as large as possible, but also to best delineate the forested areas from the other types of vegetation or loggings, and to separate the different types of forest stands with different species composition or age. Large polygons are ideal for easier visual interpretations that will be done in the following selection process of the intact forest polygons.

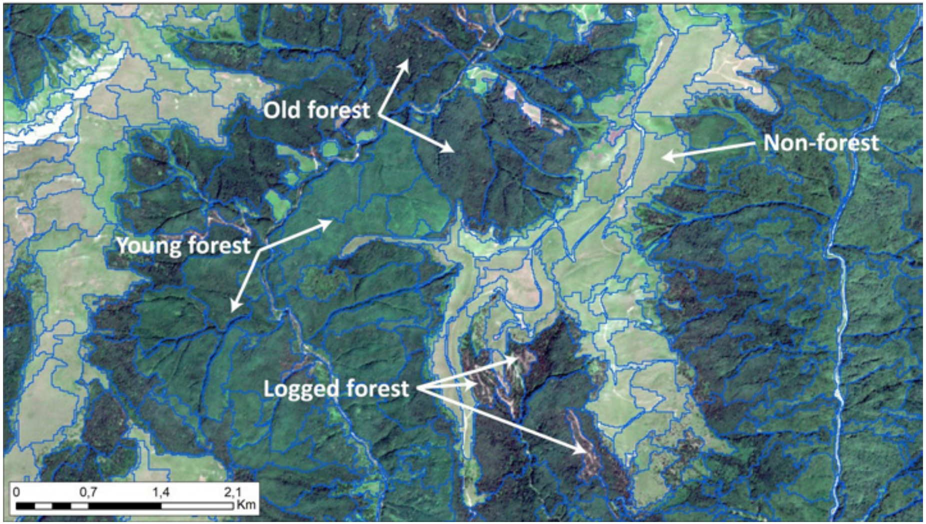


FIGURE 8. Segmented Sentinel 2 image

Because the segmentation process sometimes doesn't offer very accurate results, some polygons had to be manually reshaped. This operation was done using the "Manual Editing Toolbar" in eCognition.

4.2 Supervised classification

The forest cover was extracted using a supervised classification method applied to

1. Kumar Navulur, 2006

2. H E Adam et al, 2016

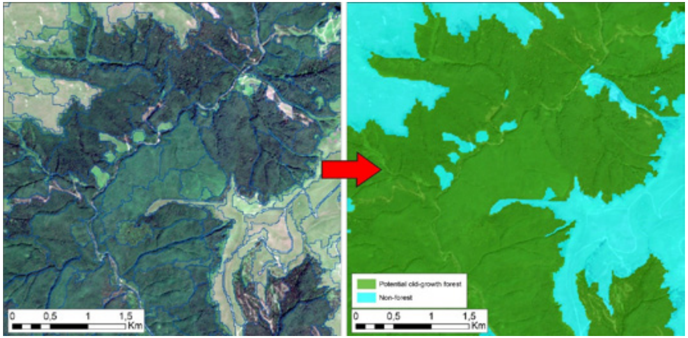


FIGURE 9. Supervised classification of the forest cover

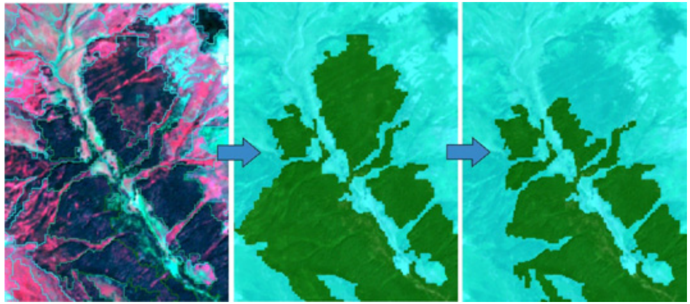


FIGURE 10. Manual corrections subsequent to the supervised classification of the forest cover

the polygons resulted from the segmentation process. The nearest neighbour classification, available in eCognition, was used. Firstly, polygons were divided in two classes, respectively forest and non-forest. Sample polygons were selected for both forest and non-forest classes. In this stage, the forest class will contain not only old-growth forests, but also young, planted or degraded forest stands. A number of six raster images were used in the classification process, respectively the bands 2, 3, 4, 5, 11 and the Normalized Difference Vegetation Index (NDVI). NDVI was calculated using the red and near infrared bands (4, 8), NDVI being very useful in the classification of the forest cover. The feature space optimization tool, available in the eCognition software, was used for the selection of the classification parameters.

In some areas manual corrections were necessary, especially in the alpine areas or croplands where some polygons were falsely classified as forest.

It is important to mention that only the crown cover was extracted. Larger canopy gaps that could potentially belong to a forest are excluded. This is the case for the highly fragmented coniferous forests situated at the transition zone to alpine meadows (Figure 10). For example, on the potential primary forest map the total area of the Museteica forest (Figure 11) will be 14% smaller when compared to the total area of the forest units. The size of the automatically identified gaps is dependent on the values of the segmentation parameters that were used previously.

4.3 Forest stand age classification

Young forest stands have different spectral and textural characteristics than primary and old-growth forests. Using vegetation indices derived from Sentinel 2 bands, young forest

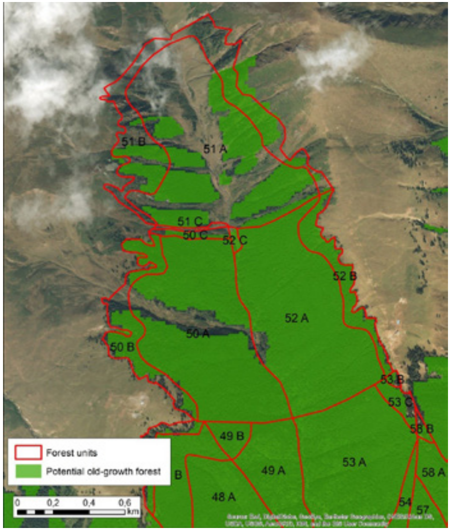


FIGURE 11. Forest units from the official management plan and potential old-growth forest polygons of the Mușeteica forest

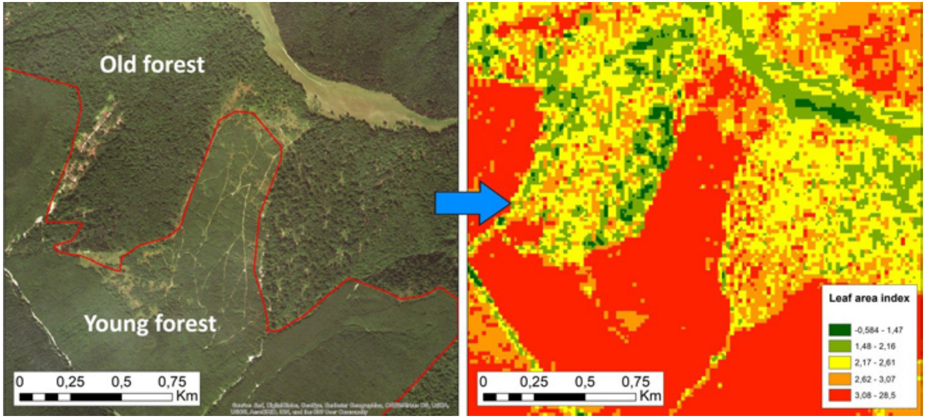


FIGURE 12. Young forest stand on Bing imagery (left) and LAI raster (right)

stands can be identified to a certain degree. Photosynthetic processes are more intense in young forest stands, than old-growth forests. Also the young stand's texture appears smoother on the satellite images because of similar tree heights and high tree density with small canopy gaps. This leads to a very high reflectance in the infrared bands compared to primary and old-growth forests.

Leaf Area Index (LAI) is defined as half the developed area of photosynthetically active elements of the vegetation per unit horizontal ground area[3]. It determines the size of the interface for exchange of energy (including radiation) and mass between the canopy and the atmosphere[4]. As demonstrated in several studies[5] the value of LAI is inversely proportional to the forest stand age. The highest LAI values were observed in the youngest forest stands. As the forest gets older, the LAI values slowly decreases.[6]

Observations made on Sentinel 2 satellite imagery also confirm that young forest stands and plantations have very high LAI values. The LAI was calculated with the biophysical processor integrated in the ESA's SNAP software.

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3. http://land.copernicus.eu/global/products/lai

4. M. Weiss, F. Baret, 2016

5. R. Pokorný, S. Stojnič, 2012

6. R. Pokorný, S. Stojnič, 2012

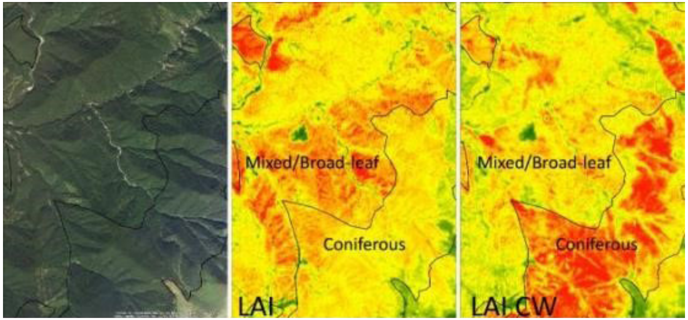

FIGURE 13. Comparison between LAI and LAI CW for different tree species

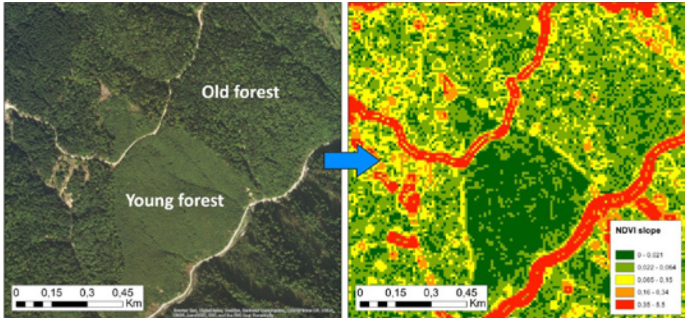

FIGURE 14. Comparison of the NDVI slope values in the case of a young and an older forest polygon

Coniferous and deciduous species have very different leaf structures, therefore LAI will have lower values in the case of coniferous species. To overcome this limitation, LAI CW (leaf water content) was used for the identification of young coniferous forest stands. LAI CW is more sensitive to coniferous forest stands and has higher values in comparison to deciduous species. Thresholds were established by analysing the LAI and LAI CW values of the primary and old-growth forests and young forests charted in the field studies made of Cumpăna and Mușeteica watersheds in August 2016[7].

To further filter the remaining forest polygons, a texture-based classification was implemented. The roughness of the forest can be quantified by calculating the slope of the NDVI (Figure 14). Thus, the mean values of the slope of the NDVI for each forest polygon were calculated, and a threshold-based classification was run. The threshold was set by analysing the values of the forests charted in the field by Greenpeace in 2016. It was considered that forest polygons with lower slope values are specific to young forest stands and classified as such.

Not all different aged forest stands could be separated using the above methods, but at least this is narrowing down the area where primary forests could be found. Extremely accurate assessments regarding the forest stand age can be done in the field studies, or using highly precise remote sensing data, like Lidar.

Because of the small number of primary and old-growth forests taken as reference in the establishment of the threshold that was used in the age classification and also because of the complex aspect, forests with similar characteristics compared to the potentially primary ones could have been automatically eliminated. The LAI values and the smoothness of a forest could differ because of the different illumination conditions created by different terrain expositions and inclinations. Atmospheric

7. http://www.greenpeace.org/romania/ro/campanii/paduri/camp/

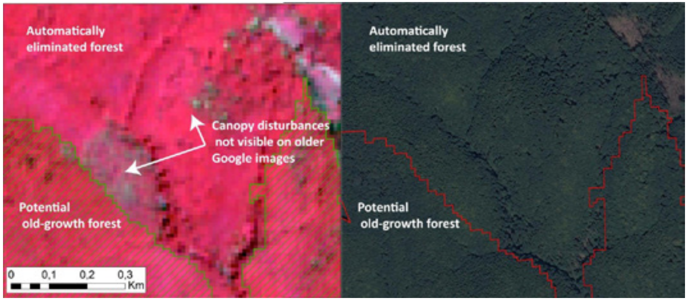

FIGURE 15. Forests with a similar appearance compared to the potentially old-growth forests could have been automatically eliminated in the process of age classification

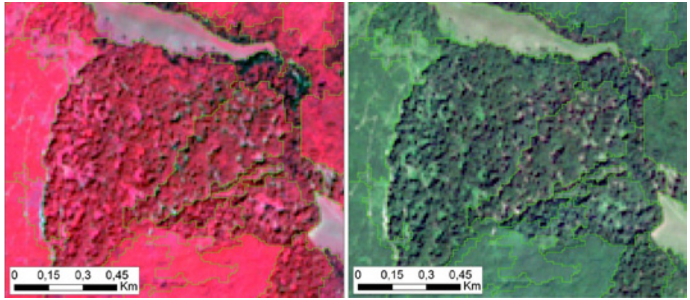

FIGURE 16. Canopy disturbances West to Cumpăna watershed

conditions could also affect the appearance of the forests, especially near the clouded areas. Thus, some potential primary forest polygons could appear truncated.

5 | Logged forest and intact forest separation

Due to the high complexity of the shape, texture or spectral characteristics of logged forests, a visual analysis was considered to be more practical and more accurate compared to automated methods. After the automatic classification of the different aged forests stands, using LAI and NDVI slope, the forest polygons that were not previously classified as young forest were analysed. Logged and intact forest polygons were manually separated by a visual interpretation of the satellite images.

For this analysis, false colour infrared (8, 4, 3) and true colour (4, 3, 2) Sentinel 2 composites were used in a side by side view in the eCognition software.

Canopy disturbances of at least 200m2 were taken into consideration. Because of the 10m spatial resolution, a pixel will have an area of 100m2.

Low near-infrared reflectance and a high reflectance in the visible spectrum is specific to bare soil blue pixels in the infrared composite from (Figure 15). Very high infrared reflectance (pink pixels) is specific to ground vegetation

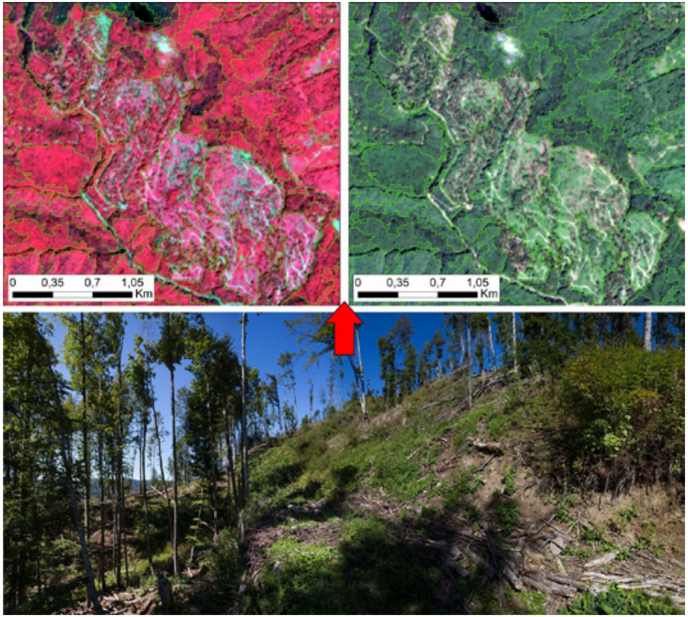

FIGURE 17. Forest thinning in Cumpăna Valley (Greenpeace, 2016)

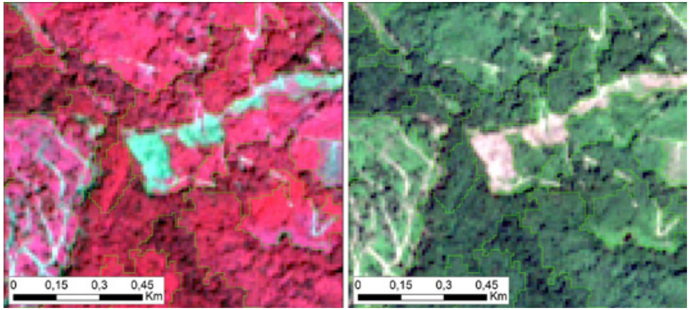

FIGURE 18. Clear cut situated on the ridge between Cumpăna and Cumpănița Valley

and shrubs or young vegetation. These two categories of pixels were considered as disturbances in the forest cover.

Forest polygons containing a mixture of different kinds of reflectances specific to different aged forests, ground vegetation and bare soil were eliminated (Figure 17).

Clear cuts are relatively easy to identify especially fresh ones, where the reflectance in the visible spectrum is high and infrared reflectance is low (Figure 18). They appear very bright compared to the forest canopy. Most of the fresh clear cuts were automatically classified as non-forest from the beginning. Below is an example of a clear cut situated on the ridge between Cumpăna and Cumpănița valley that were studied in the field.

Forest polygons containing canopy disturbances with an unnatural shape, pattern, or spatial distribution were eliminated.

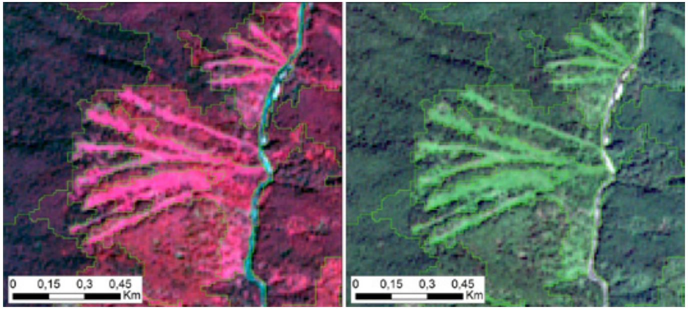

FIGURE 19. Canopy disturbances

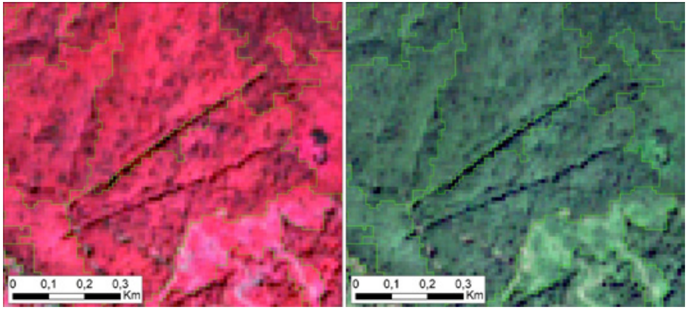

FIGURE 20. Straight lines in the canopy

For example, the presence of straight lines in the canopy are a clear indicator of anthropogenic intervention (Figure 20). These could be skidding line marks, roads or just linear cuttings.

Some canopy gaps or anthropogenic structures, like roads, cannot be successfully identified from Sentinel images, the restrictive factor being, mainly, the spatial resolution. Therefore, the potential primary forest polygons derived from the Sentinel images were imported in Google Earth and checked using high resolution satellite imagery. For example, roads can often be confused with rivers when they are partially covered by the canopy. It is possible to distinguish these features with high resolution in some cases. In addition, the 3D terrain view, available in the Google Earth software was very useful in the analysis.

Although Google images have higher spatial resolution, they do not have a very good temporal coverage. For this reason, many fresh cuttings could have been overlooked.

A fully automated methodology would have been ideal, but was not implemented due to previously mentioned reasons. For the Făgăraș Natura 2000 site, where the most potential primary forests were identified, about 50% of the excluded forests have been manually mapped, the other half being automatically classified as young forest. In other regions, where potential primary forest polygons are scarce, the ratio will turn in favour of manually mapped forests.

In order to best delineate the canopy gaps that could potentially be forest cuttings, some of the polygons resulted from the segmentation had to be reshaped, as shown before.

Although the scope was to identify the manmade canopy disturbances, some naturally occurred canopy gaps have also been mapped and erased from the forest layer. This happened especially in the high altitude coniferous forests, at the contact with the alpine meadows, where canopy gaps are large and have been classified as non-forest in the forest cover extraction step.

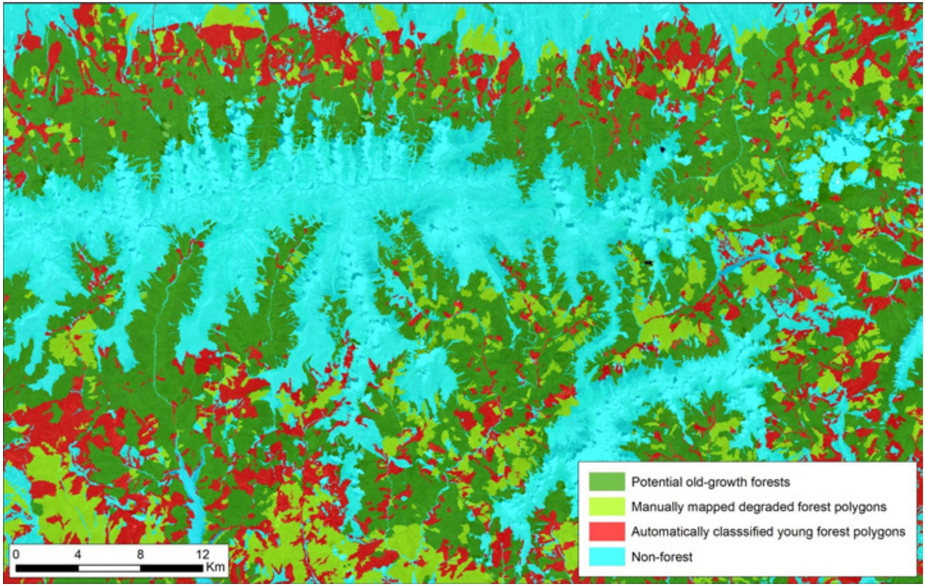

FIGURE 21. Analyzed forest polygons visualized in the Ecognition Software

The accuracy of the canopy disturbance analysis is dependent on several factors, for instance the spatial resolution, the quality of the images or the experience of the interpreter. As in the case of the forest age classification, accurate assessment of the canopy disturbances can only be done in field studies.

6 | Global Forest Change Data Exclusion

In order to further exclude potential forest loss that could have been missed when the satellite images were visually analysed, a comparison with a globally assessed and widely applied dataset was realized by using global forest loss data (Hansen et al. 2013). A total of 862,54ha were excluded, which represent 0,28% of the total area of primary forest polygons that resulted from the previous section. The Global Forest Loss Data was projected to WGS 1984 UTM Zone 35 N and polygonised. From the resulting polygon the value ‘1’ is selected, which indicates the loss. The resulting loss polygon was then erased from the potential primary forest area.

When identifying forest loss, only recent losses can be perceived as they appear in different pixel values. It is possible that older disturbances were present but not captured by this analysis.

As the minimum cell size of the Hansen data (600 m^2) is bigger than the threshold applied for the manual extraction, an inconsistency occurs because bigger gaps are considered natural. On the one hand it is possible that the forest loss is underestimated due to the threshold. On the other hand it is also possible that the area with natural disturbance patterns is eliminated especially when it comes to small and diffuse patterns.

7 | Exclusion of Plantations

Furthermore it is intended to exclude planted forests. The assessment of the plantations is based on two assumptions:

1. The plantations consist of pure coniferous stands.

2. Conifers that occur below 1200 m are planted.

As in this case it was not differentiated between northern and southern slopes, a rather conservative altitude threshold of 1200 m was selected. Conifers and contour lines in the northern Fagaras Mountains part are visualized in Figure 22. Consequently the risk of falsely excluding primary forest areas was minimized.

The altitude is assessed with contour lines derived from the SRTM. 'Contour = 1200' were selected and polygonised. With an object based classification the pure coniferous stands within potential primary forests were extracted.

In the eCognition software segmentation objects belonging to the forest class were classified

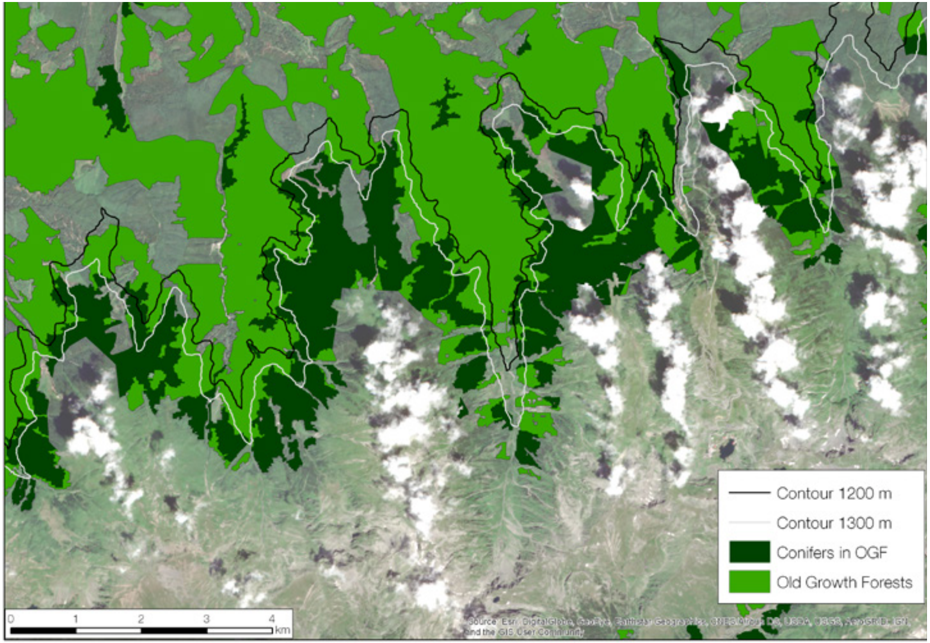

FIGURE 22. Exclusion of non-natural conifers

in coniferous and deciduous species. The nearest neighbour (NN) classification method was used, sample objects being selected by a visual assessment of the satellite images and also by using Corine Land Cover (CLC) 2012 data as reference. Bands 8 and 11, corresponding to the NIR and SWIR, were used in the classification. Coniferous species have a very low reflectance in the near and short wave infrared bands compared to the deciduous species, thus, the NIR and SWIR bands are ideal for this classification.

For the deciduous forest class, sample objects were selected from pure decidous and also mixed forests. For the coniferous forest class only pure coniferous forest polygons were used as samples, because the objective was to identify pure coniferous forest stands.

From the coniferous within primary forest layer the 1200 m contour polygon was erased. This resulted in coniferous stands below 1200m, which were then erased from the potential primary forest area derived in the previous section.

Plantations could be underestimated. Coniferous plantations occurring within their natural occurrence were not excluded. As only pure coniferous plantations are considered, other plantations may occur in the old growth forest area.

Furthermore inaccuracies the classification may exist. It is possible that not all coniferous forests in the classification are pure stands but mixed stands.

It is also possible that pure stands are qualified as mixed. An exact species distinction was not realized as it was not affordable within the scope of this analysis, due to lacking high resolution imagery. Furthermore, the threshold can possibly not fit the reality and the natural conifers were overestimated or underestimated.

The plantations can also be overestimated, as it is possible that natural coniferous forests occur below 1200 m.

8 | Exclusion of Roads and Railways

A further driving factor of forest loss is infrastructure, such as roads or railways. These are thus erased from the potential primary forest area. In contrast to Ibisch et al. (2016) there is no buffer drawn around the roads and railways, as here, the roads are solely regarded as forest area decline. The impact of roads or railways on the surrounding forests is not taken into account. Roads and railways are considered to be 10 m wide as this equals the minimum cell size. Thus, generating false accuracy is avoided.

The data was assessed from OpenStreetMap (OSM) and are available as line features. Small paths (‘fclass = path’ and ‘fclass =footway’) are not considered as their surface does not interrupt the canopy cover in a way that that it can be observed from satellite images. The non-vehicle roads were selected and erased from the roads. In order to reflect the surface a 5 m buffer for roads and railways was performed on both sides of the lines. The buffer polygons were then erased from the potential primary forest area. In the end a ‘Multipart to Singlepart’ operation is performed and polygons smaller than 200 m², resulting as leftovers from previous erasing processes, are erased.

OSM data is generated by its several contributors. Therefore a high accuracy is not guaranteed. Even though studies reveal that OSM data reaches high accuracy compared to proprietary datasets, in Great Britain and Germany (Haklay 2010; Neis et al. 2012) these results cannot be directly transferred to Romania, as the number of active users differ notably.

While Germany had from January to August 2017 420-600 daily active members, the number accounts to 13-31 for Romania in the same time period (Neis, El Loco 2017). Furthermore, Hecht, Stephens (2014) identify the data accuracy of Volunteered Geographical Information (VGI) to be decreasing with distance to urban areas. This may lead to lower accuracy in the country of Romania with focus on rural areas, than assessed by Haklay (2010) or Neis et al. (2012). Data accuracy is not only related to positional but also to thematic inaccuracies (Capineri et al., 2016), e.g. wrongly allocated classes. Consequently it cannot be ruled out that the classes footway and path, which were not erased, are logging roads. A clearly defined

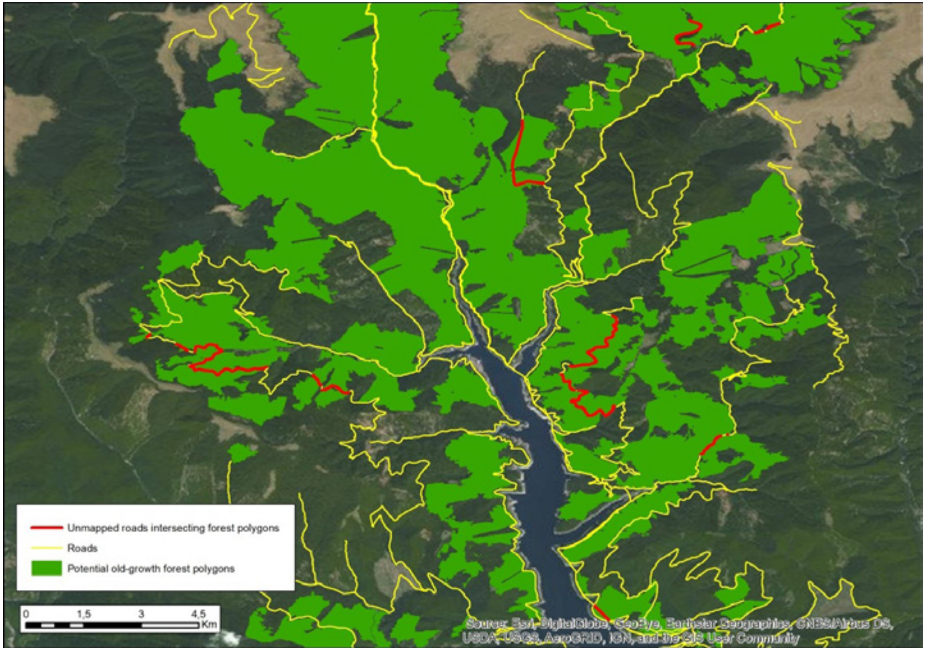

FIGURE 23. Example of roads intersecting potential primary forest polygons near Lake Vidraru

class called logging road does not exist. For the class path the use of cycles or horses cannot be excluded as it is described as a general path without the use of vehicles (OpenStreetMap Wiki 2017). To exclude major errors a visual verification with satellite images was performed. OSM data was chosen as it is open access data. Assessing proprietary data was not affordable within the study.

Some potential primary forest polygons could be crossed by roads and skidding trails that were not successfully identified on the satellite images and were not available in the OSM dataset yet. Analysing satellite images captured in the cold season could represent one solution, but this would work only for the deciduous forests.

Using a detailed road dataset provided by authorities for the Vidraru forest district, roads that intersecti potential primary forest polygons and could not be successfully mapped can be visualized. From a total of 443 km of roads existing in the Vidraru area, 17 km (4%) of roads are intersecting potential primary polygons.

9 | Size evaluation

In the end, the potential primary forest polygons are classified into 4 classes:

- 0 - 20 ha does not correspond to official criteria for virgin and quasi virgin forests
- 20.1 - 0 ha: corresponds to the official criteria for virgin forests
- 30.0 - 50 ha corresponds to official criteria for quasi-virgin forests
- > 50 ha corresponds to the criteria for primary forests applied in the PinMatra (Biriş, Veen 2005)

10 | Connectivity Assessment

Well connected forest patches have a higher ecological functionality (e.g. genetic exchange) than isolated patches. The connectivity assessment represents a first step towards a priority setting for the protection. Nevertheless it cannot be directly concluded that well connected patches have a high conservation priority. Small and isolated patches require the most urgent protection as they are the most exposed to external threats.

Connectivity was assessed with Thiessen Connectivity into all directions (according to Ibisch et al.(2016)). It is described by the proportion of a patch to its nearest surrounding area (Thiessen area)."Each Thiessen polygon defines an area of influence around its sample point, so that any location inside the polygon is closer to that point than any of the other sample points." (ESRI 2016)

To include forest patches that were cut by the study area and thus are outside, a buffer of 2000 m was applied to the study area outline. Thiessen area was calculated with the "Euclidean allocation" tool. The Euclidean output was then clipped to the study area buffer and not charted areas were erased. Thiessen Net area was calculated by erasing OGF 5 from the Thiessen area. In the end the proportion of the Thiessen net area and forest patch area was calculated. For display purposes an inside buffer of 2000 m was performed in the end. The resulting values were classified by quantiles into 5 classes (blue indicating well connected, red indicating poor connected).

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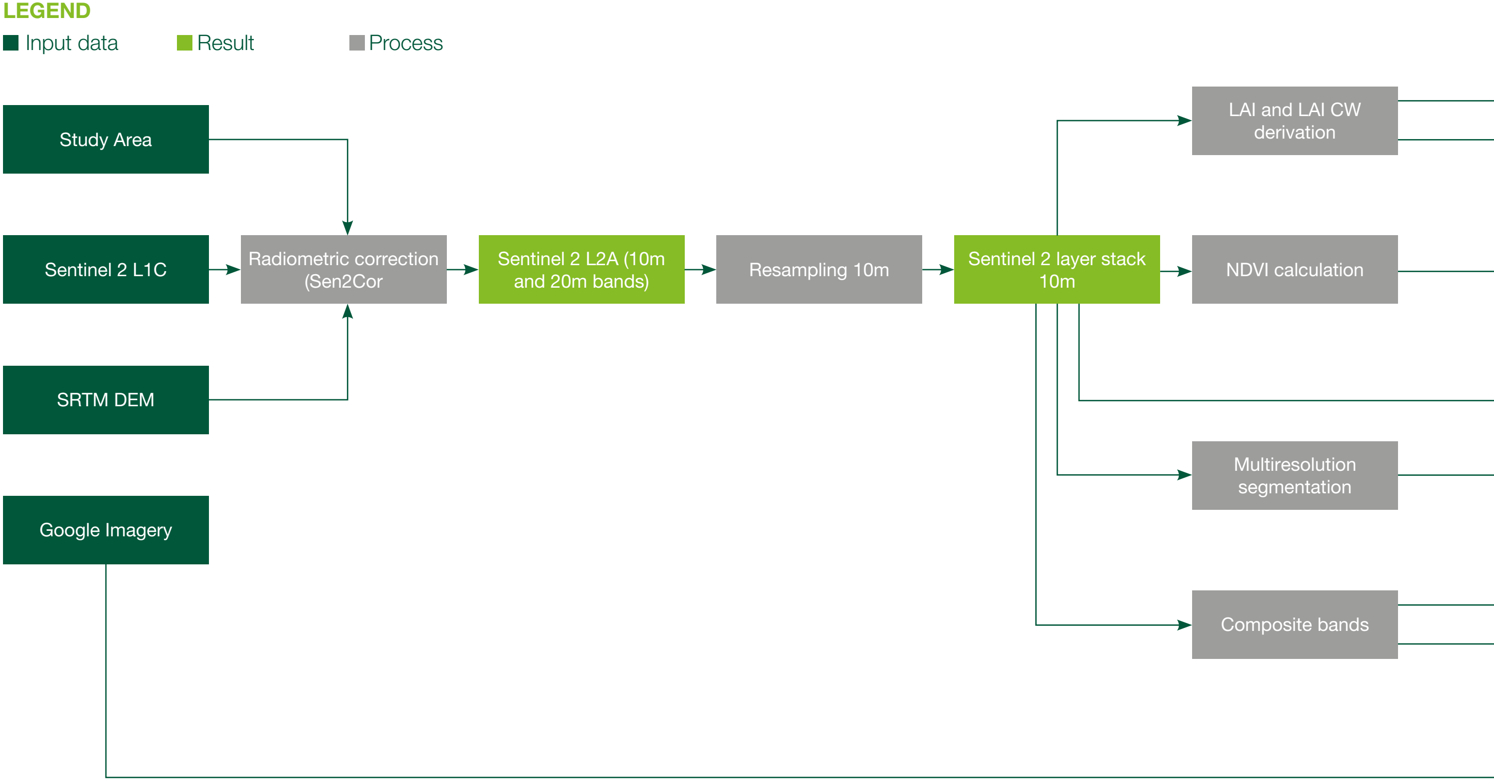
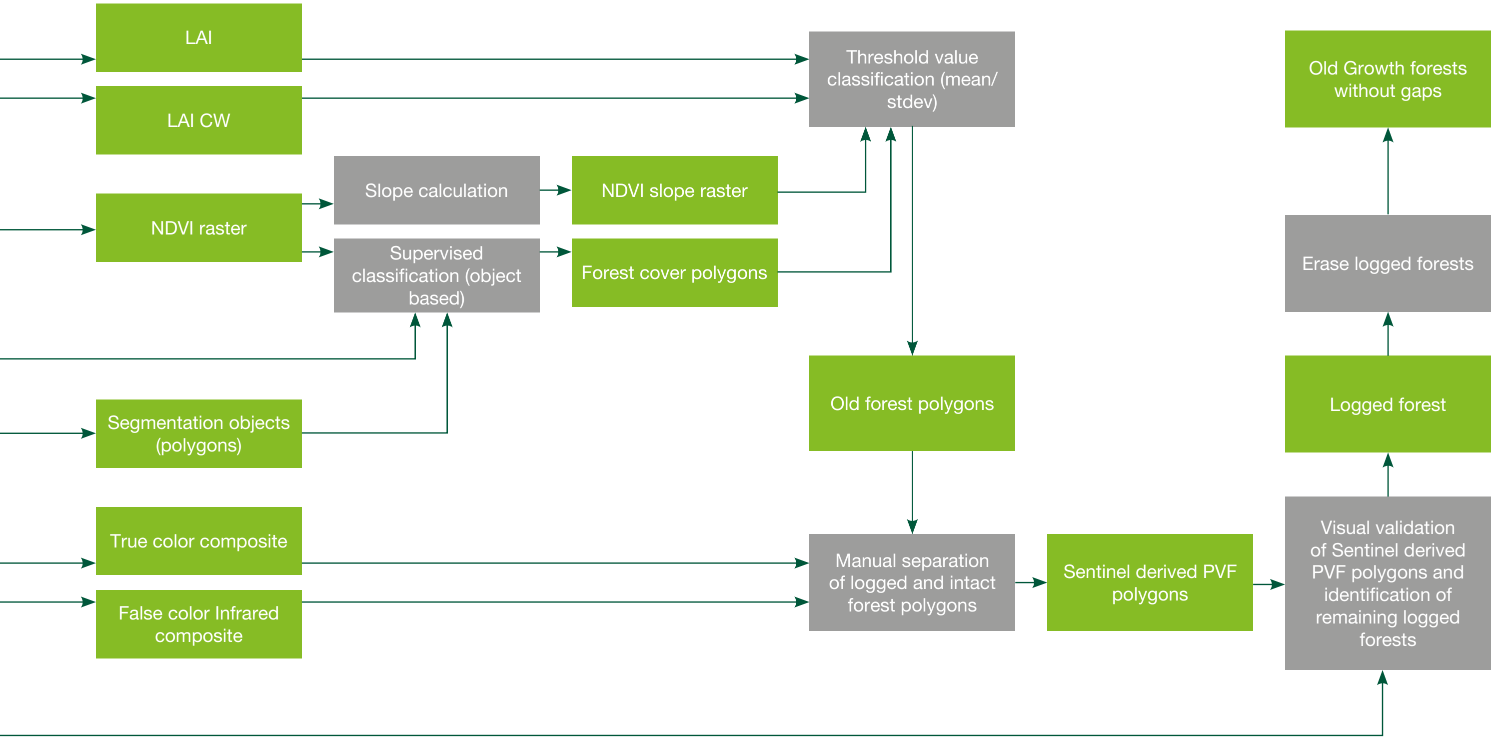
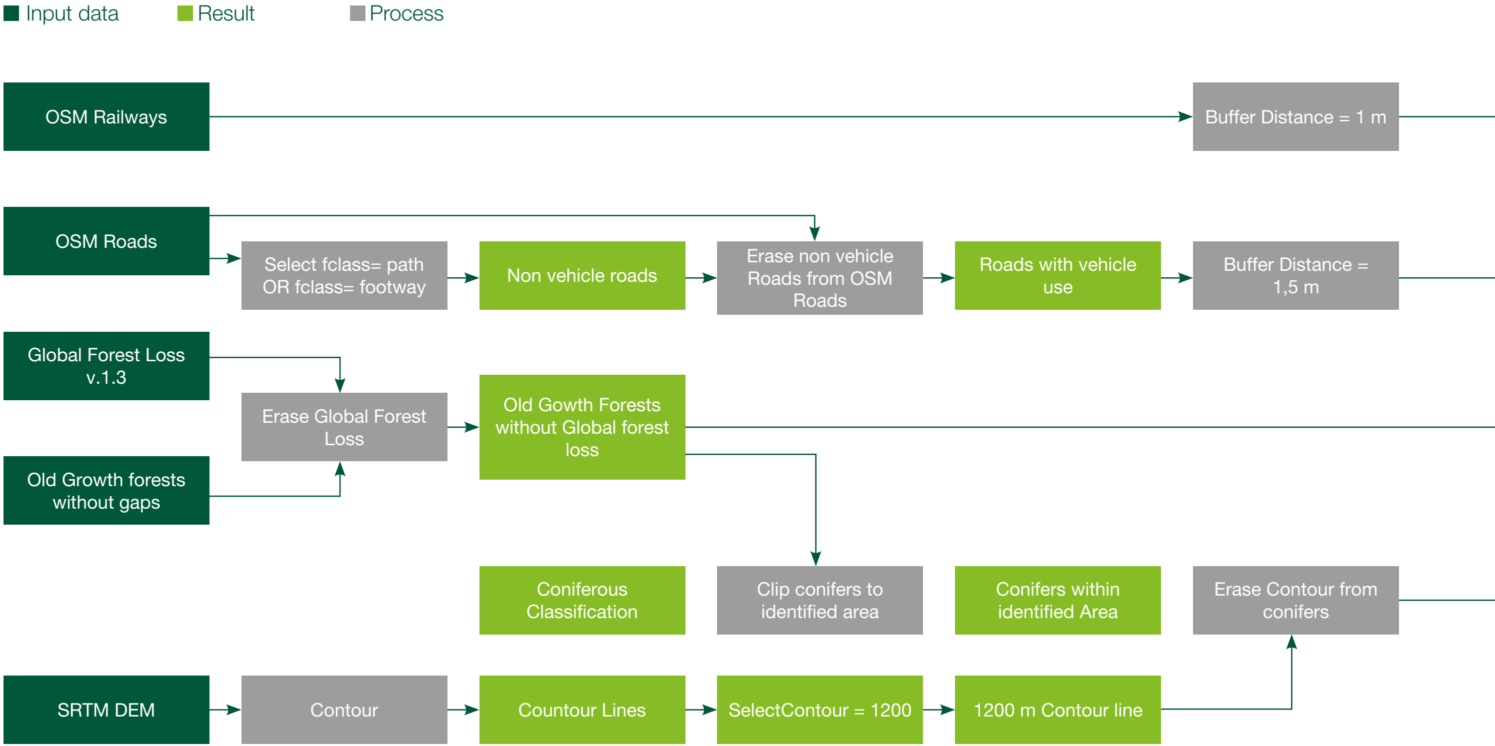
ANNEX 1. Potential primary forest polygons derivation algorithm

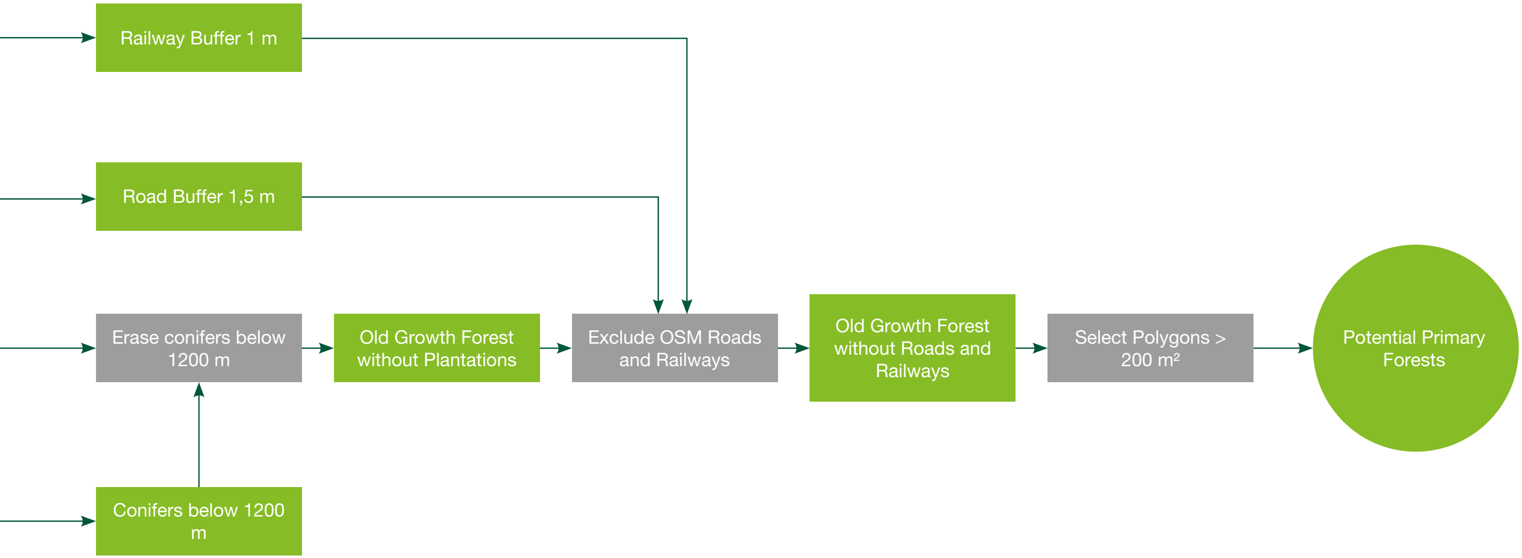



LAI
LAI CW
Threshold value classification (mean/ stdev)
Old Growth forests without gaps
Slope calculation
NDVI slope raster
NDVI raster
Supervised classification (object based)
Forest cover polygons
Erase logged forests
Old forest polygons
Logged forest
Segmentation objects (polygons)
True color composite
False color Infrared composite
Manual separation of logged and intact forest polygons
Sentinel derived PVF polygons
Visual validation of Sentinel derived PVF polygons and identification of remaining logged forests

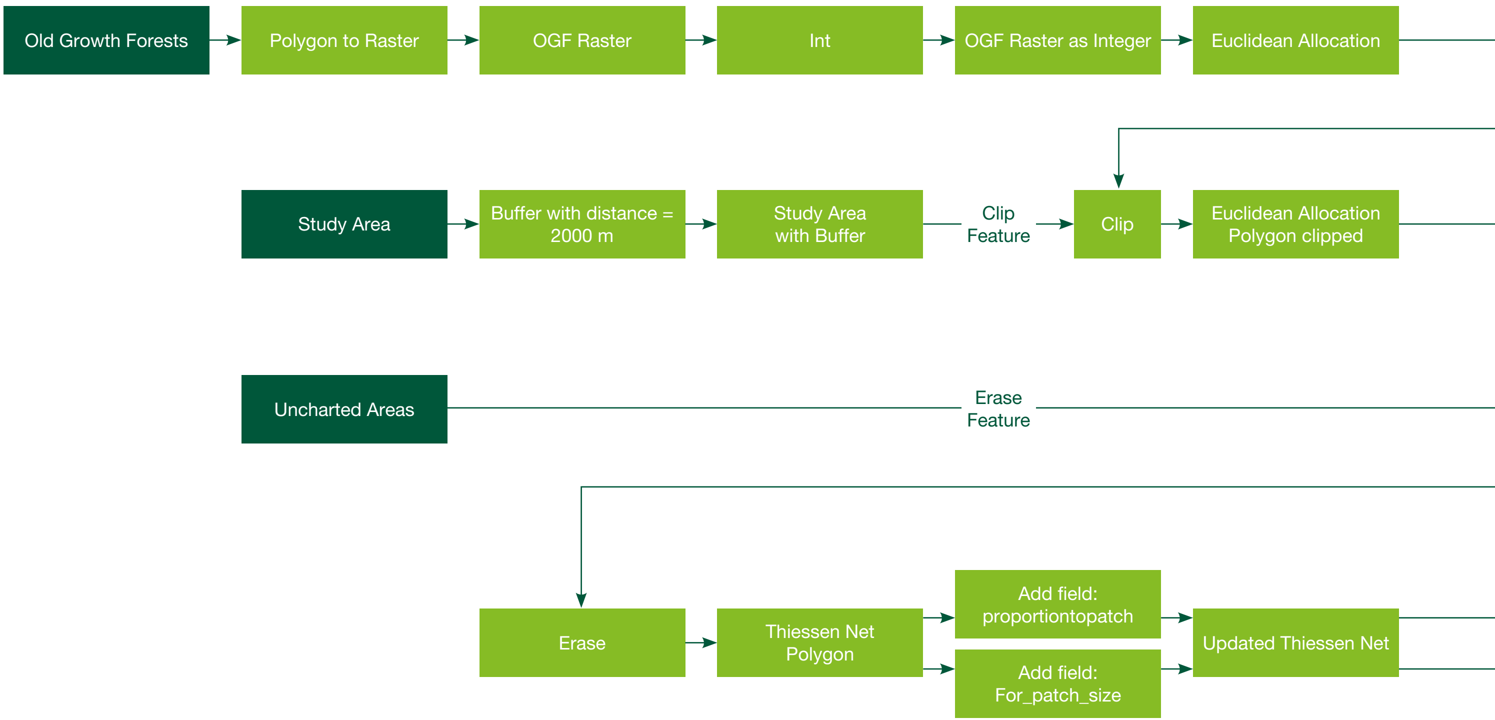
ANNEX 2. Filtering and prioritization of the potential primary forest polygons

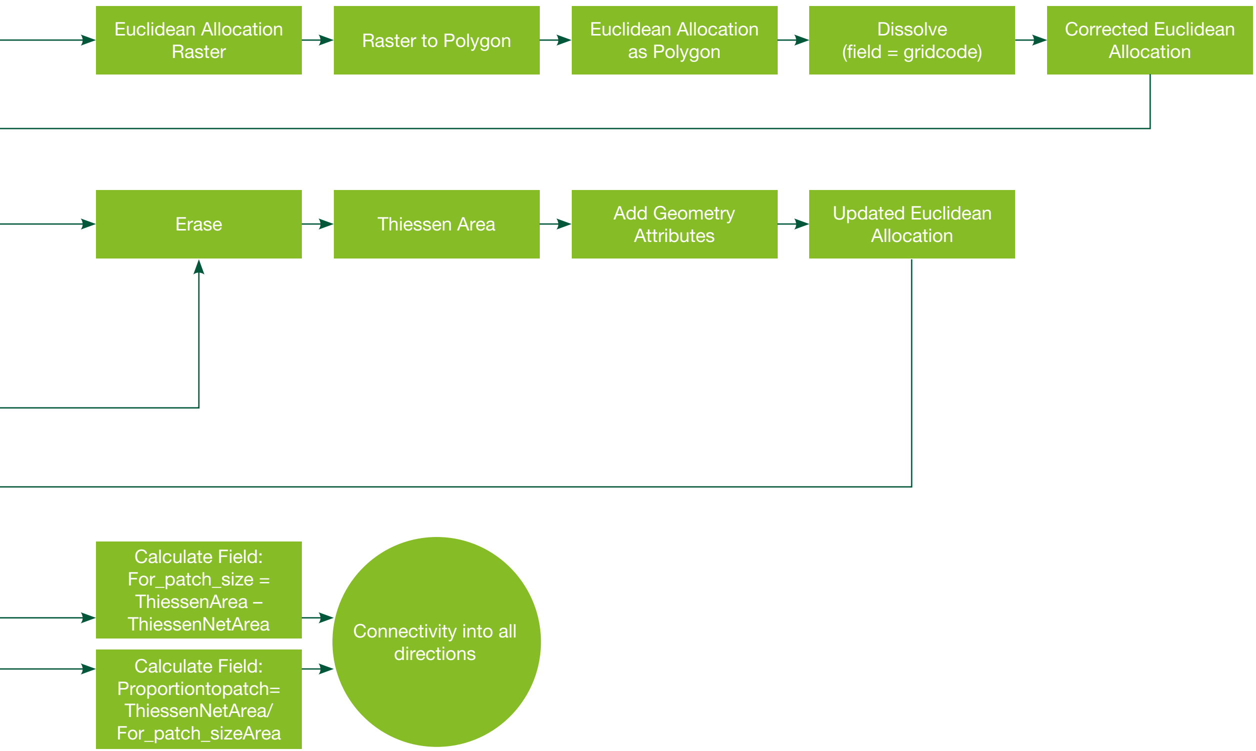
LEGEND




Railway Buffer 1 m
Road Buffer 1,5 m
Erase conifers below 1200 m
Old Growth Forest without Plantations
Exclude OSM Roads and Railways
Old Growth Forest without Roads and Railways
Select Polygons > 200 m²
Potential Primary Forests
Conifers below 1200 m

ANNEX 3. Process flowchart of the connectivity evaluation




Euclidean Allocation Raster
Raster to Polygon
Euclidean Allocation as Polygon
Dissolve (field = gridcode)
Corrected Euclidean Allocation
Erase
Thiessen Area
Add Geometry Attributes
Updated Euclidean Allocation
Calculate Field: For_patch_size = ThiessenArea – ThiessenNetArea
Calculate Field: Proportiontopatch= ThiessenNetArea/ For_patch_sizeArea
Connectivity into all directions

Glossary

For this study the following definitions have been used:

DEFORESTATION

The conversion of forest to other land use or the permanent reduction of the tree canopy cover below the minimum 10 percent threshold[1].

FOREST DEGRADATION

Changes within the forest which negatively affect the structure or function of the stand or site, and thereby lower the capacity to sup-ply products and/or services[2].

ILLEGAL LOGGING

Timber is harvested in violation of national laws[3].

CANOPY

The forest cover of branches and foliage formed by tree crowns[4].

1. FRA (2015) - Forest Resources Assessment Working Paper 180, FAO, 2015

2. FAO (2001) – Global Forest Resources Assessment 2000

3. European Commission (2003) - The European Union Action Plan for Forest Law Enforcement, Governance and Trade (EU FLEGT)

4. FAO (2001) – Global Forest Resources Assessment 2010

VIRGIN FOREST / PRIMARY FOREST[5]

A primary forest is a forest that has never been logged and has developed following natural disturbances and under natural processes, regardless of its age. It is referred to "direct human disturbance" as the intentional clearing of forest by any means (including fire) to manage or alter them for human use. Also included as primary, are forests that are used inconsequentially by indigenous and local communities living traditional lifestyles relevant for the conservation and sustainable use of biological diversity. In much of Europe, primary forest has a different connotation and refers to an area of forest land which has probably been continuously wooded at least throughout historical times (e.g., the last thousand years). It has not been completely cleared or converted to another land use for any period of time. However traditional human disturbances such as patch felling for shifting cultivation, coppicing, burning and also, more recently, selective/partial logging may have occurred, as well as natural disturbances. The present cover is normally relatively close to the natural composition and has arisen (predominantly) through natural regeneration, but planted stands can also be found. However, the suggested definition above would include other forests, such as secondary forests.[6]

Naturally regenerated forest of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed[7].

Virgin forest is a natural woodland where the tree and shrub species are in various stages of their life cycle (seedlings, young growth, advanced growth, maturity and old growth) and as dead wood (standing and laying) in various stages of decay, thus resulting in more or less complex vertical and horizontal structures

5. Some key characteristics of primary forests are: - they show natural forest dynamics, such as natural tree species composition, occurrence of dead wood, natural age structure and natural regeneration processes; - the area is large enough to maintain its natural characteristics; - there has been no known significant human intervention or the last significant human intervention was long enough ago to have allowed the natural species composition and processes to have become reestablished.

6. CBD - https://www.cbd.int/forest/definitions.shtml

7. FRA (2015) - Forest Resources Assessment Working Paper 180, FAO, 2015

as a product of a dynamic process, which enables the natural forest community to exist continuously and without limit in time.
In virgin forests the dynamics inherent to living systems are connected to ecological properties (including longevity) of the dominant tree species, impact of other organisms (e.g. outbreak of insects) and to the impact of abiotic factors related to substrate, climate and to the complex of topography and water table (e.g. wind, snow, flooding). Part of this dynamics is the temporary occurrence of gaps or larger tree-less stages.
Virgin forests differ within the given phytogeographic zone, forming specific types of forest communities with characteristic species composition, spatial structure, dynamics and overall diversity due to site conditions related to the position above sea level and topography, macroclimate, and nutrient and water availability. Virgin forests reflect herewith the natural unity of forest community and abiotic conditions, fully rooted in their millennia-long continuous Holocene development[8].

OLD-GROWTH FORESTS / PRIMEVAL FOREST

A former virgin forest which has suffered in the meantime some anthropogenic influences but without experiencing a significant degradation of structure or function.

ANCIENT FOREST

A forest old enough to include a natural diversity of species and ages, trees that reached physiological longevity, and other characteristics that certify the naturalness (standing dead wood, lying dead wood in various decaying stages, certain species of plants and animals, which indicate the health status, and the naturalness of the forest), from which there is the possibility of some isolated tree extractions, but without modifying the forests composition and structure. This concept especially emphasizes the continued existence of forest over time and does not necessarily refer to the complete absence of human activity.

8. Biriş şi Veen (2005)

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