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Vegetation monitoring with remote sensing

Individual assignment 2

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Contents

1. Introduction

In the world the land cover is changing rapidly, specially in areas with a high population density. The effects of the mentioned changes are specially encountered in ecological systems. Consequently, land cover changes are important in terms of spatial planning, resource evaluation and ecological modelling (de Wit). In order to detect land cover changes the use of remote sensing has bee recognized has an important resource of information. Basically, It is a map which represent the surface of the Earth and is available at various temporal and spatial scales (Foody, 2002).

A clear perspective of how the land cover is changing can serve for multiple purposes, one of them is maintenance. The vegetation near the coastal zones can be mapped using remote sensing methods. Which principally focus in the monitoring and detection of characteristics of an specific area by measuring its reflected and emitted radiation (de Wit). This process is carried out by a satellites, aircrafts or drones. The characteristics obtained from the area are usually described with the use of indices which makes use of hyperspectral or multispectral imagery bands.

For this study a Dutch dune has been selected in order to quantify its land cover and vegetation distribution. This analysis will provide the necessary information in order to establish management rules for the maintenance of the vegetation and make a vegetation monitoring plan.

In the following report, the objectives of applying vegetation monitoring with remote sensing are established. Then, the study area is described. After that, the steps realized to obtain the remote sensing indices are described together with the classification of land cover. The results of the temporal variation of vegetation are discussed, at the same time some management rules are established. Later, a vegetation monitoring plan is elaborated. Finally, a conclusion concerning the final design of the study area is described.

2. Objectives

- Comprehend and explain how remote sensing data can be used to depict land cover in dune areas.
- Use satellite imagery in order to calculate vegetation indices and classify land cover in the study area.
- Analyse the temporal and spatial variation of vegetation in order to set management rules for the final design.
- Elaborate a monitoring plan which can be applied to Almere Dune.

3. Study area

The selected area covers principally the Zuid-Kennemerland National Park, a part of Harlem, Zaandvort and other small cities.

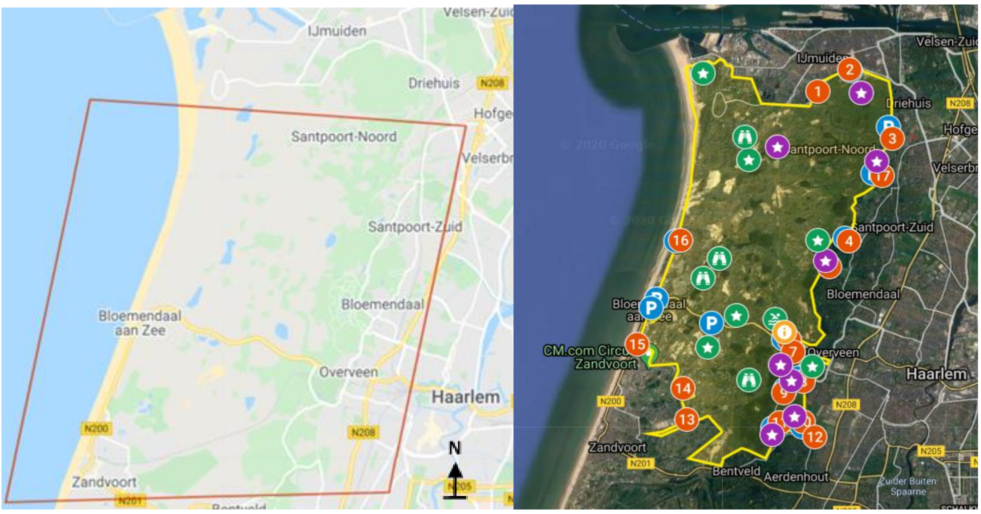

Figure 1: Selected area extended from Ijmuiden to Zandvoort

As it can be appreciated, the national park covers a big part of the selected area and is extended from Ijmuiden to Zandvoort. The area was selected because it consists of expanse dunes, which is also the habitat of countless species of animals and plants. In the western part, rugged dunes can be observed together with forests, mossy, thickets and grass. On the other hand, the young dunes area located in the Northern side (National Park Zuid-Kennemerland, n.d.). Furthermore, Zandvoort, Harlem and other cities were consider in order to visualize the behaviour of build-up areas in the remote sensing analysis.

4. Remote sensing indices

Through the analysis of multispectral or hyperspectral imagery bands, ecological information can be obtained and vegetative indices(VI) play an important role in this process. The satellites or drones retrieve spectral reflectance responses, which are utilized to calculate the remote sensing indices. These improve the accuracy of algorithms used to classify land cover or vegetation.

NDVI

The near-infrared light(NIR) is reflected by the leaves. Meaning that plants can be analysed by considering NIR and red visible light.

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)} \quad \text{Eq.(1)}$$

In a large scale this index is used to monitor disturbances in the forests and to make assessments. One of the main drawbacks is due to its sensitivity to soil, atmosphere and leaf canopy shadow effects (Medium, 2018).

Figure 2: NDVI calculation of study area

NDWI

By using NIR and SWIR bands the Normalized Difference Water Index(NDWI) can be calculated. This index measures the change in water content of leaves.

$$NDWI = \frac{(NIR - SWIR)}{(NIR + SWIR)}$$

Eq.(2)

It is more useful to record droughts,low groundwater levels and so on, due to its sensitivity(water content of plants and water bodies) (Medium, 2018).

Figure 3: NDWI calculation of study area

EVI

The Enhanced Vegetation Index (EVI) is used as an alternative since it addresses some of the aforementioned issues regarding NDVI. Those problems are related to the atmospheric and soil effects which are corrected with the introduction of a parameter.

$$EVI = 2.5 * \frac{(NIR - RED)}{(NIR + C_1 * RED - C_2 * BLUE + L)}$$

Eq.(3)

In equation 3, the coefficient L corrects the soil background, while C1 and C2 are correction coefficients for atmospheric effects. For those coefficients standard EVI values were used: L=1, C1=6 and C2= 7.5 (Medium, 2018).

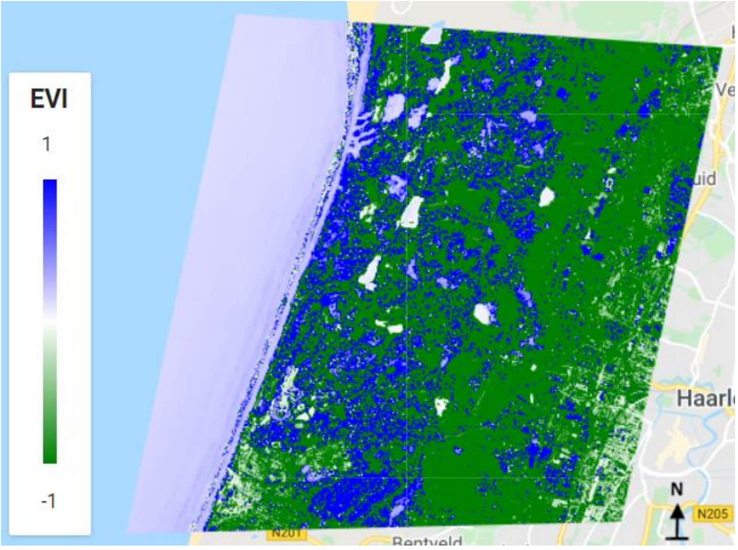

Figure 4: EVI calculation of study area

MSAVI2

As the soil brigthness is one of the principall problems of NDVI. The index MSAVI2 adresses this problem, which is mainly used to analyse plants growth. Furthermore, it is a good index for areas which have a exposed surface and there is not abundant vegetation.

$$MSAVI2 = \frac{(2*NIR+1-\sqrt{(2*NIR+1)^2-8*(NIR-RED)}}{2} \quad \text{Eq.(4)}$$

This index is better used in desert environments, in which there is a considerable amount of exposed soil. One of the disadvantages of using this index is that atmospheric conditions can also affect the results of this index (Medium, 2018).

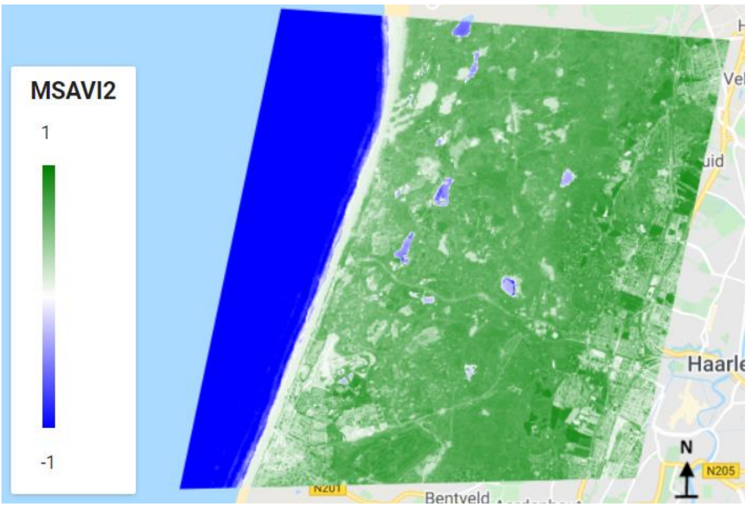

Figure 5: MSAVI2 calculation of study area

4.1. Calculation of the indices

First, it is important to select the satellite imagery which will be used in the calculation process of the remote sensing vegetation indices. For that purpose, two satellite imagery were considered: Sentinel-2A and Landsat 8. The images of Sentinel-2A where selected due to its good spatial resolution and its wide range of applications. For instance, the main visible and near-infrared bands have a spatial resolution of 10 meters. While, the “red edge” and two shortwave infrared bands have a 20-meter spatial resolution (USGS, n.d.). This is important because in order to calculate remote sensing indices some of the mentioned bands will be used. Furthermore, Sentinel-2 satellite imagery offers a collection of satellite images which are useful to assess the state and change of vegetation, soil, and water (Google Developers, n.d.).

As mentioned before Google Earth Engine was a useful tool in the remote sensing of vegetation. In the following flowchart a summary of the methodology used will be showed.

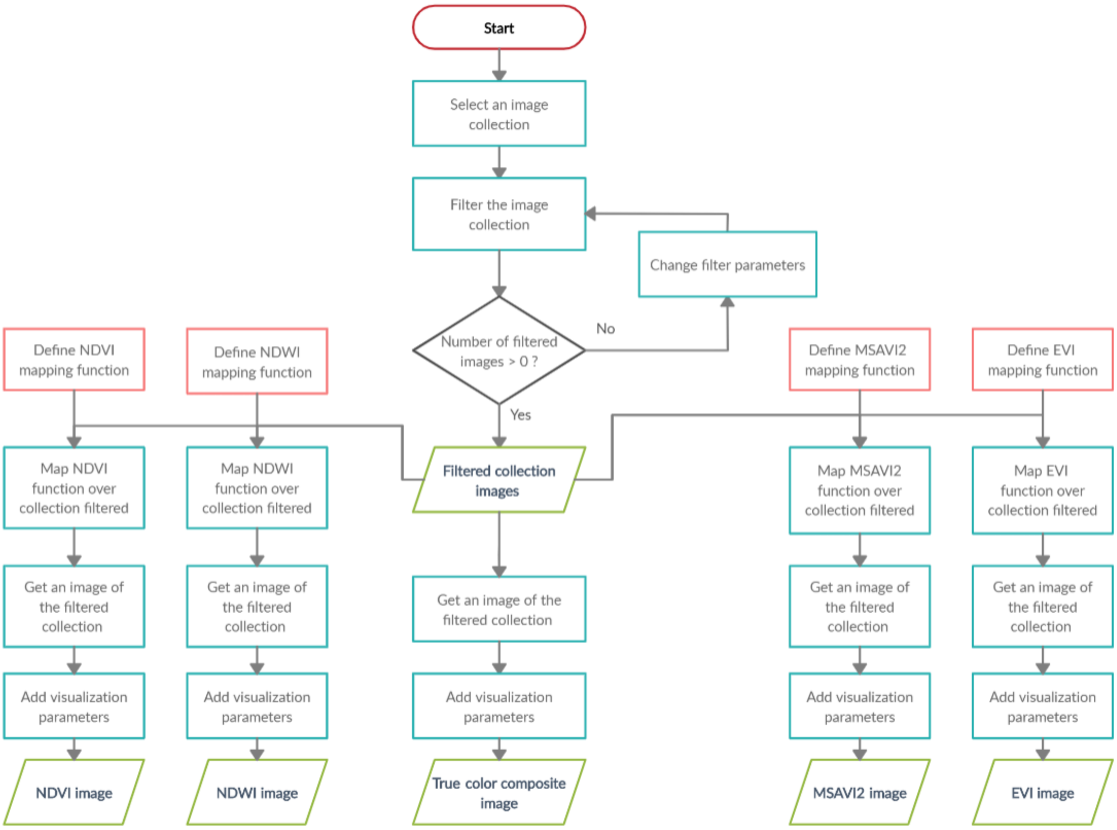

Figure 6: Flowchart showing the calculation of vegetation indices

First, the Sentinel-2 images are loaded by defining an “ImageCollection”. The image collection contains all the available Sentilel-2 images up to the current date. Therefore, it was necessary to filter the collection. The filter applied considered the specific dune area which was discussed before. Furthermore, a filter on date was applied which considered the period from the first of January of 2020 to the 30 of June of 2020. Together with a filter on cloud-free day images in which the required cloudy pixel percentage was set on 0%, as shown in the following code.

```
// select Sentinel-2 imagery and set to ImageCollection S2_collection
var s2_collection = ee.ImageCollection("COPERNICUS/S2");
// reduce the imageCollection by filtering on location and period of interest
var s2_collection_filtered = s2_collection
 .filterBounds(dune_area)
.filterDate('2020-01-01','2020-06-30')
 .filter(ee.Filter.lte('CLOUDY_PIXEL_PERCENTAGE', 0));
// print the number of images stored in imageCollection s2_collection_filtered
print('Number of images', s2_collection_filtered);
// center map on study area using zoom level 12
Map.centerObject(dune_area, 12.3);
```

After that, a decision box is shown in black in the flowchart. This is because after applying the filters the image collection can be reduced up to 0 images which would not be useful for the study. If the number of filtered images is 0 it is required to change the filters. For instance, the "CLOUDY_PIXEL_PERCENTAGE" can be increased up to 20% which according to some experts is still considered as an acceptable value (ResearchGate, 2019). This will increase the number of filtered images making possible to realize an analysis.

In this case the filtered image collection was as named **"s2_collection_filtered"**. When the number of filtered images is acceptable the calculation of the indices can be started.

4.1.1. Calculation of NDVI and NDWI

In the flowchart the start of these new processes is represented by red boxes. In order to calculate NDVI and NDWI a function was defined, which can be observed in the following code. This function calculates the normalized difference using the NIR and RED bands for NDVI, as it was shown in equation 1. Since the spectral bands correspond to data observed by Sentinel-2. The bands "B8" and "B4" represent NIR and RED respectively. Then the calculated bands can be added to the original image with the tool "image.addBands".

After creating the NDVI function, it is mapped over the filtered image collection ("s2_collection_filtered") and the NDVI band is selected. Subsequently, an image should be selected from the filtered image collection. In the studied case 8 images were available after applying the filters. It is possible to select any of them, but it was decided to take the mean of all the eight images and create a new image called "s2_NDVI_image". With the establishment of visualization parameters "ndviParams", it is possible to add the NDVI image to the map view.

The same procedure was made in order to determine NDWI, with a difference in spectral bands. In this case "B8" and "B11" represent NIR and SWIR respectively.

```
// CALCULATION OF NDVI

// define NDVI mapping function
var addNDVI = function(image) {

// calculate normalized difference using nearinfrared and red bands, and rename to NDVI.

 var NDVI = image
 .normalizedDifference(['B8', 'B4'])
 .rename('NDVI');

 // add new NDVI band to original image
 return image.addBands(NDVI);
 };

// map NDVI function over imageCollection s2_collection_filtered and select ndvi band
var s2_NDVI = s2_collection_filtered.map(addNDVI);

// get the mean of ndvi images and store in variable s2_ndvi_image.
var s2_NDVI_image = s2_NDVI.select('NDVI').mean().clip(dune_area);

// define visualization parameters for NDVI image
var ndviParams = {band: ['NDVI'],
 min: -1,
 max: 1,
 palette: ['blue', 'white', 'green']
};
// add NDVI image to map view
Map.addLayer(s2_NDVI_image, ndviParams, 'NDVI');
print('Image information', s2_NDVI_image);
```

4.1.2. Calculation of EVI and MSAVI2

In order to calculate EVI and MSAVI2 a function was also defined. But, in this case "image.expression" was added since there is not a predefined function as in the case of NDVI and NDWI. In the following code it can be observed that equation 3 corresponding to EVI is typed. Then, it is necessary to select the bands which are used in the calculation of the index. In this case "B8", "B4" and "B2" bands were selected, which correspond to NIR, RED and BLUE respectively. After that the same process applied for the calculation of NDVI and NDWI was followed.

In order to calculate MSAVI2 the function was defined in the same way as for EVI with the difference in the selection of spectral bands. In MSAVI2 the bands NIR and RED were selected, corresponding to "B8" and "B4" respectively.

```
// CALCULATION OF EVI

// define EVI mapping function
var addEVI = function(image) {

 // calculate EVI using BLUE, RED and NIR bands, and rename to EVI.

var EVI = image.expression(
  '2.5 * (NIR - RED) / ((NIR + 6*RED - 7.5*BLUE) + 1)',
  {
    'NIR': image.select('B8'),
    'RED': image.select('B4'),
    'BLUE':image.select('B2')
  }
).rename('EVI');

 // add new EVI band to original image
 return image.addBands(EVI);
 };
```

5. Classification of land cover

In order to visualize the land cover classification, several steps were performed which are summarized in the following flowchart:

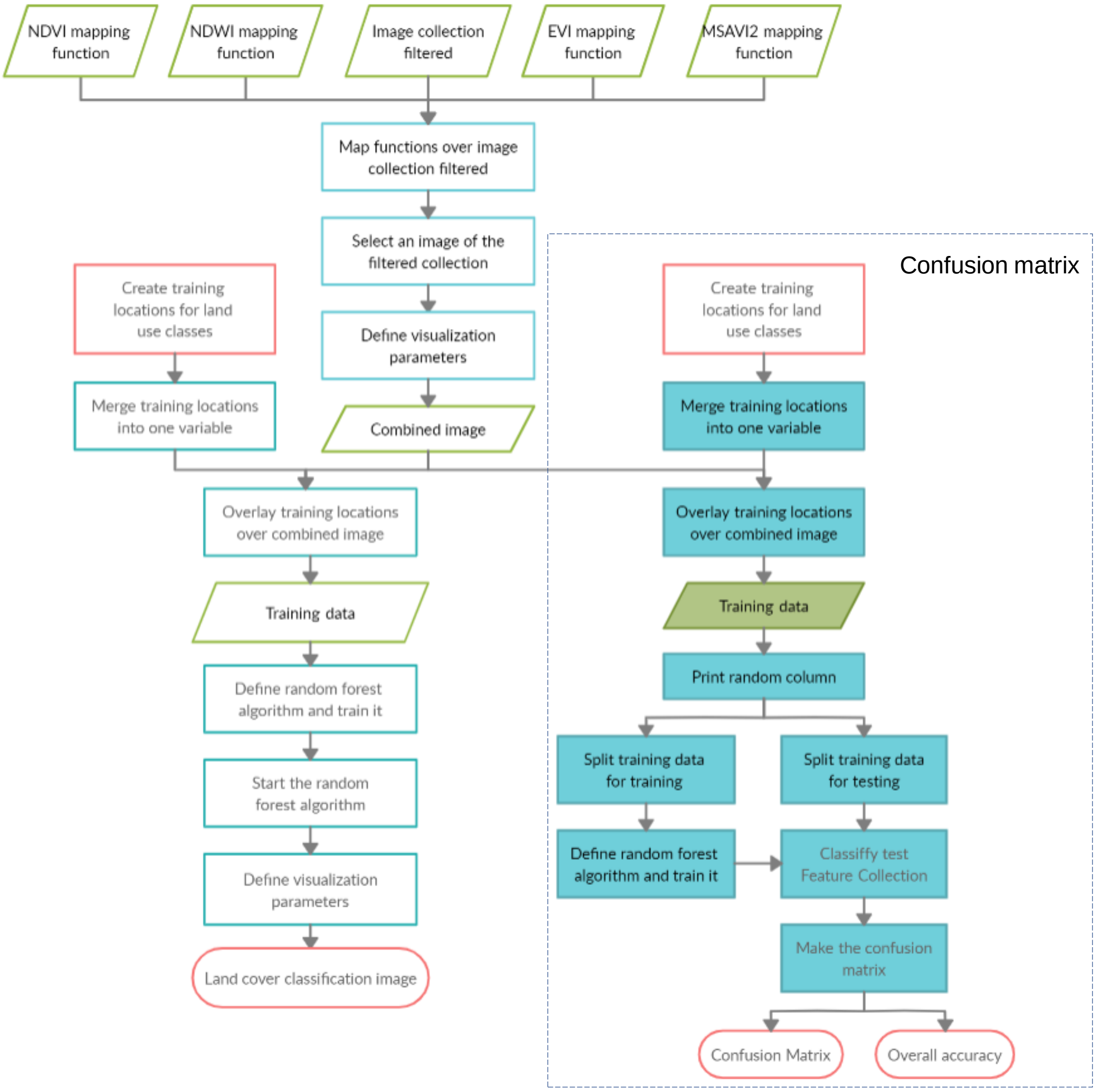

Figure 7: Flowchart showing land cover classification and accuracy assessment

5.1. Combined image

First, the functions which were created in order to calculate the indices are mapped over the image collection filtered called **"s2_collection_filtered"**. As mentioned before it is necessary to select one image, in this case the mean of all images was taken. The created image was named **"s2_img_2"** . Then, some visualization parameters were added and the image was added to the map view as a layer named "combined image". This is also shown in the following code:

```
// map the existing functions over imageCollection s2_collection_filtered
var s2_img = s2_collection_filtered.map(addNDVI).map(addNDWI).map(addMSAVI2).map(addEVI);

//select NDVI, NDWI, MSAVI2 and EVI bands and obtain the mean of the s2_img.
var s2_img_2 = s2_img.select(['NDVI','NDWI','MSAVI2','EVI']).mean().clip(dune_area);

// define visualization parameters for the combined image
var ndwiParams = {band: ['NDVI','NDWI','MSAVI2','EVI'],
 min: -1,
 max: 1,

};
// add s2_img_2 to map view
Map.addLayer(s2_img_2, ndwiParams, 'combined image');
print('Image information', s2_img_2);
```

This made possible to obtain a combination of NDVI, NDWI, EVI and MSAVI2 in one image, which can be visualized in Appendix B.

5.2. Land cover classification image

The combined image will be utilized in order to make the land use classes map. The landcover and vegetation is classified by making use of a random forest machine-learning algorithm, which is based on decision trees. As it can be appreciated in the flowchart training data was created to set-up the mentioned algorithm. In order to generate training data, five layers representing land cover were created. They were created as 'FeatureCollection' with the following properties.

Table 1:Properties of land cover layers

Landcover	Property	Value
Grass and agroforestry	landcover	0
Sand and Build-up	landcover	1
Water	landcover	2
Forest	landcover	3
Crops and grass	landcover	4

In order to identify the different land use classes in the map two options were considered. The first option is to have a look at the true colour composite layer and visually inspect the land cover. Subsequently the polygons should be drawn in the layer corresponding to the identified land use class.

Table 2: Classification of land use classes according to NDVI

Features	NDVI (range)
Water(deep & shallow)	-0.41379 to -0.10401
Build-ups/ river sand	-0.10401 to 0.055727
Crops & grass	0.20579 to 0.37035
Agroforestry	0.37036 to 0.51073
Forest	0.51074 to 0.82051

Another option would be to take a look at the NDVI values with the use of the Inspector tool. For instance, by clicking on an specific area the NDVI value in that area is shown. It could be the case of an specific area having a NDVI value of - 0.37. Since this value lies between the NDVI range of -0.41 to -0.10 according to table 2, it should be considered as a water body. Therefore, the water layer was selected and a polygon was drawn in the mentioned area. Another example can be the case of the NDVI value in an area having a value of 0.63, then a polygon pertaining to the forest layer should be drawn. Because 0.63 lies between the range 0.51 to 0.82. This procedure was repeated for the remaining land use classes. It is important to mention that each of the five layers(grass and agroforestry, sand and build-up, water, forest and crops and grass) contained at least 5 polygons. This was made in order to increase the accuracy of the random forest algorithm.

After that, it is necessary to merge all the five layers into one variable ("training_locations"). That variable represents the polygons which should be overlayed on the combined image("**s2_img_2**"). That action created the training data, which is used to set-up the random forest algorithm and train it. Then, the algorithm should be started and the landcover is classified. In the end, it necessary to define visualization parameters and add the layer to the map. The layer is named as "Land cover classification".

```
// merge training locations into one variable
var training_locations = agroforestry.merge(sandandbuildup).merge(water).merge(forest).merge(cropandgrass);
// overlay the polygons on the combined image to get the training data
var training_data = s2_img_2.sampleRegions({
 collection: training_locations,
 properties: ['landcover'],
 scale: 20
});
print('Information', training_data);

// define random forest (RF) algorithm and train it
var RFclassifier = ee.Classifier.randomForest().train({
 features: training_data,
 classProperty: 'landcover',
 inputProperties: ['NDVI','NDWI','MSAVI2','EVI']
});
// start the random forest algorithm to classify land cover using the "combined image" layer
var trained_RF = s2_img_2.classify(RFclassifier);

// define color palette for each land use class
var palette = [
 '83dd00', // agroforestry, value 0, yellow green color
 'fde512', // sand, value 1, yellow color
 '0000FF', // water, value 2, blue color
 '0a8f0b',// forest, values 3,darkgreen color
 'd2ff00'// crop and grass 4, green color

 ];

 // define visualization parameters for land cover image
 var land_coverParams = {min: 0,
 max: 4,
 palette: palette
 };

 // add land cover image to map
 Map.addLayer(trained_RF, land_coverParams, 'Land cover classification');
```

The code shown above was used in order to obtain figure 8 which shows the land use grouped into five classes:

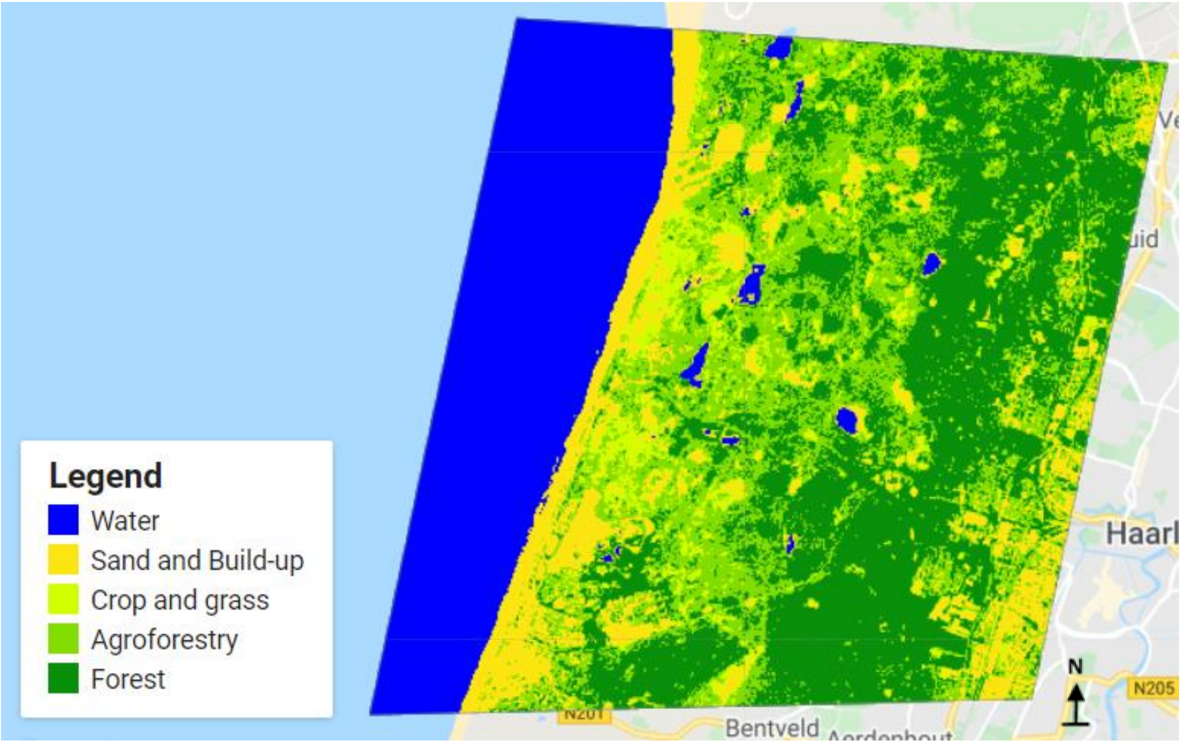

Figure 8: Land use classification taking into account the combined layer

5.3. Confusion matrix

The confusion Matrix is used to evaluate the accuracy of a classifier (Google Earth Engine, n.d.). In this case polygons should be drawn as before. Therefore five new layers representing the land cover were added to the map, each layer contained at least five polygons.

As shown in the following code the layers were merged and then overlayed over the combined image(“**s2_img_2**”), with that the training data could be obtained. The obtained training data should be split in two groups, one should be used for training and one for testing. In this case 70% of the data was used for training and 30% for testing. With the training data group it was possible to define a classifier called **“trainedClassifier”** and train it. Next, the testing data group makes use of the “classify” tool on “**trainedClassifie**r”, this is stored in a variable called “test”. With this variable the “errorMatrix” tool can be called, which makes possible to visualize the confusion matrix and the accuracy which in this case was 0.9900497512437811.

```
// merge training locations into one variable
var training_locations2 = agroforestry2.merge(sandandbuildup2).merge(water2).merge(forest2);
// overlay the polygons on the "combined image" to get the training data
var training_data2 = s2_img_2.sampleRegions({
 collection: training_locations2,
 properties: ['id'],
 scale: 20
});
print('Information', training_data2);

var withRandom = training_data2.randomColumn('random');
print('Information', withRandom);

var split = 0.7;  // Roughly 70% training, 30% testing.
var trainingPartition = withRandom.filter(ee.Filter.lt('random', split));
var testingPartition = withRandom.filter(ee.Filter.gte('random', split));
print('Information', trainingPartition);
print('Information', testingPartition);

// Trained with 70% of our data.
var trainedClassifier = ee.Classifier.randomForest().train({
  features: trainingPartition,
  classProperty: 'id',
  inputProperties: ['NDVI','NDWI','MSAVI2','EVI']
});
print('Information', trainedClassifier);

// Classify the test FeatureCollection.
var test = testingPartition.classify(trainedClassifier);

// Print the confusion matrix.
var confusionMatrix = test.errorMatrix('id', 'classification');
print('Confusion Matrix', confusionMatrix);
print('Validation overall accuracy: ', confusionMatrix.accuracy());
```

6. Temporal and spatial variation of vegetation

6.1. Spatial variation

In order to visualize the temporal and spatial variation of vegetation it was necessary to know the value of the area occupied by the different land use classes. In order to do that the image with the land use classes was exported as a raster to an Earth Engine asset.

```
Export.image.toAsset({
  image: trained_RF,
  description: 'land cover classes',
  assetId: 'users/tjpilataxiaraujo/class',
  scale: 20,
  region: dune_area,
});
```

In the following code the image which was saved as an asset is called. After that it is possible to calculate the area with the use of the tool “ee.Image.pixelArea”, which generates an image in which the value of each pixel is the area of the pixel in square meters (Google Earth Engine, n.d.). This is done for every land use class. Because the area is calculated in square meters it was necessary to transform the obtained value to hectares which is better for understanding purposes.

```
var image = ee.Image('users/tjpilataxiaraujo/2020_summer')

for(var a=0; a < 5; a++){

  var x = image.eq(a).multiply(ee.Image.pixelArea())

  var calculation = x.reduceRegion({

    reducer:ee.Reducer.sum(),

  })

  print('ID' + a + 'Hectares',calculation, ee.Number(calculation.values().get(0)).divide(1e3))
}
```

6.2. Temporal variation

In order to know the temporal variation, it is necessary to establish which period of time will be studied. Along the year the land use changes due to different factors, one of them are the seasons. It was decided to study the year 2019 in order to observe the seasonal changes. Due to the low availability of filtered images two periods were considered: spring & summer (2019-03-21 to 2019-09-23) and fall & winter(2019-09-23 to 2020-03-20).

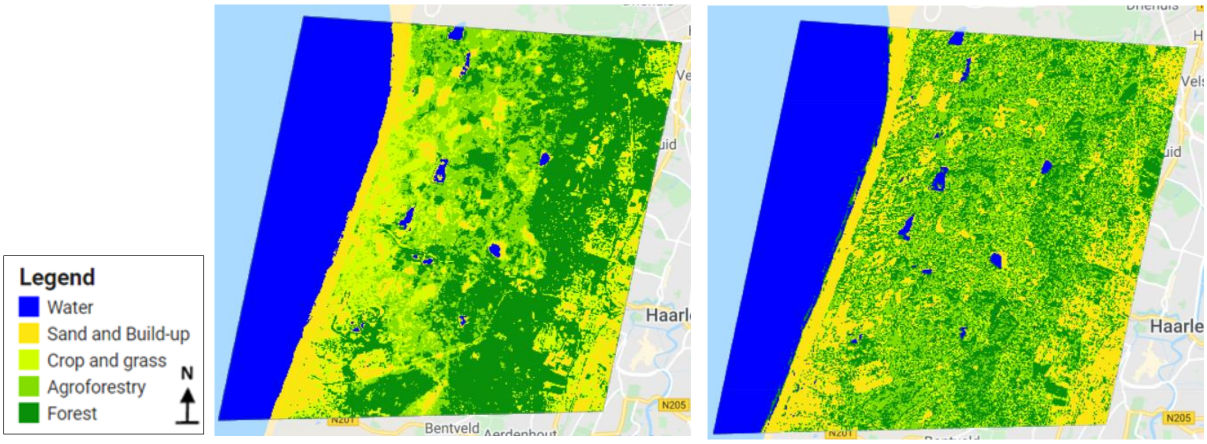

Figure 9: Land cover in two periods: spring & summer and fall & winter

The resolution of the first image seems better than in the second one. Furthermore, as it can be appreciated in table 3 the first period has better accuracy than the second period.

Table 3: Area covered by each land use class

Period	Water	Sand and Build-up	Crop and grass	Agroforestry	Forest	Accuracy
Spring and summer	15162.387	7530.399	10689.268	10470.335	22156.512	0.9834
Fall and winter	14817.592	12049.347	7715.710	11913.407	19512.845	0.9539

6.3. Results

Therefore, it was decided to take the first period(spring & summer) which would comprehend from 2016 to 2020. The retrieved images from the analysis can be visualized:

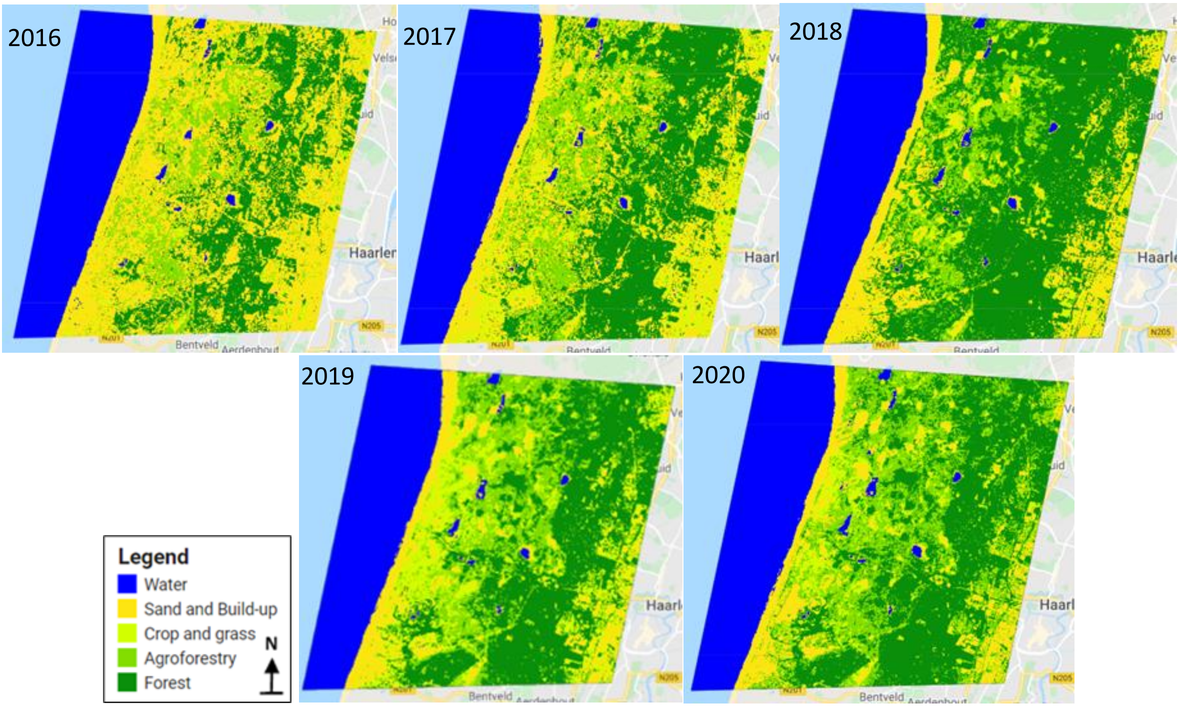

Figure 10: Land cover changes from 2016 to 2020

In the following graph the area covered by each land use class is showed per year.

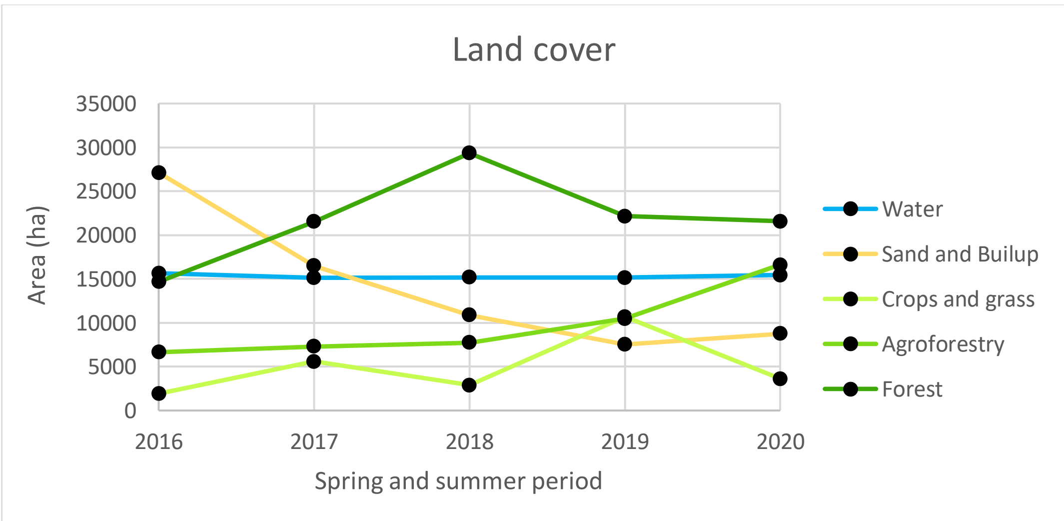

Figure 11: Area covered by each land use class from 2016 to 2020(spring & summer period)

As it can be appreciated the area occupied by water does not change considerably through the time. This makes sense due to the fact that the same period(spring & summer) is considered in all the years. The table with the values of the area of each land use class can be found in Appendix C.

The area occupied by sand and build-up land use declines through the years. Owing to the project 'Dutch Dune Revival'. This major restoration project started in 2011 and finished on 2016 (Natuurmonumenten, n.d.). The project was realized in order to restore and preserve the diverse and wonderful dune grasslands with plants typical of a dune environment. The results would be noticeable in the following years(from 2016 onwards) (Levend duin Zuid-Kennemerland, 2015). Which is the reason why the area covered by vegetation increases along the time(after 2016), while the area covered by sand and built-up decreases. This will also will influence in some way the crops & grass and agroforestry land use classes, which cover more area through the time.

With regards to the forest, at the start of 2016 the area covered by forest was around 14000 and until 2018 it increased considerably reaching 29000 hectares approximately. But, in the next year the area covered by forest is smaller compared to 2018. This could be due to the fact that in the end of 2018 some dune works for nature restoration were applied in the area. It was mainly focused on the removal of American bird cherry, which is a shrub that spreads quickly and overgrows the local plants and flowers (Natuurmonumenten, 2018).

Figure 12: American bird cherry

7. Vegetation in the area

The vegetation in the area should have specific characteristics (Gadgil & Ede, 1997):

(i) In order to avoid the drifting of sand, only sand-binding plants can be established in the area. The mentioned are perennial species grow rapidly and have an extensive root system which can help to prevent erosion.
(ii) The sand drift should be stopped before non-san-binding plants are introduced.
(iii) In places where there is not drift of sand long-lived plants and trees will be introduced.

The list of plants suitable for the dune environment will be discussed together with their attributes:

Table 4: Proposed vegetation for Almere Dune

Plant	Description	Image
Ammophila arenaria or marram grass	It is a grass which can easily be established for sand-binding, which can stop drifting sand. It is a perennial plant which as mentioned before is good for this type of environment. They can live for many years and in winter they grow slowly due to the cold weather. It differentiates from other plants because	

	it can withstand burial up to a meter in a year, by elongating its leaves (CABI, n.d.).	
Ligustrum vulgare	This specie forms dense thickets and is also highly adaptable to different environments. Their berries are consumed by birds.	
Craetegus monogyna (eenstijlige meidoorn)	They act as shelters for many birds and small mammals. Therefore, they are important for nature protection purposes. Also this specie is tolerant to air pollution (CABI, n.d.).	
Artemisia campestris s. campestris	This bush is a perennial plant, from which their rhizomes can reach up to a meter and a half underground.	
Hippophae rhamnoides (duindoorn)	The berries of this bush give colour to the dunes in autumn season. The berries are rich in vitamin C and are consumed by migratory birds. Furthermore, apports nitrogen to the soil and also allows the growth of other plants (ecomare, n.d.).	
Sambucus nigra (gewone vlier)	It is very useful for erosion control and dune stabilization. Furthermore, the fruits are used for making products for the human consume (CABI, n.d.).	
Pinus nigra subsp. laricio (corsicaanse zwarte den)	It is typical of a dune environment which can grows up to 50 meters. It is mainly used for ornamental purposes (HORTUS, n.d.).	

8. Management processes

As it was mentioned before the studied area is not the actual area which will be monitored. The study area is very attractive for tourists due to the fact that activities such as cycling, hiking, horseback riding and so on are carried out. Therefore, management rules which were implemented in this area can be useful for the management of Almere Dune, since they share similar characteristics.

Through the years Almere Dune will face some problems which will require maintenance. Those problems are specially associated with the human activity. The South area is more focused on recreational activities which can represent an important threat to the sand dune stability. Some of the management problems which will be faced are closely related to erosion and deposition of sand grains. Therefore, it is necessary to establish management rules which can prevent this from happening.

The prevention of erosion and deposition of sand are the result of stabilization techniques, which are realized as part of the sand dune management. One of the things to be considered is the introduction of grass before shrubs and trees are planted in the area. It is important to take into account that grasses alone cannot prevent the aforementioned problems. Although is a good way to start the management of a dune area. Therefore, a few hectares of sand dunes will be covered by shrubs and pines typical of a dune environment, which will enhance the soil and climate. As part of the actions which should be taken along the years is the replacements of dead plants, this minimizes the chance of blowouts, this operation should be carried out annually. Because, it is important to consider that only dry sand grains are vulnerable to wind movement. Therefore, the covering of the sand dune is important to prevent erosion, which in the end can avoid the destruction of stable dunes (Gadgil & Ede, 1997).

In the study area Scottish highlanders and koniks are important in the conservation of the environment. Because, they graze the tall grass making space for the dune flowers (Natuurmonumenten, n.d.). This is feasible in this area because is bigger compared to Almere Dune. But nevertheless, it was decided that trampling or grazing by animals cannot be allowed in the actual area. Since this will cause the sand to be exposed to the wind action (Gadgil & Ede, 1997).

In the study area also invasive shrubs were removed in the maintenance works. Sometimes they can have a negative effect by overgrowing all dune plants in dune valleys (Natuurmonumenten, 2018). Furthermore, overgrown dune grasslands were cut, which are measures that can also be applied to the vegetation of Almere Duin.

It is also important to take into account the damage that the excess of nitrogen can cause in the vegetation. In the studied area sheep and cattle keep the areas open, mow the grasslands extra, cut heather and remove nitrogen-rich soil environment. Because, they graze the tall grass making space for the dune (Natuurmonumenten, n.d.). This is feasible in this area because is bigger compared to Almere. On the other hand grazing is not allowed in the actual area. Therefore, other interventions can be applied such as: of digging peat holes, dredging fens, removing young trees and shrubs to restore heather and drifting sand or raising the water level to prevent drying out and acidification of the soil. With the mentioned measures it is assured that nature can resist the excess of nitrogen. The measures assure that certain plant and animal species can survive (SFGATE, 2018) .

8.1. Management rules

The area is open for residents and visitors which should be able to take advantage of the facilities in the dunes. Throughout the year many people will visit the area, therefore it is necessary to stablish some rules for the maintenance of the place:

- The visitors should use the long paths which connect all the facilities.
- The vegetation of the area should be respected meaning that the flowers and plants cannot be picked up.
- The fauna should be respected by leaving animals and their nests alone.
- Camp in the area designated for that purpose, it is not allowed to stay overnight in the dunes.

- The waste should be disposed in the corresponding bins.
- Swimming is only allowed at the beach and small lake(not in other water bodies in the area).
- Animals can not be released at the dunes since this can cause damage or disturb the ecosystem.
- Use the bike in the designated paths for that purpose.
- Do not dig in the dunes or cause any related damage.
- Be careful while smoking and do not light an open fire(making a barbecue is not allowed).

9. Monitoring plan for Almere Dune

All the south area will be monitored, but it is important to put some attention to specific places in which the human activity can cause significant damage. The areas near the coast are more vulnerable because of action of the wind. Moreover, the expected concurrence of people is high due to the recreational activities offered in the area. The areas catalogized as normal will be less concurred by people.

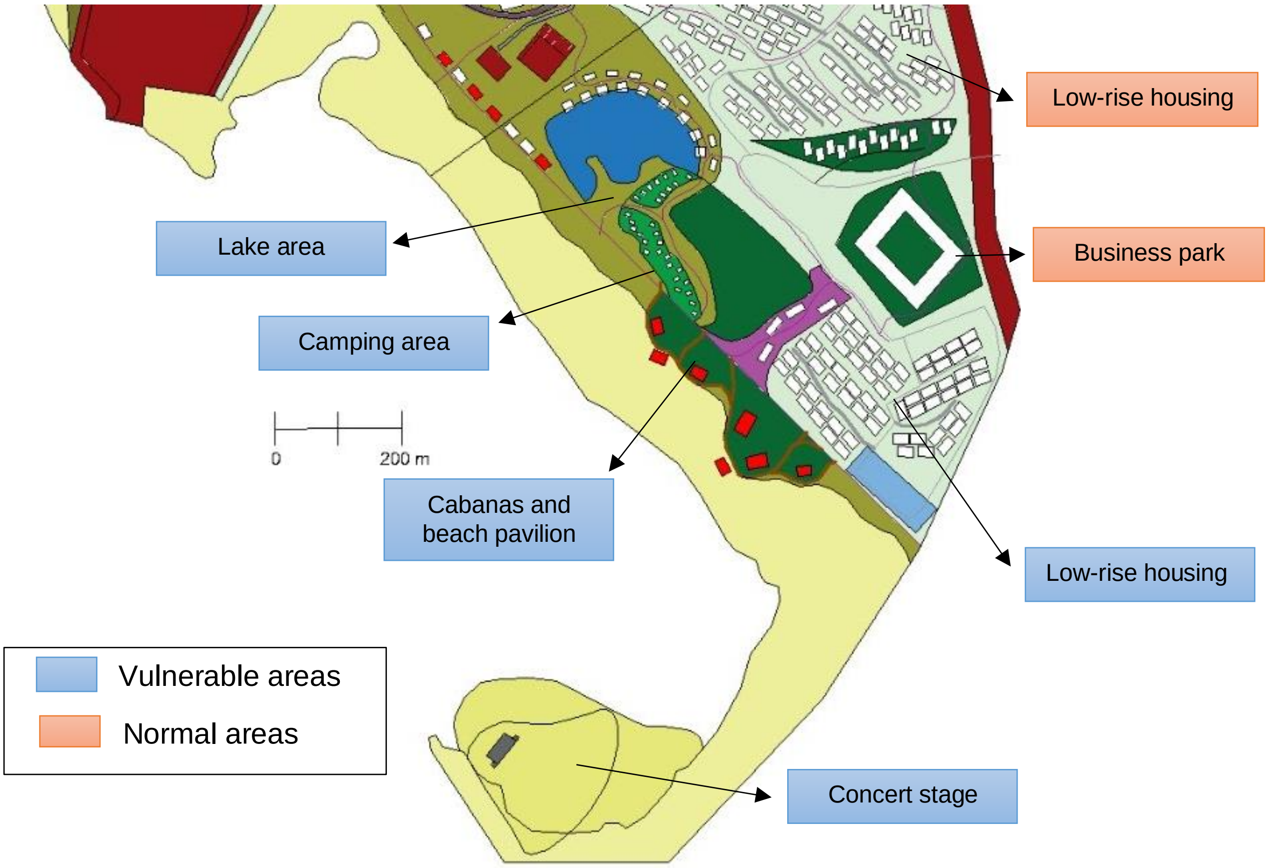

Figure 13: Land cover of Almere Dune

9.1. Monitoring plan scope

1. Identify the possible impacts or motives to monitor vegetation.
2. Identify the areas which may suffer important impacts.
3. Decide how the impacts are going to be monitored

4. One of the important things to do is collect the data before the start of the operations, which can form baseline data.
5. Continuation of monitoring following commencement of operations to gather initial comparative data.
6. Compare the data obtained before and after the start of operations in the area to note fluctuations in vegetation health.
7. Identify the causes of any decline in vegetation health
8. Report the findings of monitoring to the interested stakeholders in order to decide what to do in case of unhealthy vegetation

9.2. Monitoring plan

According to the mentioned points a monitoring plan was elaborated which is summarised in table 5:

Table 5: Monitoring plan for Almere Dune

Motive	Area	Monitoring program	Dimensions	Parameters to be monitored
Weed infestations	Entire area	Visual assessment	NA	• Specific location of weeds • species of weeds • % cover alive weeds • % cover dead weeds • site conditions including; visible erosion and dust deposition (Gadgil & Ede, 1997).
Decrease in vegetation	Vulnerable areas	Field sampling with quadrants	10m x 10m	The monitoring should be done to identify: • % of dead plants • % of alive plants (Gadgil & Ede, 1997).
	Entire area	Remote sensing	NA	• Calculate how much the area covered by vegetation has been reduced. • Identify the location in which the problem is happening.
Unhealthy vegetation	Over the entire area	Visual Assessment	NA	• Identify the areas in which there is unhealthy vegetation. • Identify unhealthy species.
		Remote sensing	NA	When the plants are healthy they will reflect a lot of NIR and very little RED otherwise the plants will be catalogued as unhealthy (DeRiggi, 2017)
Erosion and sand deposition	Vulnerable areas	Field sampling with the use of transects parallel to the dune crest	10m x 2m	• See the gradual influence of the wind and human activity along the vegetation of the coast.

				• Number dead plants in the area. • Number of alive plants. • Site conditions including; dust depositions and erosion.
State of vegetation	Over the entire site	Remote sensing	NA	Images taken biannually, which can be used for comparison of: • density (cover) • extent (cover) • health (cover, colour) (Gadgil & Ede, 1997).
		Field sampling with the use of quadrants.	10m x 10m quadrants	The field sampling can be done twice a year in order to identify: • Identify the state of species in the area • Species density (Sampling strategies, 2015)

Cape Preston proposed the monitoring of the vegetation quarterly, meaning that it will be carried out in four periods. Which will be used to collect information in wet, dry and intermediate seasons. This will be proposed for the first year, it is not supposed to discover significant variations between the four samplings. Therefore, the schedule can be reviewed and if necessary changed to biannual sampling (Gadgil & Ede, 1997).

Table 6: Periods in which the management will be carried out

Sample	Rainfall Season	Timing
1	Wet Season	Late December to early January
2	Post-Wet Season	Late March to early April
3	Dry Season	Late June to early July
4	Pre-Wet Season	Late September to early October

Discussion

- In order to create the legend for the maps of the indices NDVI, NDWI, MSAVI2 and EVI one code was used in which only the “palette” and tittle on the legend was changed. The code can be visualized in Appendix A.
- Table 2 used in order to inspect NDVI is based in the following table. As it can be appreciated is the same table with a small difference. Build-ups/ river sand together with fallow/ wasteland were combined in one class called “Build-ups/ river sand”.

Table 7: NDVI values according to a specific land use class

Features	NDVI (range)
Water (deep & shallow)	-0.41379 to -0.10401
Builtups /river sand	-0.10401 to 0.055727
Fallow/ Wasteland	0.055727 to 0.20579
Crop, grass	0.20579 to 0.37035
Agroforestry	0.37036 to 0.51073
Forest	0.51074 to 0.82051

Features	NDVI (range)
Water(deep & shallow)	-0.41379 to -0.10401
Build-ups/ river sand	-0.10401 to 0.055727
Crops & grass	0.20579 to 0.37035
Agroforestry	0.37036 to 0.51073
Forest	0.51074 to 0.82051

- The code used for the calculation of the vegetation indices and the realization of the land cover map can be found in the following link. https://code.earthengine.google.com/6254098d22cdebf4174d740ca93fe28b

Conclusion

After analysing the land-use change in the study area, from 2016 to 2020. It can be concluded that vegetation monitoring was accurate, which was shown with the Confusion Matrix. The obtained values were considerably high, meaning that all of them were above 0.95. Furthermore, by analysing the different maintenance works realized in the area it was possible to identify some of the reasons for the increase or decrease in a certain land-use class. Therefore, the realized analysis is considered to be reliable and the same process can be applied to Almere Dune.

The vegetation selected for the Almere Dune was carefully studied taking into account their benefits and how it can be maintained through the years. Furthermore, it was necessary to implement some management rules such as replacement old dead plants, cutting of tall grasses, control of nitrogen revels and so on. They also have been applied in the study area. It is important to take into account that the management of vegetation should be persistent and carefully considered. Especially, the authorities uncharged of this should be committed to constantly and sporadically take care of the vegetation. Furthermore, the cooperation of the residents and people is essential to maintain the dunes, flora and fauna. If the maintenance practices are applied and the management rules are followed by residents and visitors. It will be possible to maintain healthy dune vegetation and it will prevent erosion and deposition of the sand dunes.

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Appendix

Appendix A

```
//==================================================================
// create vizualization parameters
var viz = {min:-1, max:1, palette:['blue','white','green']};
// set position of panel
var legend = ui.Panel({
style: {
position: 'bottom-left',
padding: '8px 15px'
}
});

// Create legend title
var legendTitle = ui.Label({
value: 'NDVI',
style: {
fontWeight: 'bold',
fontSize: '18px',
margin: '0 0 4px 0',
padding: '0'
}
});

// Add the title to the panel
legend.add(legendTitle);

// create the legend image
var lon = ee.Image.pixelLonLat().select('latitude');
var gradient = lon.multiply((viz.max-viz.min)/100.0).add(viz.min);
var legendImage = gradient.visualize(viz);

// create text on top of legend
var panel = ui.Panel({
widgets: [
ui.Label(viz['max'])
],
});

legend.add(panel);

// create thumbnail from the image
var thumbnail = ui.Thumbnail({
image: legendImage,
params: {bbox:'0,0,10,100', dimensions:'10x200'},
style: {padding: '1px', position: 'bottom-center'}
});

// add the thumbnail to the legend
legend.add(thumbnail);

// create text on top of legend
var panel = ui.Panel({
widgets: [
ui.Label(viz['min'])
],
});

legend.add(panel);

Map.add(legend);
//==================================================================
```

Appendix B

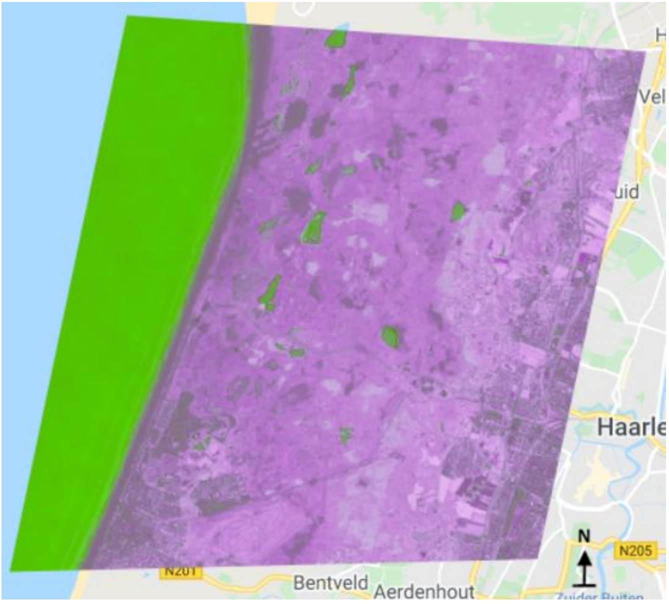

Figure 14: Combined image

Appendix C

Table 8: Area covered by each land use class from 2016 to 2020(spring & summer period)

Year	Water	Sand and Build-up	Crops and grass	Agroforestry	Forest	Accuracy
2016	15654.518	27117.604	1920.900	6645.036	14670.844	0.9955
2017	15130.100	16478.381	5580.303	7306.024	21514.093	0.9674
2018	15194.799	10875.129	2869.170	7740.816	29328.988	0.9825
2019	15162.387	7530.399	10689.268	10470.335	22156.512	0.9834
2020	15450.008	8754.205	3617.555	16623.380	21563.754	0.9617