Term project paper

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Mystery at the Wildlife Preserve: Multispectral Imagery

Introduction

The problem that was stated in the task is that the number of nesting pairs of pipits (fig.1) is decreasing in their habitat near Bonsoong lake but the reason for that is not clear.
Pipits are little birds which primarily live on the ground and are known for their beautiful feathers and attractive singing.
There are several data sources available referring this region which can help to define the reasons why this happens, but I will focus on multispectral satellite images.
Multispectral imagery is a technology of capturing image data within specific wavelength ranges across the electromagnetic spectrum. This can be useful as different objects, substances, materials can be sensitive to specific wavelengths which do not belong to visible spectrum. However, the amount of absorbed and reflected light can provide information on concentration of various substances (water, minerals, chlorophyllin, etc.) and allows to determine its dynamics leading to certain subsequences.

Fig.1. Pipit bird

Dataset description

The dataset contains 12 multispectral images in TIFF and CSV files. Each image contains 6 channels described in the table below.

Table 1. Description of available bands

Band	**Color**	**Wavelength (nm)**	**Useful for Mapping**
B1	Blue	450-520	Penetrates water, shows thin clouds and general visible brightness
B2	Green	520-600	Shows different types of plants and general visible brightness
B3	Red	630-690	Vegetation color and certain mineral deposits.
B4	Near Infrared (NIR)	770-900	Partially absorbed by water, sensitive to vegetation structure and chlorophyll
B5	Short-wave Infrared (SWIR) 1	1550-1750	Completely absorbed by liquid water. Sensitive to moisture content of soil and vegetation; penetrates thin clouds
B6	Short-wave Infrared (SWIR) 2	2090-2350	Insensitive to vegetation color or vigor, shows differences in soil mineral content

It should be admitted that each object has its own optical characteristics, and it is not possible to define precisely if one region in the image contains more water or minerals than another. However, these channels can be used to obtain averaged information. In the image below the examples of given images are provided.

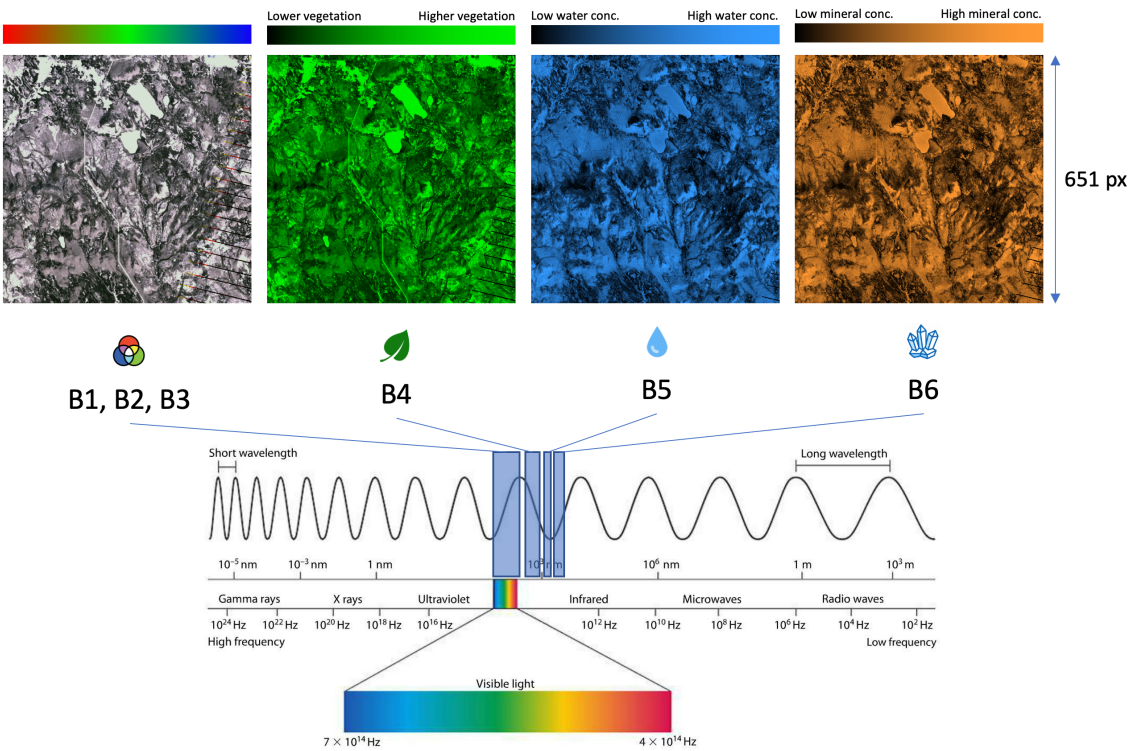


Fig.2. Example of image in RGB (bands B1, B2, B3), NIR and SWIR (bands B4, B5, B6)

Each image is square with a side length of 651 pixels. 1 pixel corresponds to 100 feet or 30 meters (fig.3).

Fig.3. Satellite images of Bonsoong lake

For the further analysis I used CSV files which allowed to manipulate data in a more convenient way.

The data ranged from 2014 to 2016 with the distribution depicte in Fig. 4.

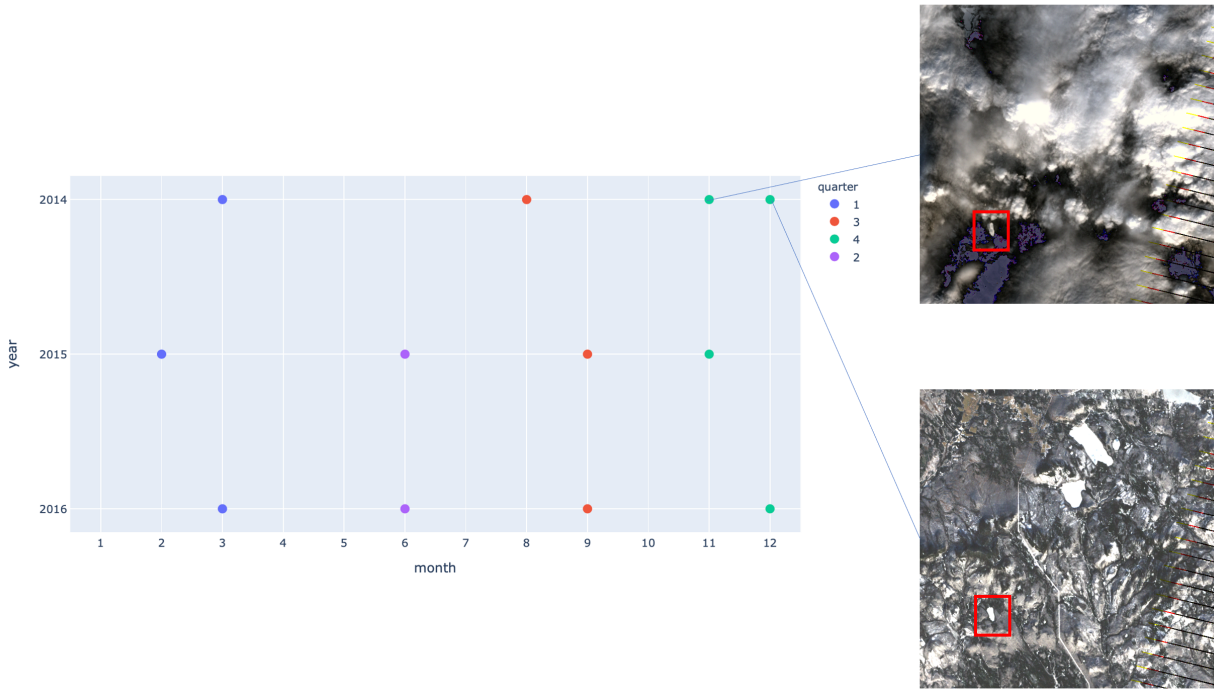


Fig.4. Distribution of images over time

It can be noticed that images are almost evenly distributed over the year but my attention was drawn by this 2 images close to each other in terms of time. One of them contains mostly clouds and some strangely colored regions. Probably it is a good idea to consider this image as an outlier. But as soon as there is an acute shortage of images and the region around the lake is visible, I will keep this image in the dataset.

Data preparation and analysis

Visual analysis

As for the first step I decide to use visual inspection of the images. To do that I distributed RGB images over a time plane (years and months) to detect the differences easier (fig.5).

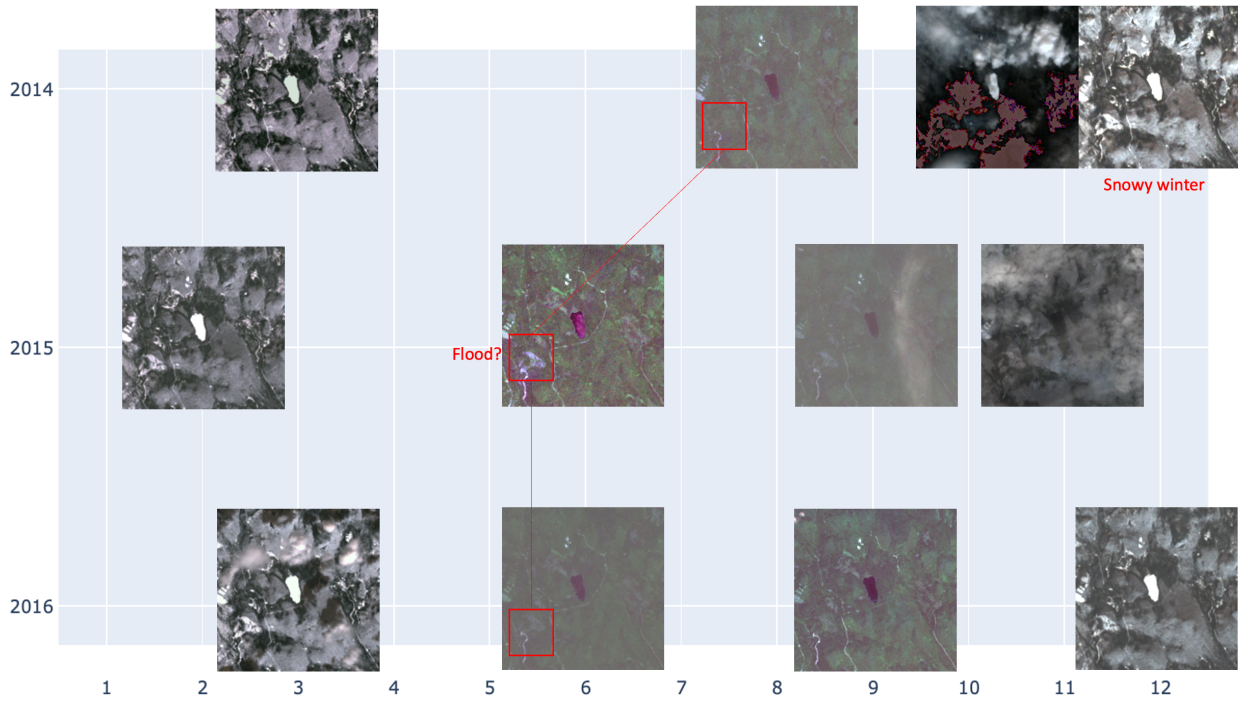


Fig.5. Distribution of images on the time plane

The first thing that can be noticed is that there is a clear difference between winter and summer seasons due to the presence of the snow from December to March.
One of the images (October 2014) contains strange red spots the origin of which is not clear and presumably can be a subsequence of postprocessing or defect. I cannot state that it is a fire as in this case the smoke should be present.

Another observation which I made is that in the summer of 2015 there was a spot of a presumably flooded region which was not present on other images belonging to the summer season. Then I had a look at the preceding images and found out that winter of 2014 was remarkably snowy compared to the other ones. Probably the excess of snow which then obviously melted resulted in the flood in this region. As soon as pipits are birds which nest on the ground this can be the reason for decreasing of their nestings.

Numerical analysis

Machine vision

Even though visual analysis is a powerful tool, I decided to perform some numerical analysis as a more objective approach. There are two main approaches which I initially came up with in order to conduct it.
The first one involves machine vision techniques which allow to detect objects present on the image, their position and movement, changes in area of certain regions of interest.

As for the first step I tried to find available ready-to-use pretrained models which could allow detection and classification of objects. I did not succeed in that, but I found several labeled datasets containing satellite images (mainly in RGB spectrum) with corresponding polygon coordinates and class name. But each of them was concentrated on a particular category of objects such as planes, boats, swimming pools, buildings, etc. Which were not useful in my case as in the images I had forest, lakes, and roads.

The only model which could be potentially used is the model which allows to count number of trees. But it is trained on satellite images of significantly higher resolution compared to the ones I have in the dataset.

Therefore, the only way that could be realized in terms of this approach is to label the images myself. However, it is obvious that 12 images of fairly low resolution is not enough to obtain even a modestly accurate model. I could split images into multiple images e.g., into 4 or 16 images, and label them manually, but I hardly doubt that the number would be sufficient, and it is worth time spent on labeling.

Therefore, I came to a conclusion that this approach cannot be realized, and I decided to opt for another one.

Band statistics analysis

Algorithm for this approach includes following steps:

- Frame the region of interest
- Calculate statistical metrics for each band for that region
- Visualize and analyze dynamics of metrics

The schematic representation of this approach is provided in the image below.

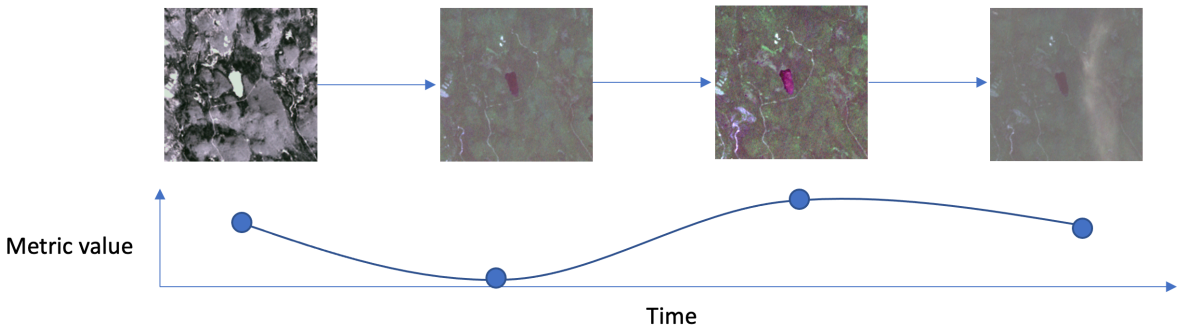


Fig.6. Schematic representation of the approach

As for the metrics I chose:

- Minimum and Maximum value as they represent the range
- Median and mode as they are not sensitive to outliers
- Mean value as most common measure of central tendency
- Variance as a measure of variability

Let's first have a look at distributions of the channels for the images.

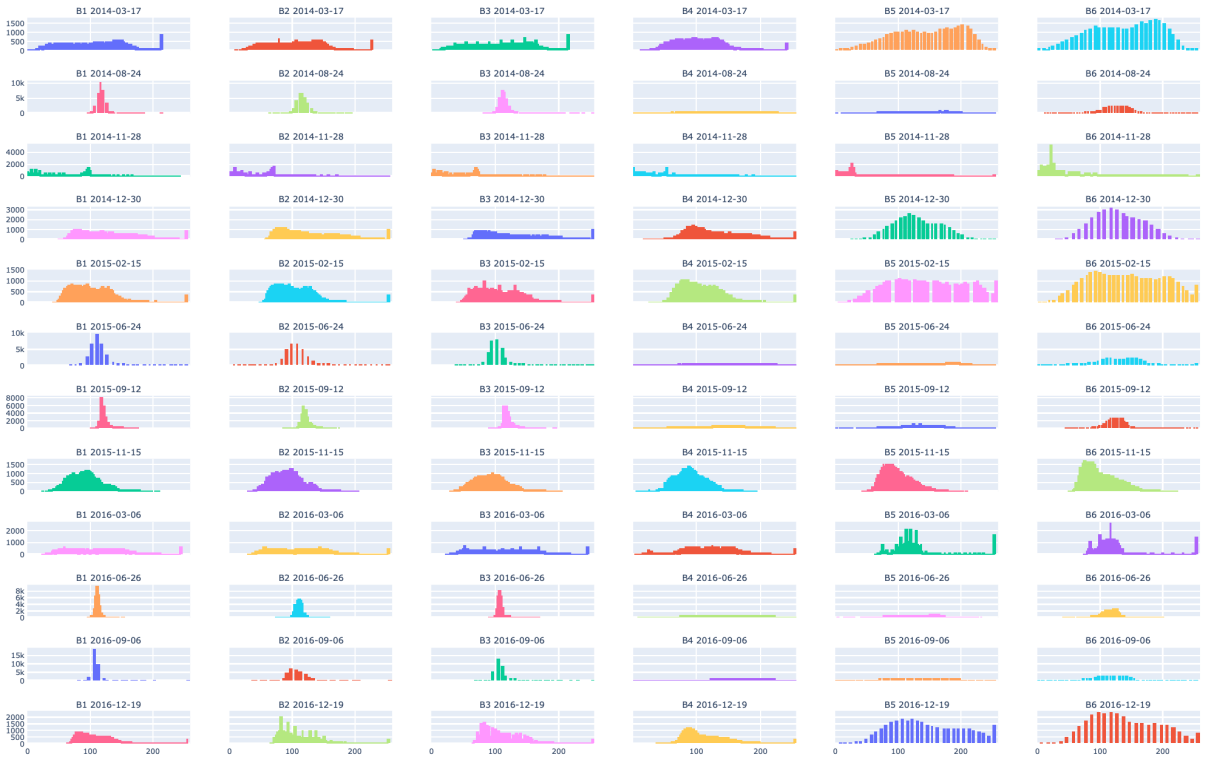


Fig.7. Distributions of pixel intensity for each channel for each image

As we can see there are mostly unimodal and bimodal distributions, but it is challenging to recognize dynamics of distributions in this form. Therefore, I decided to plot distribution parameters on timeline.

Results and discussion

In the figure below metrics for all of the channels are provided. As soon as visual analysis was conducted before I consider that the visible spectrum was already analyzed. Therefore, we can go focus on the rest NIR bands.

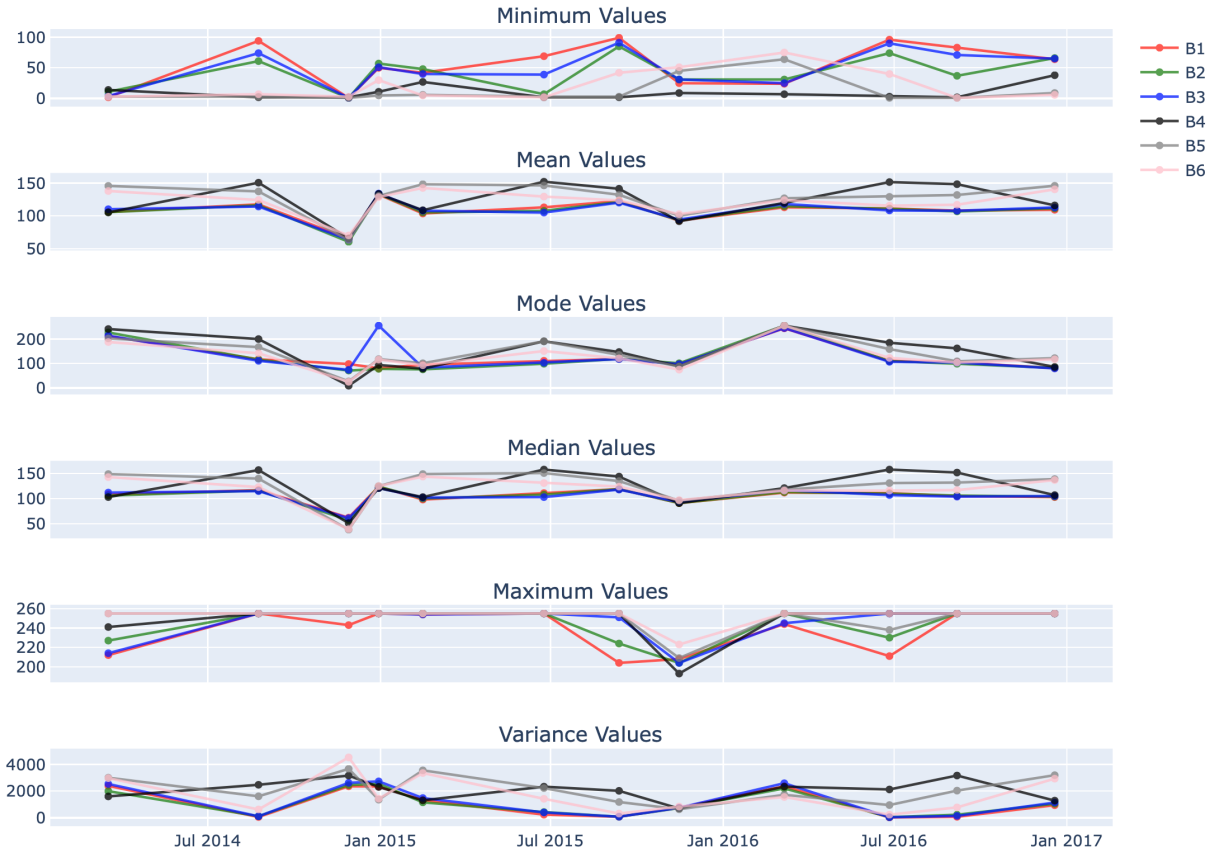


Fig.8. Dynamics of statistical metrics for all channels

In the figure below I filtered only B4,B5 and B6 bands which correspond to vegetation, water and mineral concentration respectively. It can be seen that there is no visible trend present in the values and I consider this time series stationary.

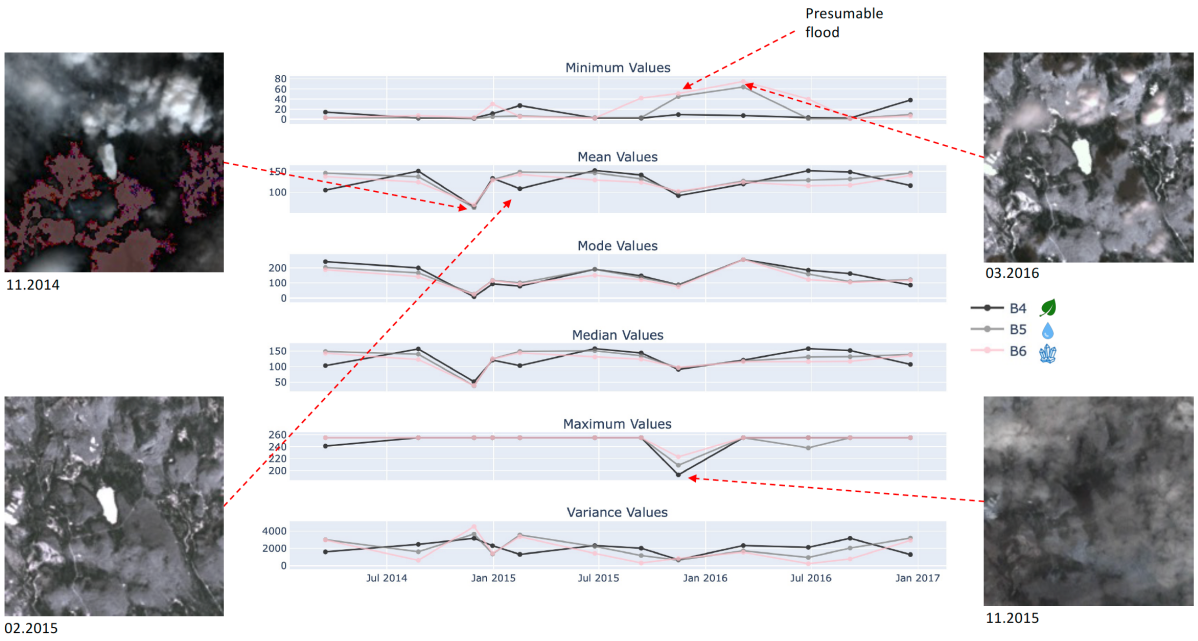


Fig.9. Dynamics of statistical metrics for NIR channels

Here several outliers can be noticed. The first one is a rise and peak of minimum value for B5 and B6 channels. This corresponds to the previously found flooded areas and supports this assumption.

Another point of interest is the minimum of mean values of all of the 3 bands. As it canb seen in the RGB image there are peculiar red spots present of unknown origin. But it can be admitted that if it was a fire there would have been local maximum of mean value as IR radiation correlates positively with heat.

The next interesting point is February 2015 where mean values of B5 and B6 channels are higher than B4. That can be explained by the preceeding minimum and by probable process of stabilization.

The last point is a minimum in maximum values and fairly low variance which can be explained by the presence of the clouds.

I would consider asking the source of the provided images if any of them were processed or modified because there are some unnaturally bright colors and spots in some of the images (fig.10).

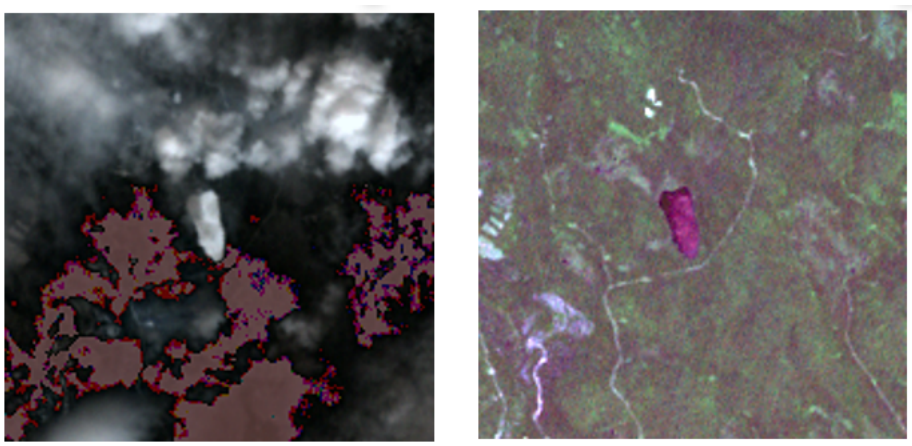


Fig.10. Example of unnatural coloring of the images

Another question which arouses during this project is: if the images were not modified were the settings of the sensors the same for all the images? This question appeared due to the differences in vegetation colors (fig.11).

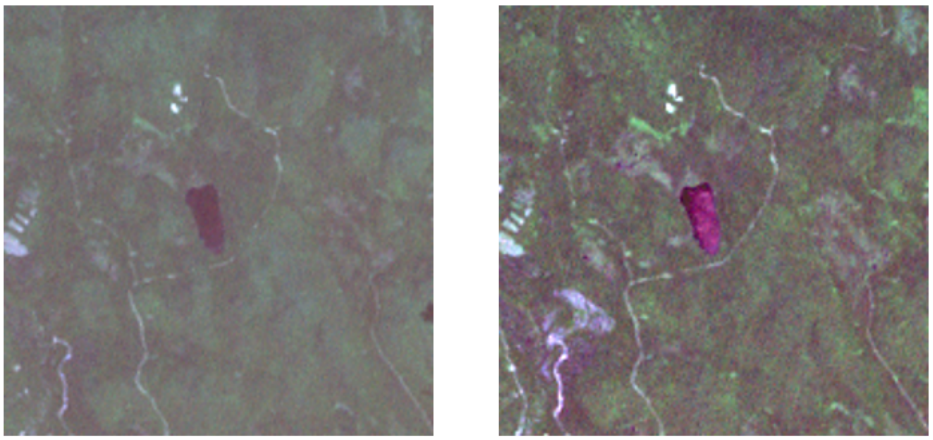
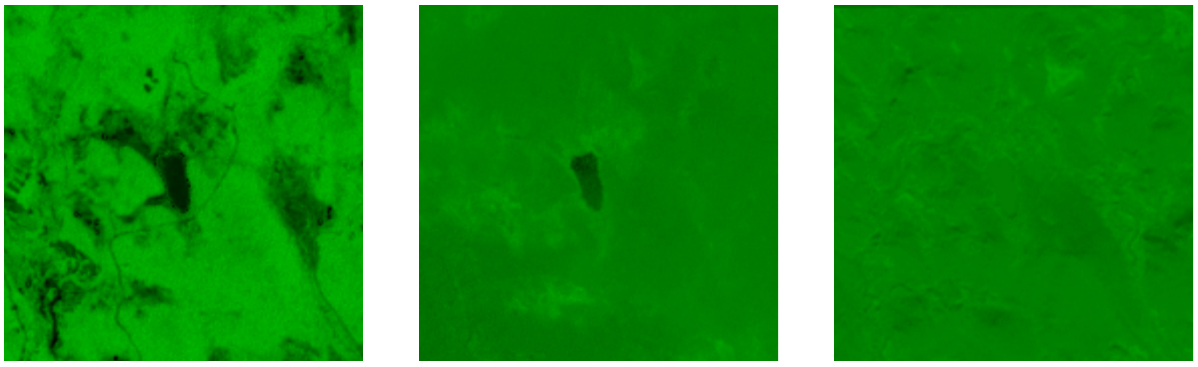


Fig.11. Examples of the differences in vegetation colors

In the light of the obtained findings it can be concluded that the possible reason for pipit population reduction is a snowy winter which lead to floods in the region which made nesting impossible in certain areas around Bonsoong lake.

This version is supported by the differences in Normalized Difference Vegetation Index (NDVI) which reflects the health of vegetation. The comparison of the image of the summer with the presumable flood to other images shows that it is closer to the winter image which obviously lacks vegetation (fig.12). Therefore, another factor which could contribute to the problem is unhealthy vegetation.



Summer | Summer (flood) | Winter

Fig.12. Comparison of images with NDVI

Regarding the next steps which could help to find other reasons, they are as follows:

1. Get data on population dynamics to combine it with obtained data to verify the assumption.
2. Obtain more images to get a better understanding of band dynamics and exclude possible erroneous data
3. Analyze weather data for the region (compare amount of precipitation, temperatures, wind data to satellite images data) to interpret band values in a more precise way
4. Analyze news data for the region (define the most frequent ones using NLP) for possible discovery of other possible reasons

Conclusion

The conducted visual and numerical analysis allowed to find out possible cause for the reduction of nesting pairs of pipits in their habitat near Bonsoong lake. There were also formulated several questions to be clarified by the source of the images. Further steps are described to achieve more precise results.