The correlation of the highest temperature and fire weather forecast with detection of wildfires around Puerto Rico using the Landsat 7 ETM+ images

Karimar Ledesma Maldonado[1] and Lydia Velez[2]
[1]Department of Physics, [2]Department of Geology
University of Puerto Rico, Mayagüez Campus
Arts and Science Faculty

Abstract

Puerto Rico is susceptible of wild fires due to its topography and global location. In this research it is proposed to present the areas of Puerto Rico affected by wild fires. The images used were from the sensor of ETM + of Landsat 7, to study the correlation within the highest temperatures and the wildfires around Puerto Rico detected by the National Weather Service of San Juan (NWS). Despite the limitation to the lack of data on date and time of the wildfires that occurred in Puerto Rico it was possible to make an interpretation following the date of highest temperatures. ENVI Software was used to process and analyze image applying the Normalized Burn Ratio (NBR) equation index. The results show a poor correlation with highest temperatures. This study serves to other investigations and collects more data of date and time of the wildfire to validate the results.

Key words: wildfires, ENVI, Landsat 7 ETM +, NWS

1.Introduction

1.1 Background

What are wildfires? The wildfires are a chemistry process in which three essentials elements are needed to a wildfire to exist: the presence of heat, oxygen and combustion at the same time (Carles J., 2011). Forest fires are a major global role in ecological and climatic systems; they are responsible for much of the emissions of greenhouse gases into the atmosphere, in addition to causing tropical forest degradation with multiple impacts on forest structure, biodiversity and nutrient cycling in soil. These fires can propagate in different ways. It can be divided in two:

natural causes or human causes (DRNA, 2006). The natural causes could be rays or spontaneous combustion. Some wildfires, whose causes can be identified as natural are a benefit to the reproduction of plants and trees. Certain flora (shrubs) needs fire in order to release their seeds contents and thus perpetuate their species (Vélez J., 2010).

Another way is due to human activities such as; agricultural, recreational, accidental or criminal, vandalism, cigarette butts, or bonfires. Depending of its intensity and frequencies the wildfires can have different effect as the followings: raze wood, destroy the habitat of wildlife and there directly, destroy flora lacking adaptations to arise fire, pollute the air and cause accidents due to loss of visibility due to smoke, contribute to global climate change, they promote soil erosion, altering the hydrological regime, can cause loss of human life (by burning, choking or suffocation), destroy food (crop, fodder), increase operating expenses (supplies and equipment, air operation, labor). Summarizing, the wildfires causes serious health, environmental, economic, social and operational impacts to short and long terms. (DRNA, 2006)

The peak season of wildfires matches the dry season, which is favored with changes in drought conditions associated with the phenomenon El Niño Southern Oscillation (ENSO) (Rodriguez A. 2012).The months of February to April, are known as the dry months (NWS, 2014), during these months it increases the chances of wildfires. The wildfires season can be extended if there is no precipitation. Areas more susceptible to be affected are primarily the southern region of Puerto

Rico. These includes: Salinas, Santa Isabel, Coamo, Cabo Rojo, Guanica, Guayama and Ponce. It should be emphasized that although the conditions are suitable, these conditions are no favorable to produce wildfires by natural causes.

1.2 Area of study

Figure 1.1 Study area of the center of Puerto Rico, area enclosed in the orange box.

1.3 Objective

This research pretends to correlate the highest temperature with the wildfires that occur around of Puerto rico using the images from the sensor of ETM +. Applying the techniques of analysis and processing imagery using the program ENVI, to detect wildfires in Puerto Rico.

2. Methodology

2.1 Procedure

The images were downloaded from the USGS Earth explorer website. After obtaining the images at Level 1 is necessary to get done a series of steps in order to get the result wanted. The images were processed in the program ENVI, first it was

needed to do a layer stacking, which means the download of the images where in level one, and the layer stacking is putting together all the bands. Once it is performed it is necessary to perform a dark subtract method. It was performed a spatial subset of the center of the island, this is done because the images contained some error in the east and west side of Puerto Rico. After the previous steps it was implement the following equation known as Normalized Burn Ratio (NBR):

$$\frac{float(b4) - float(b7)}{float(b4) + float(b7)}$$

Where the b4 (band 4) is the near infrared (0.76-0.9μm) and b7(band 7) corresponds to the short wave infrared (2.08-2.35μm), equation was proposed by Key and Benson, (2002). The band 4 is sensible to the water content in the soil and vegetation; the band 7 is sensible to dead vegetation.

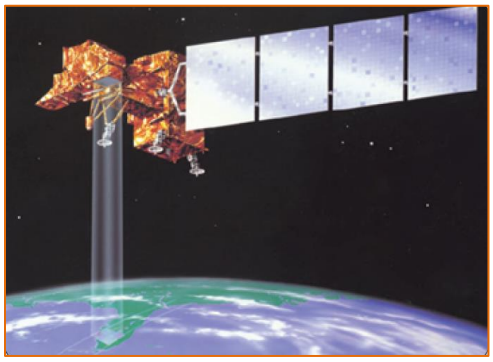
Then it was built a mask within the value range between 0 to 1. After the mask was built we applied it with a value of -2.For last we added color, the legend (color ramp) and text to the image and it was saved in JPEG format.

2.2 Sensor

The satellite used was Landsat 7 which has the sensor ETM+. The characteristics of this sensor are presented in table below Table 2.1. This sensor is appropriate for the study due to the high spatial resolution and numbers of bands.

Type	Opto-Mechanical Scanner (whiskbroom)
Spatial Resolution	15/30/60 m
Spectral Range	0.45-12.5
Number of bands	8
Temporal Resolution	16 days
Radiometric Resolution	8 bits
Size of image	183x170km

Table 2.1 Characteristics of the ETM, information obtained from the Earth Explorer USGS.



Figuere 2.1 Schematic image of ETM+ from http://science.nasa.gov/missions/landsat-7/

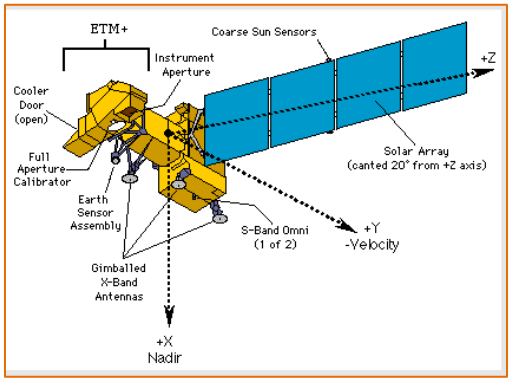


Figure 2.2 Schematic image of ETM+ with identified parts obatined from http://earthexplorer.usgs.gov/

3. Analysis and Results

3.1 January 17,2013

The first image studied was for January 17, 2013. The figure 3.1.1 corresponds to the true color image and the figure 3.1.2 corresponds to the image using the NBR. To analyze the image we needed to define the color ramp. A value of 0 that is represented in color red is the detection of fires and

contrary to the value 1 that is represented in color blue are the no detection fires. When we see the figure 3.1.2 that parameter identified various wildfires, but when we see the image of true color part by part we cannot distinguish any wildfire. To compare both images we see that some clouds are detected as wildfires.

Figure 3.1.1 True Color

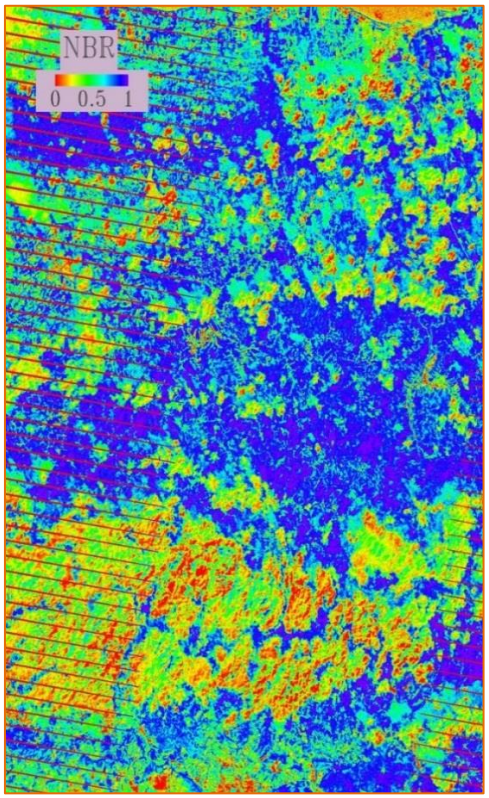


Figure 3.1.2 NBR

In other hand for this date we can find the fire weather forecast which is presented below from the NWS:

FIRE WEATHER...STILL BREEZY TODAY WITH WARMER TEMPS AND LOWER RHSDUE TO SIG MORE BREAKS IN THE CLOUD CVR THAN YDAY. CLOUDY AGAINFRI WITH MORE SUNSHINE SAT AND SUN. WINDS WILL DIMINISHCONSIDERABLY OVER THE WEEKEND AND NEXT WEEK TO LESS THAN 15 MPH.ANY SHOWERS WILL ONLY LEAVE TRACE OR VERY LIGHT AMOUNTS MAINLYFRI.

Figure3.1.3 Fire Weather Forecast

Also the temperatures for this date were following 80°, 72° maximum and minimum. These temperatures are relative low to produce or generate a wildfire. In addition the highest temperature for this month is present below in the Figure 3.1.4. This date does not correlate with the highest temperature.

JAN	San Juan
High	86°F January 23rd and 22nd
Low	70°F January 14th

Figure3.1.4 Temperatures from NWS

3.2. February 2, 2013

The image 3.2.1 shows the true color of the area studied, the next image (see figure 3.2.2) shows the image with the NBR equation. For this image we can see the fire in many parts of Puerto Rico, but when we compare with the true color image it also tends to confuse with clouds. Figure 3.2.3 is a zoom of the North East from the true color image, the area enclosed in the circle shows what it can be a fire and using the link display and cursor locator value from the NBR image, it gives us a value of -2 at that particular enclosed area.

Figure 3.2.1 True Color

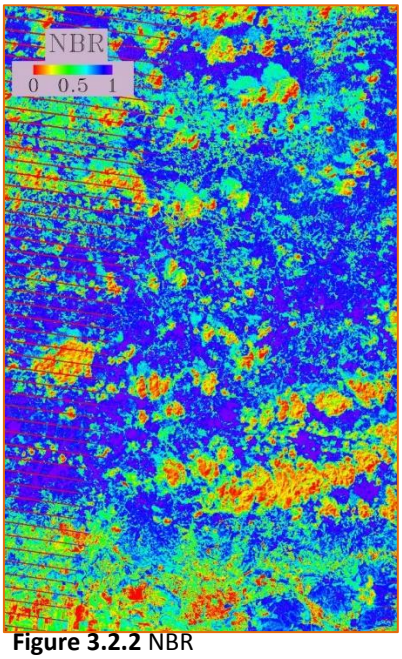


Figure 3.2.2 NBR

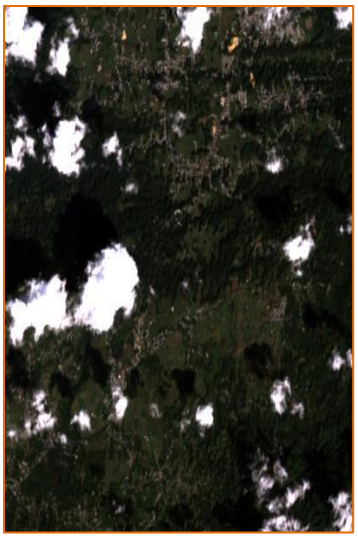


Figure3. 2.3 True Color Zoom

The fire weather forecast by the NWS of

San Juan is presented below:

> **FIRE WEATHER...**EXCEPTIONALLY DRY AIR WILL CONTINUE THROUGH TUERESULTING IN CLEAR SKIES AND VERY LOW HUMIDITIES KEEPING FIREDANGER VERY HIGH. LIMITING FACTORS FOR A MORE SIG THREAT ARE WEAKERTHAN NORMAL WINDS AND STABLE CONDITIONS

Figure3.2.4 Fire Weather Forecast

The fire weather forecast was right based on the images but the temperatures for this date are maximum and minimum 71°, 83°, 71°, and 81°. This temperatures are relative low to produce a wildifre. In addtion the highest temperature for this month is presented below in the figure 3.2.5. For this date we don't have a record of the highest temperature:

FEB	San Juan
High	86°F February 23rd and 18th
Low	69°F February 4th

Figure3.2.5 Temperatures from NWS

3.3 February 18, 2013

The true color image is representing in the figure 3.3.1, applying the NBR to the image the result is the figure 3.3.2. Again to compare with the true color image, this parameter tend to confuse with clouds. To distinguish a fire was observed with zoom by part by part of the image. Then other image the figure 3.3.3 is a zoom of the North West from the true color image. The area enclosed in the circle it shows a possible fire and then using the link display and cursor locator value in the NBR image the value from this point that we said is fire has a value of -2.

Figure 3.3.1 True Color

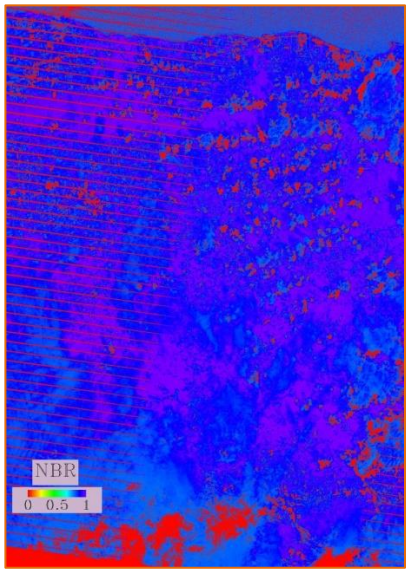


Figure 3.3.2 NBR

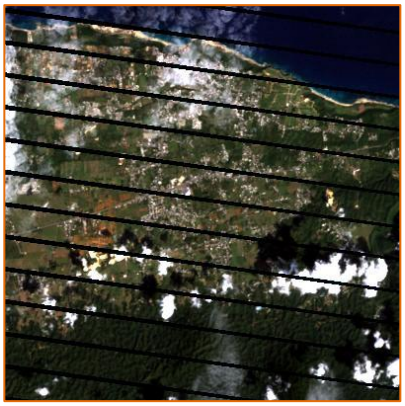


Figure 3.3.3 True Color Zoom

The fire weather forecast by the National Weather Service is presented below: We can infer that the fire detect in the images above is right.

FIRE WEATHER...BUILDING HIGH PRES NORTH OF THE AREA WILL RESULT INSTRENGTHENING TRADE WINDS TOMORROW WITH WINDS IN EXCESS OF 20 MPHWITH GUSTS TO 30 MPH EXPECTED. HUMIDITIES ARE ALSO EXPECTED TO DROPAND WHEN COMBINED WITH THE EXTREMELY DRY FUELS WILL RESULT INHEIGHTENED FIRE WEATHER CONDITIONS. THE STRONG WINDS WILL CAUSEANY SUPPRESSION EFFORTS HAZARDOUS AND DIFFICULT. OVERALL...HIGH TOVERY HIGH FIRE DANGER OVER THE NEXT SEVEN DAYS AS UPPER LEVELRIDGE DOMINATES.

Figure 3.3.4 Fire Weather Forecast

In addition we can see the correlation with temperatures. These were the temperatures of this date71°, 83°, 72°, and 83°. For this date we have a record of the hisget tempeature (see Table 3.3.1)

FEB	San Juan
High	86°F February 23rd and 18th
Low	69°F February 4th

Figure3.3.5 Temperatures from NWS

3.4. March 22, 2013

First we observed the true color image and then compare it with the images that it was applied the NBR equation. For the other side the zoom of the North east of the true color image we can see a fire that is enclosed in the circle. Using the link display and cursor locator for this point it was marked with a value of -2 said according with the legend of NBR.

There was not a fire weather forecast for this date, but the highest temperature record is for this day (see Table 3.4.1) The maximum and minimum temperatures of this day were 75°, 89°, 73°,and 86°.

Figure 3.4.1 True Color

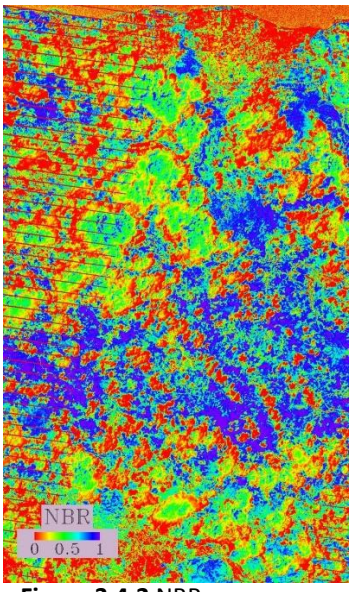


Figure 3.4.2 NBR

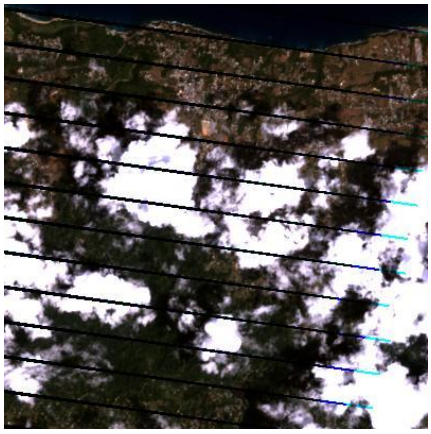


Figure 3.4.3 True Color Zoom

MAR	San Juan
High	93°F March 22nd
Low	71°F March 15th,14th and 9th

Figure3.4.5 Temperatures from NWS

As a matter to compare the values fluctuation of the masking to see if it were any differences in the images, a mask was created with the range value of -1 to 1. We analysed the figure but got the same poor result as for the first values, it was also used a value of masking of -2. Figure3.4.5 shows the final result after all the procedure is the same date that it was used above.

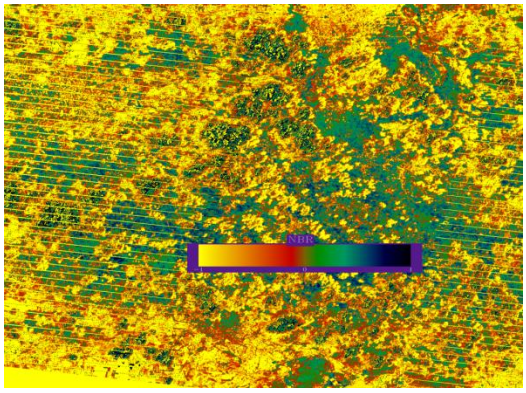


Figure 3.4.5 NBR with mask values -1 to 1.

4. Conclusion

After observing and analyzing all the images processed we can say that NBR confuses fires with clouds. Thus a correlation with highest temperatures was found in the dates of February 18, 2013 and March 22, 2013, but not necessarily a logic correlation due to the temperatures aren't the highest recorded. The highest temperature records do not necessarily correlate with those of wild fires.. The fire weather forecast was right in most of the dates except January 17, 2013, by judging the images there is not any clear evidence of a fire occurring. There was not a fire weather forecast for March 22, 2013 which can lead us to think that it was by a human cause not naturally. Also, NBR is not the best algorithm to use for the detection of fires.

5. Recommendations

For future research of wildfires is necessary to record data by date and time of each fire, for analyzing correctly the dates, and avoid assumptions. In addition, use sensors with high spatial resolution like IKONOS or MODIS sensor which is primarily the sensor to detect wildfires around the America (thermal infrared bands). Also use index such as Surface temperature and Fire anomalies algorithm by Giglio et al. 2003 to detect active fires.

6. Future Work

Due to the global role that has the wild fires in the ecological and climatic systems as a future relevant research could be the effect of these wildfires in the environments, especially the nearby areas. Some of these studies could be: the loos in vegetation and

the amount of CO_2 that are released into the atmospheres. This last one because no matter the small amount it could be is important and contributes to the increase of the global warming.

7. Referecnes

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